INFLUENCE OF INORGANICS AND ORGANICS ON SOIL CHARACTERISTICS AND CROP YIELD UNDER RAINFED MAIZE-GOBHI SARSON SEQUENCE

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DIVISION OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

THESIS

SUBMITTED TO FACULTY OF POST-GRADUATE STUDIES SHER-E-KASHMIR UNIVERSITY OF AGRICULTURAL SCIENCES AND TECHNOLOGY OF JAMMU (J&K) IN PARTIAL FULFILMENT OF REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY IN AGRICULTURE

(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

Regd. No. J-05-D-47 **Submitted on 17th day of Aug 2009**

Dedicated to

ALMIGHTY

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This is to certify that the thesis entitled **"Influence of inorganics and organics on soil characteristics and crop yield under rainfed maize-gobhi sarson sequence"** submitted in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Agriculture (Soil Science and Agricultural Chemistry)** is a record of bonafide research carried out by **Mr. Rahul Gupta** Registration No. **J-05-D-47** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that help and assistance received during the course of thesis investigation have been duly acknowledged.

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ACKNOWLEDGEMENTS

ACKNOWLEDGEMENTS

*First of all, I bow my head with great reverence to "**Almighty**" who is omnipresent, omnipotent and omniscient and the cause behind every effort.*

*It is uniquely proud privilege to me for expressing my heartfelt regards and sincere appreciation to **Dr. M.P. Sharma**, Professor, Division of Soil Science & Agricultural Chemistry and chairman of my Advisory Committee for his immaculate guidance, prudent suggestion, vision and empathy given to me for the present study and left no stone unturned to impart me with new dimensions in soil research.*

*I wish to extend my sincere thanks to **Dr. A.K. Mondal**, Associate Professor, Soil Science; **Dr. Abhijit Samanta**, Senior Scientist, W.M.R.C; **Dr. B.C.Sharma**, Associate Professor, Agronomy, and **Dr. Vikas Sharma**, Assistant Professor, Soil Science, members of my Advisory Committee, for their non-ending help, encouragement and moral support during study period.*

*My sincere thanks are also due to **Dr. A.K. Bhat**, Head, Division of Soil Science and Agricultural Chemistry; **Dr. K.R. Sharma,** Professor, Division of Soil Science and Agricultural Chemistry; **Dr. C.S. Kalha**, Associate Dean, Faculty of Agriculture; **Dr. V.S. Verma**, Incharge Research Experiment Station(DLRSS); **Dr.R.M. Bhagat**, Director Resident Instructions-cum-Dean, Post Graduate Studies and University Librarian, for providing necessary facilities during the course of investigation.*

I take this opportunity to extend my thanks to all the staff members and office bearers of Division of Soil Science, for their help and support during the course of investigation.

I am highly obliged by the help rendered by my loving seniors Dr.Sarabdeep Kour, Dr.Anil Sharma, Dr.Vivak Manohar Arya, Dr.Neeraj Sharma and Dr. Rohit Sharma. I also cherish with appreciation, love, affection and moral support by my colleagues Dr. Amarjit Singh, Dr. Veena Sharma, Dr. Sanjay Koushal, Dr. Jai Kumar, Dr.Brij Nandan. I am highly thankful to Dr. Harpreet Singh and Dr. Vishal Sharma for their contribution during literature collection. I would also like to thank all my juniors for their vital support.

I dare not to open the paradox of expressing the debt of gratitude to all my family members and relatives, for their everlasting love, affection and selfless sacrifice showered upon me.

Last but not the least, my thanks are due to Mr. Anil Sawhney,(Mahavir Computer) for his untiring co-operation in neat and clean typing of the manuscript.

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Abstract

Surface and sub-surface soil samples from fourty three locations from maize-gobhi sarson or related oil seed crop representing three agro-climatic zones viz., sub-tropical, intermediate and temperate zones were collected. Besides, a field experiment "Influence of inorganics and organics on soil characteristics and crop yield under rainfed maize-gobhi sarson sequence"was conducted at research farm of Dryland Research Sub-Station, Dhiansar ,SKUAST-Jammu during *kharif* and *rabi* seasons of 2006-07 and 2007-08, respectively.

The higher organic carbon, available N, P, K, S, Zn and B was observed in temperate zone soils followed by the soils of intermediate zone whereas the lower amount of these available nutrients and organic carbon was noticed in sub-tropical zone under rainfed maize-gobhi sarson or related oilseed based cropping sequence. Organic carbon ,CEC, silt and clay content were found to be significantly and positive correlated with available nutrients whereas soil pH , EC and sand was found to be negatively correlated with all the available nutrients viz. N, P, K, S, Zn and B in different agro-climatic zones .

The soil of the experiment field was sandy loam in texture, slightly acidic in reaction (pH-6.8), low in organic carbon (0.40 per cent), available nitrogen and medium in available phosphorus and potassium. Among the various inorganics and organics sources of nutrients during both the years of the experiment, the application of N, P, K, S, Zn and B at recommended level along with 25 per cent additional dose of N through vermicompost brought significant increase in grain and stover yield of maize over 100 per cent recommended NPK alone followed by supplementing recommended NPK with S, Zn and B alone and in combination of two nutrients viz.S +Zn, S+B and Zn +B but the values were at par with the treatments which received recommended level of all the nutrients(T_8) during 2006-07 while during 2007-08, all the treatments which received integrated application of inorganics and organics in ratio of 75:25 and 50:50 (T_9 to T_{12})as well as the treatment which received 25 per cent of additional dose of N through FYM (T_{13}) and all the recommended doses of inorganics (T_8) were found statistically at par with each other.Whereas the residual effect of recommended dose of fertilizer along with 25 percent extra dose of N through vermicompost applied to preceding crop and direct application of 100 per cent recommended N, P and K to gobhi-sarson produced significantly higher seed and stover yield during both the years. During the 2nd year of experimentation, the plots where integrated applications of inorganics and organics was applied were found to be statistically at par with each other.

The organic carbon, CEC, water holding capacity of soil improved significantly under the treatments which received integrated application of inorganics and organics over T_1 (100 % NPK alone) as well as initial status of soil. Whereas, bulk density reduced significantly with the integrated use of inorganics and organic sources of nutrients. Similarly direct and residual effect of inorganic and organic sources of nutrients had a significant effect on available N, P, K, S, Zn and B status of soil. The data regarding macro and micro nutrients showed that maximum gain of nutrients in soil after maize gobhi-sarson sequence was found in the plots receiving recommended NPK along with sulphur, zinc, boron and vermicompost (50 per cent N replacement). Application of vermicompost and farmyard manure coupled with inorganic sources of nutrients proved beneficial in augmenting the fertility status of the soil by improving soil characteristics and crop yield under rainfed conditions.

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17-08-09.

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Signature of Student

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INTRODUCTION

CHAPTER - I

INTRODUCTION

Jammu region of J&K state comprises of three agro-climatic zones viz. low altitude sub-tropical zone, intermediate zone and temperate zone and are situated on the Southern aspects of Panjal tract. The soils are grey brown / red yellow Podzols, red earth brown forest and alluvial which have been classified according to Soil Taxonomy into Hapludalfs, Cryorthents, Udorthents, Usttorthents, Cryofluvents, Udifluvents, Ustifluvents, Cryochrepts, Dysttochrepts, Eutrochrepts (Rana *et al.* 2000). These soils are characterized by undulating topography, subjected to severe erosion and thus the inherent nutrient status of these soils is low. Moreover, their finite nutrient reserves are continuously exhausted due to the adoption of modern agricultural technology, through intensive and exhaustive cultivation of high yielding varieties.

Rainfed agriculture in India extends over 97 million hectares across diverse agro-climatic, ecological and socio-economic situations. The area represents 68 per cent of the net cultivated area of 142 million hectares contributing 44 per cent food grain production and supporting nearly 40 per cent and 60 per cent human and live stock population, respectively (Anonymous, 2005-06). In Jammu and Kashmir, rainfed agriculture covers and acreage of 4.22 lakh hectares which represents 57.46 per cent of the net sown area of 7.34 lakh hectares (Anonymous, 2005-06(a)).

Maize (*Zea mays*. L) "The queen of cereals" is the third most important cereal crop in the world. It occupies an important place in world agriculture as a food, feed and industrial crop. It occupies an area of 157.87 million hectares producing grain yield of 784.7 million tones in the world (FAO, *2008*). In terms of acreage, India ranks fifth with the cultivated area of 7.77 million hectares and a production and productivity of 13.85 million tones and 1783 kg ha^{-1}, respectively (Dharni *et al.* 2008). Maize being the main crop of kharif season as well as staple food of *kandi* farmers of sub-tropical areas of Jammu and Kashmir and is grown on an area of 0.32 million hectare out of which 0.22 million hectare is in Jammu division. The production and productivity of maize in the state is 3847 thousand quintals and 17.33 q ha^{-1}, respectively (Anonymous, 2006-07). India occupies a premier position in world oilseed scenario. Among the oilseed crops, rapeseed-mustard though confined to the northern and eastern plains of the country contributes nearly 32.0 per cent of the total oilseed production of the nation (Pant *et al.* 2008). In Jammu and Kashmir, it is cultivated both under rainfed as well as irrigated situations over an area of 64.30 thousand hectares with a production and productivity of 413 thousand quintals and 6.42 q ha^{-1}, respectively. (Anonymous 2006-07).

Maize-wheat and oilseed-maize are the most predominant existing cropping systems of the rainfed areas of the state. However, yield of wheat in the existing system is very low due to its complete dependence on rains which is often missing during sowing and critical growth stages of this crop as compared to rapeseed-mustard. Since rapeseed-mustard is more a dry land crop than wheat and also because of its wider adaptability and suitability for early planting to exploit moisture of rainy (kharif) season, it has emerged as a potential replacement for wheat in rainfed situations.. In the present day of intensive agriculture the crop plant is unable to use all the applied nutrients in its short life span, therefore fertilizer scheduling is to be done on the basis of cropping sequence rather than individual crop to utilize residual plant nutrients for their efficient, economical and judicious use. The salient characteristics of inceptisol of the rainfed agro-ecosystem are low in organic carbon, slightly alkaline to acidic in reaction, $CaCO_3$ accumulation in the upper 150 cm of soil, moderate profile development and low biological activities due to high friability, the soils are prone to erosion. the rainfed soils are generally low in fertility due to poor organic matter content and nutrient poor materials on which they are formed.

Presently fertilizer application is based on the nutrient requirement of individual crop and the carry over effect of manure and fertilizer applied to preceeding crop are generally ignored. Further applications of inorganic fertilizer even in balanced amount does not sustain the soil health. Besides the use of chemical fertilizer causing environmental hazards, necessitated the need to develop a sustain production system with maximum productivity (Panwar, 2008).

The integrated use of fertilizer and organics like farm yard manure and vermicompost assume greater importance as both improves the soil productivity and sustainability and brings down the mounting pressure on inorganic fertilizer substantially (Pathak *et al.* 2002).

Wide spread sulphur deficiency has been reported in soils of Jammu region of Jammu and Kashmir state (Ganjoo, 1994; Koul, 1997) and is a major constraint in agricultural production, especially in oilseed crops.

Intensive cropping coupled with cultivation of high yielding varieties have extensively exhausted soil fertility not only in respect of macro-nutrients but also micro-nutrients. S and Zn have specific vital roles in growth, development, bio-synthesis of proteins and amino acids and overall quality of crops (Dwivedi *et al.* 2002). Micronutrients deficiencies of Zn and B are widespread in hill soils of India and are especially associated with specific soil, crop and their properties (Jalali *et al.* 2006). The requirement of boron vary greatly among crops and between soil and climatic conditions. Boron deficiency can cause reduction in crop yield and impair crop quality (Sharma, 2008).

Due to the ever increasing cost of inorganic chemical fertilizers, their use in combination with organic manures has become imperative for sustained crop production and maintenance of soil health (Nanjappa *et al.* 2001).

However due to paucity of organic sources of nutrients and their inability to meet total nutrient requirements to sustain large scale productivity goals to meet the demand of growing population, their integrated use with chemical fertilizers is inevitable. The productivity of soil cannot be sustained with the fertilizer alone as application of fertilizer alone has led to deterioration in health and productivity of rainfed soils.

With these points in view, a field experiment on "**Influence of inorganics and organics on soil characteristics and crop yield under rainfed maize-gobhi sarson sequence**" was conducted during 2006-07 and 2007-08 at Dry Land Research Sub-Station (DLRSS), SKUAST, Jammu with the following objectives.

1) To study the native soil status of N, P, K, S, Z and B under maize- oil seed based cropping sequence of Jammu region.
2) To find out integrated effect of organic and inorganic nutrients on grain and stover yield of maize.
3) To find out the residual effects of inorganics and organics on succeeding gobhi sarson crop.
4) To monitor the changes in physico-chemical properties and soil fertility.

Chapter-II

REVIEW OF LITERATURE

CHAPTER - II

REVIEW OF LITERATURE

In this chapter attempts has been made to review the work done in India and abroad, pertaining to "**Influence of inorganics and organics on soil characteristics and crop yield under rainfed maize-gobhi sarson sequence**".The available literature has been discussed under the following headings:

2.1 Response of maize-gobhi sarson or related oilseed based cropping sequence to inorganic fertilizer.

2.2 Response of maize-gobhi sarson or related oilseed based cropping sequence to organic fertilizer.

2.3 Effect of Integrated Nutrient Management on soil characteristics and crop yield under maize-gobhi sarson or related oilseed crops.

2.4 Total nutrient uptake.

2.5 Soil fertility status after each cropping cycle.

2.1 Response of maize-gobhi sarson or related oilseed based cropping sequence to inorganic fertilizer

This has been discussed under the following sub-headings:

2.1.1 Response of maize or related cereal crops due to direct effect of NPK in the absence of S, Zn and B.

2.1.2 Response of maize or related cereal crops due to direct effect of NPK in the presence of S, Zn and B.

2.1.3 Response of gobhi sarson or related oilseed crops due to direct effect of NPK in the absence of S, Zn and B.

2.1.4 Residual effect of S, Zn and B applied to maize on succeeding gobhi sarson or related oilseed crops.

2.1.5 Response of maize based cropping system in the absence of S, Zn and B.

2.1.6 Response of maize based cropping system in the presence of S, Zn and B.

2.1.1 Response of maize or related cereal crops due to direct effect of NPK in the absence of S, Zn and B.

Mishra (1993) reported from Madya Pradesh that maize var.Ganga-5 gave maximum grain yield (20.82 q ha^{-1}) when fertilized with 100, 60 and 40 kg ha^{-1} N, P_2O_5 and K_2O, respectively and resulted in 111.5 per cent increase in grain yield over the control. However, Gill *et al.* (1993) reported under constraint of irrigation, maximum maize grain yield of 22.9 q ha^{-1} with the application of 80, 40 and 40 kg ha^{-1} N, P_2O_5 and K_2O, respectively. Gill *et al.* (1993) further reported from Ludhiana that maize var. "Navjot" gave maximum grain yield (32.6 q ha^{-1}) when fertilized with 120, 60 and 30 kg ha^{-1} N, P_2O_5 and K_2O, respectively. Maize gave average grain yield of 1302 kg ha^{-1} when fertilized with 80 kg N and 40 kg P_2O_5 ha^{-1} at Banswara (Rajasthan) (Anonymous,1994,95a). Under rainfed conditions of Himachal Pradesh , Suri *et al.* (1995) reported that the application of 90,45 and 20 kg ha^{-1} N,P and K gave maximum grain yield of maize (52.5q ha^{-1}). Maximum grain yield of maize (62.79 and 41.27 q ha^{-1}) was obtained with 100 per cent NPK during 1993 and 1994 by Manuja and Chakor (1995). Kumar and Singh(1995) reported maximum yield (60 q ha^{-1}) of maize with 100 per cent recommended NPK without FYM, S and Zn. Srinivas and Shrinivasa (1998) reported from Andhra Pradesh that maize gave mean yield of (51.3 q ha^{-1}) with recommended dose of fertilizers. While Singh *et al.* (1999) reported that maize crop at

New Delhi gave 20.37 q ha^{-1} grain yield and 27.11 q ha^{-1} stover yield with application of 120, 60 and 40 kg ha^{-1} N, P_2O_5 and K_2O, respectively. Similarly, 27.5 q ha^{-1} grain yield of maize was reported with the application of 120, 60, 40 kg N, P_2O_5 and K_2O, respectively by Saikia and Pandey (1999) from New Delhi.

Vats *et al.* (1999) reported that in maize, maximum response (21.3 q ha^{-1}) was obtained with profit maximizing dose of 150, 75 and 75 kg ha^{-1} N, P and K respectively at Ludhiana (alluvial soils) and at Coimbatore (medium black soils) Maximum response (21.2 q ha^{-1}) was obtained with profit maximizing dose of 142, 71 and 37 kg ha^{-1} N, P and K , respectively.

2.1.2 Response of maize or related cereal crops due to direct effect of NPK in the presence of S, Zn and B.

Mehta *et al.*(2005) reported that application of 60 kg S ha^{-1} significantly recorded higher seed and stover yields over 0 and 30 kg S ha^{-1} by 29.1 and 11.0 and 25.1 and 9.5% respectively. The improvement in maize yield attributes with the application of study in cognizance with findings of Singh (2001) and Sinha *et al.*(1995).

Karki *et al.*(2005) reported that the application of 20t FYM+5 kg Zn ha^{-1} resulted in the highest contents of organic carbon (0.48%) and available N (191.6 kg ha^{-1}), P (15.2 kg ha^{-1}), K (185.7 kg ha^{-1}) and Zn (1.20 ppm).

2.1.3 Response of gobhi sarson or related oilseed crops due to direct effect of NPK in the absence of S, Zn and B.

Singh (1984) reported that the Indian mustard (*Brassica juncea*), var. 'Varuna' gave maximum yield when fertilized with 60 kg N, 40 kg P_2O_5 and 20 kg K_2O ha^{-1} under dryland condition of farmers field in Rajasthan, whereas, Tomer and Tiwari (1990) reported that maximum seed yield of Indian mustard was 18.22 q ha^{-1} with recommended dose of fertilizers 1984-85 from Morena (Madya Pradesh). Similarly, soybean gave maximum average grain yield(1786 kg ha^{-1}) at Jabalpur (Madya Pradesh) when fertilized with 20 kg N, 60 kg P_2O_5 and 20 kg K_2O (Anonymous,1991,92a). Kumar (1992) reported that standard variety of *B.juncea* gave maximum grain yield of (12.94 q ha^{-1}) with recommended dose of fertilizers under irrigated conditions in Punjab. However, under rainfed conditions of Uttar Pradesh, Tomer *et al.* (1992) reported significantly higher yield of mustard (14.33 q ha^{-1}) when it was fertilized with 120, 60 and 60 kg ha^{-1} N, P_2O_5 and K_2O respectively under rainfed condition. Gill *et al.* (1993) reported from Ludhiana that under rainfed condition gobhi-sarson (*Brassica napus* sub sp.Oleifera var.*annua*)gave maximum grain yield (13.3 q ha^{-1}) when fertilized with 125, 45 and 30 kg ha^{-1} N, P and K respectively. Similar highest seed yield of rapeseed (*B.napus*) (18.1 q ha^{-1}) was recorded with the application of 120 kg N and 60 kg P_2O_5 ha^{-1} Narang *et al.* (1993a). Singh *et al.* (1994) reported that *Brassica juncea* cv.T-59 gave highest seed yield of 18 q ha^{-1} with the application of 90 kg N 90 kg P_2O_5, 60 kg K_2O ha^{-1}, while Dubey *et al.* (1994) reported maximum seed yield (15.12 q ha^{-1}) from Madya Pradesh when Indian mustard (*B.juncea*) was fertilized with 90, 60 and 40 kg ha^{-1} N, P_2O_5 and K_2O respectively. Similarly, Rajput *et al.* (1994) Reported that the maximum yield of Ethiopian mustard was 20.37 q ha^{-1} with the application of 100 and 75 kg ha^{-1} N and P respectively. At Jabalpur soybean gave maximum mean grain yield (825 kg ha^{-1}) when fertilized with 20 kg N, 60 kg P_2O_5 and 20 kg K_2O (Anonymous,1994-95a). Sharma *et al.* (1999) reported from New Delhi that mustard (*B.juncea*) gave 19.06 q ha^{-1}

yield with 80, 40 and 40 kg ha^{-1} N, P and K respectively whereas under farmers practice (60 kg N+57 kg P_2O_5 ha^{-1}) mustard gave 12.81 q ha^{-1} yield.

2.1.4 Residual effect of S, Zn and B applied to maize on succeeding gobhi sarson or related oilseed crops.

Many scientists reported that when sulphur was applied to one crop then it can take care of S requirements of succeeding crop in rotation. Takkar and Rhandhawa (1978) reported that wheat crop significantly responded to residual effect of zinc applied to groundnut crop at the rate of 112 kg Zn ha^{-1}. Similarly, Sakal *et al.* (1985) reported that there was residual effect of pyrites application to groundut at 0.4 and 0.8 t ha^{-1} levels on wheat crop. The residual effect of pyrites increased wheat grain yield from 2560 to 3800 kg ha^{-1} whereas in press mud (1.64% S), FYM (0.76% S) application to groundnut, yield of wheat increased from 2480 to 3480 and 3280 kg ha^{-1}, respectively. Sulphur uptake was also increased due to residual effect.

Singh and Sahu (1986) reported residual effect in the following crop in rotation when mustard (*B.juncea*) was applied with elemental sulphur. Pasricha *et al.* (1988) reported that in groundnut -wheat sequence,wheat gave a significant response (6-8 q ha^{-1}) to residual S from both gypsum and pyrite applied to groundnut. Similarly, Biswas and Tewatia (1991) reported from Ludhiana that fertilizer S applied to one crop could be sufficient to meet S requirement of succeeding crop in groundnut-wheat rotation. At Jabalpur (M.P.) significant residual effect was observed in wheat due to sulphur and zinc (ZnO and $ZnSO_4$) when applied every year or alternate year to soybean (Anonymous 1991-92a). However, Saarela and Hahtonen (1993) reported from pot experiment in Finland that residual effect of S appled to turnip rape (*B.campestris* var.*Oleifera*) was not significant. On the contrary, Patel *et al.* (1994) reported significant residual effect of S application application to groundnut at 30 kg S ha^{-1} on the subsequent crop in groundnut-wheat rotation (Anonymous 1994-95a). Saroa *et al.* (1995) also reported significant residual effect of sulphur applied to soybean upto 80 kg P_2O_5 ha^{-1} through SSP containing 12% S on wheat grain yield at Ludhiana in soybean-wheat rotation. Similarly, Tiwari (1995) reported from U.P. that residual effect of S (gypsum) applied to mustard increased the grain yield of rice by 710 kg ha^{-1}. Hazara (1997) reported 26 per cent increase in yield of wheat due to residual effect of 40 kg S ha^{-1} applied to groundnut in Bihar in groundnut-wheat rotation . In groundnut-oat sequence, the residual effect of S applied to groundnut increased the yield of oat by 21 per cent . Mankotia and Sharma (1998) reported non-significant residual effect of graded levels of N, P (SSP) and FYM on maize in gobhi-sarson + toria- maize cropping system in Himachal Pradesh.

2.1.5 Response of maize based cropping system in the absence of S, Zn and B.

Soni and Vats (1989) reported from Ludhiana that maximum grain yield (52.41 q ha^{-1}) was obtained in maize-mustard sequence on chestnut brown soils at 100 per cent NPK fertilization . Tomar and Tiwari (1990) reported from Morena that maize mustard gave total grain yield of 39.07 q ha^{-1}, when fertilized with recommended dose of NPK. Raghuwansi *et al.* (1991) from JNKVV, Indore, Madya Pradesh that wheat equivalent yield (q ha^{-1}) for soyabean-wheat rotation was 87.1 and 55.8 q ha^{-1} during 1983-84 and 1984-85, respectively. Likewise they further added that wheat equivalent yield of 69.7 and 48.3 q ha^{-1} with NPK application through urea, DAP and MOP, during 1983-84 and 1984-85, respectively to soybean (T-49) – wheat in Madya Pradesh. At Jabalpur, yield of soybean was significantly lower with the application of NPK only (Anonymous,1991-92a).

Patil and Shinde (1992) reported from Jalgaon that in sesamum-sorghum cropping system, sesamum and sorghum gave 614 and 758 kg ha^{-1} grain yield, respectively with recommended NPK. They further reported that in groundnut-sorghum cropping system , groundnut and sorghum gave 1332 and 434 kg ha^{-1} yield respectively with recommended NPK.

Gill *et al.* (1994) reported from Ludhiana that with recommended NPK fertilization of maize-gobhi sarson (*B.napus* sub sp. *Oleifera* var. annua) cropping system resulted in maize grain yield of 30.27 and 38.28 q ha^{-1} and gobhi sarson yield of 16.96 and 19.39 q ha^{-1} in Hoshiarpur and Kapurthala, respectively. At Jabalpur (M.P.) soybean gave mean grain yield of 717 kg ha^{-1} and wheat gave 3258 kg ha^{-1} when fertlized with recommended dose of NPK (Anonymous, 1994-95). Reddy *et al.* (1996) reported from a study on maize and oilseed based cropping system in Andhra Pradesh that production efficiency of maize-Indian mustard rotation was 14.5 kg $ha^{-1}day^{-1}$ whereas for maize-groundnut , it was 23 kg $ha^{-1}day^{-1}$. Maximum production efficiency was observed in maize- sunflower rotation (28.7) kg $ha^{-1}day^{-1}$ and minimum in maize-Indian mustard (14.5) kg $ha^{-1}day^{-1}$ rotation. Maize equivalent yield was 2991 kg ha^{-1} in maize-Indian mustard sequence, whereas maize-sunflower rotation gave maximum maize equivalent yield of 5972 kg ha^{-1} with recommended NPK through urea, DAP and MOP.

Sahota *et al.* (1997) reported that maize-gobhi sarson (*B.napus*). Srinivas and Shrinivasa (1998) reported maximum maize grain equivalent yield was recorded in maize-groundnut cropping system (140.5 q ha^{-1}), whereas in maize-Indian mustard sequence, it was 81.3 q ha^{-1}.

The production efficiency of maize-groundnut was also higher (34.7 q $ha^{-1}day^{-1}$) compared to maize-mustard sequence(29.0 q $ha^{-1}day^{-1}$) with recommended dose of NPK.

2.1.6 Response of maize based cropping system in the presence of S, Zn and B.

The beneficial effect of FYM which is also a source of micro and secondary nutrients along with 100 per cent NPK reflected in the highest production in soybean-wheat-potato crop sequence giving 4.1 t ha^{-1} grain yield of soybean and wheat and 7.6 t ha^{-1} of potato tubers at Ranchi on acidic red loam soil(Anonymous,1984).

Among the four crop sequences tested under optimum NPK fertilization where source of P was SSP (12% S and 0.011% Zn), soybean-wheat and groundnut-wheat gave 48.80 and 55.42 q ha^{-1} wheat equivalent yield, respectively (Sahay, *et al.* 1989). At Sehore (M.P.) the yield of soybean and wheat improved significantly in the presence of sulphur and zinc in soybean-wheat sequence (Anonymous 1991-92a). In Himachal Pradesh, maize-gobhi sarson sequence produced 3520 kg ha^{-1} of maize and1867 kg ha^{-1} grain yield of gobhi sarson under rainfed conditions and 5040 kg ha^{-1} maize and 1734 kg ha^{-1}gobhi sarson grain under irrigated conditions with recommended levels of urea, SSP and MOP (Anonymous, 1994-95). As reported from Madya Pradesh, grain yield of soybean and wheat increased significantly in the presence of sulphur and zinc when applied every year or alternate year to soybean in soybean-wheat crop sequence (Anonymous 1994-95a).

Verma (1997) reported from Uttar Pradesh that with recommended NPK (P through SSP containing 12% S and 112 ppm Zn), maize-Indian mustard – green gram gave per hectare grain yield of 1867, 2676 and 440 kg during 1992-93 and 1955,2684 and 375 kg ha^{-1} during 1993-94, respectively. They further reported that in rice-Indian mustard-green gram crop rotation, maximum yield of rice was obtained (3.778 kg ha^{-1}) with 100 per cent NPK (P through SSP) while Indian mustard and green gram gave grain yield to the tune of 2111 and 428 kg ha^{-1} respectively, during 1992-93. During 1993-94, grain yield of rice, Indian mustard and green gram was 2711, 2333 and 348 kg ha^{-1} respectively.

Aulakh and Pasricha (1997) reported from Ludhiana that in soybean-wheat rotation, application of 80 kg P ha^{-1} through SSP gave maximum yied of soybean 25.7 q ha^{-1} and wheat 24.1 q ha^{-1}. Gupta and Dubey (1998) reported from their study on soybean-wheat-maize(fodder) cropping system conducted at Jabalpur, (M.P.) that the grain yield was highest in soybean (25.2 q ha^{-1}), wheat (44.2 q ha^{-1}) and maize (69.2 q ha^{-1}) when fertilized with S+FYM+ 100% NPK+ Zn gave yield of 22.8, 40.2 and 58.1 q ha^{-1}, respectively. Exclusion of Zn from the fertilizer schedule reduced the yield of soybean by 0.40 q ha^{-1}, wheat by 2.1 q ha^{-1} and maize fodder by 5.0 q ha^{-1} and exclusion of S reduced the yield of soybean by 1.4 q ha^{-1}, wheat by 2.1 q ha^{-1} and by maize fodder by 7.6 q ha^{-1}. Similarly, Rao *et al.* (1998) reported from Madya Pradesh that in soybean-wheat sequence, soybean gave maximum grain yield (2.31 t ha^{-1}) with recommended NPK fertilizers along with application of S and Zn @ 20 kg ha^{-1}, respectively and FYM @ 16 t ha^{-1}, respectively, while while wheat gave maximum grain yield (3.25 t ha^{-1}) with recommended NPK fertilizer alongwith 20 kg S ha^{-1} and 6 kg Zn ha^{-1} during first year (1992-93). With same fertilizer schedule, during second year (1993-94), the soybean and wheat yield was 1.84 and 3.93 t ha^{-1}, respectively. Mankotia and Sharma (1998) reported from HPKV, Palampur, Himachal Pradesh that in maize-gobhi sarson equivalent yield of 1391 kg ha^{-1} was obtained with application of 80 kg P through SSP (12% S, 112 ppm Zn). From the foregoing review, it appears that there is significant increase in yield of maize and gobhi-sarson or related oilseed crops due to application of S and Zn. Application of S and Zn to a crop has sufficient residual effect also on succeeding crops. In different agro-climatic zones, different maize based crop sequences have been found to give higher yield in presence of S and Zn as compared to yield in absence of S and Zn.

