INTERACTIVE EFFECT OF TILLAGE AND PHOSPHATE FERTILIZATION IN CONJUNCTION WITH FYM ON SOIL PHYSICAL PARAMETERS AND YIELD OF SORGHUM INTERCROPPED WITH GREEN GRAM UNDER DRYLAND

बारानी अवस्था में फास्फेटीय उर्वरक एवं गोबर की खाद का जुताई के साथ समन्वित उपयोग से मृदा के भौतिक प्राचलों व ज्वार-मूंग अंतराशस्य फसलों की उपज पर अंतः क्रियात्मक प्रभाव

THESIS

Submitted to

The Faculty of Agriculture

RAJASTHAN AGRICULTURAL UNIVERSITY

BIKANER

In partial fulfilment

of the requirement for the degree of

Doctor of Philosophy in Agriculture

(SOIL SCIENCE)

By

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April, 1993

PhD Chem
93

RAJASTHAN AGRICULTURAL UNIVERSITY, BIKANER
(CAMPUS : UDAIPUR)

Date 6th April, 1993

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THIS IS TO CERTIFY THAT MR. KAILASH CHANDRA LADDHA HAS SUCCESSFULLY COMPLETED THE PRELIMINARY EXAMINATION HELD ON 4th DECEMBER, 1989 AS REQUIRED UNDER THE REGULATIONS FOR DOCTOR OF PHILOSOPHY.

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Dated 6th April, 1993

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THIS IS TO CERTIFY THAT THIS THESIS ENTITLED **"INTERACTIVE EFFECT OF TILLAGE AND PHOSPHATE FERTILIZATION IN CONJUNCTION WITH FYM ON SOIL PHYSICAL PARAMETERS AND YIELD OF SORGHUM INTERCROPPED WITH GREEN GRAM UNDER DRYLAND"** SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRICULTURE IN THE SUBJECT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY OF THE RAJASTHAN AGRICULTURAL UNIVERSITY, BIKANER, CAMPUS, UDAIPUR IS A BONAFIED RESEARCH WORK CARRIED OUT BY MR. KAILASH CHANDRA LADDHA UNDER MY SUPERVISION AND THAT NO PART OF THIS THESIS HAS BEEN SUBMITTED FOR ANY OTHER DEGREE. THE ASSISTANCE AND HELP RECEIVED DURING THE COURSE OF INVESTIGATION HAVE BEEN FULLY ACKNOWLEDGED.

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CERTIFICATE - III

THIS IS TO CERTIFY THAT THE THESIS ENTITLED "**INTERACTIVE EFFECT OF TILLAGE AND PHOSPHATE FERTILIZATION IN CONJUNCTION WITH FYM ON SOIL PHYSICAL PARAMETERS AND YIELD OF SORGHUM INTERCROPPED WITH GREEN GRAM UNDER DRYLAND**" SUBMITTED BY MR. KAILASH CHANDRA LADDHA TO THE RAJASTHAN AGRICULTURAL UNIVERSITY, BIKANER, CAMPUS, UDAIPUR IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRICULTURE IN THE SUBJECT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY HAS BEEN APPROVED BY THE STUDENT'S ADVISORY COMMITTEE AFTER GETTING THE SATISFACTORY REPORT OF THE EXTERNAL EXAMINERS AND CONDUCTING THE ORAL EXAMINATION ON THE SAME.

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ACKNOWLEDGEMENT

The author feel proud privilege in expressing his profound sense of gratitude and indebtedness to esteemed major advisor ***Dr. K.L. Totawat,*** *Associate professor, Department of soil science and Agricultural chemistry, Rajasthan College of Agriculture, Udaipur for his valuable guidance in planning and conducting the present investigation. The author is also deeply beholden to him for his constructive suggestions, keen and sustained interest and pains taking efforts in preparation of this manuscript.*

The author is gratified to record his sincere thanks to the member of the advisory committee, Dr. S.S. Rathore, Professor, Agronomy, ARSS Arjia, Dr. A.S. Durge, Associate professor (Soils) and Dr. P.K. Dashora, Assistant professor (Statistics), Rajasthan College of Agriculture, Udaipur for their generous gesture and valuable suggestions in planning and execution of this experiment.

The author wishes to put on record his cordial thanks to Dr. Fateh Lal, Professor, the then Head and Dr. B.L. Baser, Professor and Head, Department of soil science and Agricultural Chemistry, Rajasthan college of Agriculture, Udaipur for extending help and facilities during the course of study.

The author gratefully acknowledge Dr. R.C. Mehta and Dr. M.S. Manohar, the then Dean and Dr. V.S. Kavidia, Dean, Rajasthan college of Agriculture, Udaipur for providing necessary facilities for successful completion of this study.

The author feels much obliged to Dr. S.S. Rathore, chief scientist and officer Incharge, Agriculture Research Substation Arjia-Bhilwara for providing full facilities and extending help during the course of investigation. The author also acknowledges the cooperation and help extended by all the staff members of ARSS Arjia (Bhilwara).

The author also deeply indebted to Dr.L.L. Somani, Professor (Soils) RCA Udaipur and Dr. P.L. Maliwal, Agronomist, ARSS Arjia for their encouragement, constructive suggestions and judicially correcting the manuscript. The author also wishes to express his gratitude to Dr. I.N. Gupta (ARSS, Arjia) and Dr. P.K. Gupta (ARS, Kota) who helped him in every respect and sustained his spirits in all situations during completion of this mission.

The help rendered by Dr. S.N. Sodani, Dr. P.C. Kanthaliya, Sh. Anil Kothari, Sh. R.P. Srivastva, Dr. K.K. Bora, Dr. K.N. Bansal and Dr. H.N. Gour at various stages of the present investigation is highly appreciated. Grateful thanks are also due to Dr. Rakesh Shah and his family members for their sincere wishes and cooperation during the course of study and preparation of this manuscript.

The author is highly indebted to his brother Sh. Banwari Lal Laddha for his extreme help in all respect and all family members of M/s Hitkar group, Bhilwara for their cooperation extended through out the course of investigation. The author also appreciate the sincere and painstaking efforts of M/s Apex Computing Centre, and their staff members for laser typesetting of this manuscript.

Last but not least, the most cordial appreciation goes to my wife Smt. Leela Laddha, for her long patience and sacrifice to see my academic mission completed as well as my sons Akhil and Atul Laddha, who were deprived of love and affection during the course of investigation.

(K.C. Laddha)

UDAIPUR
Dated : 6th April, 1993

INTERACTIVE EFFECT OF TILLAGE AND PHOSPHATE FERTILIZATION IN CONJUNCTION WITH FYM ON SOIL PHYSICAL PARAMETERS AND YIELD OF SORGHUM INTERCROPPED WITH GREEN GRAM UNDER DRYLAND

ABSTRACT

K.C. LADDHA*

A field experiment entitled "Interactive effect of tillage and phosphate fertilization in conjunction with FYM on soil physical parameters and yield of sorghum (*Sorghum bicolor* (L.) Moench) intercropped with green gram (*Vigna radiata* (L.) Wilczec) under dryland" was conducted at Agricultural Research substation, Arjia - Bhilwara during kharif 1989 and 1990. The main objectives of the study were to assess the effect of tillage, FYM and phosphorus application on the changes brought in soil physical parameters, chemical properties, soil moisture conserved and yield of intercrops.

The experiment consisted of 30 treatment combinations, comprising of 5 tillage practices, conventional (Desi plough) tillage, disc ploughing, chisel ploughing, minimum tillage (Disc harrowing) and zero tillage; 2 farmyard manure levels, 0 and 10 tons ha^{-1} and 3 phosphorus levels, 0, 13 and 26 kg P ha^{-1}. The experiment was laid out in split plot design, allocating tillage operations in main plots and combination of FYM and phosphorus fertilizer in subplots, which were replicated in quadruple.

The results indicated that all the tillage treatments in general lowered the bulk density and increased soil porosity, water holding capacity, hydraulic conductivity and basic infiltration rate of the soil, when compared with zero tillage treatment. An improvement in above soil physical parameters resulted in an increased soil moisture content in different layers of soil profile and also the total soil moisture content in the profile. Among various tillage treatments disc plough was found to be the best in improving physical parameters which was followed by chisel ploughing and minimum tillage operation.

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* *A student, under the supervision of **Dr. K.L.Totawat**, thesis submitted in partial fulfilment of the requirements for the degree of Ph.D. in agriculture in the subject of soil science and Agricultural Chemistry.*

The cumulative effect of an improvement in soil physical conditions resulted in higher soil moisture content in the profile leading to improvement in the yields of test crops during the course of study.

Different tillage treatments though did not influenced the pH, EC and available potassium status of the soil but have significantly altered the organic carbon and available phosphorus status of the soil.

Data pooled for the two years of research indicated that disc ploughing gave significantly highest grain/seed and stover yields of sorghum (28.73 and 98.10 q ha^{-1}) and green gram (2.67 and 10.04 q ha^{-1}). The sorghum equivalent yield was also highest from the plot receiving disc ploughing in either year of research.

Though the minimum tillage treatment recorded the highest net return (Rs. 1753 ha^{-1}) but was statistically at par with values observed for the plots receiving disc and chisel ploughing treatments during either year of research. Incorporation of farmyard manure at 10 tons ha^{-1} improved all physical parameters examined and ultimately resulted in an increased moisture content in the soil profile. A decreased pH and increased organic carbon, available phosphorus and potassium status of the soil was apparent under this treatment. Application of FYM definitely increased seed/grain and stover yields of intercrops and sorghum equivalent yield as well.

The phosphorus fertilization has distinct effect in altering favourably the most of the physical and chemical parameters under study. The application of phosphate fertilizer significantly increased the yields of intercrops, but the highest response was observed only upto the level of 13 kg P ha^{-1} giving an additional return of Rs. 1162 ha^{-1} over no-phosphorus application.

The various tillage treatments increased the NPK uptake, among them disc plough was found to be superior. Incorporation of FYM and phosphate fertilization alone as well as in combination increased the NPK uptake by grain/seed, stover and total harvest of intercrops. Though tillage treatments in general had no-effect on protein content of sorghum and green gram but FYM and phosphate application independently increased the protein content of sorghum grain and in combination as well increased the protein content of green gram during both the years of study.

बारानी अवस्था में फॉस्फेटीय उर्वरक एवं गोबर की खाद का जुताई के साथ समन्वित उपयोग से मृदा के भौतिक प्राचलों व ज्वार-मूंग अंतराशस्य फसलों की उपज पर अंतःक्रियात्मक प्रभाव

सारांश

कैलाश चन्द्र लद्ढ़ा★

"बारानी अवस्था में फॉस्फेटीय उर्वरक एवं गोबर की खाद का जुताई के साथ समन्वित उपयोग से मृदा के भौतिक प्राचलों व ज्वार-मूंग अंतराशस्य फसलों की उपज पर अंतःक्रियात्कम प्रभाव" नामक क्षेत्रीय परीक्षण खरीफ ऋतु में कृषि अनुसंधान उपकेन्द्र, आरजिया- भीलवाड़ा पर वर्ष 1989 व 1990 में किये गये। अध्ययन के मुख्य उद्देश्य जुताई, गोबर की खाद व फॉस्फोरस के समन्वित प्रयोग का मृदा के भौतिक प्राचलों एवं रसायनिक गुणों में बदलाव, मृदा नमी संरक्षण पर प्रभाव और अंतराशस्य फसलों की उपज थे।

यह प्रयोग 30 उपचार संयोजनों जिसमें पाँच जुताई प्रथाएं (पारम्परिक जुताई, तवा जुताई, टंकन जुताई, न्यूनतम जुताई एवं जुताई विहीन); दो गोबर की खाद के स्तर (0 एवं 10 टन प्रति हेक्टर) और तीन फॉस्फोरस स्तर (0,13 एवं 26 किलोग्राम प्रति हेक्टर) थे। यह परीक्षण 'विभक्त क्षेत्र अभिकल्पना' में किया जिसमें जुताई प्रथाएं मुख्य क्षेत्र और गोबर की खाद व फॉस्फेटीय उर्वरक संयोजन उपक्षेत्र में चार पुनरावृतियों के साथ किया गया।

परीक्षण के परिणाम दर्शाते है कि जुताई विहीन उपचार की तुलना में सभी जुताई प्रथाओ से सामान्यतया मृदा स्थूल घनत्व में कमी और कुल मृदा रंध्रता, जल धारण क्षमता, चल जलीय चालकता एवं मृदा की प्रारम्भिक प्रवेश दर में बढ़ोतरी हुई उपरोक्त भौतिक प्राचलों में सुधार से मृदा उच्छेद की विभिन्न संस्तरों में मृदा नमी में बढ़ोत्तरी हुई। भौतिक प्राचलों के सुधार लाने में विभिन्न जुताई उपचारों में तवा जुताई अति-उत्तम तद्पश्चात् टंकन एवं न्यूनतम जुताई रही।

मृदा की भौतिक अवस्थाओं में संयुक्त सुधार से मृदा उच्छेद में नमी की मात्रा बढ़ी जिससे परीक्षण फसलों की उपज में सुधार हुआ।

यद्यपि विभिन्न जुताई प्रथाओं का मृदा के पी-एच मान, विद्युत चालकता और उपलब्ध पोटाश अवस्था पर असर नहीं हुआ, किन्तु इससे मृदा के जैविक कार्बन एवं उपलब्ध फॉस्पोरस अवस्था पर सार्थक बदलाव रहा।

दो वर्षों की संकलित सूचनाएं निर्दिष्ट करती है कि तवा जुताई से ज्वार (दाना 28.73 और चारा 98.10 क्विन्टल प्रति हैक्टर) और मूंग (बीज 2.67 और चारा 10.04 क्विन्टल प्रति हेक्टर) की उच्चतम सार्थक उपज प्राप्त हुई। दोनों वर्षों में ज्वार की तुल्य उपज भी तवा जुताई में उच्चतम रही।

न्यूनतम जुताई उपचार से उच्चतम शुद्ध लाभ रु. 1753 प्रति हेक्टर रहा जो कि सांख्यिकीय दृष्टि से अध्ययन के दोनों वर्षों में उन क्षेत्रों से प्राप्त लाभ के बराबर था, जहाँ तवा एवं टंकन जुताई की गई।

गोबर की खाद 10 टन प्रति हेक्टर मिलाने से मृदा के सभी परीक्षित भौतिक प्राचलों में सुधार व अन्ततः मृदा उच्छेद में नमी की मात्रा बढ़ी। इस उपचार से मृदा में पी-एच मान घटा और जैविक कार्बन, उपलब्ध फॉस्फोरस एवं पोटाश में बढ़ोत्तरी हुई। गोबर की खाद के प्रयोग से अन्तराशस्य फसल के दाने व चारे की उपज तथा ज्वार तुल्य उपज की निश्चित बढ़ोत्तरी हुई।

इस अध्ययन में फॉस्फेटीय उर्वरक का प्रभाव स्पष्ट रूप से मृदा के अधिकतर भौतिक एवं रसायनिक प्राचलों को बदलने में रहा। फॉस्फेटीय उर्वरक के प्रयोग से अंन्तराशस्य की उपज सार्थक रूप से बढ़ी, लेकिन इसका उच्चतम परिणाम फॉस्फोरस के 13 किलो प्रति हेक्टर स्तर तक ही सीमित रहा। फॉस्फोरस विहीन प्रयोग की तुलना में फॉस्फोरस का 13 किलो प्रति हेक्टर प्रयोग करने पर अतिरिक्त लाभ रु. 1162 प्रति हेक्टर रहा।

विभिन्न जुताई उपचारों से नाईट्रोजन-फॉस्फोरस-पोटाश ग्राह्यता में वृद्धि हुई जिनमें तवा जुताई सभी से श्रेष्ठ रही। खेत में गोबर की खाद एवं फॉस्फेटीय उर्वरक अलग-अलग एवं संयुक्त रूप से प्रयोग करने पर दाना/बीज, चारा एवं अंतराशस्य फसल की कुल उपज द्वारा नाईट्रोजन-फॉस्फोरस-पोटाश ग्राह्यता में वृद्धि हुई। यद्यपि जुताई उपचारों का सामान्यतया ज्वार एवं मूंग के दानों में प्रोटीन मात्रा पर प्रभाव नहीं रहा, लेकिन गोबर की खाद एवं फॉस्फेटीय उर्वरक प्रयोग से ज्वार एवं मूंग की प्रोटीन मात्रा में वृद्धि दोनों ही वर्षों के अध्ययन में आंकी गयी।

★ छात्र द्वारा डॉ. करण लाल तोतावत के मार्गदर्शन में कृषि के मृदा एवं कृषि रसायन विषय में विद्यावाचरस्पति उपाधि की आंशिक पूर्ति हेतु प्रस्तुत शोध पुस्तिका।

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ACRONYMS

t	ton
q	quintal
kg	kilogram
g	gram
M	Metre
mm	milimetre
cc	cubic centimetre
ha	hectare
°C	degree celsius
Max	Maximum
Min	Minimum
dSm^{-1}	deci siemens/metre
$Mg\ m^{-3}$	megagram/cubic metre
Treat.	treatment
WHC	water holding capacity
SSP	Single super phosphate
NS	non significant
FYM	Farmyard manure
N	Nitrogen
P	phosphorus
K	Potassium

CONTENTS

1. INTRODUCTION

Although India is primarily an agriculture dependent country, yet agriculture in still a gamble of monsoon. Inspite of efforts to increase irrigation facilities, nearly 50 per cent of the net cultivated area will continue to be rain dependent. This calls for an urgent need to give emphasis to dryland research. Dryland area contributes about 42 per cent of food and 75 per cent of the pulses and oil seeds requirement. Indo-US sub-commission on Agriculture (1987) estimated that 57 per cent of India's gross cropped area would still be dependent on rainfall and about 49 million tons of food grains will have to come annually from rainfed agriculture sector by the year 2000 AD.

We have therefore, to think seriously about the ways and means to increase and stabilise productivity in the dry areas of the country. Efforts of scientists have been afoot to diagnose and rectify the limps and shrinks of drylands. During early thirties, researches were concentrated on better crop husbandry to improve crop production in drylands, which did not enthuse the farmers. By fifties,the emphasis shifted to soil management and thus the soil and water conservation methods were evolved. Again, the adoption of these practices were not encouraging as the yield increases were marginal. The high yielding varieties of sorghum and pearlmillet came on to the scene in sixties. These were short in duration and fitted well in many agro-ecological situations. They responded well to fertilizers and management. These results rekindled the hope of improving dryland farming by efficient tillage and fertilizer management.

The land preparation in India consists of ploughing of the land with bullock driven plough (desi plough) as frequently as possible, which not only time and energy consuming but results in the formation of a hard layer at depth of plough, limiting the rainwater intake and root development, and enhancing the runoff losses. The widespread use of high yielding varieties necessitates to break the hard layer to provide a greater soil volume for root access. The increased use of fertilizers have made the plants less dependent on the available soil nutrients, but more dependent on the amount of available soil moisture. The amount of moisture conserved in the soil is directly related to the physical condition of soils. Tillage may or may not be beneficial to tilth, depending upon the moisture content at which the soil is worked and the number as well as type of operations undertaken. Tillage practices and other cultural operations influence markedly the physical condition of surface as well as subsurface soil layer.

Much information has been generated and the beneficial effect of tillage is now being attributed to its influence on physical properties of the soil. The view is gaining ground that physical properties of the soil are as important as chemical properties (Mukherji, 1952) and that improvement in soil fertility is due more to improvement in the physical than in the chemical constitution of the soil (Eden, 1946). However, excessive tillage not only deteriorates the soil environment by way of clod destruction, increasing wind erosion, crust formation etc. but also increases the cost of production. On the other hand zero tillage seriously affects the growth and establishment of plant through increased weed competition and poor soil physical conditions. Reduced tillage has been found highly useful in improving soil physical environment and the yield of crop without adverse effect on the environment (Gupta and Agarwal, 1992).

Thus, tillage practices play an important role in dry farming/rainfed agriculture. To achieve the goal a proper choice of implements, timely operations and the method of their use would have to be specified based on agroclimatic zones.

In dryland rainfed areas, not only the total rainfall is usually insufficient, but its distribution also fails to synchronise with the consumptive use requirements of crop. For this reason, crops depend, for a significant part of their needs on the availability of reserve supplies of soil moisture.

There is an urgent need for an improved tillage system. to improve infiltration as well as to control weed (Lal, 1987; Unger 1984). Different types of tillage implements being used today, are likely to have varying effect on physical condition of the soil, and a knowledge of such effect is necessary for right selection and the proper use. Not much work appeared in the literature regarding the comprehensive effect of these commonly used implements on soil physical properties under different agroclimatic situations.

The type of tillage operations, and use of organic manure (FYM), compost or other farm wastes to improve the physico-chemical properties of the soil are salient features of efficient rainfed farming. The integrated system of nutrient supply through efficient use of organic manures, improvement in soil physical conditions and conservation of moisture can substantially increase crop production, more so in the long run.

Sorghum, with nearly 18 m ha area, occupies an important place among the cereals grown in India, especially in arid and semiarid regions of the country. In *Kharif*, this crop is generally sown as mixed with pulses or oil seeds. Legumes intercropped with sorghum may help in stabilising yields and returns over space and time apart from stepping up the pulse production in the country.

Green gram is an important and popular crop in India. It is highly beneficial to Indian farmers due to its low cost of production, inclusion in intensive crop rotations and multipurpose uses. The growth and yield of the pulse crop is dependent on the nodulation and rhizobial activity, which is influenced by soil pH, aeration and nutrients like phosphate, calcium and molybdenum. Application of phosphorus to pulse crops has been found very effective and is considered to be the master key element for increasing yield of pulse crops. Production of all pulse crops has been found to increase with the increasing levels of phosphorus. It is known to hasten development of deeper roots which enables plant an access to deeper layer moisture.

Adoption of high yielding varieties of sorghum as a sole crop poses a threat to pulse production and taking the pulse crop as an intercrop with sorghum is a good proposition under rainfed agriculture. Such a practice not only increases the cropping intensity but also insures crop production under drought, which otherwise may lead to a total crop failure. For a particular disaster level sole pigeonpea would fail in one out of five, sole sorghum in one out of eight years but intercropping in one out of thirty six years (Rao and Willey, 1980).

In the light of the above facts the present investigation entitled "Interactive effect of tillage and phosphate fertilization in conjunction with farmyard manure on soil physical parameters and yield of sorghum intercropped with green gram under dryland" was conducted with the following objectives:

1. To elucidate the interactive effect of tillage, farmyard manure and phosphate fertilization on physico-chemical properties of the soil.

2. To assess effectiveness of different tillage practices on productivity of sorghum-green gram intercropping.

3. To workout optimum level of phosphorus fertilization for intercropping.

4. To study the interaction effect of various factors under investigation on production and nutrient uptake by crops under study.

2. REVIEW OF LITERATURE

A compendium of the recent research work carriedout in India and abroad on the aspect of interactive effect of tillage, farmyard manuring and phosphate fertilization on soil physical and chemical parameters, yield attributing characters, yield and nutrient uptake by crop under dryland have been reviewed in this chapter. This will elucidate the situation with clarity, pertaining to the investigation under study, since sufficient information on specific tillage treatments and crops under study is lacking, work done on related tillage treatments and crop is also presented wherever deemed necessary. A brief summary of the work done on various aspects of the present investigation is presented in the following subheads.

2.1 Effect of Different Tillage Practices :

2.1.1 Soil properties

2.1.2 Yield and yield attributing characters

2.1.3 Content and uptake of nutrient

2.2 Effect of Farmyard Manuring :

2.2.1 Soil properties

2.2.2 Yield and yield attributing characters

2.2.3 Content and uptake of nutrient

2.3 Effect of Phosphorus :

2.3.1 Soil properties

2.3.2 Yield and yield attributing characters

2.3.3 Content and uptake of nutrients

2.4 Interactive Effect of Tillage, Fertilizers and Organic Manures :

2.5 Effect of Tillage, Phosphorus and Farmyard Manuring on Root Growth :

2.1 Effect of Different Tillage Practices :

One plough as deep as possible was the slogan of the early American writers on the subject of dry farming. The justification lies on the facts that deep ploughing makes the land suitable for the maximum absorption of rainwater, destroys all weeds and exposes the lower layers to the sun and air. Beneficial effects of deep ploughing on higher moisture content and yields have been reported by several workers.

2.1.1 Soil properties

Though three primary aims generally attributed to tillage are control of weeds, incorporation of organic matter into the soil and improvement of soil structure, yet the auxillary function of tillage, still insufficiently understood, is the conservation of soil moisture, where the process of rain infiltration, runoff and evaporation are involved (Hillel *et al.*, 1969). The study of changes in physical properties of soil due to different tillage methods is of great significance in relation to soil productivity and better soil-plant relationship. The optimum soil physical condition is essential for the growth and production of crop. The tillage implements are used to create such physical condition which will be conducive to plant growth.

The results of studies on tillage showed that soil preparation with conventional tillage (3 discing) and reduced tillage (one discing) and post sowing compression of seeded rows with an iron roller of 100 kg weight provided favourable environment for faster seed germination, seedling emergence of mustard in *Rabi* and the yield of pearlmillet grown in *Kharif* (Gupta, 1986).

Tillage is used to conserve soil, increase water infiltration, reduce runoff, improve soil water use efficiency (Follett *et al.*, 1987). Summer cultivations reduced both surface runoff and sediment concentrations from the conventional tillage system. This may signify that a combination of conventional tillage and summer cultivation has the potential for controlling weeds without enhancing soil erosion (Yoo *et al.*, 1988). Mwonga and Mochoge (1989) have clearly stated that cultivation can lead to adverse or beneficial effects on soil properties, depending on the type of tillage and soil management involved. Loosening of the dense layer by deep tillage would provide a larger soil volume available for the crop roots to develop and move downwards (Rahman, 1991). Better utilization of soil water and nutrients from the subsoil through these roots would lead to increased crop yields.

2.1.1.1 Bulk density : Bulk density which is directly related to soil structure is also affected by the tillage implements as reported by various workers. Cultivation of soil at optimum soil moisture by different tillage implements decreased the bulk density of soil (Tamhane and Tamboli, 1955; Antonov, 1963; Nyiri, 1963; Bhagat and Tamboli, 1966 ; Krishnamoorthy, 1966). In studying the effect of deep cultivation, several workers have reported that deep cultivation by any tillage method decreased the bulk density of soil (Bhushan *et al.*, 1973; Chaudhary *et al.*, 1983; Fernandes *et al.*, 1983; El-Gayar *et al.*, 1986; Ike, 1986 ; Wang *et al.*, 1986 Sharma *et al.*, 1988 and Rahman, 1991). El-Gayar *et al.* (1986); and Wang *et al.* (1986) have reported that chisel type sub-soiler decreased the soil bulk density and penetration resistance and increased the proportion of pores larger than 18 μ. In the upper 20 cm the chisel system showed, in general, lowest value of bulk density and the highest values of porosity and pores (Fernandes *et al.*, 1983), while bulk density in the 0-5 cm depth under zero tillage were significantly higher than under the other tillage (Ike, 1986).

Chaudhary *et al.* (1985) observed that the tillage operations slightly decreased the bulk density of soil at all working depths. They induced deeper and greater rooting and increased profile water use when compared with conventional tillage. Tillage, both minimum and conventional lowered bulk density in the tune of 10 per cent in clayloam soil, however, incase of sandy loam soil a decreased bulk density to the tune of 70 per cent was apparent (Sharma *et al.*, 1988). Contrary to this Choi *et al.* (1990) reported that cultivation does not have significant effect on bulk density.

2.1.1.2 Hydraulic conductivity : The tillage implements and other agriculture machineries are likely to have their effect on hydraulic conductivity of soil. The tractor ploughing and disc cultivation usually reduces the hydraulic conductivity of soils (Tamhane and Tamboli, 1955). Mohsin and Alam (1966) correlated the non-capillary porosity with water holding capacity, penetrometer readings and capillary porosity. Non capillary porespace increased by ploughing, shallow ploughing with country plough increased hydraulic conductivity and soil looseness. However, Subramaniam *et al.* (1975) reported that deep tillage to 20 and 45 cm depth had shown beneficial effect in improving the hydraulic conductivity when compared to shallow ploughing upto 10 cm depth.

Allmaras *et al.* (1982) conducted an experiment to see the long term cultivation effect on hydraulic properties of silt loam soil and revealed that in the upper 40 cm layer the desorption water characteristics showed that cultivation produced more smaller pores at the expense of larger pores, in the upper 30 cm layer of the cultivated soils hydraulic conductivity was reduced at least 10-fold at water potentials less than-100 cm of water. Experiments involving various sub-soiling and discing practices showed that hydraulic conductivity was higher after tillage than in the control (Jorge *et al.*, 1984). Effect of tillage on soil permeability and porosity was studied by Correa (1985) who reported a significant reduction of macro porosity in top soil (0-20 cm) as compared to virgin primary forest site, with consequent changes in hydraulic conductivity and infiltration.

2.1.1.3 Porosity : The tillage and other agricultural implements have their variable effect on different soil physical properties depending on the type of implements and the moisture content at the time of tilling. Thus, these implements are also likely to have their effect on the porosity and pore size distribution of soil. Deep ploughing to a depth of 45 - 60 cm increased soil porosity in 20-40 cm layer. These beneficial effects were due to the loosening and mixing of transitional illuvial sod horizon (Pavlovskil and Mokaron, 1956; Bhushan *et al.*, 1973). Nyiri (1963) pointed out that loosening of the soil did not materially affect the total pore volume, but increased non-capillary pore space from 10-20 to 40-50 per cent.

Similarly Bhagat and Tamboli (1966) observed that due to tillage implements in a clayloam soil percentage of porespace remained unchanged. Tractor cultivation affected the structural condition as was evidenced by the change in permeability, porespace, volume weight and the distribution of water stable aggregates where as mechanical composition was unaffected (Tamhane and Tamboli, 1955).

Subramanian (1975) observed that deep tillage had shown beneficial effect in improving the capillary porosity when compared with shallow ploughing. Borreson (1987) observed that in porosity there was no difference between cultivation treatments, but Riley and Ekebergy (1989) reported lower soil porosity in the absence of ploughing. Further, Quiroya and Monsalvo (1990) compared conventional tillage and direct sowing and observed a reduced porosity in the surface soil layers and increased. structural stability and total infiltration rate.

2.1.1.4 Water holding capacity : Like that of other soil properties the tillage implements also have their effect on the moisture retention characteristics of soil. Most of the workers are in agreement that ingeneral cultivation increases the total as well as available water capacity of soil. Dreibelbis and Nair (1951) observed that soil moisture in the disced plots were higher both in surface and subsoil than in ploughed plots. Mikhailenko (1956) also reported that when ploughing was followed by harrowing, the moisture content of the top 30 cm layer was markedly increased. Similar observations were also made by Laskowolli and Zbiec (1964) and Bhushan *et al.* (1973). The effect of ploughing on the moisture capacity of the soil showed that depth of cultivation increased the moisture content of the soil (Nyiri, 1963; Antonov, 1963).

2.1.1.5 Infiltration rate : Cultivated soils have higher infiltration rate as compared with soils having crust on the surface (Das and Choudhary, 1981). Similarly Ambegaonkar *et al.* (1984) reported that the highest infiltration rate occurred in ploughed soil as compared to other un-ploughed and cropped land. The regular discing increased the initial water intake rate by two-fold and steady intake rate by three-fold as compared with untilled land (Joshi *et al.*, 1987).

However, Correa (1985) stated that tillage treatment caused a significant reduction in topsoil (0-20 cm) macro porosity as compared to virgin primary site, with consequent change in hydraulic conductivity and infiltration. Further, Mead and Chan (1988) reported that the effect of deep tillage was short lived. The destruction of the soil macroporosity reduced water infiltration down the soil profile.

Paster (1989) observed that use of superficial tillage (5 cm deep) and weed mowing though increased infiltration rates under no-tillage but one annual tillage (10 cm deep) is enough to maintain soil infiltration rates comparable to those under conventional tillage. Franchi *et al.*, (1990) reported on the basis of two years of research that in the first year, the tillage technique had no significant effects on infiltration, but in second year it tended to increase with tillage depth. On the other hand Rahman and Islam (1989) stated that although the initial infiltration was higher and different in different tillage treatment, it decreased with time and tended to be more or less similar for all tillage.

2.1.1.6 Soil chemical properties : Deep tillage involving ploughing up to 18-20 cm depth helped in improving the level of available P and K in the soil (Gaikwad and Khuspe, 1976). However, Prochazkova and Hudcova (1989) were of the view that the soils chemical properties were influenced by use of fertilizer rather than tillage. Ike (1987) reported that nutrient distribution was significantly influenced by tillage practice in the 0-5 cm depth but not in the deeper layers. However, the level of fertilization did not influence nutrient distribution in any soil depth, except for organic carbon content in the 0-5 cm and available P content in the 5-20 cm depth. Both deep ploughing and superficial disc harrowing significantly decreased the organic carbon, pH, exchangeable Ca and CEC. Decreases in all variables except pH were significantly higher in deep ploughing than in disc harrowed plots (Madeiva *et al.*, 1989). Wrucke and Arnold (1985) stated that organic matter, phosphorus and potassium were concentrated in the surface 8 cm of the reduced tillage system but were evenly distributed throughout the upper 23 cm of the ploughed plots. Soil pH was higher at the surface of the no-tillage system than in the other tillage systems. Nitrate nitrogen was low in all system but significantly greater in the ploughed plots.

Mc Andrew and Malhi (1990) found that deep ploughing resulted in significant improvement in soil chemical properties at most sites. The pH of the Ap horizon increased from acidic to neutral at three sites, while Ec of the Ap horizon decreased at two sites. MYS'KO'W, (1990) reported that deep ploughing decreased soil pH by 0.2 to 0.6 unit; this caused unfavourable changes in soil microorganisms, the activity of fungi relatively increased as compared to bacteria and actinomycetes. These changes were reflected in the slower rates of carbon and nitrogen transformation. Direct drilling caused changes in soil macro-aggregation and reduced the evaporation rate, and increased microbial biomass, C and N, total organic carbon and N and extractable ions at the soil surface (0-5 cm) as that under MB ploughing (Carter *et al.*, 1988).

2.1.2 Yield and yield attributing characters

Reports of tillage practices on the production of different crops are very much confusing. Some workers observed increase in yield under the condition of zero tillage while others reported that yields under both conventional and zero tillage practices were comparable. It is not possible to trace the reason for observed yield differences between zero and conventional tillage practices in every individual case but can be attributed to a number of factors like disparities in plant population, differences in weed infestation, various climatic, edaphic and soil factors (Baeumer and Bakemans, 1973). Increased grain and straw yield can be argued on the basis of better growth and yield attributing characters like number of tillers, plant height, root volume etc. A number of investigators have tried to establish the relationship between crop yield and the usage of different tillage implements.

Anderson and Cassel (1984) reported significant interactions between tillage and soil unit for grain yield revealing a variable response to tillage due to variation in depth of 'B' horizon. However, grain yield response to deep tillage (Sub-soiling and Chisel ploughing) was significant during 1981 but not in 1982; this differential behaviour was attributed to difference in rainfall distribution in two years. Subsoiling, mould board (M.B.) ploughing and deep digging increased plant height by 30-35 cm and resulted in 80-100 and 75-350 per cent more stover and grain yield of maize than the control in different experiment (Chaudhary *et al.*, 1985). In a field trial deep tillage treatment resulted in the highest yield of maize crop. (Popesen and Visoianu, 1986; Sharma and Acharya, 1987).

Wielhelm *et al.* (1991) conducted an experiment at two different locations to evaluate the response of 8 maize hybrid to tillage practices and reported that tillage practices had a significant effect on plant emergence at Lincoln in 1982 and 1983 and at Gothenberg in 1983 on dry-matter production. Likewise, Dick *et al.* (1991) reported that no-tillage have significantly lowered yield of corn and soybean as compared to conventional tillage. Rahman and Islam (1986) concluded that depth of cultivation treatments had significant effect on yield and several yield components. The deep tillage upto 15 cm and 22-23 cm produced significantly higher wheat yield as compared to traditional ploughing up to 7-8 cm depth.

The differences in stored water due to tillage significantly affected sorghum growth, grain and forage yield (Unger, 1984; Dedecek *et al.*, 1986). Vivas (1984) while studying three tillage systems viz., MB plough, disc and no-tillage, revealed that plough and disc treatment produced more dry matter than the no-tillage treatment which may be attributed to greater soil water retention and less residue cover on the surface. Deep tillage with chisel plough or MB plough increased sorghum grain yields by 50-70 per cent as compared with conventional tillage (Hazra, 1988).

2.1.3 Content and uptake of nutrient

Influence of tillage practices on the growth and yield attributes may be due to differential soil water-air-plant relationships, which caused increased uptake of nutrients in plants (Sephra *et al.*, 1976). Rahman and Islam (1986) reported that nitrogen, phosphorus and potassium uptake was always higher in deep tillage treatments as compared to traditional ploughing. Similarly, Carter *et al.* (1988) reported that direct drilling reduced the accumulation of nitrogen and potassium in the plant and reduced grain nitrogen when compared with MB plough.