2.2 Response of maize-gobhi sarson or related oilseed based cropping sequence to organic fertilizer.

This has been discussed under the following sub-headings:

2.2.1 Direct effect of farm yard manure and vermicompost under maize-based cropping sequence

2.2.2 Residual effect of farm yard manure and vermicompost applied on succeeding gobhi sarson or related oilseed crop

2.2.1 Direct effect of farm yard manure and vermicompost under maize-based cropping sequence

Mahala *et al.* (2006) reported that the FYM @ 10 tonnes ha^{-1}had a significant effect on the grain and stover yields of maize, increasing the grain yield by 9.70 and 11.86 % and stover yield by 9.82 and 9.11 % over the control during 2001 and 2002 respectively. FYM had the favorable effect on the chemical, physical and biological properties of soil, resulting in better growth conditions for the crop, leading to higher grain and stover yields. The available N and P status of the soil was also significantly improved under FYM application. FYM @ 10 tonnes ha^{-1} improved the available N by

6.2 and 7.9 % and available P by 11.9 and 13.4 % compared with its non-application during 2001-02 and 2002-03 respectively.

Mehta *et al.* (2005) reported that the application of FYM @ 10 t ha^{-1} significantly improved the cobs/plant, rows/cob, weight of cob, grain weight/cob, seed index and seed and stover yield, N, P, S and Fe uptake by seed and stover yield was to the extent of 13.9 and11.2 % with the incorporation of 10 t FYM ha^{-1}over no organic farming .It may be owing to beneficial effect of FYM on crop growth and various physiological parameters, which affected yield attributes, yield and nutritional status positively. Khandey and Thakur (1990) also reported similar, effect on seed and stover yields. In general, improved nutritional status of seed and stover under FYM application primarily seems to be on account of enrichment of these nutrients in soil while secondarily on maintenance of better physico-chemical and biological properties of the soils. Babariya and Patel (1980) and Sharma and Gupta (1998) also reported increase in uptake of nutrients by maize when fertilized with FYM.

Kumar and Puri (2001) reported that FYM application recorded 20.55 and 35.65 % more grain and sover yields respectively over no FYM application. The increase in yield may be owing to the favourable effects of FYM on growth and yield attributes in plant. (Minhas and Singh, 1998) also recorded higher yield with FYM application in maize. The FYM application recorded more agronomic efficiency than no FYM. It might be due to the presence of nutrients in FYM which increases the efficiency.

Nanjappa *et al.*(2001) reported that the highest grain yield was recorded with 75 % recommended dose of fertilizer + vermi-compost 2.7 tonnes ha^{-1} which was on par with 75 % recommended dose of fertilizer + FYM 6 tonnes ha^{-1}, 100 % recommended dose of fertilizer, 50% recommended dose of fertilizer + FYM 12 tonnes/ha, recording 6.05, 5.99, 5.65 and 5.64 tonnes ha^{-1} grain respectively. The vermi-compost besides having higher available N, P_2O_5 and K_2O status has rich population of microbes which might have degraded and mobilized the nutrients to available form. Further several enzymes and hormones present in the vermi-compost might have stimulated the growth and development of maize. The higher yield with 75 % recommended dose of fertilizer + FYM 6 tonnes ha^{-1} was due to the added FYM which acts as store-house of several macro- and micro-nutrients, apart from improving the soil physical conditions. They further concluded that the combined application of 50 or 75 % recommended dose of fertilizer +12 tonnes/ha FYM or 2.7 tonnes ha^{-1} vermi-compost would enhance the productivity of maize apart from reducing the loss of nutrients in the soil.

Kale *et al.* (1991) suggested that the quantity of chemical fertilizers could be reduced by 25-50 % when applied with vermi-compost.

2.2.2 Residual effect of FYM and VC on succeeding gobhi sarson or related oilseed crop.

Mahala *et al.* (2006) reported that the residual effect of FYM 10 tonnes ha^{-1} significantly improved the seed and straw yields of mustard over no FYM application during both the years. The results indicating a profound influence of residual effect of FYM on mustard productivity are in close conformity with the findings of Sahoo and Panda (1999). The uptake of N and P by mustard was also significantly improved by the residual effect of FYM applied to preceding crop. Further, the residual effect of FYM had significant positive effect also on the available N and P status of the soil after harvest of mustard. This might be due to fact that it modified the soil environment besides improving the physical properties of the soil, and also the slow microbial decomposition of humus gradually increased the nutrients during the succeeding crop, which was manifested in higher nutrient uptake by the mustard crop. Jamwal (2006) reported that the mean available P after chickpea and gobhi sarson harvest was the highest with 10 tonnes FYM/ha, closely followed by recommended NPK + 20 kg $ZnSO_4$ ha^{-1} and the recommended NPK. This increase in available P status of the soil might be due to favourable effect of FYM and the residual effect of applied fertilizers.He further concluded that application of 10 tonnes FYM ha^{-1} and recommended dose of NPK to maize during kharif had significant residual effects on the succeeding crops of chickpea and gobhisarson. Patidar and Mali (2002) found similar results. Out of the total utilizable nutrient content of FYM, only one-third N and two-thirds P are available to the current season crop, leaving the rest to the succeeding crops (Yawalkar *et al.* 1992)

2.3 Effect of Integrated Nutrient Management on soil characteristics and crop yield under maize-gobhi sarson or related oilseed crops

Kumpawat (2004) reported that integrated use of organic and inorganic fertilizers improved the organic carbon and infilteration rate. Among the fertilized plot, more organic carbon was present in FYM-incorporated plots. This result confirms the finding of Kumar *et al.* (2001). Available P was enhanced in organic manured plots, whereas it was slightly decreased in inorganic fertilized plots. The maximum build-up was with FYM. There was a decline in vailability of K in all the treatments except in 100% recommended N through crop residue-incorporated plots. The magnitude of decline was high in inorganic but low in organic added plots. The findings corroborated the results of Raju and Reddy (2000).

Sharma and Gupta (1998) reported that the application of 100% NPK and their combined use with orgnic manure, viz. FYM, white popinac leaves and blackgram straw showed remarkable increase in the water-holding capacity, organic carbon content and available N and P status of soil while bulk density and available K status decreased in all the treatments. Integrated nutrient management involving conjunctive use of organic, inorganic and crop residues may improve the soil productivity (Patra *et al.* 2000, Kumar *et al.*2001) and system productivity becomes sustainable (Raju and Reddy, 2000).

Kumar *et al.*(2005) reported from Kangra (Himacal Pradesh) from a study on maize(Zea mays)-gobhi sarson (*Brassica napus* ssp.oleifera var.annua) cropping system under rainfed conditions that the total grain production was higher (110.5 q ha^{-1}) when both crops in the system are given 150 % of the recommended NPK and was 28 and 26 % higher over the recommended fertilizer application in maize and gobhi sarson, respectively. However,an application of 150 % of the recommended NPK to maize and 100% NPK+ 10 t ha^{-1} FYM to gobhi-sarson also resulted in statistically similar grain yield (108 q ha^{-1}). Application of 10 t FYM along with 100 % NPK either to one or both crops increased the system productivity by 7.7 % compared to the 100% NPK application. The N, P and K uptake in the system was higher when both crops in the system were given 150 % NPK, followed by 100 % NPK +10 t FYM ha^{-1} application.

2.4 Total Nutrient Uptake

The uptake of total N, P, K, S, Zn and B has been discussed under the following sub-heads:

2.4.1 Nitrogen, Phosphorus, Potassium, Sulphur, Zinc and Boron uptake by maize/cereal crop.

2.4.2 Nitrogen, Phosphorus, Potassium, Sulphur, Zinc and Boron uptake by gobhi sarson /oilseed crop.

2.4.3 Nitrogen, Phosphorus, Potassium, Sulphur, Zinc and Boron uptake by maize-gobhi sarson sequence or related crop sequence.

2.4.1 Nitrogen, Phosphorus, Potassium, Sulphur, Zinc and Boron uptake by maize/cereal crop

Rajgopal and Mehta (1971) reported that hybrid maize removed 222.2, 23.3, 203.5 and 808 mg N, P, K and Zn pot^{-1}, respectively when supplied with 100 kg P_2O_5 ha^{-1} and 5.0 ppm zinc along with uniform dose of 200 kg N [$(NH_4)_2$ SO_4] and 100 kg K (K_2SO_4). On the other hand in field with yield level of 113 q ha^{-1}, removed142, 124, 156 and 12 kg ha^{-1} of N, P, K and S, respectively, alongwith removal of 113 g Zn ha^{-1} (Anonymous,1983). While Jain *et al.* (1984) estimated that the removal of N, P, K and S in maize crop producing 51.4 q ha^{-1} was 300.6, 35.8, 180.7 and 18.7 kg ha^{-1}, respectively. Nad and Goswamy (1984) reported that the cereal crop reducing 4000 kg ha^{-1} grain removes 12-16 kg S. In a pot study, Singh and Singh (1984) reported that maize removed 1533.1μg of zinc with yield level of 40.4 g pot^{-1} fertilized with 20 ppm zinc. At Jabalpur, K uptake was highest in case of fodder maize followed by wheat and soyabean in soyabean-wheat-maize (fodder) cropping sequence but P uptake by fodder maize was just half of the wheat (Anonymous,1988). Maize crop removed 99.99,18.46 and 28.92 kg ha-1 N, P_2O_5 and K_2O, respectively with 100 per cent NPK fertilization(Anonymous 1989-90). Prasad and Kerketta (1991) reported that maize crop removed 162.0, 22.1 and 45 kg ha^{-1} N, P_2O_5 and K_2O, respectively under 100 per cent NPK fertilization. In another study, maize removed 194.6, 36.0 and 57.1 kg ha^{-1} N, P and K, respectively when fertilized with 100 per cent N, P and K only and 24.2, 43.2 and 68.3 kg ha^{-1}, respectively in combination with 20 t ha^{-1} FYM (Anonymous 1999).

Mishra (1993) reported from Madya Pradesh that Maize removed 66.5,77.4 and 95.2 kg N ha^{-1} with application of 100, 150 and 200 kg N ha^{-1} respectively. Similarly, Sawat and Dayanand (1994) reported from New Delhi that maize (Zea *mays*) removed maximum N (260.25 kg ha^{-1}) and K (92.96 kg ha^{-1}) with application of 225 kg N and 50 kg P. It was reported from Madya Pradesh that sulphur application increase the uptake of N, P, K, S and Zn in wheat due to its residual effect and residual effect was maximum with sulphur. Zn as $ZnSO_4$ applied every year or alternate year to soybean in soybean-wheat crop sequence(Anonymous 1994-95a). Tandon (1995) reported from New Delhi that range for sulphur uptake by main produce of maize varied from 2.2-4.6 kg S t^{-1}, with mean value of 3.4. At Hyderabad, maize crop (Zea *mays)* producing 144 g dry matter $plant^{-1}$ removed 206.3, 40.3 and 183.2 kg ha^{-1} N, P_2O_5 and K_20, respectively (Sreenivas and Satyanarayana,1996).

2.4.2 Nitrogen, Phosphorus, Potassium, Sulphur, Zinc and Boron uptake by gobhi sarson /oilseed crop

Singh *et al.* (1993) from Samastipur, found that zinc uptake in seed and stover increased with increasing zinc application. Shukla and Kumar (1997) from Pantnagar, reported significantly higher nitrogen uptake (76.6 kg/ha) at 120 kg N/ha than lower levels. Tomar *et al.* (1997) from Haridwar, reported that increasing levels of nitrogen upto 180 kg/ha significantly increased the seed and stover nitrogen, phosphorus and sulphur uptake. Garnayak *et al.* (2000) working at IARI, New Delhi, noted that uptake of nitrogen, potassium and sulphur increased significantly with the application of nitrogen upto 120 kg/ha and phosphorus upto 80 kg/ha.

Malewar *et al.* (2001) from the trials conducted at Parbhani, observed maximum uptake of zinc (256.3 g/ha) and boron (201.9 g/ha) at 30 kg $ZnSO_4$ and 10 kg borax/ha.

Sharma and Jalali (2001) noted that total sulphur uptake increased significantly with increasing levels of sulphur upto 60 kg/ha under hilly soils of Jammu. Shukla (2002) from Pantnagar, reported that crop receiving integrated application of recommended NPK with farm yard manure, sulphur, zinc, boron and *Azotobacter* removed maximum nutrient of 184.4 kg N, 68.3 kg P_2O_5 and 223.6 kg K_2O/ha. Mandal and Sinha (2002) from Coochbehar, found that combined application of recommended NPK and farm yard manure (10 t/ha) resulted in maximum nitrogen (162.7 kg ha^{-1}), phosphorus (41.3 kg ha^{-1}), potassium (134.2 kg ha^{-1}) and sulphur (16.0 kg ha^{-1}) removal by the crop. Bharti and Prasad (2003) from Pusa (Bihar), reported that application of 30 and 45 kg S ha^{-1} being on par recorded significantly higher sulphur uptake (21.6 and 22.2 kg ha^{-1}) than the 0 and 15 kg S/ha. Giri *et al.* (2003) from Akola, noted that total uptake of sulphur, nitrogen and phosphorus were significantly higher (23.5, 120.6 and 24.2 kg ha^{-1}) with 30 kg S ha^{-1}.

Rana and Rana (2003) from IARI, New Delhi, found significant increase in sulphur and nitrogen uptake upto 40 and 80 kg N/ha, respectively. Singh and Prasad (2003) from the experiments conducted at CSAUAandT, Kanpur, concluded that uptake of nitrogen, phosphorus and potassium increased with increasing levels of nitrogen fertilizer upto 120 kg ha^{-1}. Singh *et al.* (2004) working at Bikaner, indicated that nitrogen and sulphur content and uptake both in seed and stover enhanced due to application of 90 kg N ha^{-1} over its preceding doses. Singh and Meena (2004) from Bharatpur, reported that crop fertilized with 80 kg N and 60 kg S/ha removed 74 and 34 per cent more nitrogen than that of control.

Thanki *et al.* (2004) from Navsari, reported significantly higher nitrogen (52.5 kg/ha), phosphorus (10.9 kg ha^{-1}) and potassium (40.2 kg ha^{-1}) uptake at 10 t FYM ha^{-1} over control. Lanjewar and Selukar (2005) from Akola, reported that uptake of nitrogen (41.3 kg ha^{-1}), phosphorus (11.81 kg ha^{-1}), potassium (25.4 kg ha^{-1}) and sulphur (6.17 kg ha^{-1}) in seed increased significantly with corresponding increase in the doses of phosphorus upto 50 kg ha^{-1}. Rana *et al.* (2005) working at IARI, New Delhi, noted that increasing phosphorus fertilization upto 50 kg ha^{-1}resulted in maximum phosphorus (24.5 kg ha^{-1}), sulphur (32.3 kg ha^{-1}) and boron (211 g/ha) uptake. Kumar *et al.* (2006) from Agra, reported that crop fertilized with 60 kg S ha^{-1}removed significantly higher sulphur (19.1 kg/ha) than control (9.7 kg/ha). Singh and Sinsinwar (2006) working at Bharatpur, noted that application of farm yard manure (5 t/ha) coupled with *Azotobacter* and *Azospirillum* increased the uptake of nitrogen and sulphur in seed from 34.6 to 50.6 and 5.9 to 8.5 kg ha^{-1}, respectively over control. Nitrogen, Phosphorus, Potassium, Sulphur, Zinc and Boron uptake by maize-mustard sequence or related crop sequence.

2.4.3 Nitrogen, Phosphorus, Potassium, Sulphur, Zinc and Boron uptake by maize-gobhi -sarson sequence or related cropping sequence

Nambiar and Ghosh (1984) reported that under optimum NPK application, oileed based cropping sequence like soybean-wheat and groundnut-wheat-guar removed 242 and 504 g Zn ha^{-1}, respectively with yield level of 5.7 and 26.2 t ha^{-1}, respectively. Intensive cropping system may remove upto 70 kg S ha^{-1} $year^{-1}$ from the soil (Tandon 1984a), while Nad and Goswami(1984) reported annual removal of 10 to 70 kg S ha^{-1}

Nambiar and Ghosh(1984) reported that soybean-wheat-maize cropping system removed about 49 kg S ha^{-1} $year^{-1}$. In the same rotation, when maize is taken as fodder crop,then sulphur uptake varied from 36 to 43 kg ha^{-1} at optimal to super optimal NPK inputs with single super phosphate as sulphur source.

Sharma *et al.* (1987) reported from a study on oilseed based cropping sequences, that groundnut-bread wheat and groundnut Indian mustard removed 193, 17.5, 106 and 27, 5.7 and 21 kg ha^{-1} N, P and K respectively. Uptake of P and K by crops in acidic soils of Ranchi is generally very low as compared to N. The low P and K uptake by the crop sequence soybean-potato-wheat in these acid soils may be attributed to very high fixation capacity and low native source of K (Anonymous, 1988). Cereal based crop rotation having maize, potato and rice as one of the crop remover higher amount of NPK than oilseed based cropping systems. Groundnut-wheat rotation removed 115.1, 16.86 and 84.92 kg ha^{-1} $year^{-1}$ N, P and K respectively (Thakur *et al.* 1990).

Islam *et al.* (1997) reported that in rice-mustard crop rotation, rice removed 9.49 kg S ha^{-1} with 100 per cent NPK + 25 kg S(gypsum), 7.6 kg S with 4 kg Zn (ZnO), 11.51 kg ha^{-1}S with 25 kg S ha^{-1} + 4 kg Zn ha^{-1} (ZnO) as compared to control (0.161 kg ha^{-1} Zn with 100 % NPK). Following mustard crop removed 4.21, 3.56, 4.08 and 2.94 kg ha^{-1} S and 0.077, 0.082, 0.094 and 0.54 kg Zn ha^{-1} with same treatments as in rice indicating that rice is heavy feeder of nutrient compared to mustard.

Sakal *et al.*(1999) reported that increasing levels of B and FYM progressively increased the B-uptake by grain and straw in both the crops(in maize-lentil cropping system).However, the B-uptake by straw was higher than grain which is attributed to higher B content in straw and more straw yield compared to grain. Cumultative B uptake (grain+straw) response in treatment (T_{13}) receiving 16 kg borax+5t FYM ha^{-1} was 399 g ha^{-1} being higher than 317 g ha^{-1}, the additive effect of B-uptake at 16 kg borax ha^{-1} alone (125 g ha^{-1}) and at 5 t FYM ha^{-1} alone (192 g ha^{-1}). This reflects the beneficial effect of FYM to enhance B availability to crops.

Panwar (2008) reported that in maize-mustard system, the maximum uptake of nutrient was found when 100% NPK was substituted either with 50 or 25% of N through farm yard manure in maize crop followed by 100% NPK to mustard crop. Higher production improvement in NPK content in plants of the treatment seems to be responsible for higher NPK uptake in both individual crops and the system. Yadav *et al.* (2005) also reported that the uptake pattern of nutrients in rice-wheat system behave similar manner to yield of component crops.

2.5 Soil fertility status after each crop cycle

Fertility status of soil after harvest of each crop has been under the following sub-heads:

2.5.1 Fertility status of soil after maize or related cereal crops

2.5.2 Fertility status of soil after harvest of gobhi sarson or related oilseed crops

2.5.3 Fertility status of soil after harvest of maize-gobhi sarson or related oilseed crop sequences

2.5.1 Fertility status of soil after maize or related cereal crops

Sakal et al. (1985) reported that the soil available Zn after harvest of maize/cereal crops fertilized with 5 and 10 kg ha^{-1} as $ZnSO_4$ and ZnO was 1.60, 2.97 and 2.29, 3.61 ppm, respectively as against 0.48 ppm in control. Zinc frits did not improve soil available Zn as they are sparingly soluble material and release Zn very-very slowly. After harvest of maize crop, the available nitrogen, phosphorus and potassium contents of the soil were 507.8, 27.6 and 241.5 kg ha^{-1} respectively (Anonymous,1988-89). However in another study the available nitrogen, phosphorus, potassium and contents after the harvest of maize were found to be 489.1, 14.3, 164.6 and 1.53 kg ha^{-1} respectively(Anonymous, 1988-89). Still another study reported that available nitrogen, phosphorus and potassium contents, after harvest of maize was 652.1,31.5 and 129.1 kg ha^{-1}, respectively and organic carbon contents was 0.52(Anonymous,1990-91). In another study these values were 677.2, 33.9 and 162.8 kg ha^{-1} and organic carbon was 0.56 per cent after the harvest of maize crop (Anonymous,1992,93).

Indulkar and Malewar (1994) reported that the available Zn decreased in control by 0.08 ppm after the harvest of sorghum. This indicates that sorghum removes sufficient amount of zinc, the Zn content in soil decreases significantly if it is not added from outside.

2.5.2 Fertility status of soil after harvest of gobhi sarson or related oilseed Crops

Kumar(1992) reported that available nitrogen, phosphorus and potassium of the soil after the harvest of gobhi sarson (B.napus sub sp. Oleifera var. annua) crop of 1990-91 was 316.5,16.25, 182.59 kg ha^{-1}, respectively. The organic carbon and pH was 0.71 per cent and 5.63 respectively. The respective values were 329.31, 18.10, 198.12, 0.69 and 5.3 during 1991-92. On the other hand, Chaudhary (1998) reported that available nitrogen, phosphorus , potassium and sulphur was 374.65, 20.97, 294.91 and 34.33 kg ha^{-1} respectively when the gobhi sarson was fertilized with 100 kg N, 60 kg P_2O_5 (through SSP containing 12% S) and 45 kg K_20 ha^{-1}. With the application of above mentioned dose of fertilizer, the N, P and K status of soil was maintained while that of available S and organic carbon decreased by 0.11 per cent. Similarly, Mankotia and Sharma (1998) indicated a build up of nitrogen and phosphorus and slight decline in available potassium due to N, P and FYM fertilization of gobhi sarson. After the harvest of gobhi sarson, the available nitrogen was 294.5 and 292.1, available phosphorus was 209.0 and 217.8 kg ha^{-1}.

2.5.3 Fertility status of soil after harvest of maize-gobhi sarson or related oilseed cropping sequence

Rao and Sharma (1976) reported from Pantnagar that in maize-rapeseed-wheat sequence, there was slight increase during first year and appreciable increase during second year in the soil pH, but organic carbon, total nitrogen, available phosphorus and available potassium decrease after rapeseed crop at 100 percent NPK level. However, decrease in organic carbon was non-significant durng second year. Biswas et al. (1977) clearly indicated that application of organic manures enhances Zn availability for the entire cropping system and maintain the soil fertility level of Zn also. Dhillon and Dev (1979) reported from Ludhiana that after two cycle of groundnut-wheat rotation, available N increased in both layers (0-15 and 15-30 cm) and this build up was more in the surface layer and in soil having low initial fertility level. However, the available P and K status of both the layers declined after two cropping cycles and this reduction was more in soil with high fertility status. Growing a groundnut crop resulted in a decrease in the available nutrient status of the soil. Rao and Ghosh (1981) reported that continuous intensive cropping for seven years without S application reduced available sulphur to about 50 per cent of the initial level. At Jabalpur, in Soybean-wheat-maize-fodder sequence, soil available Zn as 0.7 ppm with 100 per cent NPK, 1.0 ppm with 100 per cent NPK + FYM and 6.5 ppm with 100 per cent NPK+Zn whereas in control it was 0.9 ppm after 10 cropping cycles (Anonymous,1985). While in acidic red loam soil of Ranchi, there was slight decline in available Zn (9%) after soybean-wheat-potato cropping system when at 100 per cent NPK. Addition of FYM enhanced Zn contents in soil by 97 per cent and application of Zn recorded about three times the values obtained at 50 to 150 per cent NPK levels cropping cycles(Anonymous,1985). In medium black soils of Jabalpur, in soybean-wheat-maize fodder crop sequences there was increase in availability of nitrogen content by 84 per cent with 100 to 150 per cent NPK levels. Available P and K status also improved due to application of 150 per cent NPK with FYM(Anonymous,1985). Under intensive cropping (1971-82),available Zn decreased by 45 per cent in light textured alluvial soils at Ludhiana. Addition of Zn enhanced the level of available Zn markedly in medium black soil of Coimbatore, Jabalpur and Bhubneshwar (Anonymous,1985).Thakur et al. (1990) reported from Ranchi, Bihar that crop rotation (3 cycles) deplete organic carbon content of the sandy clay loam soil. However, sequences consisting of legumes had significantly higher organic carbon than that without legumes. Organic carbon content of soil after soybean-wheat rotation was found to be maximum (4.5 g ha^{-1}) and significantly higher than that obtained with other sequences. In general, available P status of soil during 1985-86 increased over the initial value irrespective of the crop sequence. Available K status of soil increased over the initial value under all sequences particularly after rabi crop.

Sharma and Gupta (1992) reported from JNKVV, M.P. that after two cropping seasons of soybean-wheat there was net depletion of available N, P, K and S in 30 cm soil layer of unfertilized plots. The plots treated with N and S, probably due to symbiotic biological fixation of atmospheric N by soybean and oxidation of pyrites, respectively. Available P and K however, showed net depletion except at 100 kg S ha^{-1}.

Sanyal et al. (1993) reported that in potato-groundnut-rice-cropping sequence, the N content of soil slightly improved or remained constant at 100 or 150 per cent recommended fertilizer dose or at 75 per cent NPK + FYM or with incorporation of the crop residue. The P status of soil was improved by 2-19 per cent under different treatments. The K status of the soil also improved wherever K was applied to crop.

Sinha and Sakal (1993) reported that in groundnut-wheat rotation, availability of S in soil was increased by pyrite, FYM and press mud. Mishra (1994) reported from Orrisa that after continuous cropping for 20 years, the available S in soil was 15.7 kg S ha^{-1} without S addition and 43.2 kg S ha^{-1} with S addition. Sudhir et al. (1997) reported from their studies on long term fertilization and continuous cropping at Bangalore that Zn concentration remain above critical limits, even without supplementary addition of this element from external source in alfisol.

Mankotia and Sharma (1998) reported from Himachal Pradesh that at the end of two years cropping system of gobhi sarson + toria-maize, the available N content did not register any change. While the available P was up by 5.2 kg P ha^{-1} and available K by 5.4 kg ha^{-1}.

Srinivas and Shrinivasa (1998) reported that in maize-groundnut, available N, P and K contents were 208.56 and 482 kg ha^{-1} after the harvest of maize-groundnut rotation during 1994-95 and respective values were 220, 58 and 525 kg ha^{-1} during 1995-96 indicate slight build up of N, P and K during second year. They further reported from Andhra Pradesh that available nitrogen, phosphorus and potassium contents were 200, 51 and 475 kg ha^{-1} after the maize-Indian mustard during1994-95 and these values were 188, 50 and 502 kg ha^{-1} during 1995-96. There was slight decline in N, P and K status of soil after the harvest of crops. Thakur *et al.* (1998) reported that after three years cycle in rice-linseed sequence, the available N, P and K content was 250, 28.1 and 90 kg ha^{-1}, respectively.

Chapter-III

MATERIALS AND METHODS

CHAPTER - III

MATERIALS AND METHODS

The present investigation entitled "Influence of inorganics and organics on soil characteristics and crop yield under rainfed maize-gobhi sarson sequence" comprised collection of surface and sub-surface samples from three agro-climatic zones of Jammu region and a field experiment which was conducted at Dry land Research Sub-Station, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu at Dhiansar, during the year 2006-2008. The details of materials used and methods employed either in the field or in the laboratory for achieving the objectives of the current investigation has been given in this chapter under the following sub-heads:

3.1 General description of soils of study area

3.1.1 Physiographic features

The state of J&K is located in north western corner of India between $32^0 15'$ and $37^0\ 05'$ N latitude and $72^0 35'$ and $83^0 20'$ E longitude. It covers an area of 22.2 million hectares and accounts for 6.8 per cent of total geographical area of the country. The state comprises three administrative region viz. Jammu, Kashmir and Ladakh. Jammu division is situated south of Pirpanjal in the Shivalik range having lower eluviations. Jammu region can be classified two main physiographic regions i.e. Shivalik and Plains. Shivalik track lies between Chenab and Ravi rivers and consist mostly ravine land locally known as "*Kandi*" areas. The Jammu hills lie above the Punjab plains with gentle slope and follow as succession of narrow parallel ages separated by valleys. The plains consist of narrow strips wounded by Ravi and Chenab.

3.1.2 Geology

Jammu region presents mixed geological formations and composed of sand stones, dunes and conglomerates. Foot hill plains and valleys are formed from alluvial deposits.

3.1.3 Climate

Jammu region broadly divided into three climatic zones: low altitude sub-tropical, intermediate and temperate zone

3.1.3.1 Low altitude subtropical zones

Low altitude subtropical zone the area which falls under this region are foot hill plains and Shivalik hills of Jammu and is characterized by monsoon precipitation, hot summer and relatively dry winter. The mean annual temperature is $25^{0}C$ and rainfall is 1115 mm and 40 per cent is contributed by monsoon and 20 per cent by western disturbances.

3.1.3.2 Intermediate zone:

It represents mid to high altitude intermediate zone and consists of Poonch, Bhaderwah and Kishtwar Tehsils. The region is characterized by cold winter high annual rainfall of 1110-1476 mm and mean annual temperature of $13^{0}C$. The soil is shallow to moderately deep and moderately and severely eroded.

3.1.3.3 Temperate zone:

It consist of high areas of Doda, Poonch, Udhampur and this region is characterized by wet and cold winter with relatively dry and moderately hot summer altitude vary between 1500 to 2500 m AMSL. The mean annual precipitation is 600 to 900 mm and most of this is received in the form of snow fall.

3.1.4 Soils

Shivalik soils are shallow to deep, well drained, coarse loamy ,fine loamy, calcareous as well as non-calcareous, severely eroded with varying degree of stoniness. They occur on moderate to steep slopes. They are neutral to slightly alkaline in reaction with low to medium organic carbon content. They are classified as Lithic and Typic Udorthents and Dystric and Typic Eutrochrpts (Rana *et al.*2000). Alluvial soil are shallow to deep , well to excessively drained , fine loamy moderately eroded occurring on varying gentle slopes. They are neutral and slightly alkaline with low organic carbon and are classified as Udic/Typic Ustochrepts and Typic Ustorthents (Rana *et al.*,2000).

3.1.5 Crops and cropping pattern

Maize, wheat, rice, pulses and oil seeds are some of the main crops of the region. Amongst various grasses, napier, setaria, pennisetum are very promising. Red clover is grown in grass land and meadows to improve the quality of natural grass.

3.1.6 Vegetation

The physico-chemical properties of soils are influenced by natural flora. Pine and deciduous forests form natural vegetation under coniferous groups. The most promising species are *Pinus roxburghii* (Chir pine), *Pinus wallichina* (Blue pine) and A*lvus pienron* (Sur). Under broad leaved species common are Maine, Tali (*Dulbergia sisoo*), Vancour phulai (Daman), Kikar, Khirik and Kamila etc.

3.2 Collection of Soil samples:

On the basis of various physico -chemical properties 43 composite surface (0-15 cm) and sub-surface soil samples (15-30 cm) were collected from different agro climatic zones of Jammu region (Sub-tropical:12; Intermediate-19 and Temperate-12) under maize- gobhi sarson or related oilseed cropping sequence.

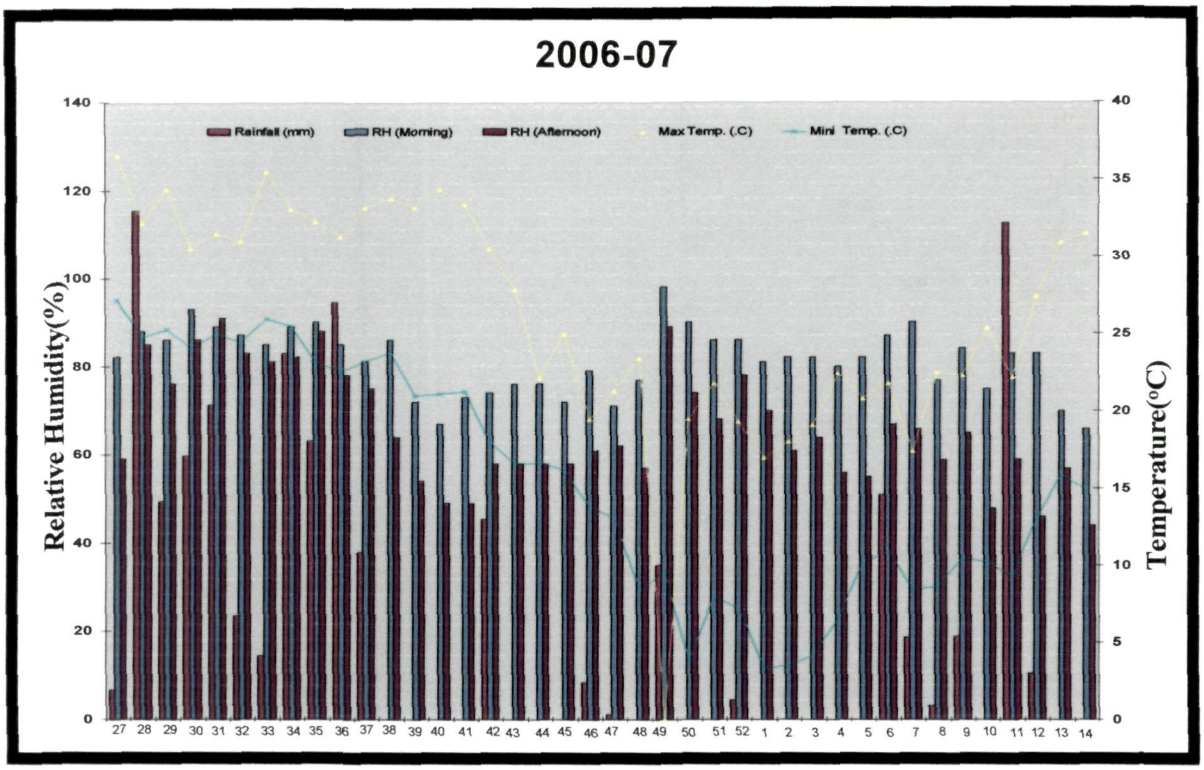
3.3 Experimental site and location

The field experiment was conducted during both *Kharif* and *Rabi* seasons of 2006-2007 and 2007-2008 at at Dry land Research Sub-Station, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu at Dhiansar. Jammu is located at an latitude of 32^0-$39^/$ N and longitude of 74^0-$53^/$ E with an altitude of 332 m above mean sea level. The research farm represents the rainfed belt of Jammu plain areas and part of Kathua and Udhampur districts of Jammu province.

3.4 Climate

The climate of the experimental site is sub-tropical in nature and endowed with hot and dry early summer followed by hot and humid monsoon and cold winter. The mean annual rainfall varies from 1050- 1115 mm of which 70 per cent is received from south-west monsoon (June-September).

However, the total rainfall and its distribution is subjected to large variation. Winter rains are scanty and a few showers of cyclonic rains are received during December to January or late spring. The maximum and minimum temperature shows considerable fluctuations during summer and winter. The temperature often rises to as high as 45 ^{0}C in the month of May-June, while the temperature touches to 0.14 ^{0}C during winter months especially in December-January. The meteorological data collected at the weather observatory of SKUAST-Jammu during the crop season have been presented graphically. (Fig-3.1)



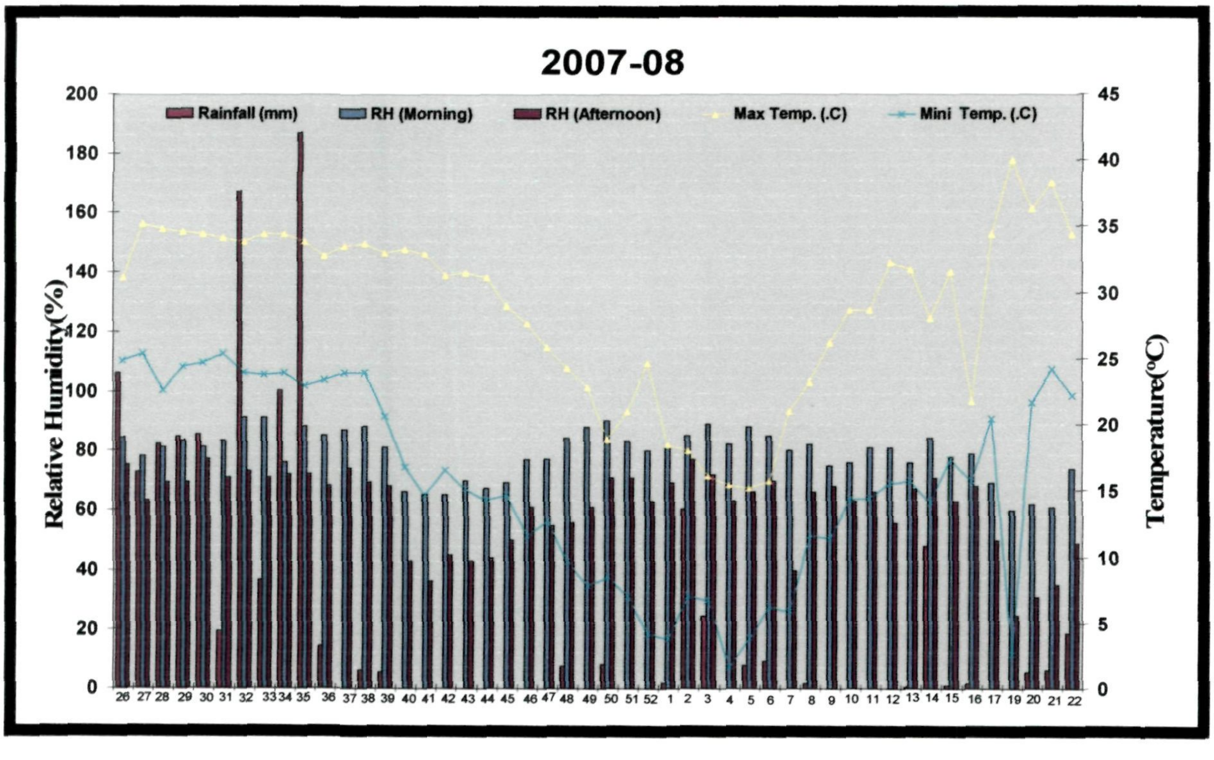


Fig. 3.1 Weekly mean weather parameters prevailing during the crop season

The weather data for the crop season was recorded at the Agro-meteorological observatory located very close to the experimental site at the Research Farm, Dhiansar. The maximum and minimum temperature during the crop growing season ranged from 13.9 to 42.9^{0}C and 2.8 to 27.1^{0}C, respectively in year 2006-07 and maximum and minimum temperature ranged from 16.6 to 40.8^{0}C and 1.7 to 28.7^{0}C, respectively in crop season 2007-08. The mean weekly relative humidity ranged from 35 to 82 per cent and 42 to 86.50 per cent in the year 2006-07 and 2007-08, respectively. The mean weekly rainfall ranged between 0 to 115.3 mm in 2006-07 and 0 to 186.7 mm during 2007-08. Total rainfall received during 2006-07 was 1051.6 mm whereas 1,304 mm of rainfall was received during the succeeding year i.e. 2007-08, which was 252.4 mm more than the previous year.

3.5 Soil characteristics

In order to find out mechanical composition and fertility status of the soil of experimental site, samples were collected randomly from 0-15 cm soil layer just before starting the experiments, during both the years. A composite soil sample was prepared and analyzed separately for different physico-chemical characteristics of the soil (Table 3.1).The analysis revealed that the soil of the experimental site was sandy loam in texture, low in organic carbon, low in available nitrogen and medium in available phosphorus and potassium contents (Table 3.2).

Table 3.1 Mechanical composition of soil

Soil depth (cm)	Soil parameters			Method employed
	Sand (%)	Silt (%)	Clay (%)	
0-15	63.4	18.0	18.6	International Pipette method (Piper, 1966)
15-30	71.4	15.8	12.8	
Textural Class		**Sandy loam**		Textural Diagram (Black, 1965)

Table 3.2 Physico-chemical properties of soil

S. No.	Soil parameters	Values 0-15cm	15-30cm	Methods employed	Reference
A	**Chemical properties**				
1	pH	6.80	6.60	Suspension of soil and water (1:2:5) using glass-calomel electrode	Jackson, (1967))
2	EC (dS m^{-1}) at 25 °C	0.21	0.19	Salt bridge measurements from the suspension used for pH determination	Jackson, (1967))
3	Organic carbon (%)	0.40	0.34	Dichromate oxidation of organic matter	Walkley & Black (1934)
4	Cation Exchange Capacity	9.1	8.9	1N NH_4OAc method	Piper (1966)
5	Available nitrogen (kg ha^{-1})	149.3	136.4	Alkaline $KMnO_4$ method	Subbiah and Asija (1956)
6	Available phosphorus (kg ha^{-1})	14.90	12.57	Olsen's method	Olsen *et al.* (1954)
7	Available potassium (kg ha^{-1})	117.7	112.7	NH_4OAC method	(Hanway and Heidel, 1952)
8	Available sulphur (ppm)	9.10	8.90	Turbidemetric method	Williams and Steinbergers, 1959
9	Available zinc (ppm)	0.54	0.49	DTPA- $CaCl_2$- TEA method	Lindsay and Norvell, 1978
10	Available boron (ppm)	0.41	0.38	Azomethine- H method	Mahler *et al.*, 1984
B	**Physical properties**				
1	Bulk density (Mg m^{-3})	1.24	1.36	Keen Rackzowski method	Piper (1956)
2	Water holding capacity (%)	17.25	15.78	Keen Rackzowski method	Piper (1956)

3.6 Cropping history of the experimental field

Table 3.3 The cropping history for last 5 years of the experimental site is given in table below

Year	Crop sequence
2000-01	Fallow
2001-02	Maize-Wheat
2002-03	Maize- Wheat
2003-04	Fallow- Wheat
2004-05	Maize- Wheat

3.7 Experimental details

3.7.1 Treatments

The experiment consisted of following 14 treatments:

Treatments	Maize	Gobhi- sarson
T_1	NPK	NPK
T_2	NPK+S	NPK
T_3	NPK+Zn	NPK
T_4	NPK+B	NPK
T_5	NPK+S+Zn	NPK
T_6	NPK+S+B	NPK
T_7	NPK+Zn+B	NPK
T_8	NPK+S+Zn+B	NPK
T_9	NPK+S+Zn+B+FYM(25% N replacement)	NPK

Contd...

T_{10}	NPK+S+Zn+B+VC (25% N replacement)	NPK
T_{11}	NPK+S+Zn+B FYM(50% N replacement)	NPK
T_{12}	NPK+S+Zn+B VC(50 %N replacement)	NPK
T_{13}	NPK+S+Zn+B FYM(25% N additional)	NPK
T_{14}	NPK+S+Zn+B VC(25% N additional)	NPK

3.7.2 Design and layout

Field experiment was conducted during *kharif* and *rabi* seasons of 2006-07 and 2007-08 in randomized block design with 3 replications. The layout plan is given in Fig- 3.2. The other details are as under:

Crop	:	**Variety**
Maize	:	Kanchan 517
Gobhi-Sarson	:	DGS-1
Total number of treatment	:	**14**
Gross plot size	:	4.0 m × 3.0 m
Net plot size for maize	:	2.5 m × 2.50 m
Net plot size for Gobhi-sarson	:	3.0 m × 2.75

The sources of nitrogen, phosphorus and potassium were urea, diammonium phosphate and muriate of potash, respectively. The sources of sulphur and zinc were elemental sulphur and zinc oxide, respectively while borax was used as a source of boron. The amount of different fertilizers required to supply the needed quantities of nutrients was calculated on per plot basis. Full doses of FYM, phosphorus, potassium, sulphur, zinc oxide, boron and half dose of nitrogen was applied at the time of sowing.

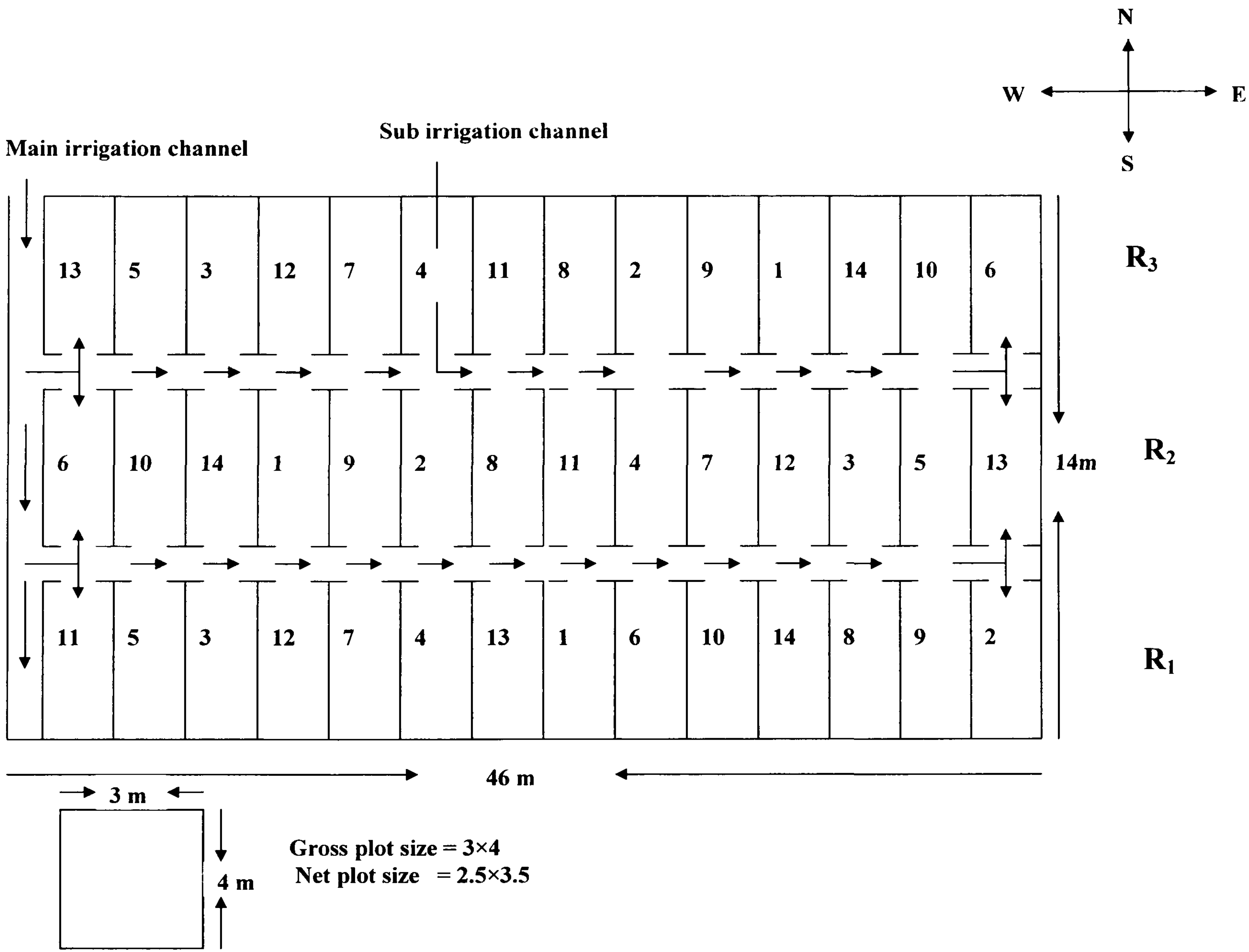


Fig. No. 3.2 Layout plan of field experiment

3.8 Details of cultural operations

Various cultural operations were done as per the details given in Table-3.4.

Table 3.4: Details of various field operations

S. No.	Operation	Dates of operation 2006-07	Dates of operation 2007-08	Details of cultural operation
A	**Maize**			
1	Preparatory tillage	7-7-2006	27-6-2007	After one deep ploughing the experimental field was cross harrowed and leveled properly with the help of tractor drawn implements.
2	Layout of experiment	8-7-2006	28-6-2007	Raised seedbeds of 10-15 cm high each 1.25m wide and 7.5m length was prepared by dry method.
3	Sowing of Maize and Treatments applied	8-07-2006	28-06-2007	The organic sources viz., FYM (0.55 % N) and vermicompost (1.6 % N) used as a source of nitrogen were analysed before applying to field for determining the N content (oven dry basis) for deciding the total quantity to be used to supplement 50 and 25 per cent of N in addition to inorganic fertilizer. Full dose of P, K, FYM and vermicompost were applied as basal at the time of sowing along with balance amount of nitrogen. Rest of N was top dressed in two equal splits. Where as recommended dose of maize was 60,40,20,10,25,1 kg ha^{-1} N,P,K,Zn,S and B respectively
4	Thining and filling	10,11-07-06	30,31-07-07	Thinning was done with the help of khurpi to remove the extra plants and maintain plant to plant distance of 20 cm. Efforts were made to remove the weak plants during thinning,wherever required.Gap filling was also done at the time of thinning,wherever required to maintain proper plant population.
5	Earthing up	13-07-06	01-08-06	At knee height stage earthing up was done with the help of khurpi to cover the roots and provide mechanical support to the plant
7	Harvesting	17-09-06	22-09-07	Crop was harvested manually from net plot size.

Contd...

S. No.	Operation	Dates of operation		Details of cultural operation
		2006-07	2007-08	
B	**Gobhi-sarson**			
13	Preparatory tillage	11-10-06	10-10-07	Field was prepared with power tiller without disturbing the bunds.
14	Fertilizer application	12-10-06	11-10-07	Uniform basal application 50 kg N/ha,30 kg P_2O_5/ha and 15 kg K_2O/ha through inorganic fertilizers were applied and remaining N was top dressed in two splits
15	Sowing of Gobhi-sarson	12-10-06	11-10-07	Sowing of gobhi-sarson at 3cm depth by opening furrows in lines at a distance of 20 cm apart between the rows.
18	Harvesting	06-04-07	10-04-08	Crop was harvested manually from net plot.
19	Threshing and winnowing	13-04-07	8-04-08	Threshing was done manually and grain yield was recorded plot wise.

3.9 OBSERVATIONS RECORDED

The following observations were recorded on maize and gobhi-sarson crop.

3.9.1 Yield

3.9.1.1 Maize (*Zea mays*)

Grain Yield

The cobs were removed from each net plot. The grain yield per net plot was calculated after shelling the grain. The grain yield so obtained was adjusted at 15 per cent moisture and recorded as grain yield and expressed as q ha^{-1}.

Stover yield

The stover from each net plot was harvested after decobing, sun-dried for 6-8 days and then the weight was recorded after conversion to q ha^{-1}.

3.9.1.2 Gobhi-Sarson (*B.napus* var.*oleracea*)

Seed yield

From the individual plot, net plot area was harvested, air dried and produce was threshed and cleaned. The final weight was recorded in kg/plot and converted into q/ha.

Stover yield

Plot wise stover yield was computed by deducting the biological yield of each net plot and expressed in q ha^{-1}.

3.10 Chemical studies

3.10.1 Chemical studies of soil samples

The initial soil samples were collected from 0-15 cm soil layer from ten randomly selected spots with the help of spade and *khurpi*. The samples were pooled and processed for the determination of initial physico-chemical properties (Table 3.1).

3.10.2 Chemical studies of plant samples

The uniform representative plant samples taken for growth analysis at different stages were dried and processed separately. These processed samples were used for different chemical studies as under:

3.10.2.1 Nutrient content in different plant parts

The processed plant samples were analyzed by Micro-kjeldahl method (Jackson, 1967) to determine nitrogen content. Wet digestion (di-acid) method (Jackson, 1973) was used for preparation of aliquot to determine P, K, S, Zn and B content in plant. However, boron free glassware were used for boron determination. These nutrients were analyzed as per procedure described by Singh *et al.* (1999). N, P, K and S content were expressed in per cent while Zn and B content were expressed in ppm.

3.10.2.2 Nutrient uptake by the crop plants

The nutrient uptake (N, P, K, S in kg ha^{-1} and Zn and B in g ha^{-1}) by crop at different stages and in different plant parts was obtained by multiplying their nutrient concentration with respective dry matter yield on hectare basis.

3.11 Quality Studies

3.11.1 Oil content and oil yield

Seed samples from all branches were collected and analyzed for oil content (%) in seeds with the help of Soxhlet's extraction method taking petroleum ether as a solvent (ISI, 1975). The oil content was expressed in per cent. Oil yield was calculated by multiplying seed yield and oil content in the seeds.

3.11.2 Protein content

Grain and Seed samples after harvesting of crops were collected and analyzed for protein content in grain and seeds of maize and gobhi-sarson by multiplying N content with a constant factor of 6.25 and expressed in per cent.

3.12 Statistical analysis

The experimental data obtained during the course of study were subjected to statistical analysis by applying the technique of analysis of variance (ANOVA) to test the significance of the overall differences among treatments by the 'F' test. The conclusion was drawn at 5 per cent probability level. When the 'F' value from analysis of variance tables was found to be significant, the critical difference (CD) was computed to test the significance of the difference between the two treatments mean (Gomez and Gomez, 1984).

Chapter-IV

EXPERIMENTAL RESULTS

CHAPTER - IV

EXPERIMENTAL RESULTS

The results pertaining to the present investigation "Influence of inorganics and organics on soil characteristics and crop yield under rainfed maize-gobhi sarson sequence" have been presented in this chapter under the following heads:

4.1 Physico-chemical properties of soils under different agro-climatic zones of Jammu region.

4.2 Available nutrient status and their distribution under different zones of Jammu region.

4.3 Correlation between soil properties and available soil nutrients

4.4 Crop response to inorganics and organics sources of nutrients

4.4.1 Effect of different sources on grain and stover yield of maize

4.4.1.1 Grain yield of maize

4.4.1.2 Stover yield of maize

4.4.2 Residual effect of inorganics and organics on seed and stover yield of gobhi-sarson

4.4.2.1 Seed yield of gobhi-sarson

4.4.2.2 Stover yield of gobhi-sarson

4.5 Nutrient uptake studies

4.5.1 Nutrient uptake by grain and stover in maize

4.5.2 Nutrient uptake by seed and stover in gobhi-sarson

4.6 Quality studies

4.6.1 Protein content in maize

4.6.2 Oil content,oil yield and protein content in gobhi-sarson

4.7 Soil analysis of experimental site

4.7.1 Physico-chemical properties of soil after harvest of maize-gobhi-sarson sequence

4.7.2 Changes in pH, EC (dSm^{-1}), organic carbon content of soil (%),CEC ($Cmol(p^{+})\ kg^{-1}$) bulk density ($Mg\ m^{-3}$) and water holding capacity (%) of soil after each maize-gohi-sarson sequence

4.7.3 Changes in available nitrogen, phosphorus, potassium($kg\ ha^{-1}$),sulphur, zinc and boron ($mg\ kg^{-1}$) in soil after each maize-gohi-sarson sequence

4.7.4 Balance sheet

4.1 Physico-chemical properties of soils under different agro-climatic zones of Jammu region.

The data with respect to physico chemical properties of soil of maize-gohisarson or related oil seed crop sequence under different agro-climatic zones of Jammu region are presented in Appendix I. The range and mean values of these properties are given in table 4.1, 4.2 and 4.3. The data presented in tables indicates that soil pH of the sub-tropical zone varied from neutral to slightly alkaline in reaction ranging from 7.34 to 8.35 and 7.20 to 8.52 with mean value of 8.01 and 7.95 in surface and sub-surface soils, respectively. However, the pH values of surface soils were slightly higher as compared to sub-surface soils. The pH of the soils of intermediate zones varied from 6.8-7.9 and 6.7-7.7 with mean value of 7.47 and 7.16 in surface and sub-surfaces soils, respectively. The pH values of the soils under temperate zone varied from 6.30-7.28 and 6.40-7.42 with mean value of 6.60 and 6.71 in surface and sub-surface soils, respectively. The overall pH value of soils under sub-tropical zone was higher followed by soils of intermediate zone where as lowest values of soil pH were recorded under the soils of temperate zone.

The salinity status of soils was found to be under the safe limits in all the three agro-climatic zones considering 4.0 dsm^{-1} as critical limit. In general, EC values decreased in sub-surface layer in all the soils of three agro-climatic zones of Jammu region. In the soils of sub-tropical zone the EC values ranged from 0.13-0.23 and 0.09-0.21 dsm^{-1} with average value of 0.16 and 0.14 dsm^{-1} in surface and sub-surface soil layer, respectively. In surface and sub-surface soils of the intermediate zone EC values varied from 0.08-0.25 and 0.07-0.24 with mean values of 0.14 and 0.12 dsm^{-1}, respectively. The EC values of the soils under temperate zone varied from 0.06-0.24 and 0.09-0.19 with mean values of 0.16 and 0.14 dsm^{-1} respectively. The higher EC values amongst the three agro-climatic zones was found in sub-tropical zone followed by temperate and intermediate zone.

The organic carbon content of the three agro-climatic zones ranged from 0.29-0.99 per cent in surface soils and it decreased in the sub-surface soils. The organic carbon content of surface and sub-surface soils of sub-tropical zone was found to be falling in low category and varied from 0.28-0.51 per cent with mean value of 0.39 per cent where as it varied from 0.25-0.46 per cent with mean value of 0.33 percent in sub surface soil. In the sub-tropical zone, the highest organic carbon content was found in surface soils of Hiranagar with 0.51 per cent and lowest value 0.27 percent was observed in sub-surface soil of Thandi. Medium to high organic carbon content ranging from 0.60 to 0.83 per cent with mean value of 0.71 percent was observed in surface of soils of intermediate zone, where as it varied from 0.48 to 0.69 per cent with mean value of 0.59 per cent. The highest organic carbon content was observed in the soils of temperate zone amongst the three agro-climatic zones that ranged from 0.60 to 0.99 per cent and 0.54 to 0.79 percent with mean values of 0.83 and 0.69 per cent in surface and sub-surface soils, respectively. The highest organic carbon content 0.99 percent was found in surface soil of Dhomail Bhaderwah and lowest value 0.53 percent was found in sub-surface soil of Kud.

The cation exchange capacity (CEC) of surface soils of sub-tropical zone ranging from 8.1 to 10.4 [Cmol(p^+)kg^{-1}] with mean value of 8.85 [Cmol(p^+)kg^{-1}], where as in sub-surface soils, the value of CEC varied from 8.4 to 10.8 [Cmol(p^+)kg^{-1}], with mean value of 9.23 [Cmol(p^+)kg^{-1}], respectively. In surface and sub-surface soils of the intermediate zone, CEC values varied from 9.4-14.8 and 9.8-14.5 with mean values of 12.49 and 12.51 [Cmol(p^+)kg^{-1}], respectively. The highest values of cation exchange capacity was observed in temperate zone soils amongst the three agro-climatic zones ranging from 12.2-14.7 and 12.28 to 15.2 with mean values of 14.31 and 15.83 [Cmol(p^+)kg^{-1}], in surface and sub-surface soils respectively.