2.2 Effect of Farmyard Manuring :

The low content of organic matter in the cultivated soil necessitates replenishment through periodic addition of organic matter and waste to maintain soil productivity. Though chemical fertilizers account for 40-50 per cent of the world Agricultural production but rise in cost of non-renewable energy and its products has definitely influenced the availability and use of inorganic fertilizers. Further, exclusive use of chemical fertilizers may lead to loss in productivity in longrun by emerging deficiency of secondary and/or micronutrient elements (Nambiar, 1992). Though organic manures are a very good plant nutrients source but their availability is limited. The superiority of organic manures over inorganic source of nutrients is because of its beneficial effect on soil physical condition apart from acting as nutrient source as well as improving the fertilizer use efficiency, in particular the P fertilizers.

Results of long term fertilizer experiment conducted in India during 1885-1985 clearly indicated that neither the organic matter alone nor the chemical fertilizers can achieve the yield sustainability under modern farming where the nutrient turnover in the soil plant system has been enormous (Nambiar, 1992). Integrated use of chemical fertilizers and organic manures is considered to be most efficient proposition of nutrient management which not only reduces the sole dependence on chemical fertilizers but also enhances productivity and minimises the environmental degradation. Long term residual effect of FYM on soil fertility and crop yield has also been reported by Maurya and Ghosh (1972); Goswami and Singh (1976).

2.2.1 Soil Properties

A study on long term effect of chemical fertilizers with and without organic manure on soil fertility under All India Coordinated Project on Long Term Fertilizer Experiment revealed that available soil phosphorus was raised from low to high with the application of chemical NPK fertilizers at optimal to superoptimal doses on almost all the soils. The available soil phosphorus build-up was further enhanced when farmyard manure was incorporated in conjunction with chemical fertilizers. However, a marked decline in available P was noted (39-70%) in the absence of P application for over 15-16 years (Nambiar, 1992).

FYM treatment in the long-term trial have better influence upon the tilth and water holding capacity. Mandal and Pain (1965) have reported a continuous increase in the water holding capacity of soil over control as a consequence of improvement in aggregate status. Similar were the finding of Larson (1964) and Lutz *et al.* (1966). The rise in hydraulic conductivity was associated with build-up of organic matter level of a non-calcareous sandy loam (Biswas and Khosla, 1971). In some other long term field experiments on alluvial, black and laterite soils, regular addition of FYM resulted in positive improvement in hydraulic conductivity in comparison to the application of chemical fertilizer (Biswas *et al.*, 1970,1971).

An improvement in porosity, hydraulic conductivity, water holding capacity, pH and CEC were observed as a result of manure application (Singh and Singh, 1974). However, the effect of organic matter in improving WHC was quite prominent in soils with comparatively less clay (Somani and Saxena, 1975).

Khanna *et al.* (1975) reported that FYM increased the organic carbon content and improved the physical properties of the soil. Though the addition of 15 ton ha^{-1} of FYM did not have significant effect but addition of 30 and 45 tons ha^{-1} had significant beneficial effect on physical properties of soil. Kofoed (1987) reported a better soil structure, increased content of stable aggregates and also macro porosity under FYM treatment as compared to fertilizer application. Further, a higher biomass C content was observed after application of FYM than after fertilizer. There was also a significant seasonal variation in earthworm number after FYM application. Ghatol and Malewar (1978) reported that the effect of high organic matter content in the surface soil are the high moisture holding capacity and porosity.

Annual addition of manure for 100 years significantly decreased bulk density and increased the saturated hydraulic conductivity with an alteration of the pore-size distribution (Anderson and Gantzer, 1989). A significant improvement in soil physical as well as chemical characteristics like available N, P and K was observed with the use of 6.2t ha^{-1} of FYM (Gaikwad and Khuspe, 1976). It was further observed that maximum water holding capacity and moisture retention at 0.33 bar were significantly influenced by the continuous application of FYM at 6.2 t ha^{-1} (Khiani and More, 1984). Available moisture was higher in plots receiving FYM or compost than those to which chemical fertilizers were applied (Mandal and Pain, 1965; Ramaswamy, 1965; Biswas *et al.*, 1971; Muthuvel, 1973). Bhatia and Sukla (1982) have reported that regular addition of FYM for five years helped in maintaining and improving physical properties of erroded alluvial soil and gave higher crop yields as compared with the use of chemical fertilizers.

Availability of nutrient in the soil is more with organic matter than with inorganic fertilizers. Organic matter undergoes slow decomposition producing acids which increases availability of phosphate (Somani, 1983). A significant improvement in the organic carbon and structural status of the soils with an application of FYM and phosphatic fertilizer was also reported by Biswas *et al.* (1969). However, Gupta *et al.* (1988) reported that the available P content of the soil remained in sufficient range with the application of FYM. Application of 90 kg N ha^{-1} or 10 t manure ha^{-1} often significantly increased the grain yield of pearl millet and sorghum. The FYM increased the level of organic carbon, total N and available P and K where as a significant reduction in pH was recorded under N, P and manure treatment (Kwakye, 1988).

Generally, addition of organic manures in adequate amounts increased the available P content to a variable extent over the initial level (Basu and Vainkar 1942; Srivastava, 1960; Kanwar and P rihar, 1962). Similarly increase in organic carbon content by FYM application has been reported by various workers (Havangi and Mann, 1970; Biswas *et al.*, 1969, 1971; Maurya and Ghosh, 1972). Substantial increase in available phosphorus due to FYM was reported by Datta and Goswami (1962), Havangi and Mann (1970) and Maurya and Ghosh (1972). Vyas and Motiramani (1971) reported that organic matter at the rate of 1 g/100 g soil proved to be effective in increasing the availability of phosphate from native as well as added phosphorus.

2.2.2 Yield and yield attributing characters

Grewal *et al.* (1985) suggested that under rainfed conditions, plants heavily depend upon profile stored water to overcome moisture stress and the application of FYM was better than NPK in ensuring exploitation of profile water and resulting in better crop yields. Grass mulch or organic manuring at 5, 10, 20 and 30 tons ha^{-1} increased the shoot dry weight of sorghum and the increase recorded was linear with the rate of application (Brachett, 1991). Das *et al.* (1966) observed that application of 5 tons poultry manure ha^{-1} mitigated P deficiency symptoms in the plants and increased crop yield.

2.2.3 Content and uptake of nutrient

FYM appears to have shown a favourable effect on the uptake of all the ingredients. McAllister and McConaghy (1960) and Sharma (1987) reported that FYM increased N, P and K uptake in plant. However, Naik and Ballal (1968) observed that except for nitrogen the uptake of other nutrients was not very much improved by the application of manures or fertilizers. Higher yield and uptake of phosphorus due to application of FYM may be attributed to increasing availability of phosphorus from soil to plants (Havangi and Mann 1970), Chaudhary *et al.* (1981) and Khiani and More (1984) and Somani and Saxena (1977) also reported that FYM application has significantly increased the availability of N,P and K in soil and their uptake by plant. Application of lopping of subabul increased the N and P content of sorghum as reported by Narkhede and Ghugare (1987). Similarly, Dahiya *et al.* (1987) observed that application of FYM increased the concentration and uptake of N, P, K and Na.

2.3 Effect of Phosphorus :

2.3.1 Soil properties

Increasing levels of P application increases the availability of phosphorus in soils (Maurya and Ghosh, 1972; Sandhu and Neelu, 1974; Smith, 1974; Chaudhary *et al.*, 1974). Khanna and Chaudhary (1979) were of the opinion that P status of soil increased remarkably with continuous application of phosphorus to both *Rabi* and *Kharif* crops. Further, application of phosphorus markedly improved the water holding capacity. Phosphate fertilization was associated with increasing hydraulic conductivity and water retention at lower tension (Biswas *et al.*, 1964; Das *et al.*, 1966; Pharande and Biswas, 1968). Apart from improvement in soil physical condition phosphate fertilization have significantly improved the soil organic matter level (Ghosh and Kanzaria, 1964).

Biswas *et al.* (1967), however, reported that the phosphate application, in the form of superphosphate, has resulted in significant improvement in organic carbon, soil structure, mean weight diameter, permeability and moisture retention at different tensions along with other physical properties. It is expected that improvement in the soil structure by the application of phosphate will also result in lowering of the bulk density. Such a change have been evidenced in alluvial soil of Delhi (Pharande *et al.*, 1969). However, in the silty loam soil of Sabour (Biswas *et al.*, 1971) and alluvial soil of Jaipur (Gattani *et al.*, 1976) the density increased with an application of phosphate.

2.3.2 Yield and yield attributing characters

Phosphorus is a structural component of the cell constituent and plays vital role in energy transformation. The deficiency of phosphorus affects the plant growth and N-metabolism in plants resulting in low grain yield. Remarkable effect of phosphate fertilization is manifested in luxuriant growth of legumes, better nodulation, better enzymatic activity, nitrogen fixation and addition of organic matter (White *et al.*, 1953). Fertilization of phosphorus gives higher yield of crops, however, the response of a crop is determined by its availability to the crop which in turn, is governed by moisture and levels of P application (Sharma and Yadav, 1976; Sharma *et al.*, 1977; Sharma *et al.*, 1984). A number of workers have reported an increase in grain yield of cereal and pulse crops by the application of phosphatic fertilizers (Ahmed and Khan, 1978; Chaudhary *et al.*, 1979; Singh *et al.*, 1980; Prasad *et al.*, 1981; Rai *et al.*, 1982; Kalia *et al.*, 1984 and Patel *et al.*, 1984).

Application of 30-60 kg N and 30 kg P_2O_5 ha^{-1} to rainfed sorghum grown on vertisol increased the plant height, leaf area, fresh fodder and dry matter yield (Raut and Ali, 1987). Oleksenko *et al.* (1988) reported that application of NPK at 90 + 90 + 30 kg ha^{-1} gave average grain yield of sorghum as higher as 6.23 tons ha^{-1} as compared to 4.88 tons ha^{-1} under no-fertilizer application. Though the head yield increased with P and K application but grain yield increased at the highest P and K rates, when sorghum was given O, 60 or 120 kg N + O, 25 or 50 kg P and K ha^{-1} (Kargbo and Kwakge, 1989).

Puranik *et al.* (1990) while comparing the effect of 100 kg N + 50 kg P_2O_5 + 50 kg K_2O ha^{-1} as 100 per cent NPK rate with 50 or 75 per cent NPK accompanied with wheat straw alone and in combination with subabul on total biomass production reported that grain yield and NPK uptake by sorghum hybrid CSH-9 was the highest where 100 per cent NPK or 75 per cent NPK + wheat straw + subabul was applied as compared to untreated control. However, Elkased and Nadi (1987) observed an improvement in grain sorghum with P fertilization only upto 22 kg P ha^{-1}.

Seshaiah and Kandaswamy (1989) also observed that straw and grain yields of sorghum (Co-24) at maturity increased with increasing P rate upto 90 kg P ha^{-1}. Further, Bishnoi and Singh (1990) reported that dry matter yield of sorghum increased with P application on all soils regardless of available P status of the soil. The critical level of P application was calculated to be 20 kg P ha^{-1}, below which response of sorghum to P could be predicted. An increased content of P and K in sorghum plant tissue was observed with the increase in level of P and K (O, 60 or 120 kg P_2O_5 /K_2O ha^{-1}) application (Tsai *et al.* 1990). Somani and Kanthaliya (1988) while reviewing the effect of P application with special reference to SSP on yield and quality of pulses have pointed out that (i) none of the pulse crop can produce a normal growth or give a good yield if it suffers from phosphorus deficiency, (ii) about 14 and 24 kg P_2O_5 is needed for every tone of pulse and oil seed production, respectively as compared to 10 kg for cereals, (iii) increase in pulse yield brought out by application of SSP are wide spread, significant and economically attractive. Its application also improve the content and quality of protein.

Ravankar and Badhe (1975) in pot experiment on urd, mung and soybean, with O-120 kg P_2O_5 per hectare observed highest seed yields with 80 kg $P_2O_5ha^{-1}$ incase of mung and soybean and with 120 kg P_2O_5 ha^{-1} for urd. They also found that applied P increased N and P uptake by plants. Tandon (1987) reported that groundnut and green gram responded well to phosphate application and had marked residual effect on the succeeding wheat crop. Dry matter accumulation and seed yield were highest in arhar and urd with 60 kg P_2O_5 ha^{-1} (Nandal *et al.*, 1987). Further, application of 20 kg N and 60 kg P_2O_5 ha^{-1} separately and in combination was the optimum for most of the yield characteristics of *V. radiata* (Samiullah *et al.*, 1982).

The response to P application was based on the available P status of the soil. Chaudhary *et al.* (1984) observed that under low P status soils, the effect of added phosphorus on forage sorghum yield was more pronounced than those fields where available P was high irrespective of texture and stage of crop growth. A positive response to P application on growth and seed yield of green gram was observed at varying level of P by a number of workers, Mahaboob *et al.* (1984); Venugopal and Morachari (1974); Panwar *et al.* (1976); Singh *et al.* (1981); Srivastva and Verma (1981). Singh (1982) conducted a field experiment on green gram (S-12) involving four levels of phosphorus (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) and four methods of phosphorus application and reported that phosphorus application (30 to 60 kg P_2O_5 ha^{-1}) to green gram significantly increased the yield over control in two out of three years of experimentation. The response decreased with an increase in the level of phosphorus. A subsequent increase in P application up to 60 kg P_2O_5 ha^{-1} resulted in increased plant growth parameters including grain and straw yield of green gram (Singh *et al.*, 1982; Ahmed *et al.*, 1986). Bishnoi and Balwinder Singh (1982) observed that level of 15 kg P_2O_5 ha^{-1} (Olsens P) was the critical P level, below which a response by *V. radiata* to applied P can be predicted. An increase in seed yield, DM accumulation, number of pods/plant, seeds/pod, 1000 seed weight and seed protein content of *V. mungo* was also observed by the application of 50 kg P_2O_5 ha^{-1} (Reddy *et al.,* 1990). Patel *et al.* (1984) observed that phosphorus applied @ 40 kg P_2O_5 ha^{-1} significantly increased the seed yield of summer mung bean. Further increase in P rates was not economical.

Likewise Gill *et al.* (1985) reported that application of 56.09 kg P_2 O_5 ha^{-1} increased significantly seed pod, grain yield and harvest index of mung (*Vigna aureus*) compared with no-phosphorus (control) treatment. However, Tomar *et al.* (1985) observed that fertilizer were highly profitable for mung, the optimum economic rate was 20 kg N + 40 kg P_2O_5 +20 kg K_2O ha^{-1}. Kalita (1989) observed that application of 30 kg P_2O_5 ha^{-1} to green gram gave seed yields of 0.90-0.96 tons ha^{-1} as against 0.59-0.68 tons ha^{-1} under treatment receiving no phosphorus.

2.3.3 Content and uptake of nutrient

Bisnoi and Singh (1990) classified the soils under study into three fertility classes namely low (<12.4 kg P ha^{-1}) medium (12.4 to 22.4 kg P ha^{-1}) and high (above 22.4 kg P ha^{-1}). They have further reported maximum uptake of P with 25.9, 16.9 and 16 ppm of P when applied to low, medium and high P soils. The critical level reported was 20 kg P ha^{-1} (Olsen's extractable P) below which response of P to sorghum could be predicted in these soils. Tsai (1990) reported that the response of sorghum to P (0, 60, or 120 kg P_2O_5 ha^{-1}) and K was reflected with an increased content of P and K in plant tissue.

The uptake of P was, however, similar to that of nitrogen and was directly related to the quantity of P supplied to the crop. Higher uptake of phosphorus in plant and grain with the application of phosphate was also reported by Mariakulandi and Soundarajan (1958); Unikrishnan (1961); Indiraja *et al.* (1963) and Singh and Pancholy (1967).

2.4 Interactive Effect of Tillage, Fertilizers and Organic Manures :

Application of fertilizer has generally resulted in small or marginal differences in soil porosity. An appreciable rise in per cent pore space in alluvial and mixed red and black soils due to combined addition of FYM and NPK fertilizers was observed by Biswas and Khosla (1971) and Manickam and Venkatarman (1972 b). In almost all situation, irrespective of the soil type and cropping system followed, a significant rise in available P content of the soil took place as a result of regular addition of fertilizer phosphorus. A combination of bulky organic manure like FYM and phosphate fertilizers had the best effect in increasing the phosphate availability (Patel *et al.*, 1963; Ray Chaudhari 1967; Havangi and Mann 1970). However, Khaiani and More (1979) reported that various tillage treatment did not effect the soil reaction (pH) and electrical conductivity. Similarly, Biswas *et al.* (1971) and Maurya and Ghosh (1972) observed no marked effect of manuring and fertilization on soil reaction.

It is possible to have phosphorus build up in the soil through judicious use of phosphatic fertilizers and organic manures (Krishnamoorthy and Ravikumar, 1973; Sandhu and Meelu, 1974; Chaudhary *et al.*, 1977). Patel *et al.* (1963) reported that there was significant increase in the organic carbon and nitrogen status of the soil by phosphate manuring of berseem at 72 kg P_2O_5 ha^{-1}, lower doses being less effective. The maximum values were observed under a particular combination of FYM (63 kg P_2O_5) and superphosphate (9 kg P_2O_5).

Loganathan *et al.* (1975) observed that ploughing up to 10 and 20 cm depth increased the yield of tapioca tubers besides improving permeability, porosity and aggregate stability of soil. FYM, flue dust and rice husk improved the physical properties of soil when incorporated at a depth of 10 and 20 cm. Popescu and Visoianu (1986) found maize grain yields were 4.11, 3.40, 3.84 and 4.24 t ha^{-1} with different ploughing with no-fertilizers or 20 or 40 t FYM ha^{-1} alone or with 50 kg N + P_2O_5 ha^{-1} or 50-100 kg N + 30-60 kg P_2O_5 + 0-60 kg K_2O ha^{-1}.

Hossain (1990) observed that maximum yields were obtained when conventional tillage was combined with fertilizers (20 kg N, 40 kg P_2O_5 and 30 kg K_2O ha^{-1}).

Sharma (1987) reported that grain yield of sorghum was highest due to application of 50 kg P_2O_5 ha^{-1} in conjunction with FYM. Highest uptake of phosphorus was recorded for the treatment giving higher yield of sorghum grain. Similarly Veeraswamy and Rathnaswamy (1974) reported that application of 50 kg N, 50 kg P_2O_5 and 50 kg K_2O gave highest yield of soybean with a basal dressing of 25 tons ha^{-1} farm yard manure. Much of the prospective deficiency could be made good by greater use of phosphates in conjunction with organic manures, because it is claimed that when they are used together nitrogen fixation is accentuated (Dhar, 1959).