The textural separate of the soils of three agro-climatic zones varied widely and are presented in appendix I. Texturally, all the soils varied from loam to sandy loam and silty clay. Higher sand content was found in the surface soils of sub-tropical zone, ranging from 46.0 to 83.4 per cent with mean value of 64.05 per cent and decreased in sub-surface in almost all the soils ranging from 44.3 to 80.4 percent with mean value of 61.76 per cent, respectively. In surface and sub-surface soils of intermediate zone, sand values varied from 20.1 to 56.3 and 18.3 to 53.8 with mean values of 32.51 and 30.31 per cent respectively. Lowest sand content was found in sub-surface soils of temperate zone ranging from 17.6 to 47.4 per cent with mean value of 40.62 per cent. The variation in silt

TABLE: 4.1 Ranges and means of soil properties under sub-tropical zone of Jammu region

S.No.	Property	Depth(cm)			
		0-15		15-30	
		Range	Mean	Range	Mean
1.	pH(1:2.5)	7.34-8.35	8.0	7.20-8.52	7.95
2.	EC(dSm^{-1})	0.13-0.23	0.16	0.09-0.21	0.14
3.	OC(%)	0.28-0.51	0.39	0.25-0.46	0.33
4.	CEC [Cmol(p^{+})kg^{-1}]	8.1-10.4	8.85	8.4-10.8	9.23
5.	Sand(%)	46.0-73.4	64.05	52.6-80.4	61.76
6.	Silt (%)	9.1-27.2	19.75	10.2-34.2	20.82
7.	Clay(%)	7.7-21.6	16.19	9.4-22.7	17.40

TABLE: 4.2 Ranges and means of soil properties under intermediate zone of Jammu region

S.No.	Property	Depth(cm)			
		0-15		15-30	
		Range	Mean	Range	Mean
1.	pH(1:2.5)	6.8-7.9	7.47	6.7-7.7	7.16
2.	EC(dSm^{-1})	0.08-0.25	0.14	0.07-0.24	0.12
3.	OC(%)	0.60-0.83	0.71	0.48-0.69	0.59
4.	CEC[Cmol(p^{+})kg^{-1}]	9.4-14.8	12.49	9.8-14.5	12.51
5.	Sand(%)	20.1-56.3	32.51	18.3-53.8	30.31
6.	Silt (%)	22.4-46.3	36.83	20.3-45.1	35.91
7.	Clay(%)	17.3-39.3	29.45	20.7-42.1	32.49

TABLE: 4.3 Ranges and means of soil properties under Temperate zone of Jammu region

S.No.	Property	Depth(cm)			
		0-15		15-30	
		Range	Mean	Range	Mean
1.	pH(1:2.5)	6.3-7.28	6.60	6.4-7.42	6.71
2.	EC(dSm^{-1})	0.06-0.24	0.16	0.09-0.19	0.14
3.	OC(%)	0.60-0.99	0.83	0.54-0.79	0.69
4.	CEC [Cmol(p^+)kg^{-1}]	12.2-14.7	14.31	12.28-15.2	15.83
5.	Sand(%)	29.7-47.4	44.65	17.6-47.4	40.69
6.	Silt (%)	28.3-48.4	33.10	25.9-49.6	33.04
7.	Clay(%)	9.3-28.0	22.23	9.0-36.5	26.26

content was ranging from 9.1 to 27.2 and 10.2 to 34.2 per cent with mean values of 19.75 and 20.82 per cent in surface and sub-surface soils, respectively in the sub-tropical zone. Higher silt content was found in surface soils of intermediate zone ranging from 22.4 to 46.3 per cent with mean value of 36.8. The silt content in temperate zone varied from 28.4-48.4 and 25.9 to 49.6 per cent with mean values of 33.1 and 33.04 per cent in surface and sub-surface soils, respectively. The clay content ranged from 7.7 to 21.6 in surface soils of sub-tropical zone with mean value of 16.19 per cent and increased in sub-surface soils which ranged from 9.4-22.7 with mean value 17.40. Higher clay content was observed for intermediate zone soils ranging from 17.3-39.3 and 20.7-42.1 per cent with mean values of 29.45 and 32.49 per cent in surface and sub-surface, respectively. Temperate zone soils contained clay content in the range of 9.3-28.0 and 9.0-36.5 per cent with mean values of 22.23 and 26.26 per cent in surface and sub-surface, respectively.

4.2 Available nutrient status and their distribution under different zones of Jammu region.

The available N content of surface soils of sub-tropical zone ranging from 195.4 to 325.0 kg ha^{-1} with mean value of 263.36 kg ha^{-1}, whereas in sub-surface soils, the value of available N status varied from 161.7 to 312.0 with mean value of 256.08 kg ha^{-1}, respectively.(Table 4.4, 4.5 and 4.6). In surface and sub-surface soils of the intermediate zone, the value of available N status varied from 258.7 to 375.1 and 242.3 to 355.7 kg ha^{-1} with mean values of 318.53 and 291.84 kg ha^{-1}, respectively. The highest values of available N status was observed in soils of temperate zone amongst the three agro-climatic zone ranging from 284.2 to 394.2 and 272.3 to 389.8 with mean values of 322.34 and 308.25 kg ha^{-1}, respectively(Appendix II).

The available P content of surface soils of sub-tropical zone varied from 12.6-15.8 kg ha^{-1} with mean value of 13.90 kg ha^{-1}, whereas in sub-surface soils, the value of available P content varied from 12.4 to 15.6 with mean value of 13.61 kgha^{-1}, respectively. Higher available P content was observed in surface soils of intermediate zone ranging from 14.1 to 21.7 with mean value of 17.32, where as in sub surface soil it varied from 13.3 to 20.8 with mean value of 15.74 kg ha^{-1}. The available P content in temperate zone varied from 15.4 to 16.8 and 15.2 to 16.7 with mean values of 16.07 and 15.83 in surface and sub-surface soils, respectively(Table 4.4, 4.5 and 4.6 and Appendix II).

The available K content of surface soils of sub-tropical zone varied from 112 to 202.6 with mean value of 143.53 kg ha^{-1} and decreased in sub-surface soils in almost all the soils ranging from 98.2 -193.7 kg ha^{-1} with mean value of 134.75 kg ha^{-1}, respectively. In surface and sub-surface soils of the intermediate zone, the value of available K content ranged from 203.7-321.3 and 151.2-298.3 kg ha^{-1} with mean values of 274.91 and 219.0 kg ha^{-1}, respectively. The highest values of available K was observed in soils of temperate zone amongst the three agro climatic zones ranging from 276.3-349.6 and 262.1-304.8 kg ha^{-1} with mean values of 295.89 and 277.48 kg ha^{-1} in surface and sub-surface soils, respectively(Table 4.4, 4.5 and 4.6 and Appendix II).

The available S content ranged from 8.6 to 41.3 mg kg^{-1} of the three agro-climatic zones in the surface soils and it decreased in the sub-surface soils. Highest average content of available sulphur (41.31 mg kg^{-1}) was found in the surface soils of intermediate zone with variation being 13.2 to 41.3 mg kg^{-1} with mean value of 13.96 where as in sub-surface soil, the value of available sulphur varied from 10.9 to 35.1 mg kg^{-1} with mean value of 18.58 mg kg^{-1}. Surface soils of temperate zone contain less available S content than intermediate soils with a mean value of 24.85 and it decreased with depth with mean value of 21.40 mg kg^{-1} in sub-surface soils. The available S content of surface soils of sub-tropical zone varied from 8.6 to 27.4 mg kg^{-1} with mean value of 13.96 mg kg^{-1} and it decreased with depth. In the sub-tropical zone, less than 10 mg kg^{-1} available S content was observed in soils of Raya more Thandi, Vijaypur, Gurha Slathia, Gobindsar, Lakhanpur and Jhajarkotli and this accounted for 58.3 per cent of the soils of this zone. Where as sub-surface soils of Samba, Dyalachak and Thein showed available sulphur content in medium range and rest of remaining soil were found in high range. In the intermediate zone, 68.4 percent soils fall in the medium category. In the soils of temperate zone, the available S content varied from 16.8 to 32.5 and 12.3 to 28.2 with mean value of 24.85 and 21.40 mg kg^{-1} in surface and sub-surface, respectively(Table 4.4, 4.5, 4.6 and Appendix II).

The available Zn content ranged from 0.49 to 3.20 mg g^{-1} of the three agro-climatic zones in the surface soils and it decreased in the sub-surface soils. The soils of the sub-tropical zone were lowest in available B amongst three agro-climatic zones, ranging from 0.49 to 1.12 and 0.41 to 1.08 mg Kg^{-1} with mean values of 0.64 and 0.58 mg kg^{-1} in surface and sub-soil surface, respectively. In the sub-tropical zone, 50 percent of soil samples found to be deficient. The intermediate zone soils contained more available Zn than sub-tropical zone and it varied from 0.62 to 2.22 and 0.58-2.16 with mean values of 1.64 and 1.59 mg kg^{-1} in surface and sub-surface soils, respectively.

Amongst the three agro-climatic zones, the highest content of available Zn was observed in soils of temperate zone and it varied from 1.66 to 3.20 mg kg^{-1} with mean value of 2.59 mg kg^{-1} and it decreased in sub-surface layer with mean value of 2.47 mg kg^{-1}.

In the temperate zone, highest content (3.20 mg kg^{-1}) of available Zn was observed in surface soil of Nathatop and lowest (1.58 mg kg^{-1}) was observed in sub-surface soil of Assar. In the intermediate zone, highest content of available Zn was found in surface soil of Kallar (2.22 mg kg^{-1}) and lowest in sub-surface soil of Madha (0.58 mg kg^{-1}). Amongst the soils of sub-tropical zone, highest content of available Zn was observed in surface soil of Gobindsar (1.12 mg kg^{-1}) and lowest in sub-surface soil of Thandi (0.41 mg kg^{-1}). (Table 4.4, 4.5, 4.6 and Appendix II)

The available B content in surface soils of the three agro-climatic zones of Jammu region varied from 0.23 to 0.95 mg kg^{-1}. The soils of sub-tropical zone contained lower amount of available B amongst three agro-climatic zones, which ranged from 0.23 to 0.51 mg kg^{-1} with mean value of 0.40 mg kg^{-1} in surface soils (Table 4.2 and Appendix II) and decreased in sub-surface layer. In the sub-tropical zone of soil samples less than 0.50 mg kg^{-1} available B content was observed in 83.0 per cent of the soils. The intermediate zone soils contained more available B than sub-tropical zone and it varied from 0.30 to 0.66 and 0.23 to 0.54 mg $kg^{-1}$with mean values of 0.48 and 0.41 mg kg^{-1} in surface and sub-surface soils, respectively. Amongst the three agro-climatic zones, the highest content of available B was observed in soils of temperate zone and it ranged from 0.40 to 0.89 mg kg^{-1} with mean value of 0.59 mg kg^{-1} and it decreased in sub-surface layer with mean value of 0.49 mg kg^{-1}.

TABLE 4.4 **Ranges and means of available nutrients under sub-tropical zone of Jammu region**

S.No.	Available Nutrients	Depth(cm)			
		0-15		15-30	
		Range	Mean	Range	Mean
1.	N(kg ha^{-1})	195.4-325.0	263.36	161.7-312.0	256.08
2.	P(kg ha^{-1})	12.6-15.8	13.90	12.4-15.6	13.61
3.	K(kg ha^{-1})	112.0-202.6	143.53	98.2-193.7	134.79
4.	S(mg kg^{-1})	8.6-27.4	13.96	8.1-27.8	13.29
5.	Zn(mg kg^{-1})	0.49-1.12	0.64	0.41-1.08	0.58
6.	B(mg kg^{-1})	0.23-0.51	0.40	0.16-0.45	0.31

TABLE 4.5 **Ranges and means of available nutrients under intermediate zone of Jammu region**

S.No.	Available nutrients	Depth(cm)			
		0-15		15-30	
		Range	Mean	Range	Mean
1.	N(kg ha^{-1})	258.7-375.1	318.53	242.3-355.7	291.84
2.	P(kg ha^{-1})	14.1-21.7	17.32	13.3-20.8	15.74
3.	K(kg ha^{-1})	203.7-321.3	274.91	151.2-298.7	219.0
4.	S(mg kg^{-1})	13.2-41.3	22.52	10.9-35.1	18.58
5.	Zn(mg kg^{-1})	0.62-2.22	1.49	0.58-2.16	1.45
6.	B(mg kg^{-1})	0.30-0.66	0.49	0.23-0.54	0.42

TABLE 4.6 **Ranges and means of available nutrients under Temperate zone of Jammu region**

S.No.	Available nutrients	Depth(cm)			
		0-15		15-30	
		Range	Mean	Range	Mean
1.	N(kg ha^{-1})	284.2-394.2	322.34	272.3-389.8	308.25
2.	P(kg ha^{-1})	15.4-16.8	16.07	15.2-16.7	15.83
3.	K(kg ha^{-1})	276.3-349.6	295.89	262.1-304.8	277.48
4.	S(mg kg^{-1})	16.8-32.5	24.85	12.3-28.2	21.40
5.	Zn(mg kg^{-1})	1.66-3.20	2.59	1.58-3.01	2.47
6.	B(mg kg^{-1})	0.40-0.95	0.59	0.33-0.77	0.49

In the temperate zone, highest content (0.95 mg kg^{-1}) of available B was observed in surface soil of Sartangal and lowest (0.33 mg kg^{-1}) in sub-surface soil of Derodu. In the intermediate zone, highest content of available B was found in surface soil of Palassi (0.66 mg kg^{-1}) and lowest in sub-surface soil of Lamberhi (0.23 mg kg^{-1}). Amongst the sub-tropical zone soils highest content of available B was observed in surface soil of Gurha Slathia (0.51 mg kg^{-1}) and lowest in sub-surface soil of Samba (0.16 mg kg^{-1}). (Table 4.4, 4.5, 4.6 and Appendix II)

4.3 Correlation Studies:

The availability of nutrients in the soils is governed by several interacting factors such as pH, EC, organic carbon, cation exchange capacity, sand, silt and clay etc. Hence, it becomes imperative to access the individual influence of soil properties on different available nutrients such as N, P, K, S, Zn and B. In order to access the individual influence, correlation coefficients were computed between different available nutrients and soil properties (Table 4.7)

The coefficients of correlation between different available nutrients and soil properties are given in the table A perusal of data in the tables indicated that the soil pH showed negative correlation with all the available nutrients, the correlation coefficients being r = -0.285, -0.242, 0.569**, -0.479, -0.689** and -0.371* for N, P, K, S, Zn and B, respectively. The EC was also found to be negatively correlated with the available nutrients, the correlation coefficients were -0.130, -0.336*, -0.108, -0.108, -0.082, -0.091 and -0.039 for N, P, K, S, Zn and B, respectively. The organic carbon was positively and significantly correlated with all the available nutrients, the coefficient of correlation being 0.645**, 0.829**, 0.481**, 0.788** and 0.341 for N, P, K, S, Zn and B, respectively.

Table No. 4.7 Correlation co-efficient between soil properties and available nutrients

	N	P	K	S	Zn	B
pH	-0.285	-0.242	-0.569**	-0.479**	-0.689**	-0.371*
EC	-0.130	-0.336*	-0.108	-0.082	-0.091	0.039
OC	0.645**	0.565**	0.829**	0.481**	0.788**	0.341*
CEC	0.629**	0.689**	0.763**	0.357*	0.793**	0.412**
Sand	-0.555**	-0.673**	-0.663**	-0.197	-0.456**	-0.135
Silt	0.544**	0.630**	0.684**	0.260	0.532**	0.195
Clay	0.461**	0.677**	0.498**	0.106	0.302*	0.031

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

The CEC content was also found to be positively and significantly correlated with all the available nutrients, the coefficient of correlation being 0.629**, 0.689**, 0.763**,0.357, 0.793** and 0.412** for N, P, K, S, Zn and B, respectively. The sand content was found to be negatively correlated with all the available nutrients, the coefficient of correlation being 0.544**, 0.630, 0.684**, 0.260, 0.532** and 0.195 for N, P, K, S, Zn and B, respectively. The clay content was also found to be positively and significantly correlated with all the available nutrients, the coefficient of correlation being 0.461**,0.677**, 0.498**, 0.106, 0.302* and 0.031 for N, P, K, S, Zn and B, respectively.

4.4 Crop response to inorganic and organics sources of nutrients

4.4.1 Effect of different sources on grain and stover yield of maize

4.4.1.1 Grain yield of maize

In general, the grain yield was higher during 2007-08 as compared to 2006-07. (Table 4.8 and Fig. 4.1). Significantly higher grain yield (30.60 and 31.55 q ha^{-1}) was recorded in T_{14} with the application of 100 percent recommended NPK coupled with S, Zn, B and VC over all the treatments except T_{13} and T_8 during 2006-07 and T_8, T_9, T_{10}, T_{11}, T_{12} and T_{13} during 2007-08 which were of the similar magnitude. The crop fertilized with 100 percent of the recommended NPK alone (T_1) produced lowest grain yield (26.55 and 26.68 q ha^{-1}) during 2006-07 and 2007-08, respectively which was at par with T_2, T_3 and T_4 during both the years. Supplementing recommended NPK with S, Zn and B individually (T_2, T_3 and T_4) though improved seed yield but not to the level of statistical significance. However, combined addition of S and Zn, S and B and Zn and B (T_5, T_6 and T_7) with 100 percent of recommended NPK significantly improved seed yield over the recommended NPK (T_1) as well as recommended NPK in combination with either S, Zn or B alone (T_2, T_3 and T_4). Further, supplementing recommended NPK along with S, Zn and B together, significantly improved the seed yield over all the treatments except T_{13} and T_{14} during 2006-07 and T_9, T_{10}, T_{11}, T_{12}, T_{13} and T_{14} during 2007-08 which were of the similar magnitude.

4.4.1.2 Stover yield of maize

In the case of stover yield (Table 4.8 and Fig. 4.1) T_{13} and T_{14} out yielded all the remaining treatments except T_8 where the differences were not significant during 2006-07 while in 2007-08, the treatments T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13} and T_{14} were found to be at par with each other. Differences in stover yield due to application of FYM and VC coupled with N, P, K, S, Zn and B were non-significant, however the treatments wherein VC was applied to replace 25 % N (T_{10}, T_{12} and T_{14}) were proved to be better over FYM. Significantly higher stover yield (93.33 and 95.53 q ha^{-1}) was recorded in T_{14} over all the treatments except T_{13} and T_8 during 2006-07 and T_8, T_9, T_{10}, T_{11}, T_{12} and T_{13} during 2007-08 which were of the similar magnitude. Supplementing 100 percent recommended NPK with S, Zn and B individually (T_2, T_3 and T_4) improved stover yield but not to the level of statistical significance. However, treatments T_5, T_6, and T_7 with the combined application of S and Zn, S and B and Zn and B with 100 percent of recommended NPK brought significant improvement in stover yield over T_1, T_2, T_3 and T_4.

4.4.2 Residual effect of inorganics and organics on seed and stover yield of gobhi-sarson

4.4.2.1 Seed yield of gobhi-sarson

The date presented in the Table 4.9 and Fig. 4.1 revealed that a significant and pronounced effect on seed yield of gobhi sarson was observed due to the residual effect of inorganic and organic sources of nutrients as compared to the plot with 100 percent of NPK alone through inorganic fertilizer. Significantly higher seed yield (13.78 and 14.28 q ha^{-1}) was recorded in treatment T_{14} as compared to all the remaining treatments except T_{13} and T_8 during 2006-07 and T_8, T_9, T_{10}, T_{11}, T_{12} and T_{13} during 2007-08. The treatments T_5, T_6 and T_7 recorded significantly lower yield than T_8, T_{13} and T_{14} but found to be at par with T_9, T_{10}, T_{11} and T_{12} during 2006-07 while in 2007-08, the treatment T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13} and T_{14} were statistically at par with each other. However, the treatments T_5, T_6 and T_7 gave significantly higher seed yield over T_1, T_2, T_3 and T_4 .

4.4.2.2 Stover yield of gobhi-sarson

The data pertaining to stover yield of gobhi sarson presented in Table 4.9 and Fig. 4.1 revealed that significant and pronounced effect in stover yield of gobhi sarson was observed due to the residual effect of inorganic and organic sources of nutrients. Significantly higher stover yield (58.36 and 60.36 q ha^{-1}) was recorded in T_{14} compared to all the remaining treatments except T_8 and T_{13} during 2006-07 and T_8, T_9, T_{10}, T_{11}, T_2 and T_{13} during 2007-08. The treatments T_5, T_6 and T_7 have significantly higher stover yield than T_1, T_2, T_3 and T_4. However, the treatments T_5, T_6 and T_7 have significantly lesser stover yield than T_8, T_{13} and T_{14} but found to be at par with T_9, T_{10}, T_{11} and T_{12} during 2006-07, while in 2007-08, the treatments T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13} and T_{14} were found to be statistically at par with each other.

Table 4.8. Influence of inorganics and organics on grain and stover yield (q ha^{-1}) of maize under maize-gobhi sarson sequence during 2006-07 and 2007-08

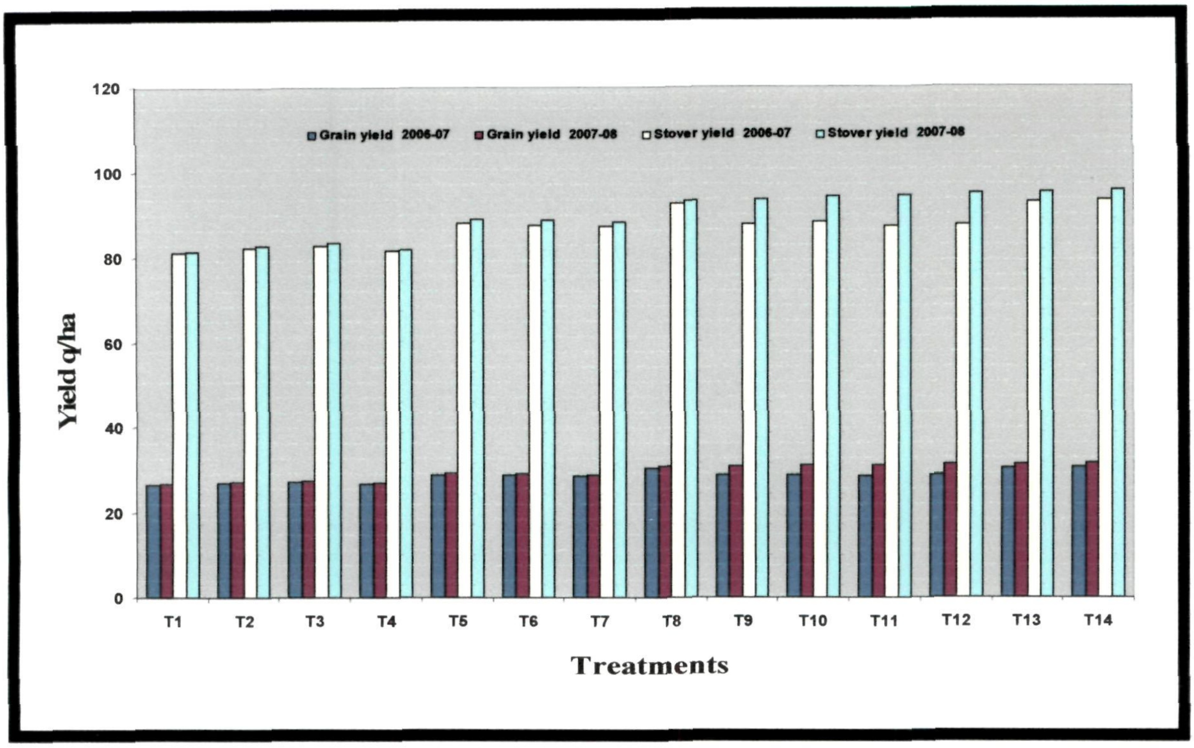
Treatments	Grain yield		Stover yield	
	2006-07	2007-08	2006-07	2007-08
T_1 NPK	26.55	26.68	81.18	81.37
T_2 NPK+S	26.90	27.20	82.24	82.75
T_3 NPK+Zn	27.10	27.32	82.65	83.32
T_4 NPK+B	26.71	26.85	81.46	81.85
T_5 NPK+S+Zn	28.85	29.20	88.04	88.90
T_6 NPK+S+B	28.68	29.08	87.47	88.68
T_7 NPK+Zn+B	28.60	28.90	87.23	88.14
T_8 NPK+S+Zn+B	30.38	30.82	92.65	93.38
T_9 NPK+S+Zn+B+FYM (25% N replacement)	28.78	30.90	87.85	93.60
T_{10} NPK+S+Zn+B+VC (25% N replacement)	28.86	31.12	88.12	94.25
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	28.55	31.20	87.25	94.53
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	28.75	31.34	87.60	94.8
T_{13} NPK+S+Zn+B+FYM (25% N additional)	30.45	31.42	92.87	95.2
T_{14} NPK+S+Zn+B+VC (25% N additional)	30.60	31.55	93.33	95.53
S.Em.±	0.47	0.53	1.58	1.67
C.D. (p=0.05)	1.39	1.56	4.63	4.88

Applied doses of N, P_2O_5, and K_2O, S, Zn, and B 60, 40, 20, 25, 10 and 1 kg ha^{-1} respectively for Maize.S was applied as elemental S, B as borax while Zn was applied as ZnO

Table 4.9: Residual effect of inorganics and organics on seed yield and stover yield (q ha^{-1}) of gobhi sarson under maize-gobhi sarson sequence during 2006-07 and 2007-08

Treatment	Seed yield (q ha^{-1})		Stover yield (q ha^{-1})	
	2006-07	2007-08	2006-07	2007-08
T_1 NPK	10.30	10.46	43.76	43.93
T_2 NPK+S	10.76	10.90	45.35	45.86
T_3 NPK+Zn	10.58	10.70	44.97	45.36
T_4 NPK+B	10.42	10.58	44.28	44.43
T_5 NPK+S+Zn	12.34	12.48	52.30	52.66
T_6 NPK+S+B	12.15	12.32	51.63	51.82
T_7 NPK+Zn+B	12.04	12.26	51.17	51.49
T_8 NPK+S+Zn+B	13.60	13.84	57.80	58.22
T_9 NPK+S+Zn+B+FYM (25% N replacement)	12.28	13.88	51.57	58.57
T_{10} NPK+S+Zn+B+VC (25% N replacement)	12.35	13.96	51.88	58.80
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	12.08	14.04	50.73	58.98
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	12.20	14.10	51.24	59.22
T_{13} NPK+S+Zn+B+FYM (25% N additional)	13.66	14.18	58.05	60.10
T_{14} NPK+S+Zn+B+VC (25% N additional)	13.78	14.28	58.36	60.36
S.Em.±	0.41	0.45	1.85	1.93
C.D. (p=0.05)	1.20	1.31	5.43	5.65

Applied doses of N, P_2O_5, and K_2O @ 50,30 & 15 kg ha-1 respectively for Gobhi sarson



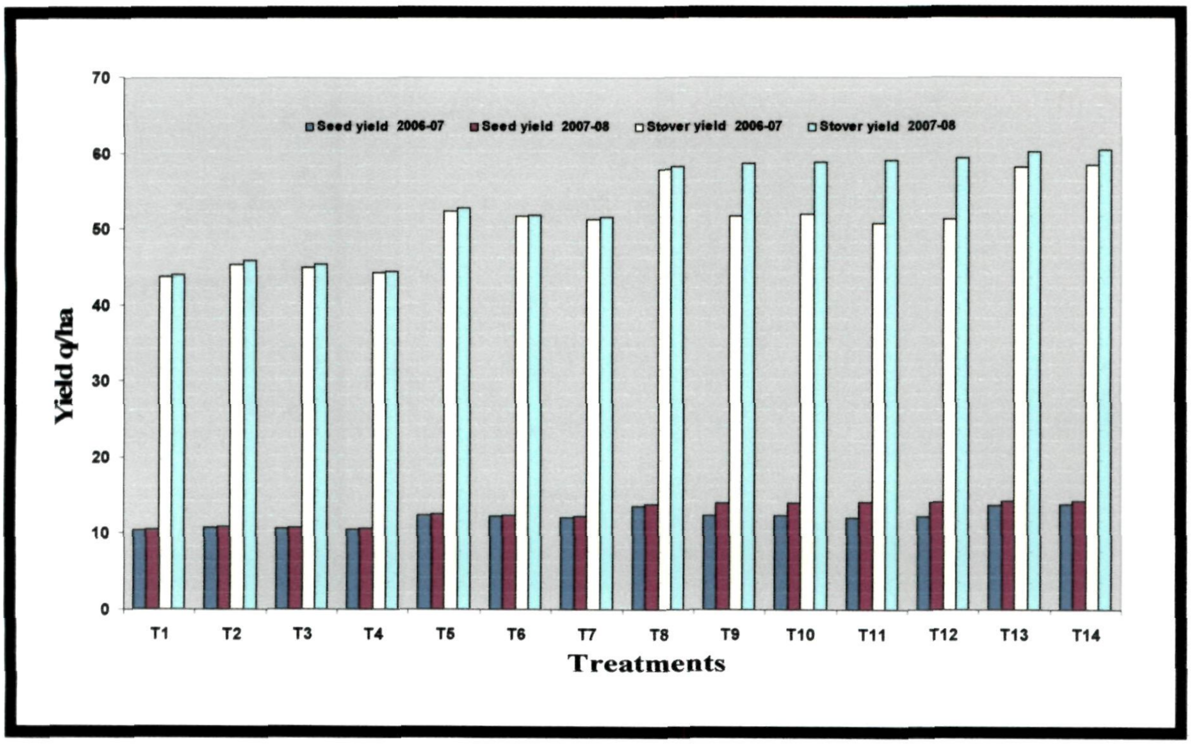


Fig. 4.1 Influence of inorganics and organics on grain and stover yield (q ha^{-1}) of maize and its residual effect on seed and stover yield (q ha^{-1}) of succeeding gobhi sarson crop

4.5 Nutrient uptake studies

4.5.1 Nutrient uptake by grain and stover in maize

In general, the N, P, K, S, Zn and B uptake in grain, Stover and total uptake was higher during 2007-08 as compared to 2006-07 (Table 4.10, 4.11, 4.12, 4.13, 4.14, 4.15 and Fig 4.2 and 4.3). Stover contained the highest N, P, K, S, Zn and B uptake value as compared to grain. Different integrated plant nutrient management practices signicantly influenced the uptake by grain, stover and total uptake during both the years. Significantly higher N, P, K, S, Zn and B uptake was recorded in grain with the application of 100 per cent recommended NPK coupled with S, Zn, B and VC (T_{14}) over all the treatments except T_{13} and T_8 during 2006-07 and T_8, T_9, T_{10} , T_{11}, T_{12} and T_{13} during 2007-08 which were of the similar magnitude.

However, in the treatments wherein FYM and VC were applied to substitute 50 per cent N (T_{11} and T_{12}) recorded significantly higher N, P, K, S, Zn and B uptake value over T_1, to T_4 during both the years. Also, during the 2nd year, the treatments which received integrated application of inorganics and organics (T_9, T_{10}, T_{11}, T_{12} ,T_{13} and T_{14}) found to be at par with each other.

N.P.K.S, Zn and B uptake by stover was also recorded significantly higher in T_{14} over all other treatments except T_{13} and T_8 during 2006-07, and T_8 to T_{13} during 2007-08. Treatments T_{13} and T_{14} during 2006-07 recorded significantly higher uptake by stover over T_1 to T_7 and T_9 to T_{12} while during 2007-08, T_{14} was found to be at par with T_9, T_{10}, T_{11} and T_{12}.

TABLE 4.10 Influence of inorganics and organics on nitrogen uptake (kg ha^{-1}) in seed, stover and total N uptake of maize during 2006-07 and 2007-08

Treatment	Nitrogen uptake (kg ha^{-1})					
	2006-07			2007-08		
	Grain	Stover	Total	Grain	Stover	Total
T_1 NPK	13.81	23.38	37.19	15.47	23.76	39.23
T_2 NPK+S	16.68	24.84	41.52	17.68	25.24	42.93
T_3 NPK+Zn	18.43	25.47	43.90	19.12	26.00	45.12
T_4 NPK+B	15.49	23.95	39.45	16.66	24.31	40.97
T_5 NPK+S+Zn	27.41	32.40	59.82	29.78	33.07	62.85
T_6 NPK+S+B	25.81	31.66	57.47	27.63	32.37	60.01
T_7 NPK+Zn+B	24.31	30.98	55.29	26.01	31.55	57.57
T_8 NPK+S+Zn+B	34.03	38.91	72.94	36.98	39.50	76.48
T_9 NPK+S+Zn+B+FYM (25% N replacement)	26.48	31.63	58.11	32.46	34.16	66.62
T_{10} NPK+S+Zn+B+VC (25% N replacement)	27.42	32.16	59.59	32.99	34.68	67.68
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	24.55	30.97	55.53	33.07	34.03	67.10
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	25.88	31.42	57.3	33.53	34.32	67.86
T_{13} NPK+S+Zn+B+FYM (25% N additional)	35.02	39.38	74.41	38.65	40.75	79.40
T_{14} NPK+S+Zn+B+VC (25% N additional)	36.12	40.32	76.44	39.44	41.56	81.00
S.Em.±	1.791	1.056	2.784	2.481	1.569	3.989
C.D. at 5%	5.235	3.087	8.138	7.253	4.586	11.659

TABLE 4.11 **Influence of inorganics and organics on phoshorus uptake (kg ha^{-1}) in seed, stover and total P uptake of maize during 2006-07 and 2007-08**

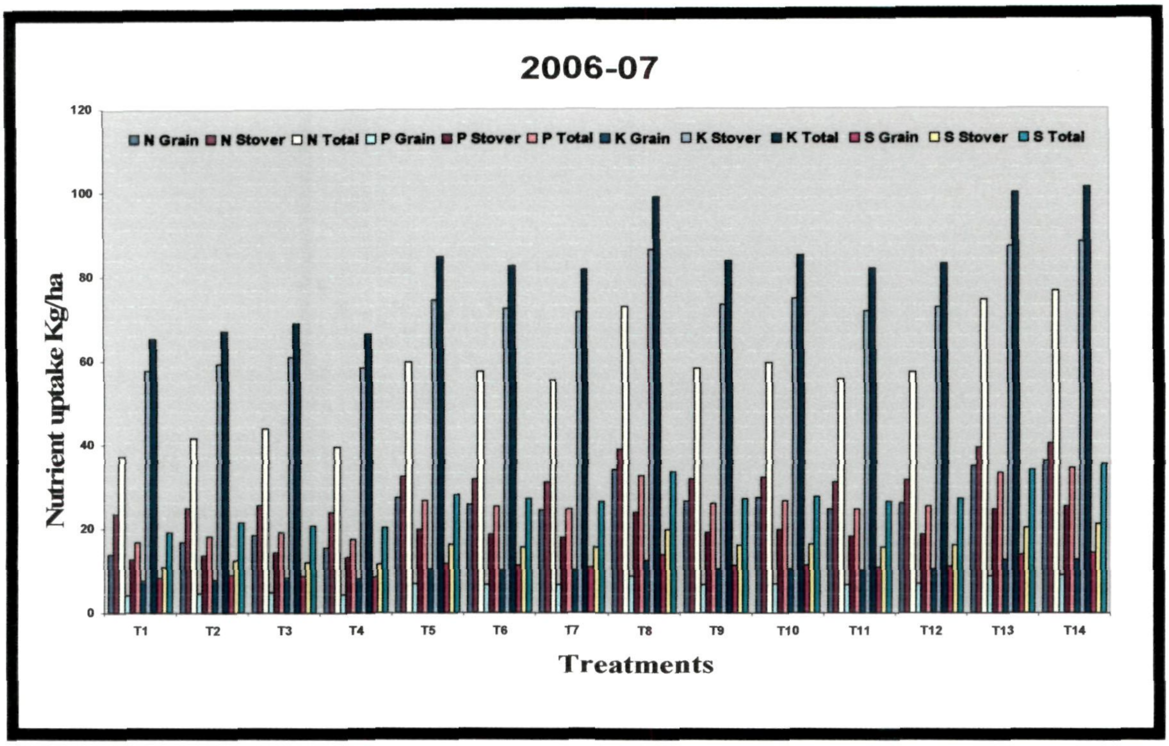
Treatment	Phosphorus uptake (kg ha^{-1})					
	2006-07			2007-08		
	Grain	Stover	Total	Grain	Stover	Total
T_1 NPK	4.14	12.58	16.72	4.48	13.18	17.67
T_2 NPK+S	4.52	13.65	18.17	4.81	14.48	19.30
T_3 NPK+Zn	4.77	14.22	19.00	5.15	15.00	20.15
T_4 NPK+B	4.35	13.03	17.39	4.62	13.75	18.38
T_5 NPK+S+Zn	6.87	19.82	26.69	7.30	20.71	28.01
T_6 NPK+S+B	6.71	18.63	25.34	7.12	19.70	26.82
T_7 NPK+Zn+B	6.58	17.98	24.56	6.99	18.86	25.85
T_8 NPK+S+Zn+B	8.75	23.90	32.66	9.34	24.84	34.18
T_9 NPK+S+Zn+B+FYM (25% N replacement)	6.73	19.15	25.89	7.57	21.26	28.83
T_{10} NPK+S+Zn+B+VC (25% N replacement)	6.84	19.74	26.58	7.84	22.16	30.00
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	6.62	18.06	24.68	7.74	20.99	28.74
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	6.79	18.57	25.37	7.99	21.52	29.52
T_{13} NPK+S+Zn+B+FYM (25% N additional)	8.83	24.61	33.44	9.58	25.70	35.29
T_{14} NPK+S+Zn+B+VC (25% N additional)	9.03	25.39	34.43	9.84	26.56	36.40
S.Em.±	0.575	0.909	1.420	0.679	0.978	1.549
C.D. at 5%	1.681	2.658	4.150	1.985	2.858	4.528

TABLE 4.12: **Influence of inorganics and organics on potassium uptake (kg ha^{-1}) in seed, stover and total K uptake of maize during 2006-07 and 2007-08**

Treatment	Potassium uptake (kg ha^{-1})					
	2006-07			2007-08		
	Grain	Stover	Total	Grain	Stover	Total
T_1 NPK	7.62	57.64	65.27	7.79	58.18	65.97
T_2 NPK+S	7.85	59.38	67.24	8.08	59.75	67.83
T_3 NPK+Zn	8.18	60.83	69.01	8.41	61.91	70.32
T_4 NPK+B	7.96	58.48	66.44	8.14	59.59	67.73
T_5 NPK+S+Zn	10.33	74.39	84.73	10.80	75.57	86.37
T_6 NPK+S+B	10.18	72.43	82.62	10.64	73.87	84.51
T_7 NPK+Zn+B	10.01	71.54	81.55	10.52	72.72	83.25
T_8 NPK+S+Zn+B	12.46	86.35	98.81	13.14	87.51	100.65
T_9 NPK+S+Zn+B+FYM (25% N replacement)	10.27	73.35	83.63	11.25	78.46	90.16
T_{10} NPK+S+Zn+B+VC (25% N replacement)	10.40	74.65	85.05	11.51	79.44	92.10
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	10.09	71.73	81.82	11.42	78.46	89.89
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	10.25	72.71	82.96	11.60	79.44	91.05
T_{13} NPK+S+Zn+B+FYM (25% N additional)	12.55	87.11	99.67	13.45	89.69	103.14
T_{14} NPK+S+Zn+B+VC (25% N additional)	12.71	88.38	101.09	13.64	91.04	104.68
S.Em.±	0.593	3.11	3.66	0.922	3.657	4.539
C.D. at 5%	1.735	9.116	10.715	2.694	10.690	13.269

TABLE 4.13 : **Influence of inorganics and organics on sulphur uptake (kg ha^{-1}) in seed, stover and total S uptake of maize during 2006-07 and 2007-08**

Treatment	Sulphur uptake (kg ha^{-1})					
	2006-07			2007-08		
	Grain	Stover	Total	Grain	Stover	Total
T_1 NPK	8.23	10.88	19.12	8.39	11.39	19.78
T_2 NPK+S	9.04	12.35	21.39	9.25	12.99	22.25
T_3 NPK+Zn	8.81	11.98	20.80	9.02	12.66	21.68
T_4 NPK+B	8.60	11.57	20.18	8.73	12.11	20.84
T_5 NPK+S+Zn	11.68	16.29	27.97	11.94	16.89	28.83
T_6 NPK+S+B	11.33	15.74	27.07	11.57	16.67	28.25
T_7 NPK+Zn+B	10.87	15.53	26.41	11.13	16.22	27.36
T_8 NPK+S+Zn+B	13.73	19.84	33.57	14.08	20.36	34.45
T_9 NPK+S+Zn+B+FYM (25% N replacement)	11.17	15.99	27.17	12.21	17.78	29.99
T_{10} NPK+S+Zn+B+VC (25% N replacement)	11.31	16.39	27.70	12.35	18.28	30.63
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	10.91	15.53	26.45	12.36	17.77	30.14
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	11.13	16.03	27.17	12.47	18.01	30.48
T_{13} NPK+S+Zn+B+FYM (25% N additional)	13.85	20.25	34.10	14.45	21.24	35.69
T_{14} NPK+S+Zn+B+VC (25% N additional)	14.26	21.19	35.46	14.89	22.16	37.05
S.Em.±	0.558	0.986	1.476	0.589	1.158	1.651
C.D. at 5%	1.632	2.883	4.315	1.721	3.384	4.827



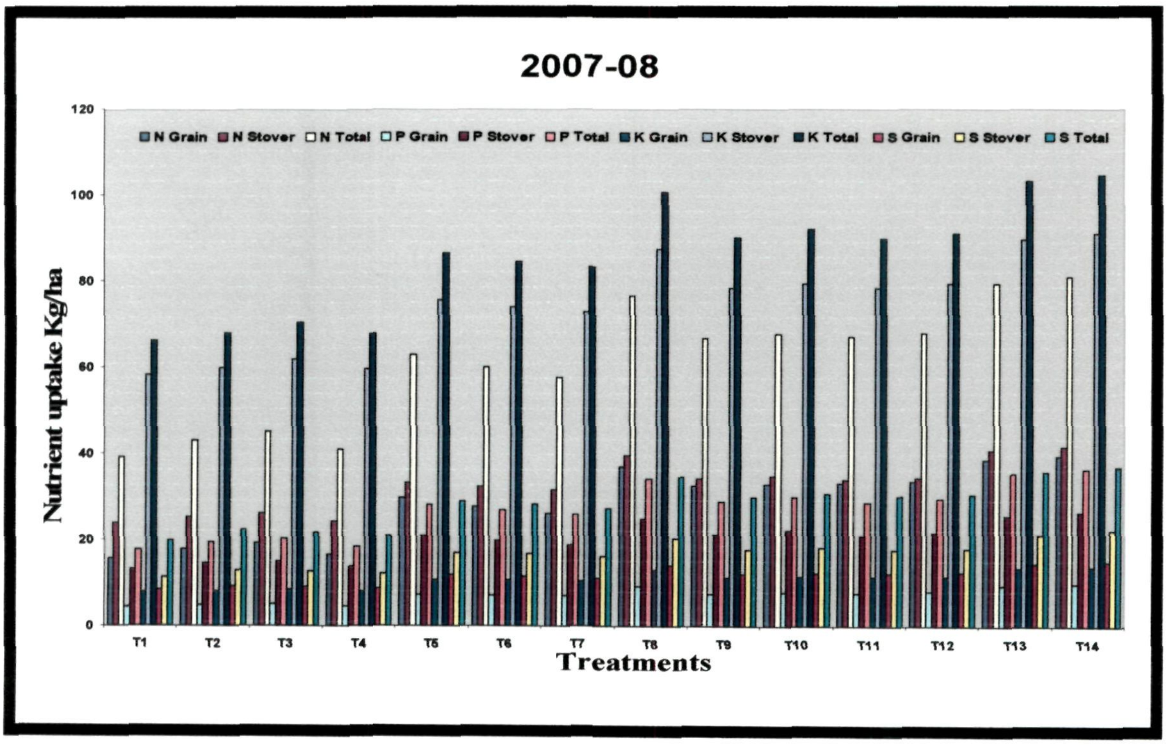


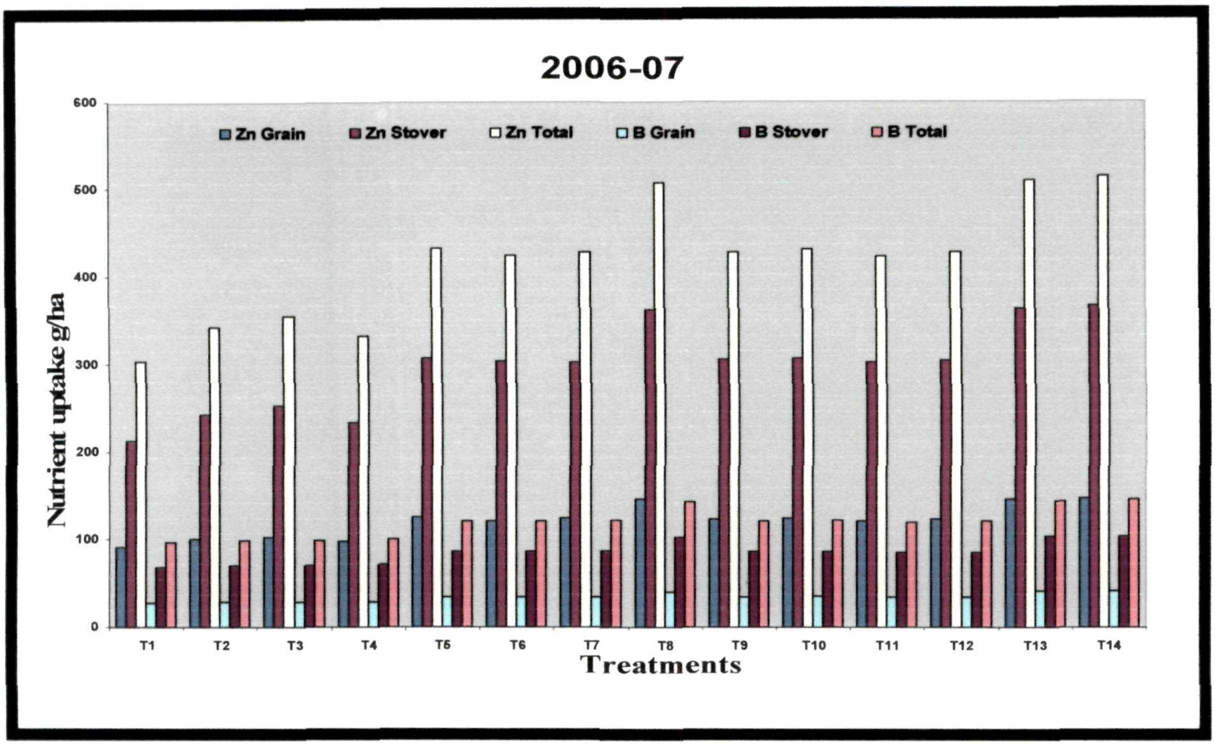
Fig 4.2 Influence of inorganics and organics on N, P, K, and S uptake (kg ha^{-1}) in grain, stover and total uptake of maize during 2006-07 and 2007-08

TABLE 4.14 : **Influence of inorganics and organics on zinc uptake (g ha^{-1}) in seed, stover and total Zn uptake of maize during 2006-07 and 2007-08**

Treatment	Zinc uptake (g ha^{-1})					
	2006-07			2007-08		
	Grain	Stover	Total	Grain	Stover	Total
T_1 NPK	90.80	212.29	303.10	96.45	230.45	326.90
T_2 NPK+S	100.50	242.44	342.94	105.67	257.35	363.03
T_3 NPK+Zn	102.18	252.50	354.68	107.83	272.29	380.12
T_4 NPK+B	97.92	233.79	331.72	103.02	251.69	354.71
T_5 NPK+S+Zn	124.92	307.08	432.00	128.77	334.53	463.30
T_6 NPK+S+B	121.03	303.36	424.39	126.79	329.45	456.25
T_7 NPK+Zn+B	124.27	302.86	427.13	127.88	328.06	455.94
T_8 NPK+S+Zn+B	145.67	361.55	507.22	156.10	393.60	549.70
T_9 NPK+S+Zn+B+FYM (25% N replacement)	122.89	305.19	428.08	149.87	351.94	501.81
T_{10} NPK+S+Zn+B+VC (25% N replacement)	124.39	306.48	430.87	151.87	355.79	507.67
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	120.71	302.59	423.31	151.79	357.32	509.11
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	122.62	304.41	427.04	153.41	359.78	513.19
T_{13} NPK+S+Zn+B+FYM (25% N additional)	146.25	363.12	509.38	159.31	401.93	561.24
T_{14} NPK+S+Zn+B+VC (25% N additional)	147.20	366.32	513.52	160.34	404.87	565.21
S.Em.±	4.535	13.278	13.658	6.088	14.678	20.539
C.D. at 5%	13.255	38.812	39.923	17.796	42.905	60.037

TABLE 4.15 : **Influence of inorganics and organics on boron uptake (g ha^{-1}) in seed, stover and total B uptake of maize during 2006-07 and 2007-08**

Treatment	Boron uptake (g ha^{-1})					
	2006-07			2007-08		
	Grain	Stover	Total	Grain	Stover	Total
T_1 NPK	28.01	68.19	96.20	33.40	75.51	108.91
T_2 NPK+S	28.69	69.99	98.68	34.76	80.27	115.03
T_3 NPK+Zn	28.64	70.67	99.32	33.41	82.07	115.48
T_4 NPK+B	28.85	71.03	99.89	33.7	83.50	117.20
T_5 NPK+S+Zn	34.74	86.28	121.02	41.17	102.24	143.41
T_6 NPK+S+B	34.76	86.16	120.93	41.73	104.38	146.12
T_7 NPK+Zn+B	34.83	86.79	121.63	41.86	104.71	146.57
T_8 NPK+S+Zn+B	40.71	102.38	143.10	48.85	122.34	171.19
T_9 NPK+S+Zn+B+FYM (25% N replacement)	34.91	85.83	120.75	47.13	108.11	155.24
T_{10} NPK+S+Zn+B+VC (25% N replacement)	35.15	86.36	121.52	47.83	110.08	157.92
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	34.35	84.81	119.16	48.52	110.60	159.13
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	34.79	85.41	120.21	49.2	112.34	161.55
T_{13} NPK+S+Zn+B+FYM (25% N additional)	40.96	102.9	143.87	49.89	125.47	175.37
T_{14} NPK+S+Zn+B+VC (25% N additional)	41.52	103.88	145.41	50.32	126.58	176.90
S.Em.±	1.395	4.714	5.828	1.901	5.948	7.724
C.D. at 5%	4.077	13.878	17.035	5.556	17.386	22.577



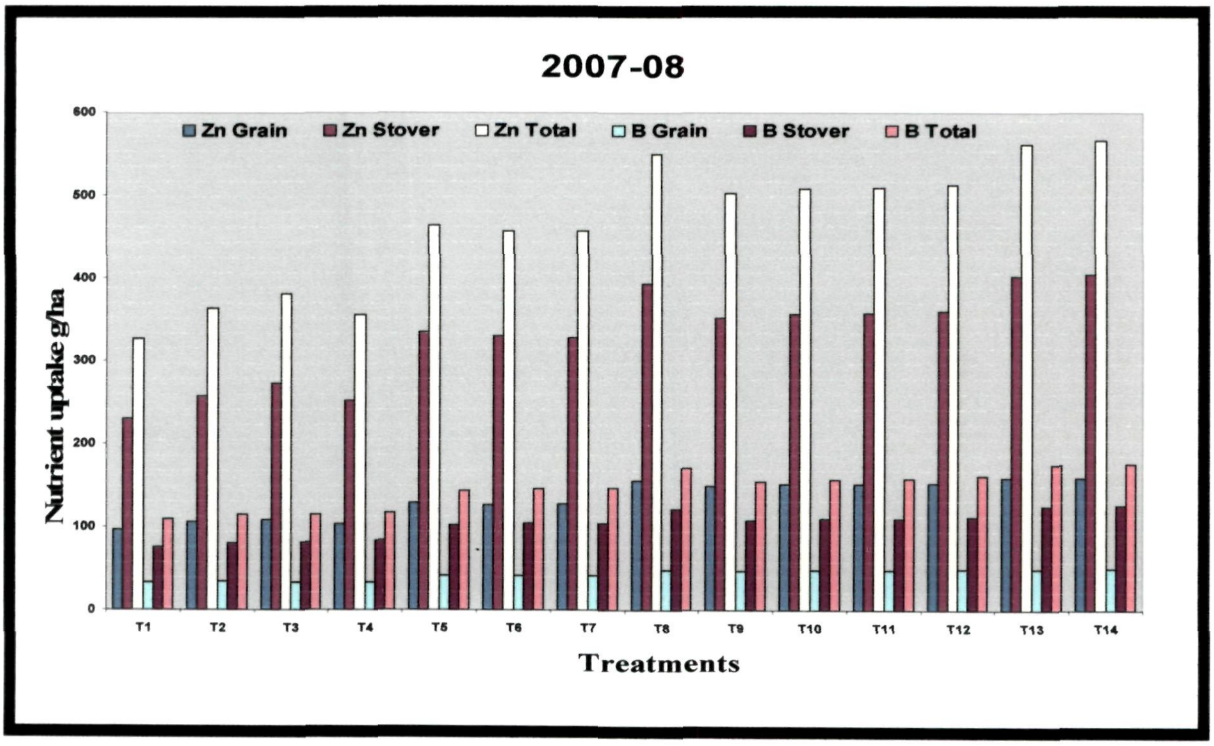


Fig.4.3 Influence of inorganics and organics on Zn, and B uptake (g ha^{-1}) in grain, stover and total uptake of maize during 2006-07 and 2007-08

The total N,P,K,S, Zn and B uptake was significantly higher with the application of 100 per cent recommended NPK coupled with S, Zn, B and VC (T_{14}) being at par with T_8 and T_{13} during 2006-07 and T_8 to T_{13} during 2007-08.

Treatments, T_8,T_{13} and T_{14} during 2006-07 reported significantly higher total N, P, K, S, Zn and B than T_1 to T_7 and T_9 to T_{12} while during 2007-08, treatment T_{14} recorded significantly higher total N, P, K, S, Zn and B uptake value over T_1 to T_4 while T_9 to T_{13} were found to be at par with T_{14}.

4.5.2 Nutrient uptake by seed and stover in gobhi-sarson

The residual effect of inorganic was remarkably observed on nutrient uptake of N, P, K, S, Zn and B in seed and stover of gobhi sarson. Significantly higher N, P, K, S, Zn and B uptake was recorded in T_{14} over all the treatments except T_{13} and T_8 during 2006-07 and T_8 to T_{13} during 2007-08 which were of the similar magnitude.

The significant and pronounced effect on nutrient uptake in treatment T_{11} and T_{12} over T_1 to T_4 was observed during both the years. During 2nd year, the treatments which received integrated application of inorganics and organics (T_9 to T_{14}) were found to be statistically at par with each other.

The data pertaining to nutrient uptake in gobhi sarson presented in Table 4.16, 4.17, 4.18, 4.19, 4.20, 4.21 and Fig. 4.4 and 4.5, revealed significant and prounounced effect in nutrient uptake by stover of gobhi sarson was observed due to the residual effect of inorganics and organic sources of nutrients. Significantly higher N, P, K, S, Zn and B uptake in stover was recorded in T_{14} over all other treatments except T_{13} and T_8 during 2006-07, and T_8 to T_{13} during 2007-08. Treatments, T_{13} and T_{14} during 2006-07 recorded

TABLE 4.16 : **Residual effect of inorganics and organics on seed, stover and total N uptake (kg ha^{-1}) of gobhi-sarson during 2006-07 and 2007-08**

Treatment	Nitrogen uptake (kg ha^{-1})					
	2006-07			2007-08		
	Seed	Stover	Total	Seed	Stover	Total
T_1 NPK	27.81	14.44	42.26	28.97	16.25	45.23
T_2 NPK+S	30.45	17.23	47.69	31.61	19.26	50.87
T_3 NPK+Zn	29.41	16.19	45.61	30.50	18.14	48.65
T_4 NPK+B	28.66	15.06	43.72	29.84	16.88	46.73
T_5 NPK+S+Zn	38.50	26.15	64.66	39.94	28.96	68.91
T_6 NPK+S+B	37.30	24.28	61.58	38.81	26.95	65.77
T_7 NPK+Zn+B	36.36	23.03	59.40	38.01	25.75	63.77
T_8 NPK+S+Zn+B	44.88	32.95	77.84	46.79	36.10	82.89
T_9 NPK+S+Zn+B+FYM (25% N replacement)	37.82	24.75	62.57	43.72	30.47	74.19
T_{10} NPK+S+Zn+B+VC (25% N replacement)	38.52	25.94	64.47	44.67	31.16	75.83
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	36.48	22.83	59.32	43.95	29.49	73.45
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	37.45	24.08	61.54	44.70	30.79	75.50
T_{13} NPK+S+Zn+B+FYM (25% N additional)	45.49	33.67	79.17	48.21	38.46	86.67
T_{14} NPK+S+Zn+B+VC (25% N additional)	46.59	36.18	82.76	49.27	40.44	89.72
S.Em.±	2.598	1.812	4.265	3.667	2.117	5.564
C.D. at 5%	7.595	5.297	12.468	10.718	6.188	16.263

TABLE 4.17 : **Residual effect of inorganics and organics on seed, stover and total P uptake (kg ha^{-1}) of gobhi-sarson during 2006-07 and 2007-08**

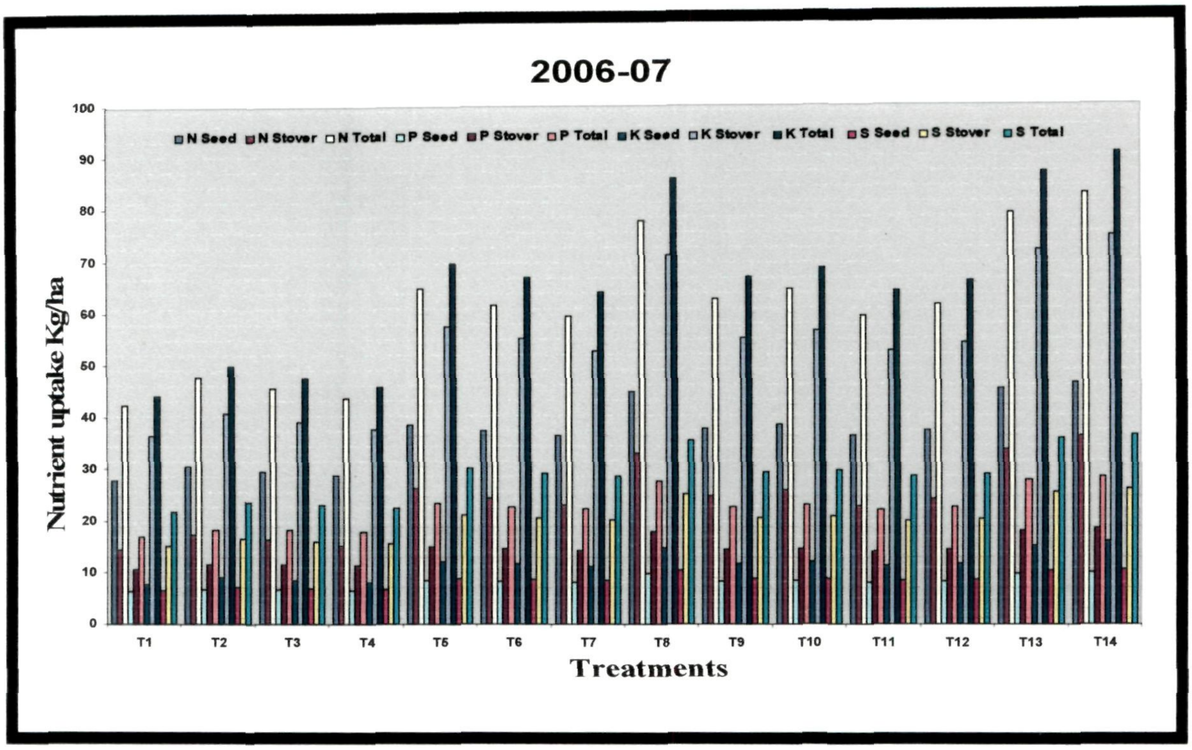
Treatment	Phosphorus uptake (kg ha^{-1})					
	2006-07			2007-08		
	Seed	Stover	Total	Seed	Stover	Total
T_1 NPK	6.3	10.59	16.89	6.46	10.98	17.44
T_2 NPK+S	6.8	11.47	18.27	6.98	11.83	18.82
T_3 NPK+Zn	6.61	11.56	18.17	6.74	12.02	18.76
T_4 NPK+B	6.44	11.29	17.74	6.61	11.64	18.25
T_5 NPK+S+Zn	8.39	14.91	23.31	8.57	15.38	23.95
T_6 NPK+S+B	8.20	14.47	22.67	8.38	14.92	23.31
T_7 NPK+Zn+B	8.04	14.17	22.22	8.31	14.67	22.98
T_8 NPK+S+Zn+B	9.72	17.80	27.52	10.03	18.34	28.37
T_9 NPK+S+Zn+B+FYM (25% N replacement)	8.30	14.34	22.64	9.56	16.58	26.14
T_{10} NPK+S+Zn+B+VC (25% N replacement)	8.40	14.63	23.04	9.66	16.93	26.59
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	8.08	14.00	22.08	9.59	16.81	26.41
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	8.21	14.35	22.57	9.69	17.06	26.76
T_{13} NPK+S+Zn+B+FYM (25% N additional)	9.81	18.00	27.81	10.35	19.11	29.47
T_{14} NPK+S+Zn+B+VC (25% N additional)	9.99	18.38	28.37	10.52	19.59	30.12
S.Em.±	0.401	0.818	1.110	0.413	0.900	1.258
C.D. at 5%	1.171	2.390	3.245	1.207	2.631	3.678