2.5 Effect of Tillage, Phosphorus and FYM on Root Growth :

Plant roots are the silent and little seen life sustainers of hidden half of natures plant kingdom. Roots have the important functions of absorption, anchorage, storage and synthesis of organic compounds. The soil environment, though complex, is more important for crop growth and specially for root proliferation. Soil physical properties like bulk density, soil water status and nutrient level play a significant role in the root development of various crops. The importance of rooting pattern and their modifications by various management practices, therefore, is of great importance from the stand point of water and nutrient uptake by plants as are related to crop yield. Nakayama and Van Banel (1963) reported 90 per cent root activity of sorghum in top 30 cm soil layer. Olsen *et al.* (1964) observed higher water uptake by corn and sorghum from 150-180 cm depth of soil. About 90 per cent root activity in CSH-1 at 90 days growth was observed between 0-20 cm soil layer.

Ram and Mohan (1971) studied the influence of different ploughing treatments on the root growth factors, soil structure in the rhizosphere and yield of maize followed by wheat and found that root penetration was better because of improvement in the soil structure in the rizoshpere, and a significant correlation was observed for relationship between root growth and soil structure. Improved soil structure increased the grain yield in crops grown under different treatments. Longer and finer roots would exploit greater soil volume than the coarser roots (Eavis, 1972; Bharat Raj, 1979 and Sharma and Ghildyal, 1977).

Allmaras *et al.* (1973) has pointed out that surface tillage results in root yields that at the best equal to ploughing when moisture is limiting. They reported, however that when moisture is plentiful, the use of surface tillage may decrease root yield over ploughing, root density decreased linearly with depth after 20 days of drying (Klepper *et al.*, 1973). Richards and Cockroff (1975) found that drying at the surface induced deeper rooting provided there is sufficient moisture deep in the soil profile. Further, impaired root growth due to absence of proper soil cultivation was also reported by P rihar *et al.* (1975) and Almond *et al.* (1983).

Stone *et al.* (1976) found that during early crop growth period maximum root and water depletion depths were nearly equal, but the depletion depth extended 15 cm deeper than the root depth during the later growth period. Further, Suresh Kumar (1981) reported that root length density (cm/cm^3 of soil) and root weight density (mg/cm^3 of soil) of green gram (*Vigna radiata*) increased in the surface layers (0-30 cm) with high initial moisture, but at low initial moisture levels both root length and root weight densities decreased in the surface layers but at the same time, depth of root penetration increased under low initial moisture conditions.

Maize root density was greater in the upper 7.5 cm soil depth and lower in the 7.5 to 15 cm soil depth in no-tillage than in chisel, ridge or conventional mould board ploughing systems. Soybean root density was higher in the upper layer and decreased with depth in all tillage systems (Cruz, 1983). Root studies under zero tillage made by several workers recorded almost unanimously, that with some exception, root length and density, root penetrability and root mass were always affected due to absence of land preparation or smaller depth of tillage.

3. MATERIALS AND METHODS

The field experiment entitled "Interactive effect of tillage and phosphate fertilization in conjunction with farmyard manure on soil physical parameters and yield of sorghum (*Sorghum bicolor* (L.) *Moench*) intercropped with green gram (*Vigna radiata* (L.) Wilczec) under dry land", was conducted for two consecutive years during *kharif* 1989 and 1990. The details of experimental techniques, materials used and criteria adopted for evaluation of treatments during the course of investigation are presented in this chapter.

3.1 Experimental Site :

The experiment was laid out in Field no. 1, Agricultural research substation, Arjia-Bhilwara during *kharif* seasons. Bhilwara is situated between 24° 20' N latitude and 74° 40' E longitude at an elevation of 432'62 m from sea level. This region falls under agroclimatic zone, sub-humid southern plane of Rajasthan (zone IVa).

3.1.1 Climate and weather conditions

This zone has typical sub-tropical climatic conditions characterized by mild winters and moderate summer associated with high humidity specially during the month of July to September. The mean annual rainfall of the region is 637 mm, most of which is received during the last week of June to mid September, while rainfall during winter season rarely occurs.

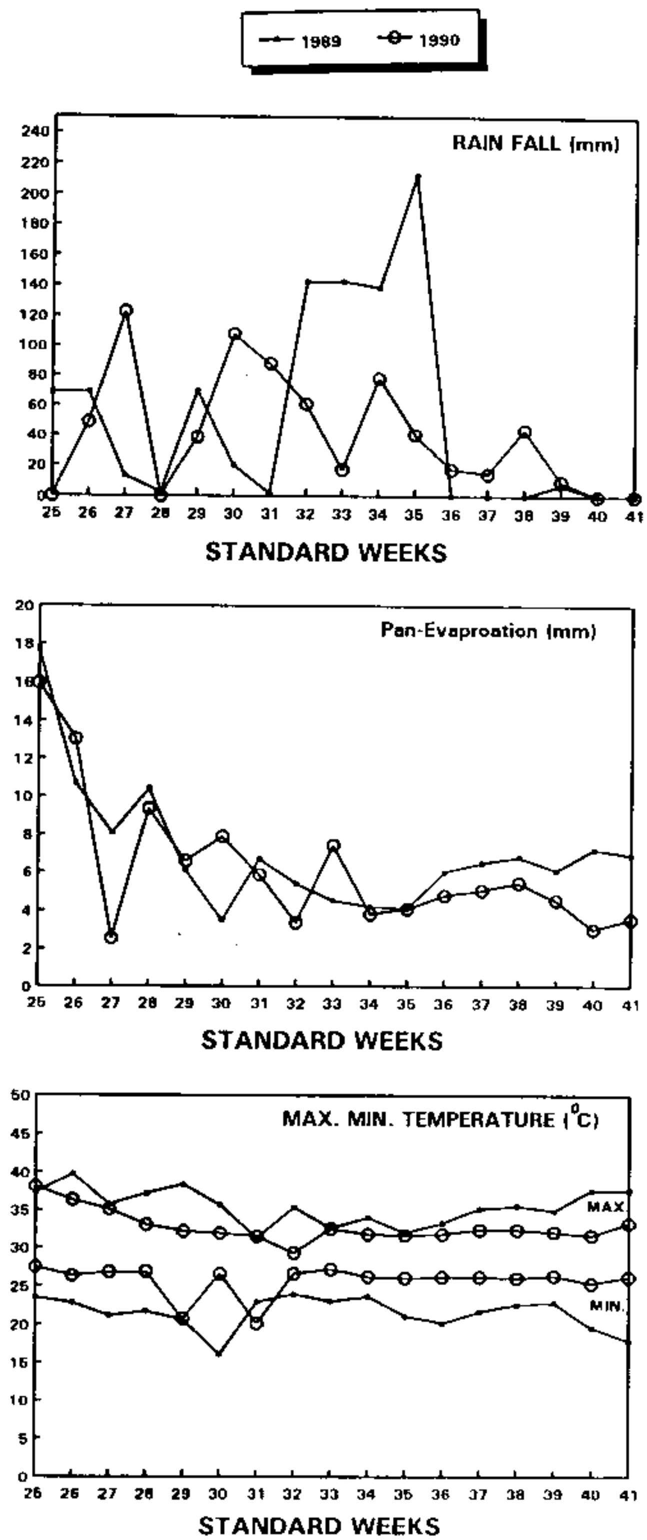
The mean weekly meteorological observations recorded during the crop growth period are presented in Table 3.1. Data show that maximum and minimum temperature varied between 39.7 to 31.2 and 16.1 to 23.9°C during *kharif* 1989, while in *kharif* 1990 the corresponding temperatures were 35.07 to 29.28 and 20.14 to 27.14°C (Fig. 3.1). During *kharif* 1989 though the total precipitation received was 811.3 mm but a long dry spell observed during grain formation lead to early maturity of crop. However, in *kharif* 1990 though the total precipitation received was only 681.3 mm but it was well distributed through out the crop growth period, maintaining a good soil moisture supply.

Table 3.1 Mean weekly weather parameters during crop growth

Standard week no.	Dates	Rainfall (mm)		Temperature °C Maximum		Temperature °C Minimum		Evaporation (mm)	
		1989	1990	1989	1990	1989	1990	1989	1990
25	June 18-June 24	68.2	0.0	37.20	38.07	23.50	27.43	17.7	15.93
26	June 25-July 1	69.0	48.6	39.70	36.28	22.80	26.28	10.7	13.03
27	July 2-July 8	13.0	122.3	35.70	35.07	21.10	26.78	8.1	2.54
28	July 9-July 15	2.4	0.0	37.10	33.00	21.70	26.86	10.4	9.36
29	July 16-July 22	69.6	38.6	38.30	32.14	20.60	20.71	6.1	6.60
30	July 23-July 29	19.9	107.9	35.60	31.86	16.10	26.57	3.5	7.90
31	July 30-Aug. 5	1.5	88.0	31.20	31.43	22.90	20.14	6.7	5.86
32	Aug.6-Aug. 12	142.2	60.7	35.30	29.28	23.90	26.57	5.4	3.37
33	Aug.13-Aug.19	142.4	17.1	32.50	32.43	23.00	27.14	4.5	7.43
34	Aug.20-Aug.26	138.4	78.2	33.90	31.71	23.60	26.28	4.2	3.80
35	Aug.27-Sept. 2	212.9	40.6	31.90	31.57	21.00	26.00	4.1	4.07
36	Sept.3-Sept.9	0.0	17.2	33.20	31.71	20.10	26.14	6.0	4.78
37	Sept.10-Sept. 16	0.0	14.2	35.10	32.28	21.60	26.14	6.5	5.04
38	Sept.17-Sept. 23	0.0	43.6	35.50	32.28	22.50	26.00	6.8	5.44
39	Sept.24-Sept. 30	7.0	9.3	34.80	32.00	22.80	26.28	6.1	4.53
40	Oct. 1-Oct. 7	0.0	0.0	37.50	31.57	19.60	25.28	7.2	3.03
41	Oct. 8- Oct. 14	0.0	0.0	37.50	33.14	17.80	26.14	6.9	3.53

***Source** : Meterological observatory, Agricultural Research Substation, Arjia-Bhilwara.*

FIG. 3.1 Mean weekly weather paramaters during crop growth period



3.1.2 Soil of experimental field

For evaluating the initial fertility and physical status of the experimental field, a representative composite soil sample was procured from 0-30 cm depth. This composite soil sample was subjected to physical and chemical analysis. However, for determination of bulk density, air space and hydraulic conductivity parameters, undisturbed soil cores were drawn from three depths (0-15, 15-30 and 30-45 cm). The data on soil physical and chemical parameters are presented in Table 3.2.

From the results of soil analysis, it can be inferred that the soil of the experimental field was sandy loam in texture, calcareous in nature, low in nitrogen and medium in phosphorus and high in potassium content. Bulk density of the soil was relatively high and increased with depth. The soil of the field under study was compact and poorly drained having very low hydraulic conductivity and basic infiltration rate.

3.1.3 Plot history

Crop sequence sorghum + green gram - fallow and sorghum + green gram - Taramira was followed during the past two years in the experimental field where the present studies were carried out.

3.2 Treatments Detail and Experimental Design :

The experiment consisted of 30 treatments comprising combinations of 5 tillage practices (Conventional tillage, Disc ploughing, chisel ploughing, minimum tillage and zero tillage), 2 farmyard manure levels (0 and 10 tons ha^{-1}) and 3 phosphorus levels (0, 13 and 26 kg P ha^{-1}). The experiment was laid out in split plot design, allocating tillage treatments in main plots (36 M x 5 M) and combinations of farmyard manure and phosphorus fertilizer in subplots replicating each treatment quadruple. The treatments were allocated in different experimental units using random number table as advocated by Fisher (1950). The gross and

Table 3.2 Initial physico-chemical characteristics of experimental field

Characteristics	Content	Reference to method of analysis
Physical:		
Mechanical separates (%)		
Sand	59.71	International pipette method as described by (Piper, 1966)
Silt	22.09	
Clay	17.29	
Textural Class	Sandy loam	
Bulk Density (Mg m^{-3})		
0-15 cm	1.47	Undisturbed core sampler method (Singh, 1980)
15-30 cm	1.52	
30-45 cm	1.59	
Particle density (g/cc)	2.65	USDA Hand book No. 60 (1954) method 40 of USDA
Total porosity (%)		
0-15 cm	44.53	Hand book No. 60 (1954)
15-30 cm	42.64	
30-45 cm	40.00	
Hydraulic conductivity (cm hr^{-1})		
0-15 cm	0.76	Undisturbed soil sample by constant head method (Singh, 1980)
15-30 cm	0.56	
Basic infiltration rate (cm hr^{-1})	0.71	Using double ring infiltrometer (Singh, 1980)
Water holding capacity (%)	33.84	Kenn Raczkowsi method (Piper, 1950)
Moisture retention (%)		
Field capacity	18.2	Using pressure plate apparatus (Singh, 1980)
Permanent Wilting point	8.9	
Chemical:		
Total nitrogen (%)	0.03	Modified Kjeldhal method, (Bramner, 1965)
Available N (kg ha^{-1})	250.20	Alkali permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	15.00	Olsen's method (Olsen et. al, 1954)
Available K (kg ha^{-1})	402.00	Muhr et. al., (1963)
Organic carbon (%)	0.37	Walkley and Black (1947)
Calcium carbonate (%)	2.90	Rapid titration method (Piper, 1950)
Physio-chemical :		
EC_2 (dSm^{-1})	0.31	Schallenberger method
pH	7.40	Beckman and Glass Electrode(Jackson, 1973)

net plot size of each experimental unit was kept 30.0 m² (6 mx5 m) & 21.0 m² (5.25mx4.0m) during both the years of experimentation.The same set of treatments in the very plot was repeated in the second year of experiment. The plan of layout along with treatment allocation is depicted in Fig.3.2.The treatment combinations and symbol used are furnished in Table 3.3.

Table 3.3 Details of treatment combinations

S.No.	Symbol	Treatments combination
1.	$T_1 F_0 P_0$	Conventional tillage, no-FYM and no-phosphorus
2.	$T_1 F_0 P_{13}$	Conventional tillage, no-FYM and 13 kg P ha^{-1}
3.	$T_1 F_0 P_{26}$	Conventional tillage, no-FYM and 26 kg P ha^{-1}
4.	$T_1 F_{10} P_0$	Conventional tillage, 10 tons FYM ha^{-1} and no-phosphorus
5.	$T_1 F_{10} P_{13}$	Conventional tillage, 10 tons FYM ha^{-1} and 13 kg P ha^{-1}
6.	$T_1 F_{10} P_{26}$	Conventional tillage, 10 tons FYM ha^{-1} and 26 kg P ha^{-1}
7.	$T_2 F_0 P_0$	Disc ploughing, no-FYM and no-phosphorus
8.	$T_2 F_0 P_{13}$	Disc ploughing, no-FYM and 13 kg P ha^{-1}
9.	$T_2 F_0 P_{26}$	Disc ploughing, no-FYM and 26 kg P ha^{-1}
10.	$T_2 F_{10} P_0$	Disc ploughing, 10 tons FYM ha^{-1} and no-phosphorus
11.	$T_2 F_{10} P_{13}$	Disc ploughing, 10 tons FYM ha^{-1} and 13 kg P ha^{-1}
12.	$T_2 F_{10} P_{26}$	Disc ploughing, 10 tons FYM ha^{-1} and 26 kg P ha^{-1}
13.	$T_3 F_0 P_0$	Chisel ploughing, no-FYM and no-phosphorus
14.	$T_3 F_0 P_{13}$	Chisel ploughing, no-FYM and 13 kg P ha^{-1}
15.	$T_3 F_0 P_{26}$	Chisel ploughing, no-FYM and 26 kg P ha^{-1}
16.	$T_3 F_{10} P_0$	Chisel ploughing, 10 tons FYM ha^{-1} and no-phosphorus
17.	$T_3 F_{10} P_{13}$	Chisel ploughing, 10 tons FYM ha^{-1} and 13 kg P ha^{-1}
18.	$T_3 F_{10} P_{26}$	Chisel ploughing, 10 tons FYM ha^{-1} and 26 kg P ha^{-1}
19.	$T_4 F_0 P_0$	Minimum tillage, no-FYM and no-phosphorus
20.	$T_4 F_0 P_{13}$	Minimum tillage, no-FYM and 13 kg P ha^{-1}
21.	$T_4 F_0 P_{26}$	Minimum tillage, no-FYM and 26 kg P ha^{-1}
22.	$T_4 F_{10} P_0$	Minimum tillage, 10 tons FYM ha^{-1} and no-phosphorus
23.	$T_4 F_{10} P_{13}$	Minimum tillage, 10 tons FYM ha^{-1} and 13 kg P ha^{-1}
24.	$T_4 F_{10} P_{26}$	Minimum tillage, 10 tons FYM ha^{-1} and 26 kg P ha^{-1}
25.	$T_5 F_0 P_0$	Zero tillage, no-FYM and no-phosphorus
26.	$T_5 F_0 P_{13}$	Zero tillage, no-FYM and 13 kg P ha^{-1}
27.	$T_5 F_0 P_{26}$	Zero tillage, no-FYM and 26 kg P ha^{-1}
28.	$T_5 F_{10} P_0$	Zero tillage, 10 tons FYM ha^{-1} and no-phosphorus
29.	$T_5 F_{10} P_{13}$	Zero tillage, 10 tons FYM ha^{-1} and 13 kg P ha^{-1}
30.	$T_5 F_{10} P_{26}$	Zero tillage, 10 tons FYM ha^{-1} and 26 kg P ha^{-1}

Fig. 3.2 PLAN OF LAYOUT (KHARIF 1989 AND 1990)

N →

R_1

$T_2F_0P_1$	$T_5F_0P_0$	$T_1F_0P_2$	$T_3F_0P_1$	$T_4F_1P_2$
$T_2F_1P_0$	$T_5F_0P_1$	$T_1F_1P_2$	$T_3F_1P_0$	$T_4F_1P_1$
$T_2F_0P_0$	$T_5F_1P_0$	$T_1F_1P_1$	$T_3F_0P_2$	$T_4F_0P_2$
$T_2F_0P_2$	$T_5F_1P_2$	$T_1F_0P_0$	$T_3F_1P_1$	$T_4F_1P_0$
$T_2F_1P_2$	$T_5F_0P_2$	$T_1F_0P_1$	$T_3F_0P_0$	$T_4F_0P_1$
$T_2F_1P_1$	$T_5F_1P_1$	$T_1F_1P_0$	$T_3F_1P_2$	$T_4F_0P_0$

3m

R_2

$T_2F_0P_1$	$T_1F_0P_2$	$T_3F_1P_0$	$T_5F_1P_1$	$T_4F_1P_2$
$T_2F_0P_2$	$T_1F_1P_1$	$T_3F_1P_1$	$T_5F_0P_1$	$T_4F_1P_1$
$T_2F_1P_2$	$T_1F_0P_0$	$T_3F_0P_0$	$T_5F_0P_0$	$T_4F_0P_2$
$T_2F_1P_1$	$T_1F_0P_1$	$T_3F_1P_2$	$T_5F_1P_2$	$T_4F_0P_1$
$T_2F_0P_0$	$T_1F_1P_0$	$T_3F_0P_2$	$T_5F_1P_0$	$T_4F_0P_0$
$T_2F_1P_0$	$T_1F_1P_2$	$T_3F_0P_1$	$T_5F_0P_2$	$T_4F_1P_0$

3m

$T_2F_1P_0$	$T_4F_1P_0$	$T_5F_0P_2$	$T_1F_1P_1$	$T_3F_1P_0$
$T_2F_1P_1$	$T_4F_0P_2$	$T_5F_1P_0$	$T_1F_0P_0$	$T_3F_0P_0$
$T_2F_1P_2$	$T_4F_1P_1$	$T_5F_1P_1$	$T_1F_0P_1$	$T_3F_0P_1$
$T_2F_0P_1$	$T_4F_0P_1$	$T_5F_0P_0$	$T_1F_1P_0$	$T_3F_0P_2$
$T_2F_0P_0$	$T_4F_1P_2$	$T_5F_1P_2$	$T_1F_0P_2$	$T_3F_1P_2$
$T_2F_0P_2$	$T_4F_0P_0$	$T_5F_0P_1$	$T_1F_1P_2$	$T_3F_1P_1$

R_3

$T_5F_1P_1$	$T_4F_1P_0$	$T_3F_0P_1$	$T_1F_0P_1$	$T_2F_0P_2$
$T_5F_0P_1$	$T_4F_1P_1$	$T_3F_1P_1$	$T_1F_1P_1$	$T_2F_1P_0$
$T_5F_1P_0$	$T_4F_0P_2$	$T_3F_1P_0$	$T_1F_0P_2$	$T_2F_0P_1$
$T_5F_0P_2$	$T_4F_0P_1$	$T_3F_0P_2$	$T_1F_0P_0$	$T_2F_0P_0$
$T_5F_1P_2$	$T_4F_1P_2$	$T_3F_0P_0$	$T_1F_1P_0$	$T_2F_1P_2$
$T_5F_0P_0$	$T_4F_0P_0$	$T_3F_1P_2$	$T_1F_1P_2$	$T_2F_1P_1$

R_4

LEGEND Treatments = 30 Replication = 4 Design = Split Plot Design

Gross plot size = 6 m x 5 m Net plot size = 5.25 m x 4 m

3.3 Details of Crop Raising :

3.3.1 Field preparation

On the receipt of first effective shower of rains each experimental unit was demarcated and layout was drawn as per plan. The experimental area was divided into 4 blocks leaving three meter alley within blocks in east-west and south-north direction to facilitate various tillage treatment application.

(a) Tillage : The tillage treatments taken as a main plot treatment using different tillage implements comprise of :

1. Conventional tillage with desi plough consisted of two cross operations.
2. Disc ploughing once followed by cross cultivator operation.
3. Chisel ploughing once to a depth of 40 cm at an interval of 52.5 cm distance followed by cross cultivator operation.
4. Minimum tillage with disc harrowing once.
5. Zero tillage having no tillage operation.

Tillage treatments were given as per the treatment plan length wise in a strip of 36 m (Main plot).

(b) Farmyard manure : Soon after the tillage treatments were over the layout was redrawn and sub-plots of the required dimensions (6 m x 5 m) were prepared. The computed quantity of well decomposed and finely powdered farmyard manure was incorporated in the furrow slice with the help of hand hoe in the sup-plot as per the plan of work.

(c) Phosphorus : As per the treatment, phosphorus was applied through SSP at the time of sowing in furrows at 8-10 cm depth with the help of seed tube (pora) attached to the device used for sowing.

3.3.3 Seed and sowing

The variety "CSH-6" of sorghum and "K-851" of green gram were used as the test crops. The crops were shown at an inter row spacing of 30 cm, planting a single row of green gram in between a paired row of sorghum. The seeds were sown in rows using a seed rate of 12 and 8 kg ha^{-1} for sorghum-green gram in an additive intercropping system. The sowing was done on 30th June 1989 in the first year and 9th July 1990 in the second year.

3.3.4 Fertilizer application

A dose of 60 kg nitrogen was given to the sorghum-green gram intercropping systems with a basal dose of 30 kg N ha^{-1} through urea given at the time of sowing in conjunction with the treatment of phosphatic fertilizer. The remaining 30 kg N ha^{-1} through urea was top dressed only to sorghum crop by applying it within paired rows of sorghum at 40-45 days of crop growth.

3.3.5 Post sowing operations

(a) Weed control and thinning : In order to minimize weed competition hoeing cum weeding was done twice i.e. at 20 and 35 days after sowing. To maintain uniform plant stand through proper spacing extra plant were thinned out at 20 days after sowing (DAS), maintaining an average spacing of 15 cm from plant to plant.

(b) Plant protection : An insecticidal spray of 0.03 per cent Endosulphan at 30-40 days of crop growth period was done during both the years to control the infestation of stemborer.

3.3.6 Harvesting and threshing

The crop was harvested from the net area of individual plot when the maximum number of pods were matured in green gram and ear head in sorghum. The harvesting of green gram was done on 8th and 19th September where as that of sorghum crop was done on 24th

September and 8th October during 1989 and 1990, respectively. The produce was sun dried and weighed for dry matter produced from each individual treatment plot. Green gram was threshed manually with the help of wooden stick where as the sorghum was threshed mechanically using power thresher followed by winnowing operation to have clean seeds for computing the yield.

The data-wise details of various agronomical operations carriedout during both the years are given in Table 3.4.

Table 3.4 Schedule of Agronomical operations during crop growth

S. No	Operations	Date	
		1989	1990
1.	Initial layout and tillage treatment	22.06.89	01.07.90
2.	Second layout and incorporation of farmyard manure	24.06.89	07.07.90
3.	Seed sowing, basal N and P fertilizer treatment and final layout	30.06.89	09.07.90
4.	Gap filling/transplanting	17.07.89	25.07.90
5.	Weeding and Thinning	20.07.89	29.07.90
6.	Hoeing and second weeding	18.08.89	16.08.90
7.	Endosulphan spray	19.08.89	17.08.90
8.	Split application of nitrogen	20.08.89	21.08.90
9.	Harvesting		
	Green gram		
	Sorghum	08.09.89	19.09.90
		24.09.89	08.10.90
10.	Threshing	15.10.89	03.11.90

3.4 Treatment Evaluation :

3.4.1 Soil analysis

A. Physical properties : To assess the various treatments under study soil physical parameters were determined after the experimentation for two consecutive years. Soil from each treatment plot were analysed for the physical properties, namely, bulk density, soil porosity, water holding capacity, basic infiltration rate and hydraulic conductivity.

For determining the bulk density and hydraulic conductivity undisturbed soil cores were drawn with the help of core sampler from two depths, 0-15 and 15-30 cm. The samples were lifted in a sectional cylinder of core samples for these parameters. Hydraulic conductivity was determined using constant head technique employing a special device for maintaining the constant head of water over the soil column. The water holding capacity was determined in the soil samples collected from each plot to a depth of 0-30 cm using keen Raczkowski boxes. The infiltration rate was determined in the field from each plot after harvesting the crop using double ring infiltrometer.

Moisture content of soil from three successive layers, 0-15, 15-30 and 30-45 cm from each individual plot were determined at the time of sowing and after the crop was harvested. Soil samples were drawn by tube auger and were kept in the moisture boxes and dried in an oven at 105°C for 24 hours till the constant weight was obtained. The soil moisture on volume basis was computed from the moisture data on weight basis.

B. Chemical analysis : Soil samples collected at the end of experimentation for the two consecutive years to a depth of 0-30 cm were analysed for organic carbon, available phosphorus, available potassium, pH and electrical conductivity using standard methods of analysis (Table 3.2).

3.4.2 Plant analysis

A. Yield : The produce of intercrop from net plot area after thorough sun drying was weighed for recording biological yield. After threshing and winnowing seed yield per plot was weighed, which was then computed on hectare basis. The stover yield was estimated by subtracting seed yield from biological yield.

B. Equivalent yield : For the valid comparison of yield data seed yield obtained for the component crop in intercrop system was converted to sorghum equivalent yield using prevailing rate of produce in the following expression :

$$\text{Equivalent yield } (\text{q ha}^{-1}) = \text{Grain yield of main crop} + \text{Seed yield of inter crop} \times \frac{\text{Price of inter crop}}{\text{Price of main crop}}$$

C. Chemical analysis : The plant samples collected at harvest (Seed and Stover) from each plot were dried and thereafter grinded to a fine powder for estimating nutrient content. Contents of nutrients in seed and stover were estimated using standard method of analysis as stated here under :

1. Nitrogen : Nesslar's reagent colorimetric method (Lindner, 1944)
2. Phosphorus : Vanadomolybdophosphoric yellow colour method (Richards, 1968)
3. Potassium : Flame photometric method No. 58 (a) of U.S.D.A. handbook No. 60 (Richards, 1968).

3.4.3 Nutrient uptake

(a) Uptake : N, P and K uptake in sorghum and green gram at harvest was estimated using the following formula.

$$\text{Nutrient uptake } (\text{Kg ha}^{-1}) = \frac{\text{Nutrient content } (\%) \times \text{Dry mater } (\text{kg ha}^{-1})}{100}$$

(b) Total uptake : The total uptake of N, P and K by sorghum and green gram at harvest was computed by summing up the nutrient uptake by seed and stover.

(c) Crude protein: The crude protein content of sorghum grain and green gram seed was derived from their corresponding values of nitrogen composition using the factor 6.25.

3.4.4 Root density

(a) Root volume : The roots of three plants of sorghum from each main treatment plots receiving farmyard manure in conjunction with 26 kg P ha^{-1} were collected (0-50 cm) with the help of root core sampler after the crop harvest and carefully washed with water using 35 mesh screen. After carefully washing the individual plant roots were dipped in a measuring cylinder filled with clean water up to a specified mark. After dipping plant roots in the cylinder the rise in water level was noted. The difference in two water levels was taken as a measure of root volume which was then computed on per plant basis.

(b) Root dry weight : The roots of individual plant were dried in a hot air circulating oven at a temperature of 60°C till the constant weight and was computed on per plant basis.

3.5 Economics of Treatments :

The economics of equivalent yield recorded from different treatments was estimated in terms of net profit ha^{-1} for each treatment. The cost of cultivation for each treatment was subtracted from gross returns and net profit was worked out. Further, to ascertain profitability on per rupee investment, Benefit : Cost (B:C) ratio was also calculated. The benefit cost ratio was calculated as follows :

$$\text{B:C} = \frac{\text{Relative income over zero tillage}}{\text{Input cost of the treatment}}$$

3.6 Statistical Analysis :

The experiment was laid out on the pattern of split plot design and data recorded were subjected to statistical analysis, employing analysis of variance technique as out lined by Fisher (1950).

The critical difference for the treatments comparison were workedout wherever the F-test were found significant at 5 per cent level of significance (Panse and Sukhatme, 1967).

For determining the nature of yield response, the main effect of phosphorus were differentiated into different components like liner and quadratic and the test of significance was done. Based on the results of test of significance the regression equation of the desired degree was fitted to specify the relationship between the level of phosphorus and grain yield of sorghum and seed yield of green gram.

4. EXPERIMENTAL FINDINGS

Results of the field experiment entitled "Interactive effect of tillage and phosphate fertilization in conjunction with farmyard manure on soil physical parameters and yield of sorghum intercropped with green gram under dryland", conducted at the Agricultural Research Substation, Arjia (Bhilwara) for two consecutive years, 1989 and 1990 during *Kharif* are presented in this chapter. Data pertaining to various criteria used for treatment evaluation were analysed statistically to test their significance. All the data for the main effects are presented as relevant tables and the effect of interactions are presented only when found statistically significant. The analysis of variance for all these data have been presented in appendices (I to XVI) at the end.

4.1 Physical Properties of the Soil :

Soil of the experimental field from each treatment plot at the end of the two consecutive years of the investigation were analysed for the physical constants, i.e., bulk density, soil porosity, water holding capacity, basic infiltration rate, hydraulic conductivity of the soil, soil moisture content at sowing and at harvest to judge the relative efficacy of various tillage treatments, incorporation of farmyard manure and levels of phosphorus fertilization and their interactions.

4.1.1 Bulk density of soil

Data on bulk density of soil as influenced by various treatments are presented in table 4.1 and their analysis of variance appended in appendix I. An examination of data revealed that various tillage treatments significantly decreased the bulk density of soil in both 0-15 and 15-30 cm soil layer as compared to zero tillage treatments. Among the various tillage treatments disc ploughing was found to be the best where decrease in the bulk density of the surface soil (0-15 cm) was to the minimum value, 1.37 Mg m^{-3} as against 1.43 and 1.46 Mg m^{-3} recorded under conventional and zero tillage treatments, respectively. This treatment was closely followed by chisel ploughing and minimum tillage where also the decrease in bulk density was statistically significant over the value recorded for zero as well as conventional tillage treatments. The effect of various tillage treatments on the bulk density of subsurface soil (15-30 cm) was also dictated the same trend as that of surface soil. All the tillage practices had the tendency to decrease the bulk density of subsurface soil over zero tillage. Though the differences recorded in the values of bulk densities were statistically significant but the magnitude of differences were less pronounced as compared to surface soil (Fig. 4.1). The respective bulk density values recorded under disc, chisel, minimum and conventional tillage were 1.46, 1.50, 1.50 and 1.50 Mg m^{-3} as against 1.53 Mg m^{-3} under zero tillage treatment.

FYM : Application of FYM significantly decreased the bulk density of both surface and sub surface soil layers as compared to no-FYM treatment. The values of bulk density recorded in 0-15 and 15-30 cm soil layers of FYM treated plot were 1.38 and 1.46 Mg m^{-3} as against 1.45 and 1.53 Mg m^{-3}, respectively, under the plots receiving no-FYM treatment.

Phosphorus : Phosphorus treatment also had a significant effect in altering the bulk density of the soils in the two soil layers examined. It was observed that the bulk density of the soil decreased with an increase in the phosphorus levels and the lowest value of bulk density was recorded under the plots receiving highest dose of P (26 kg P ha^{-1}), irrespective of the depth of soil layers examined. However, the value recorded for the bulk density remained statistically at par for the application of P at 13 and 26 kg P ha^{-1} in subsurface soil layers. The respective values of bulk density recorded under 13 and 26 kg P ha^{-1} application were 1.42 and 1.39 Mg m^{-3} in surface and 1.49 and 1.49 Mg m^{-3} in subsurface soil, respectively, as against 1.44 and 1.51 Mg m^{-3} under the plot receiving no-phosphorus treatment.

FIG 4.1 Effect of different Tillage treatments on Bulk Density (Mg per m^3)

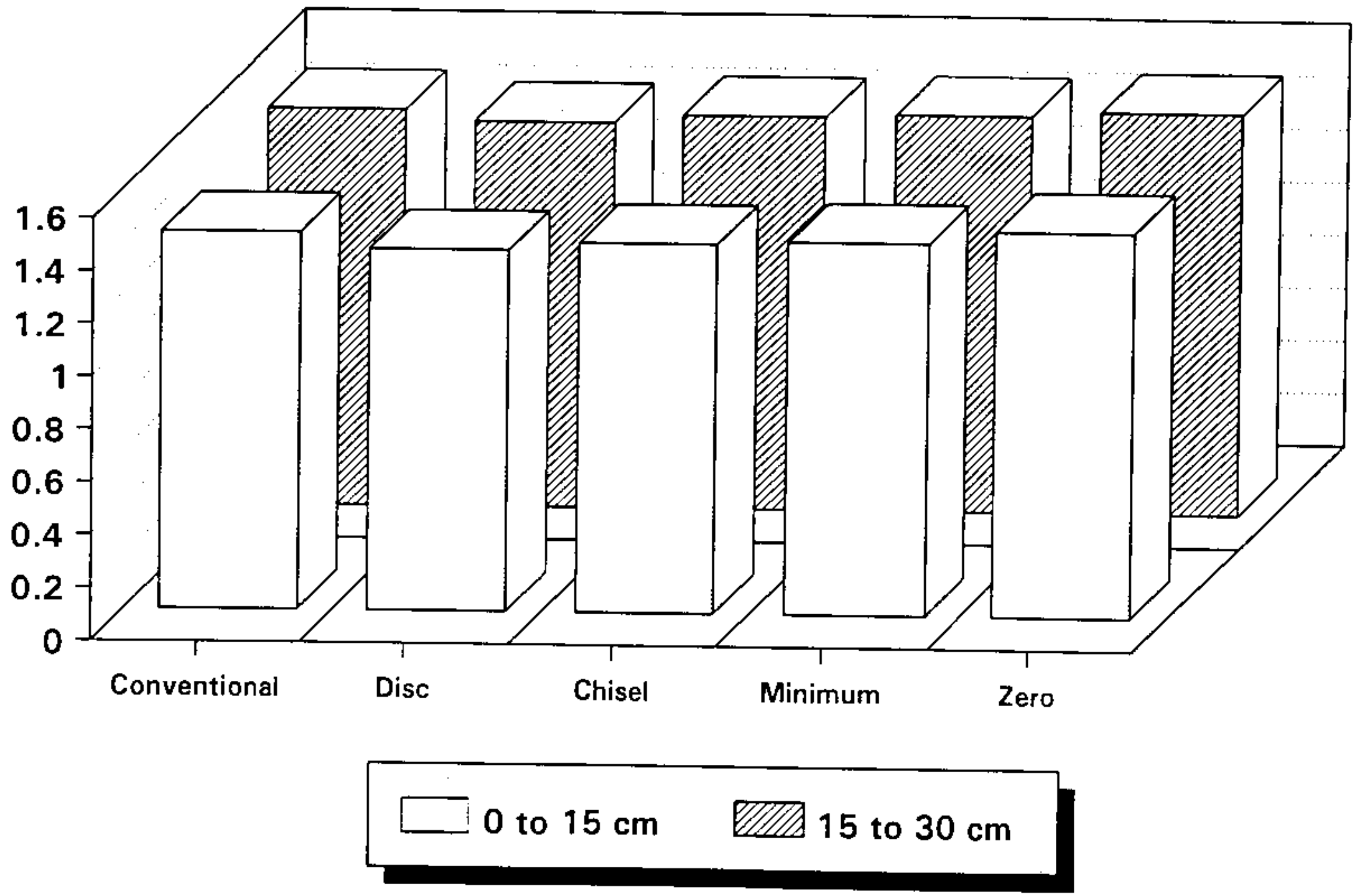


Table 4.1 Effect of tillage, FYM and levels of phosphorus on soil physical parameters