TABLE 4.18 : **Residual effect of inorganics and organics on seed, stover and total K uptake (kg ha^{-1}) of gobhi-sarson during 2006-07 and 2007-08**

Treatment	Potassium uptake (kg ha^{-1})					
	2006-07			2007-08		
	Seed	Stover	Total	Seed	Stover	Total
T_1 NPK	7.73	36.32	44.06	8.37	38.22	46.60
T_2 NPK+S	8.93	40.82	49.76	9.59	43.58	53.17
T_3 NPK+Zn	8.46	39.12	47.59	9.11	40.82	49.93
T_4 NPK+B	8.13	37.65	45.78	8.78	39.10	47.89
T_5 NPK+S+Zn	12.09	57.53	69.63	13.10	60.56	73.67
T_6 NPK+S+B	11.66	55.24	66.90	12.57	58.04	70.62
T_7 NPK+Zn+B	11.20	52.71	63.91	12.14	55.62	67.76
T_8 NPK+S+Zn+B	14.69	71.09	85.79	16.05	75.69	91.74
T_9 NPK+S+Zn+B+FYM (25% N replacement)	11.67	55.19	66.86	13.60	65.60	79.20
T_{10} NPK+S+Zn+B+VC (25% N replacement)	12.10	56.56	68.66	14.24	67.62	81.87
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	11.36	52.77	64.13	14.18	66.66	80.84
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	11.71	54.31	66.02	14.66	69.29	83.96
T_{13} NPK+S+Zn+B+FYM (25% N additional)	15.04	71.98	87.02	16.73	79.33	96.06
T_{14} NPK+S+Zn+B+VC (25% N additional)	15.85	74.70	90.55	17.56	82.69	100.25
S.Em.±	0.677	3.862	4.438	0.885	4.095	4.941
C.D. at 5%	1.980	11.288	12.972	2.588	11.970	14.443

TABLE 4.19 : **Residual effect of inorganics and organics on seed, stover and total S uptake (kg ha^{-1}) of gobhi-sarson during 2006-07 and 2007-08**

Treatment	Sulphur uptake (kg ha^{-1})					
	2006-07			2007-08		
	Seed	Stover	Total	Seed	Stover	Total
T_1 NPK	6.59	15.11	21.7	6.75	15.38	22.13
T_2 NPK+S	7.12	16.42	23.54	7.28	16.89	24.17
T_3 NPK+Zn	6.93	15.96	22.9	7.06	16.33	23.39
T_4 NPK+B	6.74	15.59	22.33	6.91	15.86	22.77
T_5 NPK+S+Zn	8.86	21.13	29.99	9.06	21.75	30.81
T_6 NPK+S+B	8.63	20.55	29.19	8.81	21.09	29.91
T_7 NPK+Zn+B	8.45	20.11	28.57	8.68	20.70	29.39
T_8 NPK+S+Zn+B	10.28	25.14	35.43	10.56	25.91	36.47
T_9 NPK+S+Zn+B+FYM (25% N replacement)	8.74	20.52	29.27	9.98	23.72	33.70
T_{10} NPK+S+Zn+B+VC (25% N replacement)	8.85	20.86	29.71	10.08	24.12	34.20
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	8.49	19.99	28.49	10.00	23.77	33.78
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	8.64	20.34	28.98	10.12	24.10	34.22
T_{13} NPK+S+Zn+B+FYM (25% N additional)	10.35	25.54	35.89	10.85	26.92	37.77
T_{14} NPK+S+Zn+B+VC (25% N additional)	10.5	25.97	36.48	11.00	27.34	38.35
S.Em.±	0.422	1.164	1.531	0.438	1.212	1.450
C.D. at 5%	1.235	3.403	4.475	1.281	3.543	4.238



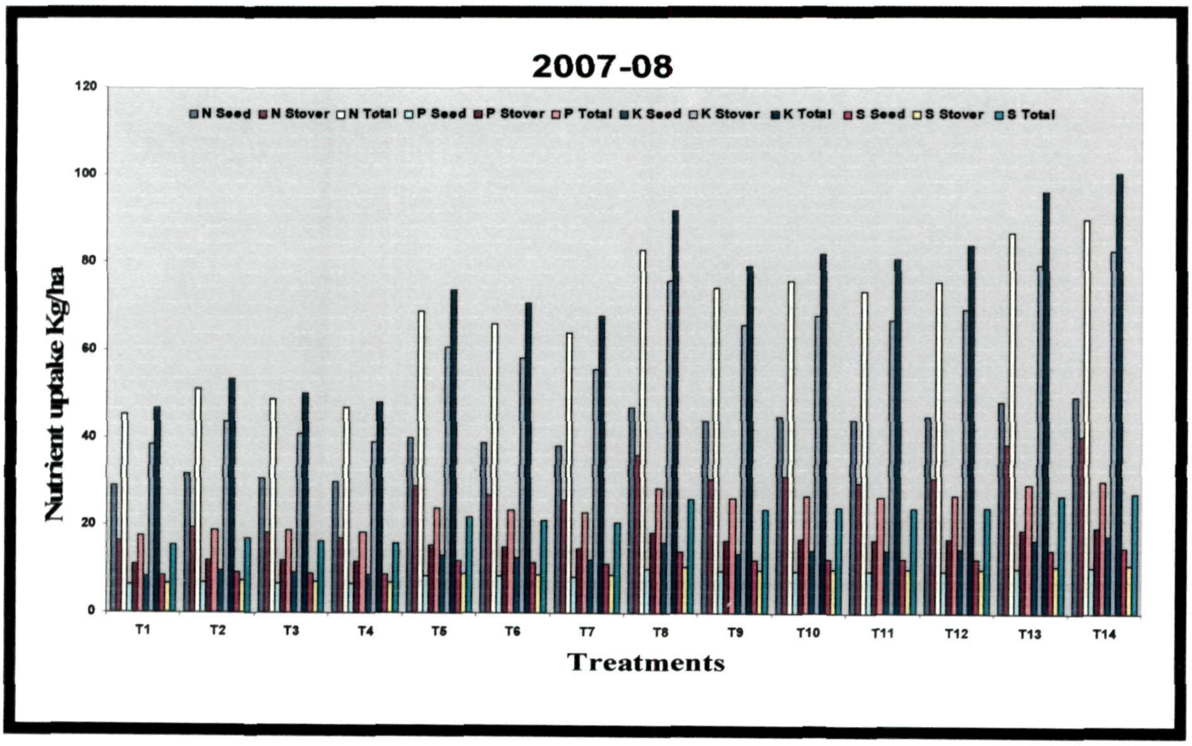


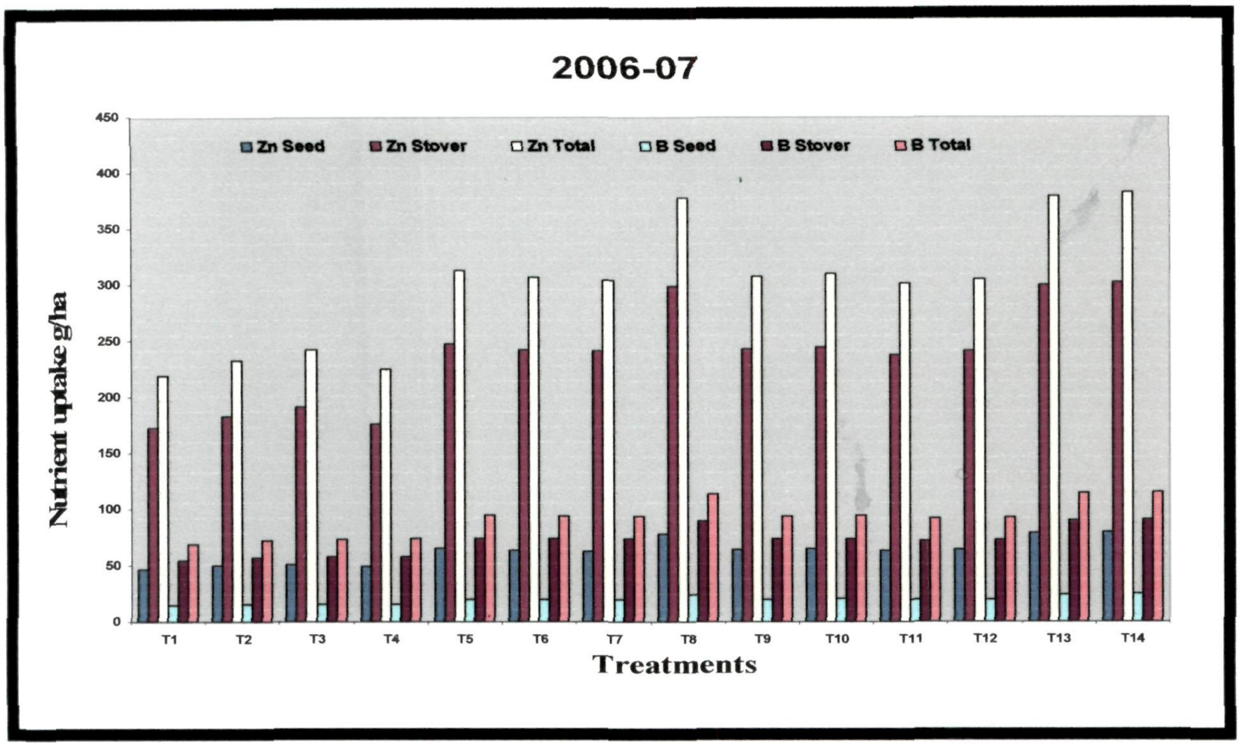
Fig. 4.4 Residual effect of inorganic and organic sources of nutrients on N,P,K, and S uptake (kg/ha) in seed, stover and total uptake of gobhi-sarson during 2006-07 and 2007-08

TABLE 4.20: **Residual effect of inorganics and organics on seed, stover and total Zn uptake (g ha^{-1}) of gobhi-sarson during 2006-07 and 2007-08**

Treatment	Zinc uptake (g ha^{-1})					
	2006-07			2007-08		
	Seed	Stover	Total	Seed	Stover	Total
T_1 NPK	46.50	172.15	218.66	48.74	178.44	227.19
T_2 NPK+S	49.82	183.12	232.94	51.61	189.63	241.24
T_3 NPK+Zn	50.89	191.57	242.46	54.20	203.09	257.29
T_4 NPK+B	49.06	176.23	225.30	51.68	182.62	234.30
T_5 NPK+S+Zn	65.65	247.64	313.30	70.01	262.67	332.69
T_6 NPK+S+B	64.15	242.51	306.67	68.25	255.47	323.73
T_7 NPK+Zn+B	63.27	241.01	304.28	68.25	255.24	323.49
T_8 NPK+S+Zn+B	78.36	298.94	377.30	84.22	316.89	401.11
T_9 NPK+S+Zn+B+FYM (25% N replacement)	64.91	243.15	308.06	77.20	294.15	371.35
T_{10} NPK+S+Zn+B+VC (25% N replacement)	65.58	245.13	310.71	78.41	296.66	375.07
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	63.52	238.34	301.86	79.28	298.73	378.01
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	64.29	241.14	305.43	80.72	301.31	382.03
T_{13} NPK+S+Zn+B+FYM (25% N additional)	78.94	300.41	379.35	86.81	327.91	414.72
T_{14} NPK+S+Zn+B+VC (25% N additional)	80.06	302.77	382.83	88.32	332.58	420.90
S.Em.±	4.078	16.427	18.499	4.754	17.512	22.143
C.D. at 5%	11.920	48.017	54.072	13.897	51.187	64.724

TABLE 4.21 : Residual effect of inorganics and organics on seed, stover and total B uptake (g ha^{-1}) of gobhi-sarson during 2006-07 and 2007-08

Treatment	Boron uptake (g ha^{-1})					
	2006-07			2007-08		
	Seed	Stover	Total	Seed	Stover	Total
T_1 NPK	14.81	53.97	68.78	16.30	55.66	71.96
T_2 NPK+S	15.56	56.69	72.25	17.17	59.07	76.25
T_3 NPK+Zn	15.63	57.47	73.11	17.30	60.10	77.40
T_4 NPK+B	15.73	58.01	73.74	17.72	61.09	78.81
T_5 NPK+S+Zn	20.21	74.37	94.59	22.75	79.52	102.27
T_6 NPK+S+B	20.00	74.09	94.09	22.85	79.14	101.99
T_7 NPK+Zn+B	19.87	73.79	93.66	23.06	80.99	104.05
T_8 NPK+S+Zn+B	24.18	89.76	113.95	28.00	98.68	126.69
T_9 NPK+S+Zn+B+FYM (25% N replacement)	20.24	73.75	93.99	26.61	92.25	118.87
T_{10} NPK+S+Zn+B+VC (25% N replacement)	20.40	74.55	94.95	27.01	93.90	120.91
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	19.79	72.19	91.99	27.59	95.08	122.68
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	20.07	73.17	93.24	28.03	96.35	124.38
T_{13} NPK+S+Zn+B+FYM (25% N additional)	24.34	90.35	114.69	28.74	102.77	131.52
T_{14} NPK+S+Zn+B+VC (25% N additional)	24.62	91.04	115.66	29.20	103.94	133.14
S.Em.±	1.144	4.683	5.488	1.642	5.452	6.958
C.D. at 5%	3.344	13.690	16.041	4.801	15.936	20.338



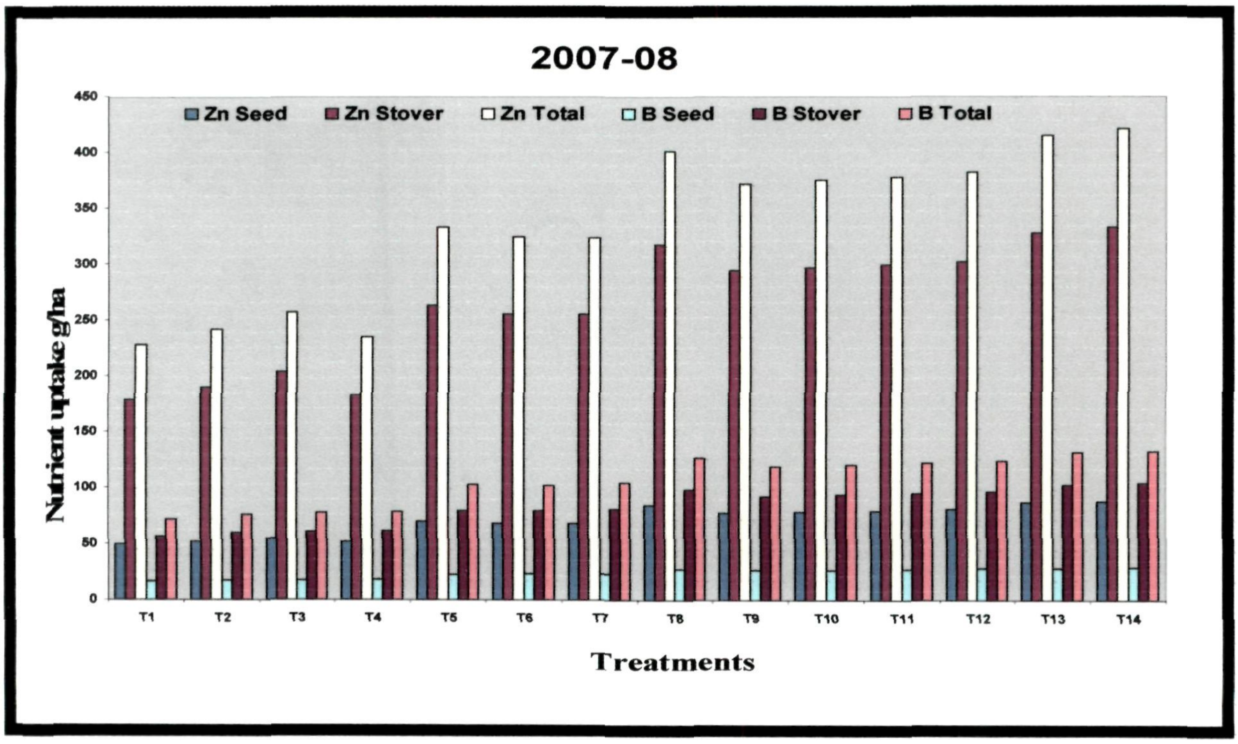


Fig. 4.5 Residual effect of inorganic and organic sources of nutrients on Zn and B uptake (g/ha) in seed, stover and total uptake of gobhi-sarson during 2006-07 and 2007-08

significantly higher uptake of N, P, K, S, Zn and B by stover over T_1 to T_7 and T_9 to T_{12} while during 2007-08, T_{14} was found to be at par with T_9 to T_{12}.

Due to the residual effect of inorganics and organic sources of nutrients, the total N, P, K, S, Zn and B uptake was significantly higher in T_{14} being at par with T_8 and T_{13} and T_8 to T_{13} during 2007-08. Treatments, T_8 and T_{13} to T_{14} during 2006-07 reported significantly higher total N, P, K, S, Zn and B over T_1 to T_7 followed by T_9 to T_{12} while during 2007-08, treatment T_{14} recorded significantly higher total N, P, K, S, Zn and B uptake value than T_1 to T_4 while T_9 to T_{13} were found to be at par with T_{14}.

4.6 Quality studies

4.6.1 Protein content in maize

The data presented in Table 4.22 showed significant variations in protein content due to different nutrient management practices during both the years. Addition of supplementary ingredients viz. FYM, VC, sulphur, zinc and boron progressively increased the protein content in grain: being maximum at recommended NPK alongwith VC (25%N additional), sulphur, zinc and boron (T_{14}) during both the years. Crop receiving 100 percent of the recommended NPK (T_1) alone, exhibited minimum protein content, though at par with that of recommended NPK in combination with either S, Zn and B alone (T_2, T_3 and T_4) during both years.

During 2006-07 significant difference were noted in protein content in T_8, T_{13} and T_{14} over T_1 to T_7 and T_9 to T_{12}. However, during 2007-08 significant differences were observed in T_8 to T_{14} over T_1 to T_7.

4.6.2 Oil and protein content in gobhi-sarson

The difference in integrated plant nutrient management practices had no remarkable effect on the oil content in seeds during both the years. (Table 4.22 and 4.23) The oil content of the crop ranged from 40.43 to 41.27during 2006-07 and 40.46 to 41.33 during

2007-08.The highest oil content was recorded in T_{12} during both the years 41.27 and 41.33 percent during 2006-07 and 2007-08 respectively.

In general, oil yield was higher during 2007-08 as compared to 2006-07. Differences in integrated application of inorganics and organics sources significantly influenced the oil yield during both the years .Significantly higher oil yield was recorded in T_{14} over all the treatments except T_8 and T_{13} during 2006-07 and T_9 to T_{13} during 2007-08. The significant and pronounced effect on oil yield in treatment T_{11} and T_{12} over T_1 to T_4 was recorded during both the years. However, during 2^{nd} year, all the organically treated plots (T_9 to T_{14}) were found to be statistically at par with each other.

The residual effect of inorganics and organics was remarkably observed on protein content of gobhi-sarson. Significantly higher protein content was recorded in T_{14} over all the treatments except T_8 and T_{13} during 2006-07 and T_8 to T_{13} during 2007-08 which were of the similar magnitude.

The significant and pronounced effect on protein content in treatment T_{11} and T_{12} over T_1 to T_4 was observed during both the years. However, during 2^{nd} year, the treatments which received integrated application of inorganics and organics (T_9 to T_{14}) were found to be statistically at par with each other.

TABLE 4.22: **Direct and residual effect of inorganics and organics on protein content of maize (%) and gobhi-sarson (%) under maize- gobhi sarson sequence**

Treatment	Protein content of Maize (%)		Protein content of Gobhi Sarson (%)	
	2006-07	2007-08	2006-07	2007-08
T_1	3.27	3.66	16.91	17.33
T_2	3.91	4.08	17.72	18.16
T_3	4.27	4.39	17.41	17.85
T_4	3.64	3.91	17.22	17.64
T_5	5.95	6.41	19.52	20.02
T_6	5.64	5.97	19.22	19.72
T_7	5.35	5.64	18.91	19.39
T_8	7.04	7.52	20.66	21.16
T_9	5.79	6.60	19.29	19.70
T_{10}	5.97	6.66	19.54	20.04
T_{11}	5.41	6.64	18.89	19.60
T_{12}	5.66	6.70	19.20	19.83
T_{13}	7.20	7.72	20.85	21.29
T_{14}	7.39	7.85	21.14	21.58
S.Em.±	0.30	0.34	0.35	0.36
C.D. (p=0.05)	0.89	0.99	1.04	1.07

Table 4.23: Residual effect of inorganics and organics on oil content (%) and oil yield (q ha^{-1})of gobhi-sarson under maize-gobhi sarson sequence

Treatment	Oil content of Gobhi-sarson(%)		Oil yield of Gobhi-Sarson (q ha^{-1})	
	2006-07	2007-08	2006-07	2007-08
T_1	40.43	40.46	4.16	4.23
T_2	40.57	40.60	4.36	4.42
T_3	40.49	40.51	4.28	4.33
T_4	40.48	40.52	4.21	4.28
T_5	40.63	40.67	5.01	5.07
T_6	40.61	40.65	4.93	5.00
T_7	40.50	40.54	4.87	4.97
T_8	40.65	40.68	5.53	5.63
T_9	40.93	40.98	5.04	5.70
T_{10}	41.12	41.19	5.09	5.75
T_{11}	41.18	41.25	4.98	5.80
T_{12}	41.27	41.33	5.04	5.84
T_{13}	40.76	40.83	5.57	5.80
T_{14}	40.85	40.93	5.63	5.85
S.Em.±	0.33	0.34	0.19	0.21
C.D. (p=0.05)	NS	NS	0.57	0.61

4.7 Soil analysis of experimental site

4.7.1 Physico-chemical properties of soil after harvest of maize gobhi-sarson sequence

Data pertaining to the mean changes in physical and chemical properties of soil as influenced by different treatments after completion of each maize gobhi-sarson sequence are summarized in table 4.24 and 4.25

4.7.2 Changes in pH, EC (dSm^{-1}), organic carbon content of soil (%),CEC ($Cmol(p^{+})\ kg^{-1}$) bulk density ($Mg\ m^{-3}$) and water holding capacity (%) of soil after each maize-gohi-sarson sequence

Soil data after completion of each maize-gohi-sarson sequence indicated that there was not much of variation in soil pH and EC during both the years. (Table 4.24 and 4.25) The value of pH and EC ranged from 6.50 to 6.80 and 0.19 to 0.23 (dSm^{-1}), respectively. While the organic carbon content, CEC of surface soil (0-15 cm) and water holding capacity increased in all the treatments over initial values except for the control during both the years of experiment. Organic carbon content and CEC increased considerably where 50 per cent of recommended dose of farm yard manure and vermicompost were incorporated along with 50 per cent inorganic fertilizer. During the 2nd year, the data on bulk density showed significant reduction where 50 per cent of recommended dose of farm yard manure and vermicompost were incorporated along with 50 per cent inorganic fertilizer. The maximum value of soil organic carbon content (0.51 %) and water holding capacity (19.86 %) whereas lower bulk density (1.18 $Mg\ m^{-3}$) in surface soil was found in the treatment T_{12} where 50% RDF was applied along with 50 per cent recommended

Table 4.24: Effect of inorganics and organics on post-harvest soil properties during 2006-07 and 2007-08

Treatment	2006-2007				2007-2008			
	pH	EC (dSm^{-1})	OC (%)	CEC (C mol (p^{+}) kg^{-1})	pH	EC (dSm^{-1})	OC (%)	CEC (C mol (p^{+}) kg^{-1})
T_1	6.76	0.21	0.40	8.62	6.66	0.20	0.39	8.60
T_2	6.70	0.21	0.38	8.83	6.70	0.22	0.38	8.81
T_3	6.66	0.19	0.40	8.75	6.76	0.20	0.40	8.72
T_4	6.80	0.23	0.40	8.68	6.80	0.21	0.38	8.65
T_5	6.60	0.20	0.39	8.67	6.70	0.21	0.39	8.63
T_6	6.63	0.20	0.39	8.78	6.73	0.20	0.39	8.74
T_7	6.50	0.21	0.41	8.56	6.60	0.22	0.39	8.53
T_8	6.70	0.20	0.40	8.68	6.80	0.21	0.38	8.66
T_9	6.60	0.20	0.39	9.38	6.70	0.21	0.48	9.47
T_{10}	6.66	0.20	0.38	9.48	6.76	0.21	0.49	9.53
T_{11}	6.73	0.20	0.43	9.52	6.73	0.21	0.50	9.58
T_{12}	6.76	0.21	0.45	9.62	6.70	0.22	0.51	9.70
T_{13}	6.60	0.21	0.46	9.28	6.80	0.21	0.47	9.34
T_{14}	6.70	0.21	0.44	9.32	6.90	0.22	0.48	9.42
Initial status	6.80	0.21	0.40	9.1				
S.Em.±	0.06	0.01	0.01	0.13	0.06	0.01	0.02	0.12
C.D. (p=0.05)	N.S.	N.S.	0.04	0.38	N.S.	N.S.	0.05	0.36

Table 4.25: Effect of inorganics and organics on water holding capacity and bulk density of soil after completion of each sequence during 2006-07 and 2007-08

Treatment	2006-07	2006-07	2007-08	2007-08
	Water holding capacity (%)	Bulk Density (Mg m^{-3})	Water holding capacity (%)	Bulk Density (Mg m^{-3})
T_1	17.24	1.27	17.22	1.28
T_2	17.25	1.28	17.20	1.29
T_3	17.23	1.30	17.21	1.31
T_4	17.28	1.28	17.23	1.29
T_5	17.33	1.27	17.30	1.28
T_6	17.27	1.29	17.24	1.30
T_7	17.32	1.28	17.30	1.29
T_8	17.39	1.27	18.32	1.28
T_9	18.85	1.23	19.42	1.22
T_{10}	18.96	1.22	19.62	1.21
T_{11}	19.15	1.21	19.72	1.19
T_{12}	19.24	1.20	19.86	1.18
T_{13}	18.65	1.23	19.22	1.22
T_{14}	18.76	1.22	19.35	1.21
Initial status	17.25	1.24		
S.Em.±	0.42	0.005	0.61	0.004
C.D. (p=0.05)	1.23	0.014	1.78	0.013

dose of N through vermicompost followed by T_{11} where 50 % RDF was applied along with 50 pr cent recommended dose of N through FYM during 2007-08.

4.7.3 Changes in available nitrogen, phosphorus, potassium (kg ha^{-1}),sulphur, zinc and boron (mg kg^{-1}) in soil after each maize-gohi-sarson sequence

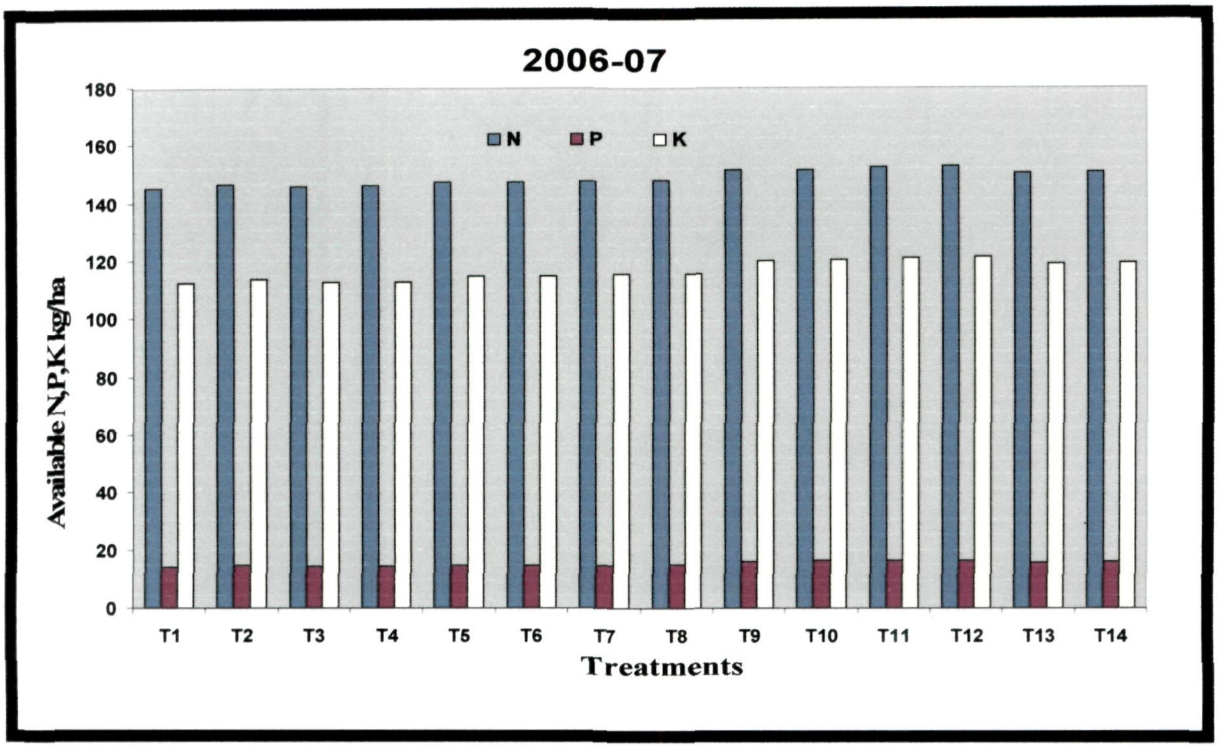
The data on available nutrients in presented in Table 4.26 and Fig 4.6 and 4.7 revealed that integrated dose of inorganics and organics sources of nutrients generally increased the nutrient status of the surface soil from their initial values during both the years. The highest status of available N, P, K, S, Zn and B was found in the treatment T_{12} followed by T_{11}, T_{10} and T_9 while the difference between former two treatments was not up to the mark. Similarly, T_{11} and T_{12} proved significantly better over T_1 to T_8 during both the years. The lower values of available nutrients were noticed in the plot receiving recommended NPK alone (T_1).