Treatment	Bulk density ($Mg\ m^{-3}$)		Soil porosity (%)		Water holding capacity (%)	Basic infiltration rate (mm/hr)	Hydraulic conductivity (cm/hr)	
	Soil depth (cm.)						Soil depth (cm)	
	0-15	15-30	0-15	15-30			0-15	15-30
Tillage								
Conventional	1.43	1.50	46.15	43.35	35.33	9.90	1.30	1.06
Disc	1.37	1.46	48.17	45.00	37.89	15.10	1.92	1.18
Chisel	1.40	1.49	47.25	43.58	36.02	13.69	1.64	1.57
Minimum	1.41	1.50	46.92	43.52	35.47	9.09	1.51	1.29
Zero	1.46	1.52	44.98	42.47	34.47	8.44	1.07	0.87
S Em ±	0.003	0.005	0.121	0.177	0.313	0.004	0.011	0.008
C.D 5%	0.010	0.014	0.372	0.546	0.963	0.012	0.035	0.027
FYM ($t\ ha^{-1}$)								
F_0	1.45	1.53	45.29	42.16	34.89	9.29	1.43	1.26
F_{10}	1.37	1.46	48.09	45.01	36.78	13.20	1.54	1.38
S Em±	0.004	0.003	0.111	0.101	0.302	0.007	0.006	0.008
C.D. (0.5%)	0.008	0.008	0.312	0.285	0.850	0.020	0.018	0.021
Phosphorus ($kg\ P\ ha^{-1}$)								
P_0	1.44	1.50	45.81	43.22	35.45	11.17	1.40	1.23
P_{13}	1.42	1.49	46.57	43.72	36.14	11.25	1.50	1.35
P_{26}	1.39	1.49	47.69	43.82	35.91	11.32	1.56	1.38
S Em ±	0.004	0.003	0.136	0.124	0.369	0.009	0.009	0.009
C.D. 5%	0.010	0.009	0.382	0.349	NS	0.025	0.022	0.026

Interaction effect of tillage and FYM on bulk density of soil:

Perusal of data on interaction between tillage treatments and incorporation of FYM (Table 4.1.1.1) revealed that significantly lowest value of bulk density was recorded under the treatment receiving disc ploughing and FYM under the two layers of soil examined. This treatment was followed by minimum tillage and chisel ploughing when accompanied with farmyard manuring in lowering down the bulk density of the soil except in sub-surface layer, where these two treatments remained statistically at par with the conventional tillage in conjunction with farmyard manuring. Further examination of data clearly indicate that application of FYM had significantly lowered the bulk density of the soil irrespective of the tillage treatment given and depth of soil layers examined. Disc ploughing, chisel and conventional tillage also resulted in significantly lower value of bulk density in surface soil as compared to minimum and zero tillage under plots receiving no-FYM treatment, however, in subsurface soil layer conventional, chisel, minimum and zero tillage treatments remained statistically at par under this set of treatment.

Table 4.1.1.1 Interaction effect of tillage and FYM on bulk density ($Mg\ m^{-3}$) of soil

Tillage→ FYM ($t\ ha^{-1}$)↓	Conven-tional	Disc	Chisel	Minimum	Zero
			0-15		
F_0	1.44	1.43	1.43	1.47	1.48
F_{10}	1.42	1.31	1.36	1.34	1.44
			15-30		
F_0	1.54	1.49	1.54	1.55	1.55
F_{10}	1.46	1.43	1.46	1.45	1.50
Soil depth (cm)		0-15		15-30	
S Em ±		0.007		0.006	
C.D. 5%		0.018		0.017	

Interaction effect of tillage and phosphorus on bulk density of soil:

An over all examination of data on interaction between tillage treatment and phosphate fertilization (Table 4.1.1.2) indicated that disc ploughing irrespective of the phosphorus levels and the highest level of phosphate fertilization (26 kg P ha^{-1}) irrespective of the tillage treatments significantly lowered down the bulk density in surface soil layer except zero tillage at this level of phosphate fertilization. Data on bulk density when examined for sub-soil layer revealed that significantly lowest value of bulk density was recorded in plot receiving disc ploughing in conjunction with highest level of phosphate fertilization. It is further evident from the data that chisel ploughing and minimum tillage operations when compared with conventional and zero tillage treatments under phosphate fertilization at 13 kg P ha^{-1} have also lowered down the bulk density of surface soil. However, no such differences were observed in values of bulk density when compared with those recorded under no-phosphate fertilization in respective tillage treatments. The highest value of bulk density was recorded from the plot receiving sole zero tillage under the two layers of soil examined.

Table 4.1.1.2 Interaction effect of tillage and levels of phosphorus on bulk density ($Mg\ m^{-3}$) of soil

Tillage→ P levels (kg P ha^{-1})↓	Conven- tional	Disc	Chisel	Minimum	Zero
			0-15		
P_0	1.47	1.38	1.42	1.42	1.49
P_{13}	1.44	1.37	1.40	1.41	1.46
P_{26}	1.37	1.37	1.38	1.39	1.42
			15-30		
P_0	1.50	1.49	1.50	1.50	1.53
P_{13}	1.49	1.46	1.48	1.50	1.53
P_{26}	1.51	1.43	1.50	1.50	1.51
Soil depths (cm)		0-15		15-30	
S Em ±		0.008		0.007	
C.D. 5%		0.023		0.020	

Interaction effect of FYM and phosphorus on bulk density of soil :

On examination of data on interaction between FYM and phosphate fertilization (Table 4.1.1.3) revealed that application of FYM significantly lowered the bulk density of soil in the two layers of soil examined irrespective of the phosphate levels being used. Further, the phosphate fertilization up to 26 kg P ha^{-1} under no-FYM and upto 13 kg P ha^{-1} under farmyard manuring has significantly lowered down the bulk density in surface soil-layer. The lowest value of bulk density recorded was from the plot receiving highest level of P (26 kg P ha^{-1}) in conjunction with FYM under the two layers of soil examined.

Table 4.1.1.3 Interaction effect of FYM and levels of phosphorus on bulk density (Mg m^{-3}) of soil

FYM (t ha^{-1})	P levels (kg P ha^{-1})		
	P_0	P_{13}	P_{26}
		0-15	
F_0	1.48	1.46	1.42
F_{10}	1.40	1.37	1.36
		15-30	
F_0	1.54	1.52	1.54
F_{10}	1.47	1.46	1.44
Soil depths (cm)	0-15		15-30
S Em ±	0.005		0.005
C.D. 5%	0.014		0.013

Interaction effect of tillage, FYM and phosphorus on bulk density of soil :

A critical examination of third order interaction between tillage, FYM and phosphate fertilization (Table 4.1.1.4) revealed that significantly lowest value of bulk density was recorded in plot receiving disc ploughing treatment in conjunction with farm yard manuring and phosphate application at 26 kg P ha^{-1} under the two soil layers examined. However, the bulk density value recorded under this treatment remained statistically at par with the values observed for surface soil layer at varying levels of phosphate used under disc ploughing and the highest level of phosphate (26 kg P ha^{-1}) applied under minimum tillage both in conjunction with farmyard manuring. It is further evident that farmyard manuring and phosphate fertilization in general have definitely lowered down the bulk density of the soil under all the tillage treatments particularly in surface soil layer, though such lowering down effect of farmyard manuring on bulk density was also apparent in sub soil layer.

Table 4.1.1.4 Interaction effect of tillage, FYM and levels of phosphorus on bulk density ($Mg\ m^{-3}$) of soil

Tillage	FYM (t/ha)					
	F_0			F_{10}		
	P levels (kg P ha^{-1})					
	P_0	P_{13}	P_{26}	P_0	P_{13}	P_{26}
			0-15			
Conventional	1.49	1.47	1.35	1.44	1.42	1.39
Disc	1.45	1.42	1.43	1.31	1.32	1.31
Chisel	1.46	1.44	1.40	1.39	1.35	1.35
Minimum	1.49	1.48	1.45	1.35	1.35	1.33
Zero	1.50	1.49	1.44	1.49	1.43	1.41
			15-30			
Conventional	1.57	1.50	1.56	1.44	1.48	1.47
Disc	1.50	1.49	1.47	1.48	1.42	1.39
Chisel	1.55	1.50	1.56	1.46	1.47	1.44
Minimum	1.54	1.55	1.55	1.46	1.44	1.44
Zero	1.56	1.56	1.55	1.51	1.51	1.47

Soil depths (cm)	0-15	15-30
S Em ±	0.011	0.010
C.D. 5%	0.032	0.029

4.1.2 Porosity of soil

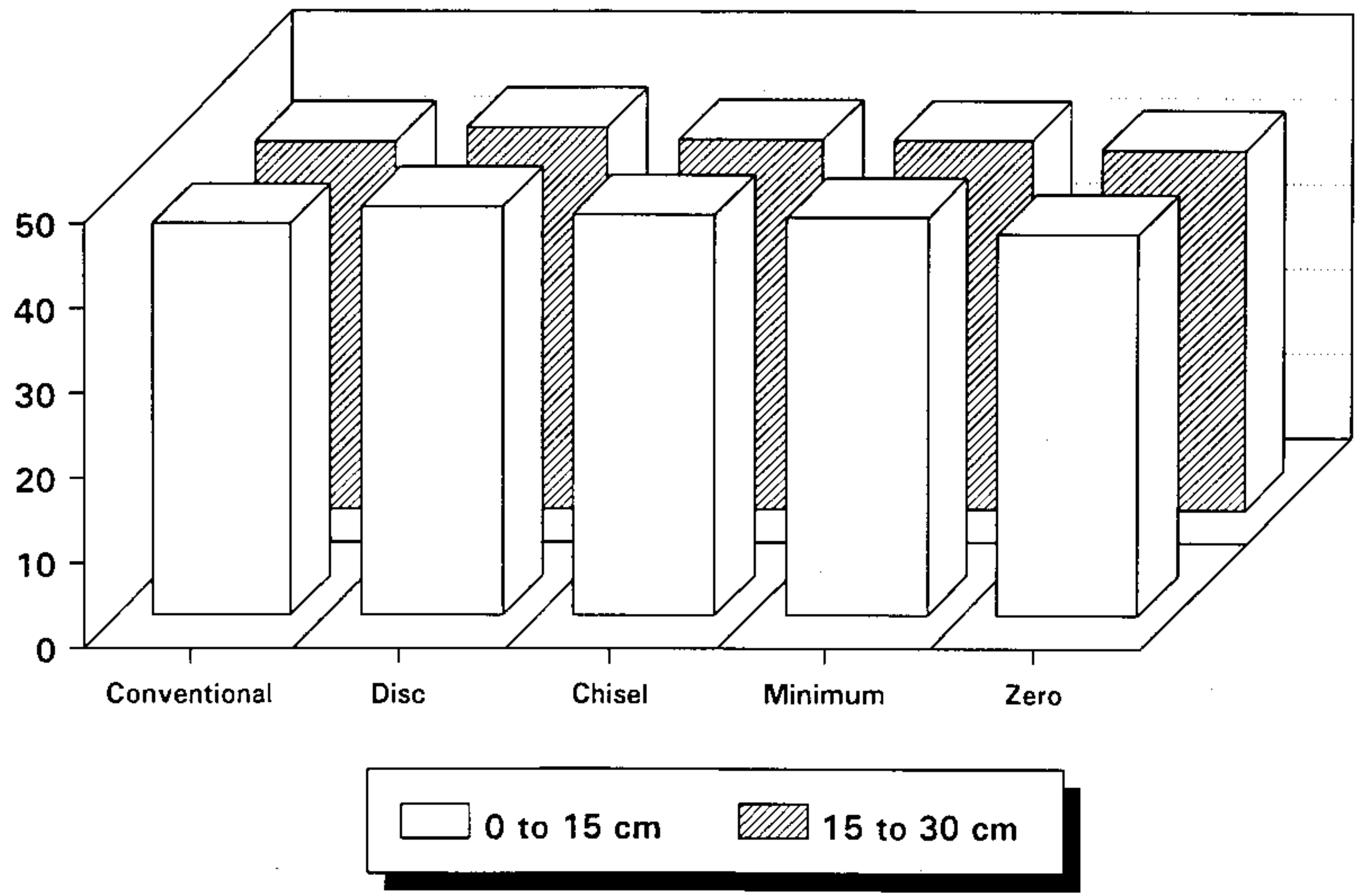
Data on porosity of soil as influenced by various treatments are presented in Table 4.1 and their analysis of variance appended in appendix I.

Tillage : It was observed from the data on soil porosity that different tillage treatments significantly increased the porosity of surface as well as subsurface layers of the soil over zero tillage treatment (Fig. 4.2). The highest value of soil porosity recorded in disc ploughing treatment under both surface (0-15 cm) and subsurface (15-30 cm) layers was statistically significant over rest of all other tillage treatments. The porosity values recorded in surface layer under disc, chisel, minimum and conventional tillage were 48.18, 47.25, 46.92 and 46.15 per cent as against 44.98 per cent under zero tillage treatment. Further, it is apparent from the data that in general all these tillage treatments differed significantly from each other in influencing, the soil porosity and can be placed in descending order as disc > chisel > minimum > conventional. On the other hand in subsurface layer, though the differences in soil porosity under various tillage treatments were statistically significant over zero tillage but the treatment chisel, minimum and conventional remained statistically at par. The values of soil porosity in subsurface layer under different tillage treatments ranged between 42.47 to 45.00 per cent.

FYM : Application of FYM at 10 tons ha^{-1} significantly increased the porosity of soil over no-FYM treatment. The porosity values in surface and sub surface soil layers were 48.09 and 45.01 per cent in plots receiving farmyard manure as against 45.30 and 42.16 per cent in plot receiving no-FYM treatment.

Phosphorus : It was observed from the data that porosity of the soil increased with increase in the phosphorus levels in the two soil layers examined and the highest value recorded was 47.70 per cent in surface and 43.82 per cent in sub-surface layer from the plot receiving 26 kg P ha^{-1}. However,in sub-surface soil layer the values of soil porosity

FIG 4.2 Effect of different Tillage treatments on Soil Porosity (percent)



recorded from the plots receiving two P levels (13 and 26 kg ha^{-1}) remained statistically at par.

Interaction effect of tillage and FYM on soil porosity :

Perusal of data (Table 4.1.2.1) on interaction between tillage treatments and farmyard manuring on soil porosity indicate that significantly highest value of soil porosity was recorded in plot receiving disc ploughing in conjunction with farmyard manuring under the two soil layers examined. This treatment was followed by treatments receiving minimum tillage and chisel ploughing under farmyard manuring. However, the soil porosity remained to be minimum under the plot receiving zero tillage with no-FYM application. Further, application of FYM had significantly improved the soil porosity under all the tillage treatments and depth of soil layers examined.

Table 4.1.2.1 Interaction effect of tillage and FYM on soil porosity (per cent)

Tillage→ FYM (t ha^{-1})↓	Conven-tional	Disc	Chisel	Minimum	Zero
			0-15		
F_0	45.79	45.91	45.91	44.53	44.34
F_{10}	46.51	50.44	48.59	49.31	45.62
			15-30		
F_0	41.82	43.87	42.07	41.64	41.38
F_{10}	44.87	46.13	45.09	45.41	43.55

Soil depths (cm)	0-15	15-30
S Em ±	0.248	0.226
C.D. 5%	0.699	0.638

Interaction effect of tillage and phosphorus on soil porosity :

It is evident from the data (Table 4.1.2.2) on interaction between tillage treatment and phosphate fertilization on soil porosity that disc ploughing when accompanied with phosphate fertilization has significantly increased the soil porosity when compared with rest of other treatment combinations under the two soil layers except the plots receiving phosphate at 26 kg P ha^{-1} in conjunction with conventional, chisel and minimum tillage in the surface layer. However, the highest value of soil porosity was apparent in the plots receiving highest level of phosphate in conjunction with disc ploughing and the lowest value of soil porosity was observed in the plots receiving zero tillage treatment accompanied with no-phosphorus application under both the soil layer examined except in sub soil layer under the plot where this tillage treatment was accompanied with 13 kg P ha^{-1} application.

Table 4.1.2.2 Interaction effect of tillage and levels of phosphorus on soil porosity (per cent)

Tillage→ P levels (kg P ha^{-1})↓	Conven-tional	Disc	Chisel	Minimum	Zero
			0-15		
P_0	44.67	47.88	46.32	46.51	43.68
P_{13}	45.52	48.30	47.36	46.70	45.00
P_{26}	48.26	48.35	48.07	47.55	46.26
			15-30		
P_0	43.35	43.87	43.30	43.40	42.17
P_{13}	43.82	45.05	44.01	43.59	42.12
P_{26}	42.88	46.08	43.44	43.58	43.11

Soil depths (cm)	0-15	15-30
S Em ±	0.304	0.277
C.D. 5%	0.855	0.781

Interaction effect of FYM and phosphorus on soil porosity :

Data on interaction between FYM and phosphate fertilization presented in table 4.1.2.3 indicate that the significantly highest value of soil porosity was recorded in the plot where farmyard manuring was accompanied by phosphate fertilization at 26 kg P ha^{-1} under the two soil layers examined. Further, significantly lowest values of soil porosity was apparent in the plot receiving no-phosphorus and no-FYM treatment. Farm yard manuring has significantly improved the porosity at all the levels of phosphate application and depth of soil examined. A subsequent increase in phosphate levels in general has improved the porosity of soil whether farmyard manuring was done or not. However, phosphate when applied with farmyard manuring has definitely improved the soil porosity, which is evident from the higher value of porosity recorded under this treatment.

Table 4.1.2.3 Interaction effect of FYM and levels of phosphorus on soil porosity (%)

FYM (t ha^{-1})	P levels (kg P ha^{-1})		
	P_0	P_{13}	P_{26}
		0-15	
F_0	44.27	45.00	46.62
F_{10}	47.36	48.15	48.77
		15-30	
F_0	41.81	42.62	42.04
F_{10}	44.62	44.81	45.60
Soil depths (cms)	0-15		15-30
S Em ±	0.192		0.175
C.D. 5%	0.541		0.494

Interaction effect of tillage FYM and phosphorus on soil porosity :

Perusal of data on third order interaction between tillage treatment, farmyard manuring and phosphate fertilization on soil porosity (Table 4.1.2.4), revealed that plot receiving disc ploughing in conjunction with farmyard manuring and phosphate fertilization at 26 kg P ha^{-1} have recorded significantly highest value of soil porosity as compared to all other treatment combinationsunder the two soil layers except the plots receiving farmyard manuring in surface soil layer with O and 13 kg P ha^{-1} under this tillage treatment and 26 kg P ha^{-1} under minimum tillage treatment. Further, in general there is an improvement in soil porosity with the combined application of FYM and phosphate fertilization under all the tillage treatments and the soil layers examined.

4.1.2.4 Interaction effect of tillage, FYM and levels of phosphorus on soil porosity (%)

Tillage	FYM (t ha^{-1})					
	F_0			F_{10}		
	P levels (kg P ha^{-1})					
	P_0	P_{13}	P_{26}	P_0	P_{13}	P_{26}
			0-15			
Conventional	43.68	44.62	49.06	45.66	46.42	47.45
Disc	45.28	46.42	46.04	50.47	50.19	50.66
Chisel	45.00	45.66	47.08	47.64	49.06	49.06
Minimum	43.96	44.34	45.28	49.06	49.06	49.81
Zero	43.40	43.96	45.66	43.96	46.04	46.86
			15-30			
Conventional	40.85	43.30	41.32	45.85	44.34	44.44
Disc	43.40	43.68	44.53	44.34	46.42	47.64
Chisel	41.60	43.40	41.23	45.00	44.62	45.66
Minimum	41.89	41.51	41.51	44.90	45.66	45.66
Zero	41.32	41.23	41.60	43.02	43.02	44.62

Soil depths (cm)	0-15	15-30
S Em ±	0.430	0.392
C.D. 5%	1.210	1.105

4.1.3 Water holding capacity of soil

Data on water holding capacity as influenced by different treatments are presented in Table 4.1 and their analysis of variance appended in appendix I.

Tillage : It is evident from data (Table 4.1) that all the tillage treatments, except conventional tillage,significantly increased the water holding capacity of soil over the treatment receiving zero tillage (Fig. 4.3). Among the different tillage treatments disc ploughing was found to be the best where the value of water holding capacity of the soil recorded was to the tune of 37.89 per cent as against 34.47 and 35.34 per cent recorded under zero and conventional tillage respectively. This treatment was followed by chisel ploughing and minimum tillage, where also a significantly higher value of water holding capacity was recorded over zero tillage. The values of water holding capacity recorded under chisel ploughing and minimum tillage were 36.02 and 35.47 per cent as against 34.47 per cent recorded under zero tillage treatment.

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased the water holding capacity of soil over no-FYM treatment. The water holding capacity value recorded in FYM treated plot was 36.78% as against 34.89% in no-FYM treatment.

Phosphorus : A look on data on water holding capacity of soil revealed that unlike tillage and FYM treatments application of phosphatic fertilizers did not significantly affect this physical parameter of the soil during the course of investigation.

4.1.4 Basic Infiltration rate of soil

Data on basic infiltration rate of soil as influenced by various treatments are presented in Table 4.1 and their analysis of variance appended in appendix I.

FIG. 4.3 Effect of different Tillage treatments on Water holding Capacity (percent)

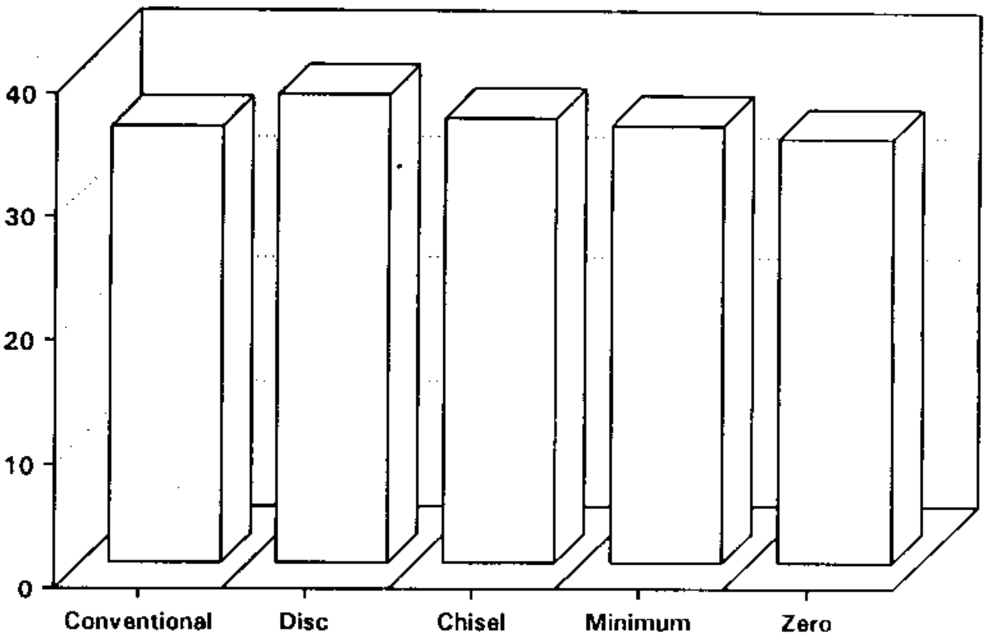


FIG. 4.4 Effect of different Tillage treatments on Soil basic infiltration rate (mm/hr)

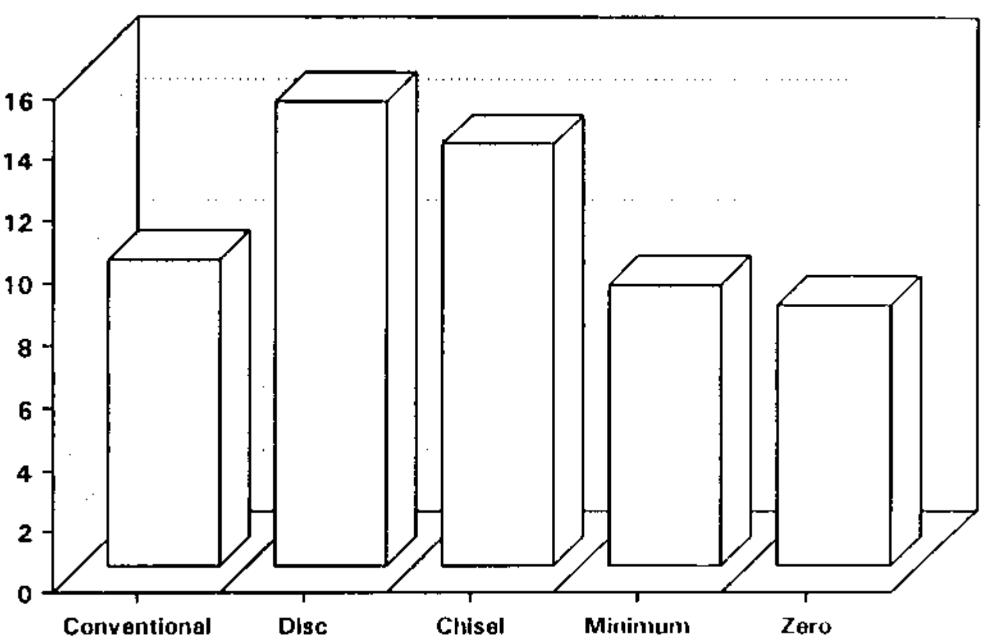
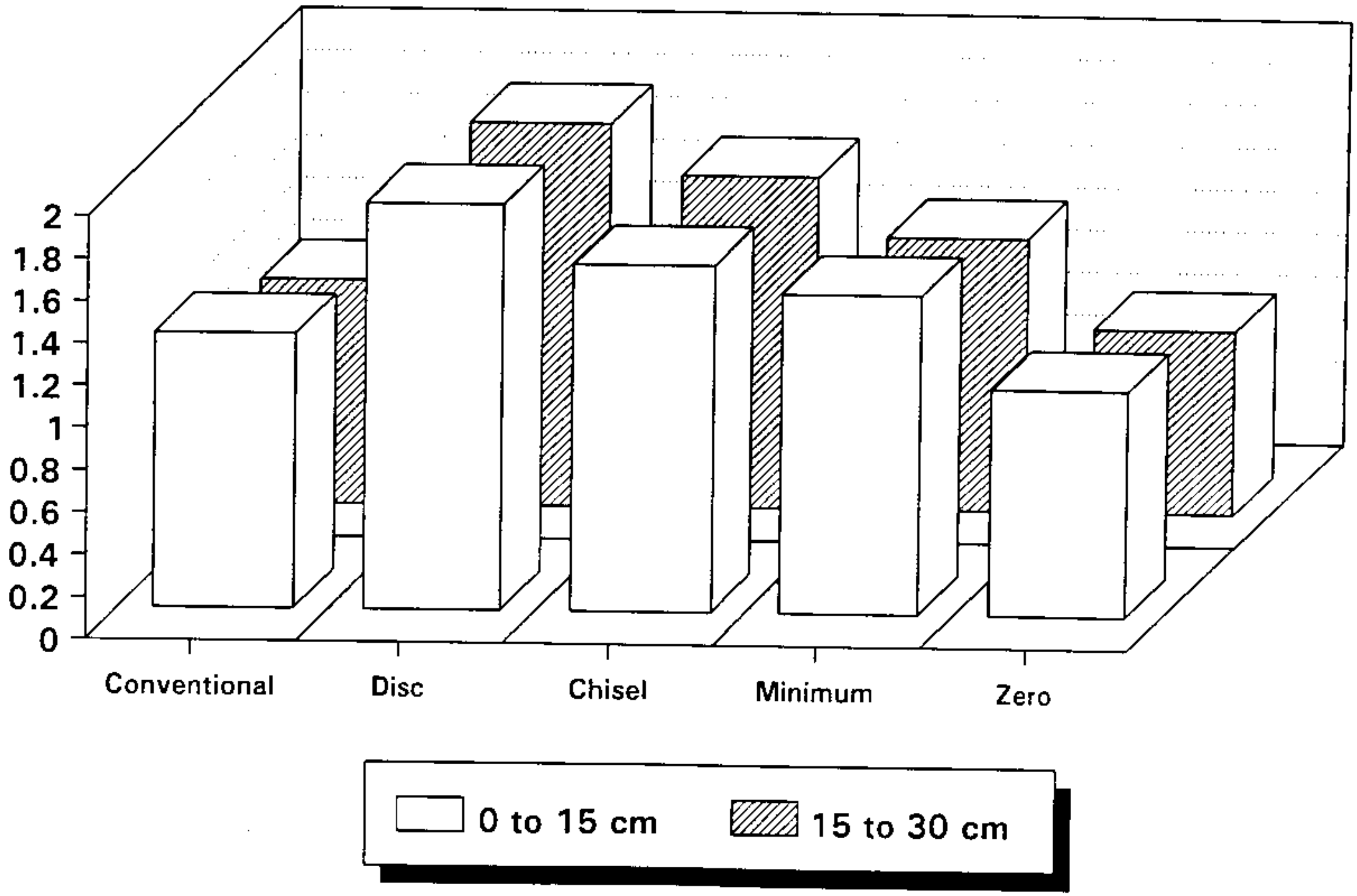


FIG. 4.5 Effect of different Tillage treatments on Hydraulic Conductvity (cm/hr)



Tillage : It is evident from the data on basic infiltration rate of the soil that when compared with zero tillage treatment all other tillage treatments had significantly increased the basic infiltration rate of the soil. It was observed that all tillage treatments differed significantly to each other in respect of the basic infiltration rate recorded (Fig. 4.4). A maximum rate of 15.10 mm hr^{-1} was recorded in disc ploughed plot which followed by chisel ploughing (13.69 mm hr^{-1}) conventional tillage (9.90 mm hr^{-1}) as against value, 8.44 mm hr^{-1} recorded from the plot receiving zero tillage treatment. The magnitude of increase in basic infiltration rate due to disc and chisel ploughing was 79 and 62 per cent over zero tillage and 52 and 38 per cent over conventional tillage treatment, respectively.

FYM : Application of FYM significantly increased the basic infiltration rate of the soil. It was observed that farmyard manuring at 10 tons ha^{-1} increased the basic infiltration rate by 42.1 per cent over no-FYM treatment.

Phosphorus : Like tillage and FYM treatments application of phosphorus significantly increased the basic infiltration rate of soil. The basic infiltration rate was increased with a subsequent increase in phosphorus levels and the maximum value being recorded from the plots receiving phosphorus treatment at 26 kg P ha^{-1} (11.32 mm hr^{-1}) as against the minimum (11.17 mm hr^{-1}) from the plot receiving no-phosphorus treatment.

Interaction effect of tillage and FYM on basic infiltration rate of soil :

An examination of data (Table 4.1.4.1) on interaction between tillage treatment and farmyard manuring on basic infiltration rate of soil revealed that significantly highest value of basic infiltration rate (17.76 mm hr^{-1}) was recorded under the treatment receiving disc ploughing with farmyard manuring while the lowest value (6.88 mm hr^{-1}) was apparent in the plot where zero tillage was practised with no-FYM treatment. Further, the chisel ploughing treatment with FYM in corporation resulted in second highest basic infiltration rate of soil (15.71 mm hr^{-1}) which was also significantly higher than values recorded for all other treatment combinations. Farmyard manuring has significantly improved the soil basic infiltration rate irrespective of tillage treatment given (Fig. 4.6). However, disc ploughing even under no-FYM treatment resulted in significantly highest basic infiltration rate which was closely followed by chisel ploughing.

Table 4.1.4.1 Interaction effect of tillage and FYM on infiltration rate (mm hr^{-1})

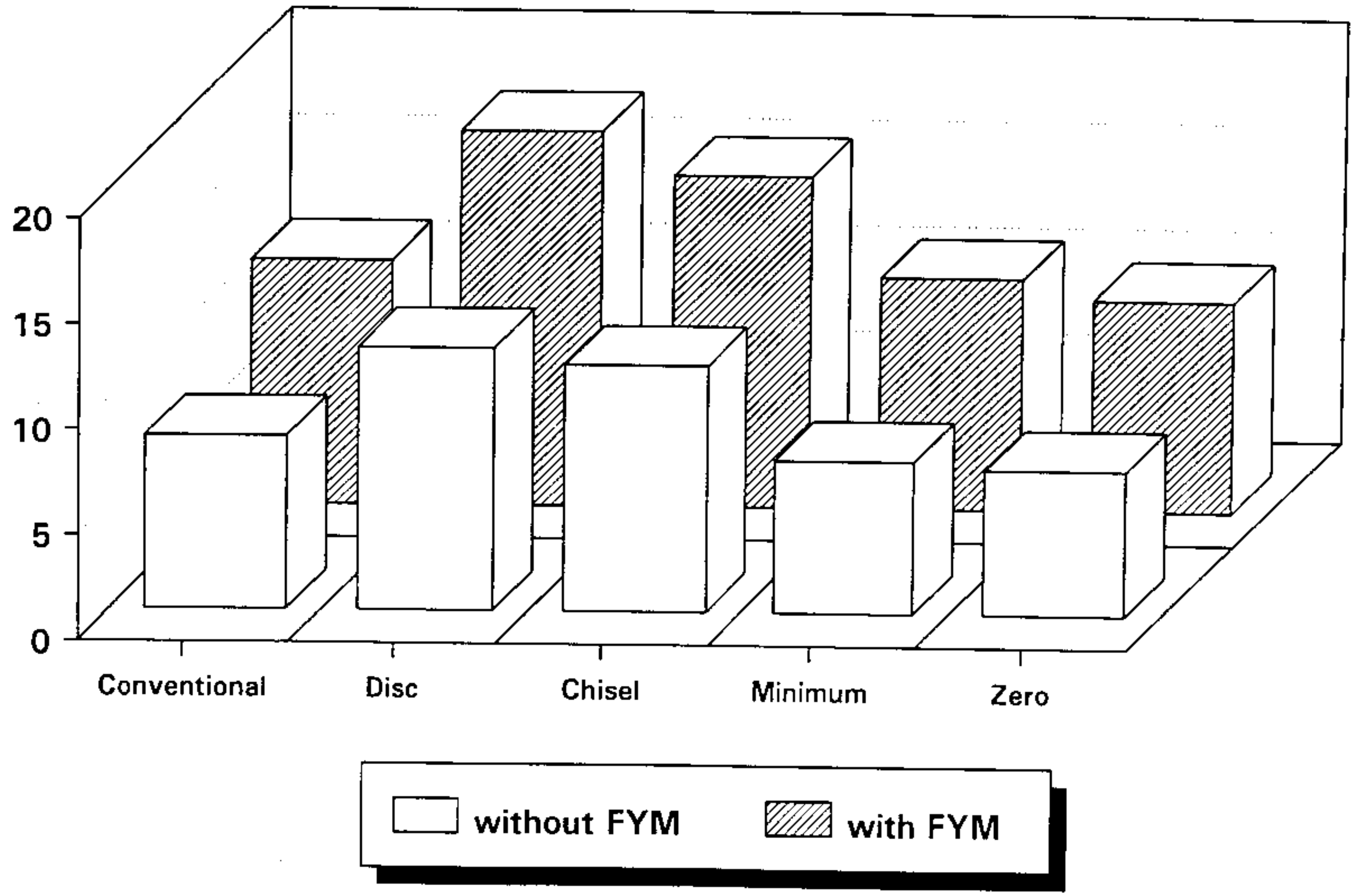
Tillage→ FYM (t ha^{-1})↓	Conven-tional	Disc	Chisel	Minimum	Zero
F_0	8.21	12.45	11.68	7.22	6.88
F_{10}	11.58	17.76	15.71	10.97	10.00
S Em ±			0.016		
C.D. 5%			0.045		

4.1.5 Hydraulic conductivity of soil

Data on hydraulic conductivity as influenced by various treatments are presented in table 4.1 and their analysis of variance appended in appendix I.