4.7.4 Balance studies

The result of estimation made to arrive at an appropriate balance sheet of available N, P and K as affected by different treatment applied to maize-gohi-sarson sequence over the two year period are presented in table 4.27. A comparison of initial status (2006) and status at the end (2008) revealed positive balance of available soil nitrogen, phosphorus and potassium in cropping sequence which received integrated application of inorganic and organic sources of nutrients. A net gain of 7.74 kg N , 1.96 kg P and 3.87 kg was observed in the treatment T_{12} where 50% RDF was applied along with 50 per cent recommended dose of N through vermi compost followed by T_{11} where 50 % RDF was applied along with 50 per cent recommended dose of N through FYM with gain of 7.46, 1.77 and 3.24 kg N, P and K, respectively. However, there was

Table 4.26: Effect of inorganics and organics on available N, P, K (kg ha^{-1}) S, Zn, B (mg kg^{-1}) status of soil after completion of each sequence during 2006-07 and 2007-08

Treatment	2006-2007						2007-2008					
	N	P	K	S	Zn	B	N	P	K	S	Zn	B
T_1	145.25	14.12	112.47	8.65	0.49	0.35	146.15	14.45	112.84	8.72	0.47	0.36
T_2	146.47	14.53	113.83	8.80	0.50	0.36	147.43	14.76	114.12	8.85	0.48	0.37
T_3	145.85	14.27	112.76	8.71	0.51	0.35	146.78	14.62	112.95	8.80	0.52	0.36
T_4	146.22	14.38	112.62	8.68	0.50	0.38	147.15	14.53	113.18	8.75	0.48	0.39
T_5	147.34	14.63	114.75	8.87	0.52	0.37	148.27	14.87	115.23	8.93	0.53	0.38
T_6	147.18	14.52	114.67	8.82	0.50	0.39	148.13	14.72	115.85	8.90	0.48	0.40
T_7	147.45	14.73	115.48	8.73	0.52	0.37	148.35	14.95	117.12	8.80	0.53	0.38
T_8	147.75	14.85	115.60	8.95	0.53	0.40	148.68	15.20	117.27	9.05	0.54	0.41
T_9	151.33	16.15	119.85	9.47	0.64	0.48	153.22	16.85	121.47	9.83	0.67	0.51
T_{10}	151.51	16.27	120.33	9.58	0.65	0.49	153.47	17.18	122.55	9.90	0.69	0.52
T_{11}	152.45	16.35	121.17	9.62	0.66	0.51	155.75	17.35	124.67	9.98	0.71	0.54
T_{12}	152.83	16.47	121.55	9.70	0.67	0.52	155.87	17.53	124.85	10.15	0.73	0.55
T_{13}	150.48	15.73	118.95	9.35	0.61	0.46	152.13	16.47	120.43	9.68	0.64	0.49
T_{14}	150.72	15.88	119.13	9.42	0.62	0.47	152.57	16.63	121.37	9.75	0.66	0.50
S.Em.±	0.90	0.27	1.11	0.16	0.025	0.024	1.31	0.31	1.58	0.21	0.035	0.028
C.D. (p=0.05)	2.65	0.80	3.25	0.47	0.074	0.071	3.85	0.92	4.62	0.62	0.102	0.083
Initial status	149.3	14.90	117.7	9.1	0.54	0.41						



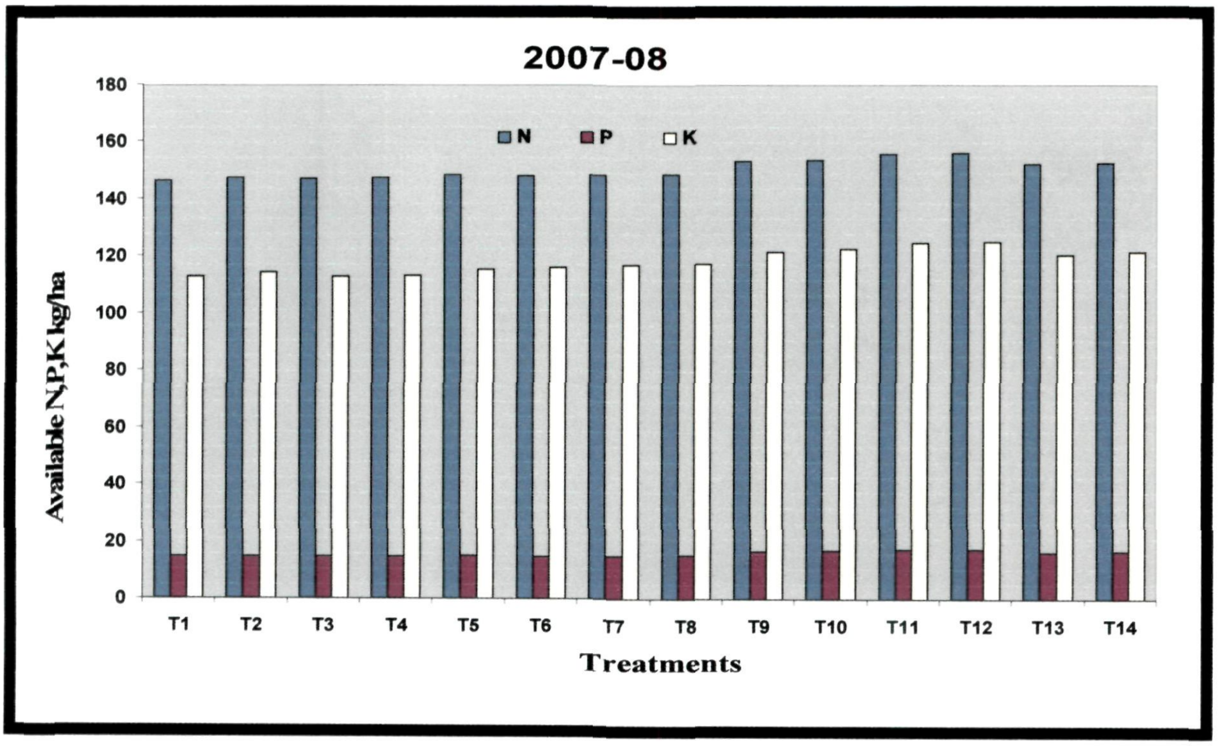
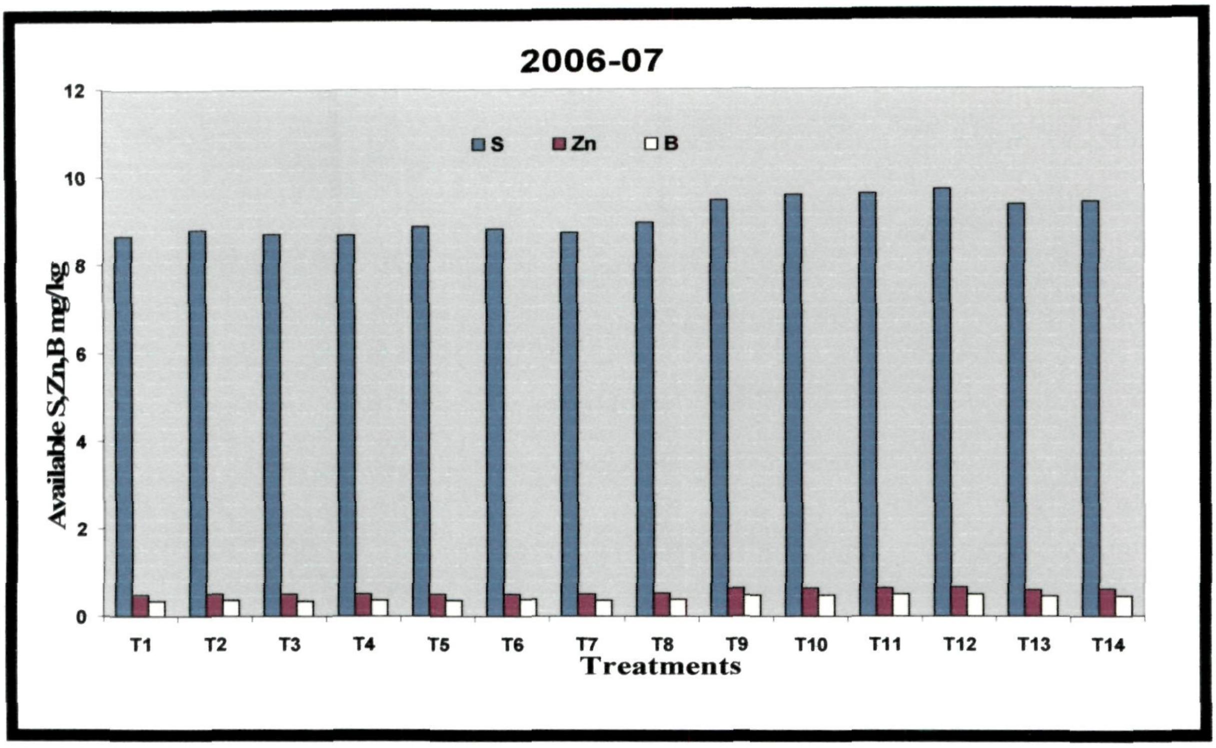


Fig.4.6 Effect of inorganics and organics on available N, P and K (kg ha^{-1}) status of soil after completion of each sequence during 2006-07 and 2007-08



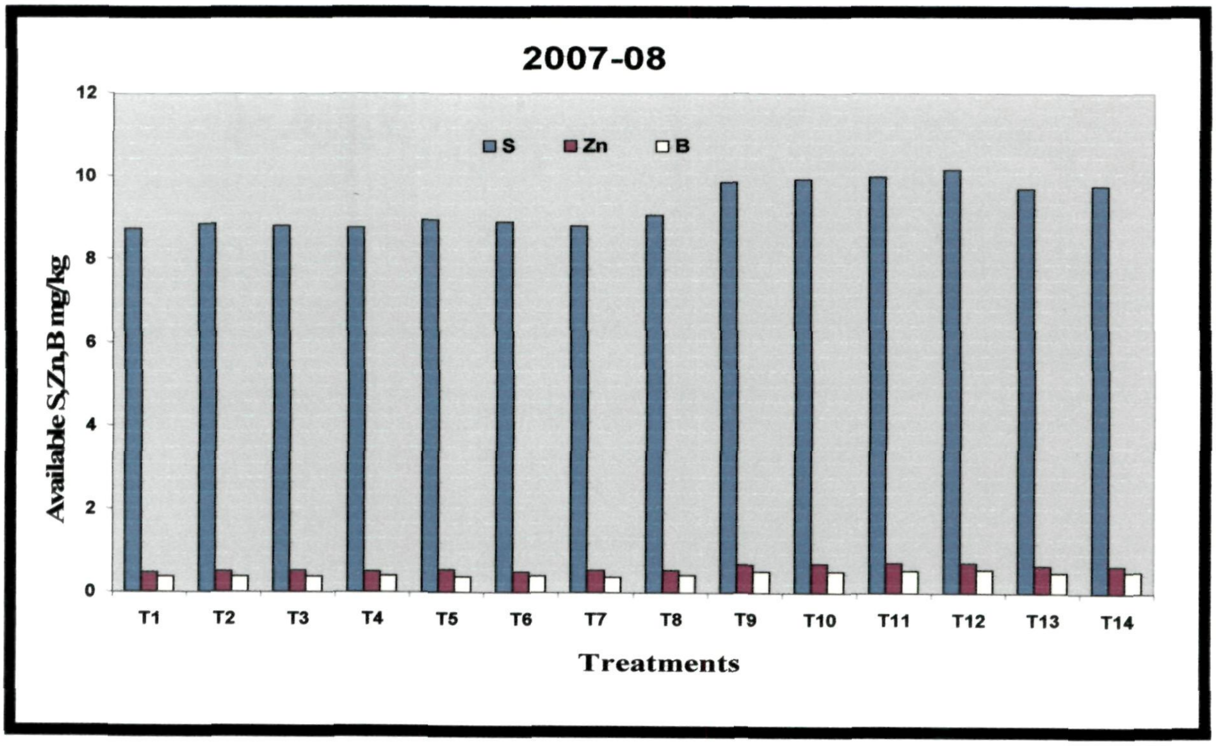


Fig.4.7 Effect of inorganics and organics on available S, Zn, and B (mg kg^{-1}) status of soil after completion of each sequence during 2006-07 and 2007-08

Table 4.27 Balance sheet of available nutrients as influenced by inorganics and organics under maize gobhi- sarson sequence

Treatment	Available N ($Kg\ ha^{-1}$)			Available P ($Kg\ ha^{-1}$)			Available K ($Kg\ ha^{-1}$)		
	Initial status (2006)	Status at the end (2008)	Net gain(+) or loss (-)	Initial status (2006)	Status at the end (2008)	Net gain(+) or loss (-)	Initial status (2006)	Status at the end (2008)	Net gain(+) or loss (-)
T_1 NPK	151.3	146.15	-5.15	16.75	14.45	-2.3	124.82	112.84	-11.98
T_2 NPK+S	151.54	147.43	-4.11	16.92	14.76	-2.16	124.65	114.12	-10.53
T_3 NPK+Zn	151.54	146.78	-4.76	15.75	14.62	-1.63	123.86	112.95	-10.91
T_4 NPK+B	151.45	147.15	-4.30	16.65	14.53	-1.82	123.62	113.18	-10.44
T_5 NPK+S+Zn	151.78	148.27	-3.51	16.55	14.87	-1.68	125.46	115.23	-10.23
T_6 NPK+S+B	150.77	148.13	-2.64	16.22	14.72	-1.50	125.76	115.85	-9.91
T_7 NPK+Zn+B	150.58	148.35	-2.23	16.42	14.95	-1.47	123.65	117.12	-6.53
T_8 NPK+S+Zn+B	150.74	148.68	-2.06	16.27	15.20	-1.07	123.65	117.27	-6.38
T_9 NPK+S+Zn+B+FYM (25% N replacement)	147.75	153.22	+5.47	15.38	16.85	+1.47	119.15	121.47	+2.32
T_{10} NPK+S+Zn+B+VC (25% N replacement)	147.55	153.47	+5.92	15.55	17.18	+1.63	119.67	122.55	+2.88
T_{11} NPK+S+Zn+B+FYM (50% N replacement)	148.30	155.75	+7.45	15.58	17.35	+1.77	121.43	124.67	+3.24
T_{12} NPK+S+Zn+B+VC (50 %N replacement)	148.13	155.87	+7.74	15.87	17.53	+1.96	120.98	124.85	+3.87
T_{13} NPK+S+Zn+B+FYM (25% N additional)	147.15	152.13	+4.98	15.28	16.47	+1.19	119.16	120.43	+1.27
T_{14} NPK+S+Zn+B+VC (25% N additional)	147.34	152.57	+5.23	15.28	16.63	+1.35	119.82	121.37	+1.55

negative balance of available N, P and K in soil when maize gobhi-sarson sequence was fertilized with inorganic nutrients alone.

Chapter-V

DISCUSSION

CHAPTER - V

DISCUSSION

The experimental findings presented in the previous chapter gave a detailed account of the effects of inorganics and organics on soil characteristics and crop yield under rainfed maize-gobhi sarson sequence. In this chapter an attempt has been made to discuss the significant experimental findings obtained during the course of present investigation with possible explanation and evidences where ever necessary in order to find out the cause effect relationship among different treatments with respect to various attributes studied and sort out information of practical value.

5.1 Soil studies of different agro-climatic zone

The higher soil pH in maize gobhi-sarson sequence of sub tropical zone of Jammu region may be due to greater use of fertilization and more accumulation of OH^{-1} ions at high temperature as compared to temperate and intermediate zone. These findings are in agreement with the Sharma and Bali (2000). Relatively lower pH of maize gobhi-sarson sequence under temperate zone might be due to lower temperature & less fertilization. Sharma et al (2001), Sharma and Gupta (1998) also showed similar results.

There was no remarkable difference was observed in EC values among all the three agro climate zones of Jammu region. It indicated that irrigation, fertilization & crop management practices could not influence the EC of soil of any agro-climatic zone. However, the EC values sub-surface soil were higher under intermediate zone followed by temperate zone whereas, lower value of EC was recorded in sub surface soil under sub-tropical zone which may be due to more percentage of sand which encourage leaching thereby accumulate more salt in sub-surface soil under temperate and intermediate soil. These findings are in line with those reported by Sharma & Bali (2000), Ram and Yadav (1994), Sharma and Gupta (1998).

The higher percentage of organic carbon was observed in soils of temperate zone may be due to greater rainfall, lower temperature resulting vigorous growth & development of plants as well as less mineralization of soil carbon. The decrease in organic carbon content under sub-surface soil might be due to lesser addition of root stubbles & other plant debris as well as poor microbial activity under surface soil as compared to sub- surface soil. The higher percentage of organic carbon in surface soils of several region are reported by many workers. Ram and Yadav (1994) review the work on organic carbon distribution affected by climate and cropping sequence & reported significant valuation in organic carbon contents due to climate & cropping sequence.

The higher content of CEC of surface soils under the temperate zone may be ascribed due to high content of organic carbon. Further the value of CEC was higher in the sub surface soil might be due to high clay content as compared to surface soil at majority of location under all the agro-climatic zones. These results are in line with those reported by Gupta *et al.* (2004).

The higher percent of sand in surface soils of sub tropical and intermediate zone might be due to formation of soil by Feldspar mica, quartz, microclime dominated minerals . The increasing clay content in sub surface soil under sub tropical zone may be due to illuviation rather than stratification of parent material. These results corroborate with the finding of Gupta *et al.* (2001).

The higher available N, P, K, S Zn and B content under soils of temperate zone might be due to favourable climate condition such as rainfall, temperature & minimum losses of these nutrients by the process of immobilization, dentrification, volatilization & fixation of nutrients. The relatively lower content of available N, P, K, S, Zn and B under sub tropical zone may be due to intensive cropping, poor organic matter status, more losses of nutrients by the process of leaching & volatilization. The content of N, P, K, S, Zn and B decreased with depth in all the agro-climatic climate zone may be attributed due to lesser plant and microbial activity, variation in organic carbon , pH and clay content of soil. These results are in agreement with those reported by Gupta *et al.* (2004), Tripathi and Singh (1992) and Ram *et al.* (1993)

5.2 Coefficient of correlation between soil properties and available nutrients

In order to access the influence of soil properties on available nutrients viz. N, P, K, S, Zn and B, the coefficient of correlation were worked out between them both individually and collectively. Soil pH , EC and sand was found to be negatively correlated with all the available plant nutrients whereas organic carbon ,CEC, silt and clay were found to be significanty and positive correlated with available plant nutrients. Sharma *et al.* (2009) reported that the coefficient of correlation between organic carbon and available N was positive and significant as expected. Further, it was observed that the N content of the soils was positively and significanty correlated with clay content. It has been noted that, in general, soil organic matter levels tends to increase with increasing clay content of soils. The available P content of the soil was positively and significantly correlated with the organic carboncontent of the soils. The mineralization of organic P contributes to the available P fraction (Lopez-Pineiro and Garcia-Navarro,2001). Similar results have also been observed by Jia *et al.* (2006). The potassium content of the soils was positively and highly correlated with the CEC and clay content. Whereas it was negatively influenced by sand, indicating the strong influence of clay mineralogy in potassium distribution of soils. Sulphur being the main constituent of organic matter possesses positive and significant correlation with organic carbon. The results are in accordance with those of Mukhopadhay and Mukhopadhay (1980), Gowrisankar and Shukla (1999a) and Sharma and Jaggi (2001). In general , available sulphur showed positive correlation with finer fractions of soils viz. silt and clay. This decrease of available sulphur with the increase in the soil particles could be due to less organic carbon accumulation and high leaching (Mishra *et al.* 1990). Similar results are observed by (Dwivedi *et al.* 1993; Arora and Takkar,1988; Tripathi and Singh 1992). Arora and Chahal(2007a) also observed a positive and significant relationship between hot water soluble boron and silt and clay content in Typic Haflustalf soils of Punjab.Whereas relationship with sand content was negatively significant. Positive and significant correlation between hot water soluble and organic carbon content were also reported by Arora and Chahal (2005c) in Ustic moisture regimes soils of Punjab. A significant positive relationship between hot water soluble boron and organic carbon confirm the fact that organic matter is one of the main sources of available boron in soil. The large amount of total boron is held in organic matter and the available boron is largely released by microbial action. Kher and Isher (2006) also observed a positive relationship between available boron and organic matter in citrus orchard soils of Jammu region. Bansal *et al.* (2003) showed that boron deficiency decreased with the increase in fineness of soil texture and organic matter content.

Results obtained in the present investigation thus indicates that distribution of different available nutrients in soil profiles is strongly dependent upon soil characteristics and relationship between them.

5.3 Crop response

Effects of inorganics and organic sources of nutrients not only improved the yield of maize crop but also increased the yield of succeeding gobhi-sarson by applying different treatments.

Maximum grain and stover yield of maize was recorded with the application of 100 per cent recommended NPK along with sulphur, zinc, boron and 25 per cent additional nitrogen through vermicompost (T_{14}) during both the years. The treatment however, exhibited statistical parity with the treatment getting 100 per cent recommended NPK along with sulphur, zinc, boron and 25 per cent additional N through FYM (T_{13}) and (T_8) where the crop was fertilized with 100 per cent NPK along with sulphur, zinc and boron during 2006-2007 while during 2007-2008, the plots where integrated applications of inorganics and organics was applied were found to be statistically at par with each other.

These results are in agreement with those of Pathak and Sarkar (1997), Bhandari *et al.* (1992), Sharma and Gupta (1998) , Singh *et al.* (1999), Sharma *et al.* (2001) and Mehta *et al* .(2005). The integrated application of organics of inorganic (T_3 and T_4) produce higher yield over the rest of the treatments. However, the values were at par with T_8. The significantly higher yield of grain and straw under the treatment T_8 might be due to balance application of most responsive secondary and micro nutrients along with NPK Diwedi *et al.* (2002) conducted a experiment on S and Zn nutrition with respect to. maize crop at Kanpur and reported that application of S and Zn @ 30and 5 kg ha^{-1} were found to be optimum for the higher yield of maize. The better response of integrated grain and stover application of organics and inorganic to grain and stover yield of maize might be due to more absorption of nutrients from soil and ultimately entranced the photosynthesis activity of the crop thereby increase the crop yield of maize Sharma and Gupta (1998) also conducted a study on effect of integrated nutrient management on maize crop and observed significant improvement in grain yield as compared to the chemical fertilizer alone. The significant reduction in grain and stover yield of maize due to 25% substitution of chemical fertilizers through organic could be because of slow release pattern of organics under the treatment under study. These results are in agreement with those reported by Mehta *et al.* 2005.

The significant and pronounced effect on seed and stover yield of gobhi-sarson was observed due to the residual effect of inorganic and organic sources of nutrients. Maximum seed and stover yield during both the years was recorded in T_{14} where the 100 per cent recommended NPK along with sulphur, zinc ,boron and 25 per cent additional N through vermicompost was applied to percceding maize crop. The residual effect of inorganic sources of nutrients in conjunction with organic sources of nutrients was more pronounced during the 2^{nd} year of experimentation. It may be ascribed to the fect that FYM and vermicompost when applied with inorganic fertilizer N act as slower releasing source of nutrients are expected to more closely match N supply and crop N demand. The residual effect of FYM and vermicompost in oil seed crop increases the soil organic carbon content which imrprove the NPK uptake by stover and seed and hence, stover and seed yield. These results are in close conformity with the findings of Jamwal (2006), Patidar and Mali (2002), Sahu and Panda (1999), Surendra and Sharanappa (2000) and Mahala *et al.* (2006). Jamwal (2006) also conducted a study of INM in maize and their residual effect on succeeding gobhi-sarson crop and reported the beneficial residual effect of inorganics and organics to enhance the seed and stover yield of succeeding gobhi-sarson crop.

5.4 Quality studies

5.4.1 Protein content in maize and gobhi-sarson

Variations in protein content was significant due to different treatments. Crop fertilized with recommended NPK along with S, Zn and B and 25 per cent additional nitrogen through vermicompost exhibited highest protein content of 7.39 and 7.85 per cent during 2006-07 and 2007-08 respectively. The higher protein content under above treatment were due to more nitrogen, and vital role of zinc in synthesis of protein, indole acetic acid, chlorophyll formation, carbohydrate and auxin metabolism in maize grain.These findings are in agreement with the results obtained by Arya and Singh (2000).

The significant and pronounced effect on oil seed quality was noticed due to residual effect of inorganics and organics applied to preceding crop. Varations in protein content were significant in different treatment. Among various treatments the highest protein content was noted where recommended NPK coupled with sulphur, zinc , boron and 25 per cent nitrogen additional through vermicompost (T_{14}) applied to preceding crop exhibiting 21.14 and 21.58 per cent during 2006-07 and 2007-08, respectively. The higher protein content and yield under above treatment may be due to more nitrogen content and high seed yield.

5.4.2 Oil content and Oil Yield in gobhi-sarson

The difference in integrated plant nutrient management practices have non-significant effect on the oil content in seeds during both the years. The highest oil content was recorded in T_{12} during both the years with 41.27 and 41.33 per cent during 2006-07 and 2007-08 respectively. The increase in oil content may be attributed to the increased availability of sulphur, zinc and boron which involved in an increased conversion of primary fatty acid metabolites to end products of fatty acids. Patagiri (1995); Subbaiah and Mittra (1996); Shankar *et al.* (2002) and Parsad *et al.*(2003) reported similar results.

The highest oil yield was recorded in T_{14} during both the years with 5.63 and 5.85 q ha^{-1} during 2006-07 and 2007-08 respectively. Since, the oil yield as well as protein yield are the function of seed yield and their respective content in the seed, they increased with the increase in fertility levels and successive addition of supplementary ingredients. The results are in close conformity with the results of Prasad (2000), Singh and Kumar (1999), Tomar *et al*(1996), Patgiri (1995) and Tomar *et al.* (1992).

5.5 Changes in physico chemical properties of experimental site

After the completion of each maize gobhi-sarson sequence, there was no significant variation was observed in soil pH and electrical conductivity due to the residual effect of organic and inorganic sources of nutrients.

The higher values of organic carbon content under integrated application of organics and inorganic could be attributed to addition of organic matter through FYM and VC as well as due to better root growth and more plant residue after harvest. These findings are in agreement with Sharma and Gupta (1998), Sharma *et al.* (2001). The significant increase in organic carbon content under T_8 might be due to enhanced root growth which leads to more accumulation of organic residues thereby increase organic carbon content of soil. However, the 100% NPK (T_1) did not show any improvement in organic carbon content of soil over the initial status of soils. These finding are in agreement with the Tolanor and Badanaur (2003), Nambiar *et al.* (1992).

The CEC of soil improved significantly under the treatments which receive integrated application of inorganic and organic over T_1 (100% NPK alone) as well as initial status of soil. These results are in line with those reported by (Bellaki and Badanaur 1997) and Sharma *et al.* (2000).

The reduction in bulk density could be due to higher organic matter content of soil which improved physical properties of soil. The significant increase in water holding capacity (WHC) under integrated use of inorganic and organic sources of nutrients may be due to reduction in bulk density. These results are corroborated with the findings of Badanaur *et al.* (1990); Ram *et al.* (1994); Badanaur (1997); Sharma and Gupta (1998) and Sharma *et al.* (2001)

Increase in available N may be attributed due to the mineralization of partially or fully immobilized N by vermicompost and farm yard manure in soil beside application of balanced higher rates of N, P and K. The noticed increase in available P of soil may be due to greater mobilization of native soil P, contribution through added biomass and fertilizers, mineralization of organic P and production of organic acids making soil more available. On the other hand increase in K applied through organic and inorganic sources of nutrients may be due to production of certain organic acids during decomposition of vermicompost and farm yard manure which have greater capacity to hold K in the available form. These results are also in conformity with those reported by Bhandari *et al.* (1992), Dudhat *et al.* (1997) and Katyal *et al.* (1998).The integrated application of organics and inorganic in combination 75:25 as well as 50:50 found to be beneficial in improving the Zn and B status of soil. It might be due to optimum addition of Zn and B in combination of organic manure which not only enhanced the availability of these nutrients in soil but also solubilise the nutrient from native source thereby enhanced their availability Sharma *et al.* (2001) also observed the beneficial effect of organic manure in improvement of Zn and B status of soil.

5.6 Balance sheet

The balance sheets of available NPK under maize gobh-sarson as influenced by inorganics and organics showed negative balance of available N,P and K in soil when maize gobhi-sarson was fertilized with inorganic nutrients alone while positive balance of available NPK was observed in the plots which received inorganic and organic sources of nutrients.The positive balance of N, P and K was the result of low uptake over total quantity of N, P and K applied to the crops. Vyas *et al.* 2003 and Tolanur & Badanur (2003) also reported similar results.

Chapter-VI

SUMMARY AND CONCLUSION

CHAPTER-VI

SUMMARY AND CONCLUSION

The fertility and productivity of soil is continuously declining due to imbalance application of nutrients and indiscriminate use of natural resources. It is further aggravated due to the application of inorganic sources. The adoption of integrated nutrient management practice under the rainfed condition not only enhance and sustain the fertility and productivity of soil but also improve the nutrient and water use efficiency besides sustaining the physical, chemical and biological properties as well as over all soil health and environment. However, very meagre information is available on integrated nutrient management practices with respect to maize-gobhi sarson sequence under rainfed condition of Jammu region.

The present investigation on "**Influence of inorganics and organics on soil characteristics and crop yield under rainfed maize-gobhi sarson sequence**" was therefore, undertaken with the following objectives.

1) To study the native soil status of N, P, K, S, Z and B under maize- oil seed based sequence of Jammu region.
2) To find out the integrated effect of organic and inorganic nutrients on grain and stover yield of maize.
3) To find out the residual effect of inorganics and organics on succeeding gobhi sarson crop.
4) To monitor the changes in physico-chemical properties and soil fertility.

In order to achieve these objectives a two fold study was undertaken. In the first phase the surface and sub surface soil samples of 43 locations under rainfed maize – gobhi sarson or related oilseed crops from three agro- climate zones of Jammu region viz. sub- tropical, intermediate and temperate zones were collected to study the physico-chemical properties and available form of nutrients and their relationship.

However, in the second phase, a field experiment was conducted at research form of DLRSS, SKUAST-J, Dhiansar during 2006-07 and 2007-08 to study the "Influence of inorganics and organics on soil characteristics and crop yield under rainfed maize-gobhi sarson sequence" The salient findings of the present investigation have been summarized in this chapter.

Native soil status of different agro-climatic zones

The soil pH of the sub-tropical zone ranged from neutral to slightly alkaline in reaction ranging from 7.34 to 8.35 and 7.20 to 8.52 with mean value of 8.01 and 7.95 in surface and sub-surface soils, 6.8 to 7.9 and 6.7 to 7.7 with mean value of 7.47 and 7.16 in surface and sub-surface soils of intermediate zone whereas 6.30-7.28 and 6.40-7.42 with mean value of 6.60 and 6.71 in surface and sub-surface soils of temperate zone, respectively. The overall pH value of soils under sub-tropical zone was higher followed by soils of intermediate zone where as lowest values of soil pH were recorded under the soils of temperate zone. The higher EC values among three agro-climatic zone was found in sub-tropical zone followed by temperate and intermediate zone. The salinity status of soils was found to be under the safe limits in all the three agro-climatic zones considering 4.0 dsm^{-1} as critical limit. In general, EC values decreased in sub-surface layer in all the soils of three agro-climatic zones of Jammu region. In the soils of sub-tropical zone the

EC values ranged from 0.13-0.23 and 0.09-0.21 dsm^{-1} with average value of 0.16 and 0.14 dsm^{-1} in surface and sub-surface soils respectively. In surface and sub-surface soils of the intermediate zone, EC values varied from 0.08-0.25 and 0.07-0.24 with mean values of 0.14 and 0.12 dsm^{-1}, respectively. The EC values of the soils under temperate zone varied from 0.06-0.24 and 0.09-0.19 with mean values of 0.16 and 0.14 dsm^{-1} respectively.

The organic carbon content of soils of different zones ranged form 0.28 to 0.51 and 0.25 to 0.46 with mean values of 0.39 and 0.33 per cent in surface and sub-surface soils of sub-tropical zone respectively, 0.60 to 0.83 and 0.48 to 0.69 with mean values of 0.71 and 0.59 percent in surface and sub surface soils of intermediate zone respectively whereas 0.60 to 0.99 and 0.54 to 0.89 percent with mean values of 0.83 and 0.68 percent in surface and sub surface soils of temperate zone, respectively. The cation exchange capacity (CEC) of surface soils of sub-tropical zone ranging from 8.1 to 10.4 [$Cmol(p^+)kg^{-1}$] with mean value of 8.85 [$Cmol(p^+)kg^{-1}$], where as in sub-surface soils, the value of CEC varied from 8.4 to 10.8 [$Cmol(p^+)kg^{-1}$], with mean value of 9.23 [$Cmol(p^+)kg^{-1}$], respectively. In surface and sub-surface soils of the intermediate zone, CEC values varied from 9.4-14.8 and 9.8-14.5 with mean values of 12.49 and 12.51 [$Cmol(p^+)kg^{-1}$], respectively. The highest values of cation exchange capacity was observed in temperate zone soils amongst the three agro-climatic zones ranging from 12.2-14.7 and 12.28 to 15.2 with mean values of 14.31 and 15.83 [$Cmol(p^+)kg^{-1}$], in surface and sub-surface soils respectively.

The textural separate of the soils of different zones varied widely in three agro-climatic zones with sand content ranging from 46.0 to 83.4 and 44.3 to 80.4 percent with mean values of 64.05 and 61.76 per cent respectively, 20.1 to 56.3 and 18.3 to 53.8 with mean values 32.51 and 30.31 percent respectively whereas 29.7 to 47.4 and 17.6 to 47.4 with mean values of 13.84 and 14.31 percent in surface and sub surface soils of temperate zone respectively. The silt content ranging from 9.1 to 27.2 and 10.2 to 34.2 with mean values of 19.75 and 20.82 in surface and sub surface soils of sub-tropical zone, 22.4 to 46.3 and 20.3 to 45.1 with mean values of 36.83 and 35.91 percent in surface and sub surface soils of intermediate zone respectively whereas 28.3 to 48.4 and 25.9 to 49.6 with mean values of 44.65 and 40.69 per cent in surface and sub surface soils of temperate zone respectively. The clay content ranging from 7.7 to 21.6 and 9.4 to 22.7 with mean values of 16.19 and 17.40 per cent in surface and sub surface soils of sub-tropical zone respectively, 17.3 to 39.3 and 20.7 to 42.1 with mean values of 29.5 and 32.49 per cent whereas in 9.3 to 28.0 and 9.0 to 36.5 percent with mean values of 22.2 and 26.2 per cent in surface and sub surface soils of temperate zone respectively. The available N content of soils of different zones ranging from 195.4 to 325.0 and 161.7 to 312.0 with mean values of 263.36 and 256.08 kg ha^{-1} in surface and sub surface soils of sub-tropical zone, 258.7 to 375.1 and 242.3 to 355.7 kg ha^{-1} with mean values of 318.53 and 291.84 kg ha^{-1}, respectively whereas 284.2 to 394.2 and 225.6 to 389.8 with mean values of 322.34 and 308.25 kg ha^{-1} in surface and sub surface soils of temperate zone respectively. The available P content of soils of different zones, ranging from 12.6 to 15.8 and 12.4 to 15.6 with mean values of 10.1 and 13.61 kg ha^{-1} respectively in surface and sub surface soils of sub-tropical zone respectively, 14.1 to 21.7 and 13.3 to 20.8 with mean values of 17.32 and 15.74 kg ha^{-1} in surface and sub surface soils of intermediate zone respectively whereas 15.4 to 16.8 and 15.2 to 16.7 with mean values of 16.07 and 15.83 in surface and sub surface soils of temperate zone respectively. The available K content of soils of different zones, ranging from 112.0 to 202.6 and 98.2 to 193.7 kg ha^{-1} with mean values of 143.53 and 134.79 kg ha^{-1} in surface and sub surface soils of sub-tropical zone, 203.7 to 315.4 and 151 to 298.3 with mean values of 274.91 and 219.0 kg ha^{-1} in surface and sub surface soils of intermediate zone whereas 276.3 to 349.6 and 262.1 to 304.8 with mean values of 295.89 and 277.48 kg ha^{-1} in surface and sub surface soils of temperature zone respectively. The higher values of available K content was observed in soils of temperate zone followed by intermediate and sub-tropical zone. The soils of the sub-tropical zone were lowest in available B amongst three agro-climatic zones, ranging from 0.49 to 1.12 and 0.41 to 1.08 mg Kg^{-1} with mean values of 0.64 and 0.58 mg kg^{-1} in surface and sub-soil surface, respectively. In the sub-tropical zone, 50 percent of soil samples found to be deficient. The intermediate zone soils contained more available Zn than sub-tropical zone and it varied from 0.62 to 2.22 and 0.58 to 2.16 with mean values of 1.64 and 1.59 mg kg^{-1} in surface and sub-surface soils respectively. Amongst the three agro-climatic zones, the highest content of available Zn was observed in soils of temperate zone and it varied from 1.66 to 3.20 mg kg^{-1} with mean value of 2.59 mg Kg^{-1} and decreased in sub-surface layer with mean value of 2.47 mg kg $^{-1}$. The soils of sub-tropical zone contained lower amount of available B amongst three agro-climatic zones, which ranged from 0.23 to 0.51 mg kg^{-1} with mean value of 0.40 mg kg^{-1} in surface soils and decreased in sub-surface layer. In the sub-tropical zone of soil samples less than 0.50 mg kg^{-1} available B content was observed in 83.0 per cent of the soils. The intermediate zone soils contained more available B than sub-tropical zone and it varied from 0.30 to 0.66 and 0.23 to 0.54 mg $kg^{-1}$with mean values of 0.48 and 0.41 mg kg^{-1} in surface and sub-surface soils, respectively. Amongst the three agro-climatic zones, the highest content of available B was observed in soils of temperate zone and it ranged from 0.40 to 0.89 mg kg^{-1} with mean value of 0.59 mg kg^{-1} and it decreased in sub-surface layer with mean value of 0.49 mg kg^{-1}.

Soil pH , EC and sand was found to be negatively correlated with all the available plant nutrients viz. N, P, K, S, Zn and B whereas organic carbon ,CEC, silt and clay content were found to be significantly and positively correlated with available plant nutrients. Results obtained in the present investigation thus indicates that distribution of different available nutrients in soil profiles is strongly dependent upon soil characteristics and relationship between them.

Yield and Quality studies

In general, the grain yield was higher during 2007-08 as compared to 2006-07. Significantly higher grain and stover yield were recorded with integrated nutrient management practices during both the years. Significantly higher grain yield of maize during 2006-07 and 2007-08 (30.60 and 31.55 q ha^{-1}), respectively was recorded in T_{14} with the application of 100 percent recommended NPK coupled with S, Zn, B and VC (25 per cent N additional) over all the treatments whereas, the crop fertilized with 100 per cent of the recommended dose of NPK alone (T_1) produced lowest grain yield (26.55 and 26.68 q ha^{-1}) during 2006-07 and 2007-08, respectively. Significantly higher protein content was observed in T_{14} during both the years with 7.39 and 7.85 per cent, respectively. Addition of supplementary ingredients viz. FYM, VC, sulphur, zinc and boron progressively increased the protein content in grain.

However, pronounced effect on seed and stover yield of gobhi sarson was observed due to the residual effect of inorganic and organic sources of nutrients as compared to the plot with 100 percent recommended dose of NPK alone through inorganic fertilizer and significantly higher seed yield (13.78 and 14.28 q ha^{-1}) was recorded in T_{14} during both the years of experimentation.

Significantly higher protein content was recorded in T_{14} during both the years with 21.14 and 21.58 per cent respectively. The residual effect of inorganic and organics was remarkably observed on protein content in gobhi sarson. The oil content of the crop ranged from 40.43 to 41.27 during 2006-07 and 40.46 to 41.33 per cent during 2007-08.. The highest oil content was recorded in T_{12} during both the years with 41.27 and 41.33 percent during 2006-07 and 2007-08 respectively. The difference in integrated plant nutrient management practices had non-significant effect on the oil content of gobhi-sarson during both the years.

Nutrient Uptake Studies

Different integrated plant nutrient management practices significantly influenced the uptake by grain, stover and total uptake during both the years. Similarly an increasing trend was observed with recommended dose of fertilizer coupled with organic sources of nutrients. During both the years significantly higher N,P,K,S,Zn and B uptake was recorded in grain with the application of 100 percent recommended NPK coupled with S, Zn, and VC (T_{14}) over all the treatments except T_{13} and T_8 during 2006-07 and T_8,T_9,T_{10} ,T_{11},T_{12} and T_{13} during 2007-08 which were of the similar magnitude.

The data pertaining to grain and stover uptake in gobhi sarson, revealed that significantly and pronounced effect in grain and stover uptake of gobhi sarson was observed due to the residual effect of inorganic and organic sources of nutrients. Significantly higher N, P, K, S, Zn and B uptake in stover was recorded in T_{14} over all other treatments except T_{13} and T_8 during 2007-06, and T_8 to T_{13} during 2007-08.

Soil studies

After the completion of each maize gobhi-sarson sequence, there was no significant variation in soil pH and electrical conductivity due to the residual effect of organic and inorganic sources of nutrients. The organic carbon, CEC and water holding capacity of soil improved significantly under the treatments which receive integrated application of inorganics and organics over T_1 (100% NPK alone) as well as initial status of soil. Whereas, bulk density reduced significantly with the integrated use of inorganics and organic sources of nutrients. Similarly direct and residual effect of inorganic and organic sources of nutrients had a significant effect on available N, P, K, S, Zn and B status of soil. The data regarding macro and micro nutrients showed that maximum gain of nutrients in soil after maize gobhi-sarson sequence was found in the plots receiving recommended NPK along with sulphur, zinc, boron and vermicompost (50 per cent N replacement) followed by 50 per cent of recommended dose of fertilizer and 50 per cent recommended dose of nitrogen compensated through FYM.

CONCLUSION

From the present investigations, following conclusions were drawn

- The soil characteristics varied from zone to zone, however the soil pH was higher under sub-tropical zone followed by soils of intermediate zone whereas lowest values of soil pH was recorded in soils of temperate zone .No remarkable difference in EC was observed under the different agro-climatic zone.

- The higher values of organic carbon and CEC were found in the soils of temperate zone followed by intermediate zone and sub-tropical zone.
- The higher values of available N, P, K, S, Zn and B were observed in soils of temperate zone followed by the soils of intermediate zone whereas the lower amount of these nutrients were noticed in soils of sub-tropical zone under rainfed maize-gobhi sarson or related oilseed based cropping sequence.
- Among the various inorganics and organic sources of nutrients, the application of N, P, K, S, Zn and B with recommended level along with 25 per cent additional dose of N through vermicompost produced maximum grain and stover yield of maize but the values were at par with treatments T_8 ,T_9 and T_{10} during the second year of experimentation.
- Whereas the residual effect of recommended dose of fertilizer along with 25 per cent extra dose of N through vermicompost applied to preceding crop and direct application of 100 per cent recommended N, P and K to gobhi-sarson produced significantly highest grain and stover yield during both the years.
- Application of vermicompost and farmyard manure coupled with inorganic sources of nutrients proved beneficial in augmenting the fertility status of the soil by improving soil characteristics under rainfed conditions.

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APPENDICES

APPENDIX – I

Physico – chemical properties of soils of various agro-climatic zones of Jammu region

a) Sub-tropical zone

S.No	Location	Depth (cm)	pH (1:2.5)	EC $dS\ m^{-1}$	OC (%)	CEC [Cmol (p^{+}) kg^{-1}]	Sand (%)	Silt (%)	Clay (%)	Textural Class
1	Raya more	0-15	7.8	0.23	0.41	8.8	67.4	14.1	18.5	Sandy loam
		15-30	7.65	0.21	0.39	9.2	65.3	15.4	19.3	Sandy loam
2	Thandi	0-15	7.74	0.15	0.28	8.1	83.2	9.1	7.7	Loamy sand
		15-30	7.56	0.13	0.25	8.4	80.4	10.2	9.4	Loamy sand
3	Vijaypur	0-15	8.32	0.19	0.38	9.1	61.2	17.8	21	Sandy loam
		15-30	8.24	0.16	0.32	9.5	59.8	18.1	22.1	Sandy loam
4	Gurha Slathia	0-15	8.24	0.16	0.36	8.3	66.8	13.9	19.3	Sandy loam
		15-30	8.16	0.12	0.29	8.7	63.4	14.2	22.4	Sandy loam
5	Samba	0-15	8.35	0.18	0.38	10.2	57.6	21.4	21	Sandy clay loam
		15-30	8.52	0.16	0.33	10.6	53.8	23.5	22.7	Sandy clay loam
6	Ghagwal	0-15	8.22	0.13	0.41	10.4	46	32.4	21.6	Loam
		15-30	8.16	0.14	0.39	10.8	44.3	34.2	21.5	Loam
7	Hiranagar	0-15	8.14	0.16	0.51	8.3	55.6	24.9	19.5	Sandy clay loam
		15-30	7.92	0.12	0.46	8.6	53.5	26.2	20.3	Sandy clay loam
8	Dyala Chak	0-15	8.2	0.21	0.38	10.3	57.4	22.6	20	Sandy clay loam
		15-30	8.14	0.18	0.33	10.8	55.7	23.7	20.6	Sandy clay loam
9	Gobindsar	0-15	7.95	0.16	0.39	8.2	73.4	18.4	8.2	Sandy loam
		15-30	7.87	0.14	0.31	8.5	70.2	19.2	10.6	Sandy loam
10	Thein	0-15	7.66	0.13	0.34	8.1	72.3	18.3	9.4	Sandy loam
		15-30	7.58	0.09	0.32	8.4	70.7	18.5	10.8	Sandy loam
11	Lakhanpur	0-15	8.2	0.14	0.39	8.3	73.3	17	9.7	Loamy sand
		15-30	8.45	0.16	0.33	8.7	71.5	18	10.5	Loamy sand
12	Jhajjarkotli	0-15	7.34	0.17	0.44	8.2	54.4	27.2	18.4	Sandy clay loam
		15-30	7.2	0.17	0.31	8.6	52.6	28.7	18.7	Sandy clay loam

b) Inter mediate zone

S.No	Location	Depth (cm)	pH (1:2.5)	EC dS m^{-1}	OC (%)	CEC [Cmol (p^+) kg^{-1}]	Sand (%)	Silt (%)	Clay (%)	Textural Class
1	Palassi	0-15	7.9	0.08	0.6	13.2	27.3	41.7	31	Clay loam
		15-30	7.7	0.07	0.48	12.6	24.7	41.5	33.8	Clay loam
2	Madha	0-15	7.4	0.17	0.78	10.6	46.8	35.9	17.3	Loam
		15-30	7.2	0.13	0.61	10.8	44.7	34.3	21	Loam
3	Chennaini	0-15	7.7	0.25	0.7	11.4	48.2	31.2	20.6	Loam
		15-30	7.3	0.24	0.57	11.9	46.4	30.8	22.8	Loam
4	Dera Baba	0-15	7.6	0.21	0.68	10.2	46.7	35.6	17.7	Loam
		15-30	7.3	0.19	0.59	10.6	44.5	34.8	20.7	Loam
5	Bhabbar	0-15	7.2	0.18	0.63	10.3	47.3	30.7	22	Loam
		15-30	6.9	0.15	0.56	10.9	45.8	29.5	24.7	Loam
6	Bagnoti	0-15	7.6	0.13	0.66	14.1	22.4	22.4	32.4	Silty clay loam
		15-30	7.2	0.11	0.58	14.5	20.3	20.3	35	Silty clay loam
7	Chowki	0-15	7.7	0.08	0.72	9.4	21.7	44.5	33.8	Silty clay loam
		15-30	7.4	0.07	0.61	9.8	19.2	44.2	36.6	Silty clay loam
8	Lamberhi	0-15	7.7	0.16	0.69	11.4	21.4	46.3	32.3	Silty clay loam
		15-30	7.1	0.14	0.54	11.8	19.8	45.1	35.1	Silty clay loam
9	Pathanu	0-15	6.9	0.15	0.75	11.3	55.6	22.9	21.5	Sandy clay loam
		15-30	6.7	0.16	0.61	11.7	52.8	21.6	25.6	Sandy clay loam
10	Thandapani	0-15	7.2	0.17	0.66	11.2	54.7	23.8	21.5	Sandy clay loam
		15-30	6.9	0.14	0.58	11.5	51.3	22.2	26.5	Sandy clay loam
11	Bal Shama	0-15	6.8	0.19	0.72	11.3	56.3	22.7	21	Sandy clay loam
		15-30	6.6	0.16	0.54	11.8	53.8	21.3	24.9	Sandy clay loam
12	Kala Kote	0-15	7.8	0.09	0.77	12.8	21.3	44.6	34.1	Silty clay loam
		15-30	7.4	0.07	0.62	13.2	19.4	44.1	36.5	Silty clay loam
13	Sailsui	0-15	6.9	0.14	0.67	14.1	21.4	44.3	34.3	Clay loam
		15-30	6.7	0.13	0.54	13.7	19.3	43.9	36.8	Clay loam
14	Siot	0-15	7.6	0.09	0.71	14.2	20.8	40.7	38.5	Clay loam

		15-30	7.2	0.07	0.62	13.6	18.7	39.2	42.1	Clay loam
15	Dahrali More	0-15	7.9	0.13	0.78	13.9	20.1	40.6	39.3	Clay loam
		15-30	7.6	0.08	0.68	13.4	18.3	42.9	38.8	Clay loam
16	Nerojal	0-15	7.4	0.11	0.81	14.6	22.2	43.2	34.6	Clay loam
		15-30	7.1	0.09	0.69	14.2	19.3	41.4	39.3	Clay loam
17	Bathuni	0-15	7.8	0.16	0.72	14.4	21.5	41.1	37.4	Clay loam
		15-30	7.5	0.13	0.61	13.9	19.4	40.8	39.8	Clay loam
18	Kallar	0-15	7.2	0.15	0.83	14.2	20.7	43.2	36.1	Clay loam
		15-30	6.9	0.11	0.68	13.7	18.4	41.7	39.9	Clay loam
19	Loorkote	0-15	7.7	0.1	0.73	14.8	21.3	44.5	34.2	Clay loam
		15-30	7.4	0.08	0.61	14.2	19.8	42.7	37.5	Clay loam

c) Temperate zone

S.No	Location	Depth (cm)	pH (1:2.5)	EC dS m^{-1}	OC (%)	CEC [Cmol (p^{+}) Kg^{-1}]	Sand (%)	Silt (%)	Clay (%)	Textural Class
1	Nathatop	0-15	6.6	0.15	0.88	14.2	45.3	28.3	26.4	Loam
		15-30	6.45	0.13	0.7	14.6	45.7	25.9	28.4	Loam
2	Kishtwar	0-15	6.7	0.17	0.91	14.1	46.4	30.3	23.3	Loam
		15-30	6.4	0.14	0.74	14.6	40.6	28.7	30.7	Loam
3	Boombarhi	0-15	6.3	0.17	0.93	13.8	46.8	30.5	22.7	Loam
		15-30	6.8	0.15	0.79	14.4	40.3	28.6	31.1	Loam
4	Batote	0-15	6.7	0.14	0.83	13.6	46.3	30.4	23.3	Loam
		15-30	6.4	0.12	0.71	14.1	40.4	29.1	30.5	Loam
5	Pranoo	0-15	6.5	0.16	0.91	14.7	45.7	33.3	21	Loam
		15-30	6.8	0.14	0.89	15.2	46.6	32.9	19.7	Loam
6	Derodu	0-15	6.3	0.18	0.89	13.9	46.8	29.7	23.5	Loam
		15-30	6.8	0.13	0.73	14.4	45.3	32.3	22.4	Loam
7	Sartangal	0-15	6.6	0.21	0.87	14.2	47.2	32.5	20.3	Loam
		15-30	6.48	0.14	0.61	14.9	46.4	31.7	21.9	Loam
8	Assar	0-15	6.9	0.19	0.78	13.7	47.3	29.9	22.8	Loam
		15-30	6.7	0.16	0.59	14.1	34.8	28.7	36.5	Loam
9	Chinta	0-15	6.7	0.16	0.6	13.9	47.4	32.4	20.2	Loam
		15-30	6.9	0.14	0.55	14.2	46.3	31.2	22.5	Loam
10	Ramgarh Baggar	0-15	6.4	0.16	0.69	13.7	44.7	29.3	26	Loam
		15-30	6.7	0.18	0.54	14.3	42.1	33.4	24.5	Loam
11	Domail Bhaderwah	0-15	6.3	0.06	0.99	14.1	42.3	48.4	9.3	Loam
		15-30	6.7	0.09	0.74	14.7	41.4	49.6	9	Loam
12	Kud	0-15	7.28	0.24	0.78	12.2	29.7	42.3	28	Loam
		15-30	7.42	0.19	0.72	12.28	17.6	44.4	38	Loam

APPENDIX – II

Available nutrient status of soils of various agro-climatic zones of Jammu region

a) Sub-tropical zone

S.No	Location	Depth (cm)	Available nutrients					
			N	P	K	S	Zn	B
			kg ha^{-1}			mg kg^{-1}		
1	Raya more	0-15	272.2	13.7	119.0	9.7	0.56	0.23
		15-30	270.0	13.5	118.7	9.3	0.44	0.20
2	Thandi	0-15	227.4	13.1	164.2	8.6	0.50	0.28
		15-30	225.2	12.7	161.5	8.1	0.41	0.22
3	Vijaypur	0-15	274.3	13.1	202.6	9.1	0.57	0.37
		15-30	268.6	13.0	193.7	8.9	0.43	0.20
4	Gurha Slathia	0-15	279.2	14.2	112.0	9.4	0.53	0.56
		15-30	271.0	14.0	98.2	9.8	0.44	0.41
5	Samba	0-15	289.7	13.3	198.8	18.2	0.52	0.30
		15-30	288.3	13.2	192.3	16.0	0.49	0.16
6	Ghagwal	0-15	325.0	14.3	161.4	27.4	0.58	0.53
		15-30	312.0	14.1	159.2	27.8	0.55	0.36
7	Hiranagar	0-15	262.4	15.6	140.2	20.0	0.49	0.45
		15-30	260.1	14.9	122.1	18.6	0.46	0.42
8	Dyala Chak	0-15	228.4	15.8	116.5	19.8	0.82	0.52
		15-30	222.7	15.6	107.3	18.7	0.85	0.45
9	Gobindsar	0-15	266.4	13.7	138.3	9.4	1.12	0.49
		15-30	260.2	13.1	120.7	8.9	1.08	0.40
10	Thein	0-15	264.7	13.6	135.5	17.9	0.98	0.51
		15-30	259.3	13.2	119.7	15.7	0.86	0.41
11	Lakhanpur	0-15	275.3	13.9	114.3	9.2	0.50	0.30
		15-30	273.9	13.7	113.9	9.0	0.48	0.26
12	Jhajjarkotli	0-15	195.4	12.6	119.6	8.9	0.58	0.31
		15-30	161.7	12.4	110.2	8.7	0.51	0.27

b) Intermediate zone

S.No	Location	Depth (cm)	Available nutrients					
			N	P	K	S	Zn	B
			kg ha^{-1}			mg kg^{-1}		
1	Palassi	0-15	319.0	15.6	231.2	31.2	1.44	0.66
		15-30	312.4	15.0	223.7	24.3	1.36	0.60
2	Madha	0-15	375.1	16.4	301.2	40.2	0.62	0.43
		15-30	360.0	16.6	298.3	25.6	0.58	0.39
3	Chennaini	0-15	390.0	14.1	315.4	18.1	1.65	0.57
		15-30	355.7	13.3	298.7	15.7	1.53	0.54
4	Dera Baba	0-15	304.7	14.7	321.3	19.3	1.31	0.59
		15-30	285.3	13.6	294.6	16.4	1.25	0.51
5	Bhabbar	0-15	298.3	16.5	312.7	18.4	1.19	0.46
		15-30	275.7	16.2	296.3	15.9	1.06	0.38
6	Bagnoti	0-15	319.7	14.3	288.3	18.9	1.48	0.52
		15-30	288.4	13.9	152.7	16.3	1.51	0.41
7	Chowki	0-15	312.3	15.2	298.4	20.7	1.42	0.36
		15-30	283.4	14.9	151.2	17.6	1.47	0.30
8	Lamberhi	0-15	328.7	14.6	286.5	19.6	1.54	0.42
		15-30	294.6	14.1	158.3	13.5	1.50	0.23
9	Pathanu	0-15	263.1	17.6	206.0	41.3	0.79	0.53
		15-30	252.9	17.2	196.7	35.1	0.81	0.46
10	Thandapani	0-15	258.7	16.9	211.3	32.6	0.98	0.62
		15-30	242.3	16.3	204.7	27.3	0.94	0.5
11	Bal Shama	0-15	267.4	17.3	203.7	23.1	1.12	0.44
		15-30	253.2	16.9	195.2	21.2	1.17	0.39
12	Kala Kote	0-15	331.1	18.7	293.0	18.2	1.86	0.63
		15-30	292.7	14.1	148.8	13.1	1.81	0.53
13	Sailsui	0-15	331.2	18.9	288.3	38.3	1.28	0.48
		15-30	293.4	14.7	151.2	31.2	1.31	0.4

14	Siot	0-15	319.4	18.6	282.7	17.3	1.63	0.39
		15-30	288.3	14.4	160.3	16.1	1.57	0.37
15	Dahrali More	0-15	327.3	20.1	275.6	15.7	2.14	0.30
		15-30	302.0	19.6	270.9	15.1	2.20	0.33
16	Nerojal	0-15	322.4	18.3	279.3	12.7	1.66	0.36
		15-30	291.3	14.1	268.2	11.3	1.65	0.33
17	Bathuni	0-15	338.3	20.9	287.4	10.5	1.88	0.61
		15-30	298.4	19.2	190.7	10.9	1.81	0.46
18	Kallar	0-15	327.1	18.7	266.4	13.2	2.22	0.56
		15-30	288.3	14.2	252.2	11.4	2.01	0.52
19	Loorkote	0-15	318.4	21.7	274.7	18.7	2.19	0.42
		15-30	286.7	20.8	248.3	15.1	2.16	0.36

c) Temperate zone

S.No	Location	Depth (cm)	Available nutrients					
			N	P	K	S	Zn	B
			kg ha^{-1}			mg kg^{-1}		
1	Nathatop	0-15	394.2	16.8	349.6	25.7	2.56	0.73
		15-30	389.8	16.7	304.8	21.2	2.45	0.63
2	Kishtwar	0-15	332.3	15.6	287.3	31.1	3.20	0.59
		15-30	313.7	15.4	271.4	28.2	3.16	0.48
3	Boombarhi	0-15	340.7	15.4	290.3	32.5	2.65	0.47
		15-30	315.3	15.2	275.4	25.3	2.56	0.39
4	Batote	0-15	333.3	15.6	283.2	31.3	2.84	0.53
		15-30	317.1	15.3	269.6	24.7	2.49	0.49
5	Pranoo	0-15	334.2	16.5	307.5	29.2	2.30	0.58
		15-30	326.0	16.3	289.7	26.1	2.41	0.51
6	Derodu	0-15	320.4	16.3	288.2	20.1	2.38	0.40
		15-30	308.2	16.1	268.4	19.4	2.43	0.33
7	Sartangal	0-15	312.6	16.5	303.2	16.8	3.08	0.95
		15-30	298.1	16.2	283.2	12.3	3.00	0.77
8	Assar	0-15	306.7	15.8	279.4	24.4	1.66	0.44
		15-30	289.4	15.5	262.1	22.9	1.58	0.36
9	Chinta	0-15	298.2	16.5	302.3	18.2	3.14	0.89
		15-30	286.9	16.3	284.6	16.7	3.01	0.65
10	Ramgarh Baggar	0-15	307.1	15.9	276.3	23.9	1.75	0.51
		15-30	296.6	15.6	263.4	20.7	1.63	0.39
11	Domail Bhaderwah	0-15	304.2	16.3	301.4	21.7	2.88	0.53
		15-30	285.6	16.1	285.9	20.0	2.47	0.47
12	Kud	0-15	284.2	15.7	282.0	23.3	2.72	0.47
		15-30	272.3	15.3	271.3	19.4	2.51	0.42

VITA

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