Tillage : It is evident from the data on hydraulic conductivity that various tillage treatments have significantly affected the hydraulic conductivity of soil in both surface and subsurface soil layers (Fig. 4.5). Of the different tillage treatments disc ploughing was found to be the best where the maximum value of hydraulic conductivity (1.92 cm hr^{-1}) was recorded as against 1.30 and 1.07 cm hr^{-1} recorded for conventional and zero tillage, respectively in surface soil. This treatment was followed by chisel ploughing and minimum tillage where the increase in hydraulic conductivity was also statistically significant over zero as well as conventional tillage treatment. Like that of surface layer, all the tillage treatments also had the tendency to increase the hydraulic conductivity of sub-surface layer over zero tillage, but

FIG. 4.6 Interaction effect of Tillage and FYM on Soil basic infiltration rate (mm/hr)



the magnitude of increase in hydraulic conductivity was less pronounced as compared to surface soil. The respective values of hydraulic conductivity recorded under disc, chisel, minimum and conventional tillage were 1.81, 1.57, 1.29 and 1.06 cm hr^{-1} as against 0.87 cm hr^{-1} under zero tillage treatment.

FYM : Application of farmyard manure at 10 tons ha^{-1} significantly increased the hydraulic conductivity of both surface and sub-surface soil layer over no-FYM treatment. The values of hydraulic conductivity observed in FYM treated plots were 1.54 and 1.38 cm hr^{-1} for 0-15 and 15-30 cm soil layers as against 1.43 and 1.26 cm hr^{-1} respectively, observed under the plot receiving no-FYM.

Phosphorus : Further examination of data in Table 4.1 show that phosphorus fertilization had a significant effect on the hydraulic conductivity of the soil in both the soil layers examined. It was recorded that the hydraulic conductivity of soil was increased with an increase in the phosphorus level and the highest value recorded was under 26 kg P ha^{-1} treatment irrespective of the depth of soil layer examined.

Though the difference in the value of hydraulic conductivity in between 13 kg P ha^{-1} and 26 kg ha^{-1} was marginal but it was found statistically significant. The maximum value of 1.56 and 1.38 cm hr^{-1} in surface and subsurface soil layer was recorded in the treatment receiving 26 kg P ha^{-1} as against the lowest value of 1.40 and 1.23 cm hr^{-1} under no-phosphorus treatment.

Interaction effect of tillage and FYM on hydraulic conductivity of soil :

An examination of data in Table 4.1.5.1 indicate that farmyard manuring significantly increased the hydraulic conductivity of the surface soil layer (0-15 cm) under all the tillage treatment examined. Further, various tillage treatments significantly improved the hydraulic conductivity of the soil when compared with zero tillage treatment irrespective of the FYM application. The highest value of this parameter (1.98 cm hr^{-1}) was recorded under the treatment receiving disc ploughing in conjunction with farmyard manuring and the lowest value (1.05 cm hr^{-1}) was observed in the treatment receiving zero tillage with no-FYM treatment. Disc ploughing even under no-FYM treatment has resulted in better hydraulic conductivity of the soil when compared with all other treatment combinations, which was followed by the treatment receiving chisel ploughing in conjunction with farmyard manuring.

Table 4.1.5.1 Interaction effect of tillage and FYM on hydraulic conductivity (cm hr^{-1} in surface soil layer (0-15 cm)

Tillage→ FYM (t ha^{-1})↓	Conven-tional	Disc	Chisel	Minimum	Zero
F_0	1.25	1.86	1.56	1.46	1.05
F_{10}	1.35	1.98	1.72	1.56	1.09
S Em ±			0.014		
C.D. 5%			0.040		

Interaction effect of tillage and phosphorus on hydraulic conductivity of soil :

Perusal of data (Table 4.1.5.2) on interaction between tillage and phosphate fertilization on hydraulic conductivity of surface soil indicate that phosphate fertilization under all the tillage treatments significantly increased the hydraulic conductivity. The highest value (1.97 cm hr^{-1}) was recorded from the plot receiving the highest level of phosphate in conjunction with disc ploughing. Further, disc ploughing under all the levels of phosphate fertilization have resulted in significantly higher value of hydraulic conductivity than the values recorded for rest of all other treatment combinations. Significantly lowest value of hydraulic conductivity (1.03 cm hr^{-1}) was observed in the plot receiving zero tillage treatment with no-phosphorus application.

Table 4.1.5.2 Interaction effect of tillage and levels of phosphorus on hydraulic conductivity of soil (cm hr^{-1})

Tillage→ P levels (kg P ha^{-1})↓	Conven-tional	Disc	Chisel	Minimum	Zero
			0-15 cm		
P_0	1.21	1.86	1.50	1.43	1.03
P_{13}	1.34	1.93	1.64	1.52	1.09
P_{26}	1.36	1.97	1.79	1.59	1.10
S Em ±			0.017		
C.D. 5%			0.049		

Interaction effect of tillage,FYM and phosphate fertilization on hydraulic conductivity:

An over all examination of data on third order interaction between tillage treatment, farmyard manuring and phosphate fertilization (Table 4.1.5.3) revealed that plot receiving disc ploughing in conjunction with farmyard manuring and phosphate fertilization at 26 kg P ha^{-1} have recorded significantly highest value of hydraulic conductivity of soil as compared to all other treatment combinations under sub surface soil layer except the plot receiving phosphate at 13 kg P ha^{-1} under this vary tillage treatment. Further, in general there is an improvement in hydraulic conductivity of soil with the application of FYM and phosphate fertilization alone as well as when applied in combination under all the tillage treatment examined. Though, it is evident that application of phosphate fertilization in conjunction with FYM have better impact in the improvement of hydraulic conductivity in sub soil layer under all the tillage treatments, however, the magnitude of improvement was more pronounced under disc ploughing followed by chisel ploughing.

Table 4.1.5.3 Interaction effect of tillage, FYM and levels of phosphorus on hydraulic conductivity of sub-surface soil layer (cm hr^{-1})

Tillage	FYM (t ha^{-1})					
	F_0			F_{10}		
	P levels (kg P ha^{-1})					
	P_0	P_{13}	P_{26}	P_0	P_{13}	P_{26}
Conventional	0.88	1.06	1.09	1.05	1.13	1.15
Disc	1.73	1.77	1.71	1.80	1.89	1.96
Chisel	1.45	1.50	1.60	1.52	1.65	1.70
Minimum	1.05	1.27	1.28	1.28	1.40	1.46
Zero	0.70	0.87	0.90	0.85	0.94	0.96
S Em ±		0.030			0.392	
C.D. 5%		0.083			1.105	

4.1.6 Soil moisture

Data on soil moisture variation in varying depths of soil profile (0-15, 15-30, and 30-45 cm) at sowing and harvest are presented in Table 4.1.6 and their analysis of variance appended in appendix II.

4.1.6a At sowing

Tillage : Perusal of data on soil moisture content at sowing revealed that various tillage treatments (Table 4.1.6) have significantly influenced the soil moisture content at varying depths of profile examined during both the years of investigation. The highest moisture content was observed in the plot receiving disc ploughing treatment in all the three soil depths during both the years of investigation. The plot receiving zero tillage treatment invariably recorded the significantly lowest moisture content when compared with other tillage treatments except conventional tillage in first year of experimentation in surface

Table 4.1.6 Effect of tillage, FYM and levels of phosphorus on percent soil moisture content (volume basis)

Treatments	At Sowing						At Harvest					
	Depths (cm)						Depths (cm)					
	0-15		15-30		30-45		0-15		15-30		30-45	
	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990
Tillage												
Conventional	18.43	19.30	20.49	25.22	16.20	28.48	10.11	16.46	12.84	19.01	17.39	21.71
Disc	18.92	20.39	21.20	26.40	16.58	29.57	11.58	18.82	14.12	20.37	18.20	23.05
Chisel	18.62	19.20	21.01	26.11	16.30	29.73	10.80	18.39	13.45	20.14	18.89	22.86
Minimum	18.51	18.92	21.23	25.70	16.19	28.59	10.44	18.01	12.34	19.94	16.62	21.94
Zero	18.15	18.20	20.46	23.48	15.79	26.14	9.48	16.29	10.70	17.94	15.71	20.83
S Em ±	0.107	0.082	0.084	0.084	0.067	0.183	0.068	0.165	0.070	0.143	0.234	0.159
C.D. 5%	0.331	0.253	0.257	0.257	0.205	0.564	0.209	0.507	0.216	0.438	0.719	0.488
FYM ($t\ ha^{-1}$)												
F_0	18.14	18.54	20.43	24.68	15.90	27.78	9.70	16.80	11.75	18.81	16.63	21.35
F_{10}	18.90	19.86	21.32	26.08	16.52	29.22	11.26	18.39	13.63	20.15	18.09	22.80
S Em ±	0.060	0.073	0.059	0.076	0.048	0.165	0.076	0.137	0.076	0.160	0.124	0.172
C.D. 5%	0.228	0.207	0.167	0.214	0.133	0.466	0.215	0.387	0.214	0.451	0.348	0.485
Phosphorus levels ($kg\ P\ ha^{-1}$)												
P_0	18.48	18.61	20.82	24.76	16.23	27.86	10.16	17.27	12.26	18.89	16.70	21.43
P_{13}	18.55	19.17	20.90	25.35	16.16	28.46	10.51	17.65	12.73	19.39	17.34	22.05
P_{26}	18.54	19.81	20.90	26.04	16.25	29.19	10.78	17.86	13.08	20.16	18.04	22.76
S Em ±	0.073	0.090	0.073	0.093	0.081	0.202	0.093	0.167	0.093	0.196	0.151	0.211
C.D. 5%	NS	0.253	NS	0.263	NS	0.569	0.263	0.473	0.263	0.552	0.428	0.595

(0-15 cm) and subsurface (15-30 cm) layer which remained statistically at par in affecting the soil moisture content. The disc ploughing treatment was either followed by chisel or minimum tillage treatment in recording the soil moisture content. However, the later two treatments remained statistically at par in all the three depths examined during first year of experimentation. Chisel ploughing recorded significantly higher soil moisture content when compared with minimum tillage in all the three depths and conventional in lower two depths of soil profile examined during second year of examination. Further examination of data clearly indicated that the moisture content at sowing in different depths of soil profile was relatively higher in second year as compared to the value recorded in first year of experimentation (Fig. 4.7).

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} has significantly improved the soil moisture content in all the depths of soil profile examined during both the years of experimentation. Like tillage treatments the magnitude of increase recorded in moisture content was little more in second year of experimentation.

Phosphorus : An examination of data on moisture content for the second year of experimentation as influenced by phosphate fertilization revealed that there was a significant increase in soil moisture content with a subsequent increase in phosphate fertilizer up to 26 kg P ha^{-1}. However, no such effect was observed in the moisture content of soil samples drawn in first year of experimentation as there was no any change has occurred in the soil to influence the soil moisture content.

Interaction effect of tillage and FYM on soil moisture content :

It is apparent from the data on interaction between various tillage treatments and farmyard manuring (Table 4.1.6.1 and 4.1.6.2) that incorporation of FYM at 10 tons ha^{-1} irrespective of tillage treatments applied has ingeneral significantly increased the soil moisture content in 15-30 and 30-45 cm layer in the first year and 0-15 and 15-30 cm layer during second year

FIG. 4.7 Effect of different Tillage treatments on percent Soil moisture content (volume basis at sowing)

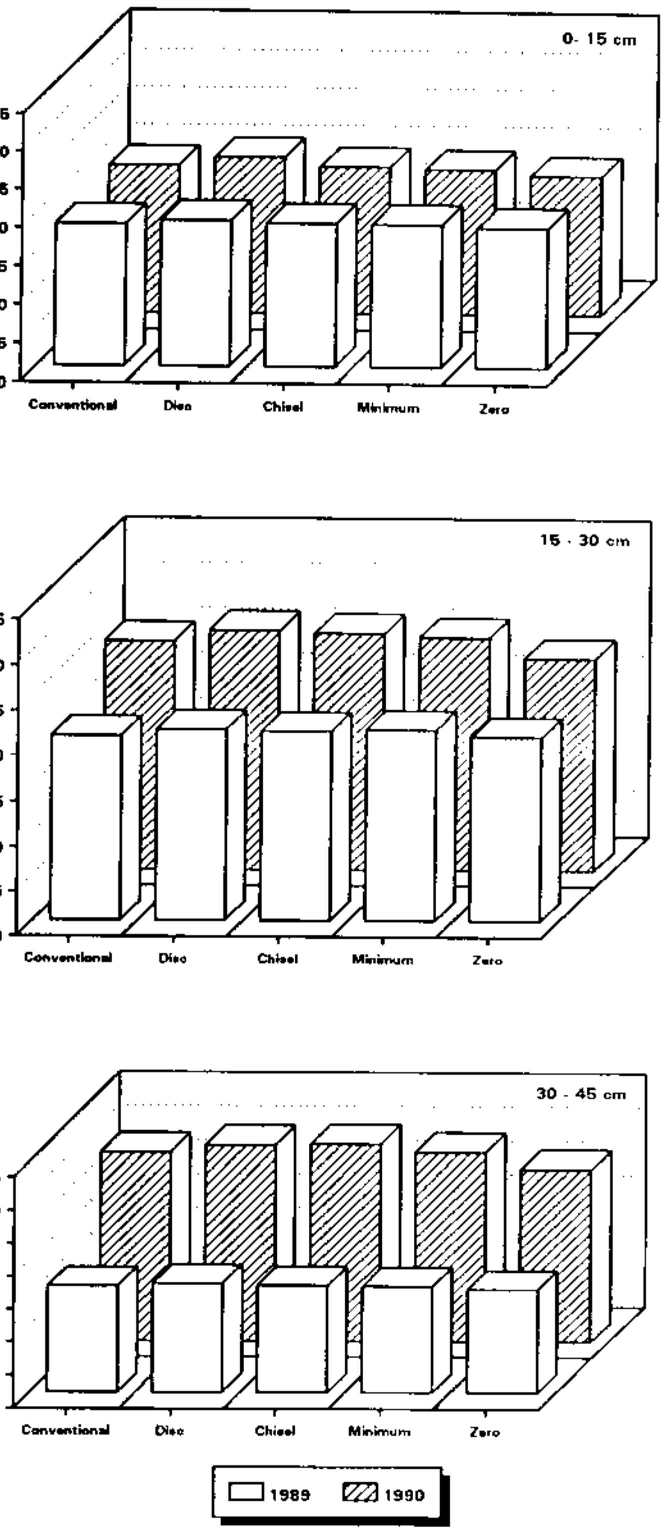


Table 4.1.6.1 Interaction effect of tillage and FYM on per cent soil moisture content (volume basis) at sowing (1989)

Tillage→ FYM (t ha^{-1})↓	Conventional	Disc	Chisel	Minimum	Zero
			15-30		
F_0	20.22	20.79	20.48	20.63	20.20
F_{10}	20.76	21.60	21.93	21.83	20.53
			30-45		
F_0	15.61	16.28	16.15	15.93	15.52
F_{10}	16.81	16.87	16.42	16.44	16.07

Soil depths (cm)	15-30	30-45
S Em ±	0.134	0.108
C.D. 5%	0.377	0.304

Table 4.1.6.2 Interaction effect of tillage and FYM on per cent soil moisture content (volume basis) at sowing (1990)

Tillage→ FYM (t ha^{-1})↓	Conventional	Disc	Chisel	Minimum	Zero
			0-15		
F_0	18.58	20.14	18.59	17.90	17.46
F_{10}	20.02	20.64	19.80	19.93	18.93
			15-30		
F_0	24.47	26.05	25.50	24.67	22.75
F_{10}	25.96	26.75	26.72	26.74	24.21

Soil depths (cm)	0-15	15-30
S Em ±	0.165	0.185
C.D. 5%	0.463	0.480

of experimentation. Further, the treatment receiving disc ploughing recorded the highest value of soil moisture while treatment receiving zero tillage recorded the lowest moisture content in various depths of soil profile examined in situations where no-FYM was given. Similarly under the plots receiving farmyard manuring treatments in conjunction with disc, chisel and minimum tillage treatment though recorded significantly higher moisture content than the treatment receiving zero tillage but remained statistically at par among each other.

Interaction effect of tillage and levels of phosphorus on soil moisture content :

An examination of data on interaction between tillage treatments and phosphorus levels in surface and subsurface layer in the second year of experimentation (Table 4.1.6.3) revealed that various tillage treatments when compared with zero tillage resulted in significantly higher moisture content when given with or without phosphate fertilization. Further, it is apparent that disc ploughing when applied with or without phosphorus application ingeneral recorded definitely higher value of moisture content. A subsequent increase in level of phosphate application there was a significant increase in soil moisture content except the phosphate fertilization at 13 kg P ha^{-1} under disc ploughing and beyond 13 kg P ha^{-1} under minimum tillage.

Interaction effect of FYM and levels of phosphorus on soil moisture content :

Perusal of data on soil moisture content as influenced by interaction effect of FYM and phosphate levels (Table 4.6.1.4) revealed that application of farmyard manuring as well as phosphate fertilization significantly increased the soil moisture content in surface and subsurface layer in second year of experimentation. However, the significance of increase in moisture content was restricted to phosphate fertilization up to 13 kg P ha^{-1} under no-FYM and upto 26 kg P ha^{-1} with 10 tons of FYM ha^{-1} treatment. Further, the significantly highest value of soil moisture content was recorded from the plot receiving 26 kg P ha^{-1} in conjunction with 10 tons of FYM ha^{-1} under both the soil layer examined. The magnitude of

Table 4.1.6.3 Interaction effect of tillage and levels of phosphorus on per cent soil moisture content (volume basis) at sowing (1990)

Tillage→ P levels (kg P ha^{-1})↓	Conven-tional	Disc	Chisel	Minimum	Zero
			0-15		
P_0	18.51	20.11	18.52	18.48	17.40
P_{13}	19.14	20.24	19.12	19.31	18.04
P_{26}	20.24	20.80	19.93	18.96	19.14
			15-30		
P_0	24.40	26.13	25.41	25.22	22.65
P_{13}	25.05	26.25	26.05	26.08	23.32
P_{26}	26.19	26.81	26.87	25.79	24.49

Soil depths (cm)	0-15	15-30
S Em ±	0.201	0.208
C.D. 5%	0.566	0.587

4.1.6.4 Interaction effect of FYM and levels of phosphorus on per cent soil moisture content (volume basis) at sowing (1990)

FYM (t ha^{-1})	P levels (kg P ha^{-1})		
	P_0	P_{13}	P_{26}
		0-15	
F_0	18.09	18.68	18.83
F_{10}	19.12	19.65	20.81
		15-30	
F_0	24.24	24.85	24.96
F_{10}	25.28	25.85	27.10

Soil depths (cm)	0-15	15-30
S Em ±	0.126	0.132
C.D. 5%	0.359	0.371

increase recorded under this treatment in surface and sub surface soil layer was to the extent of 15.0 and 12.0 per cent as compared to the minimum value of soil moisture content recorded under the plot receiving no-FYM and no-phosphorus treatment.

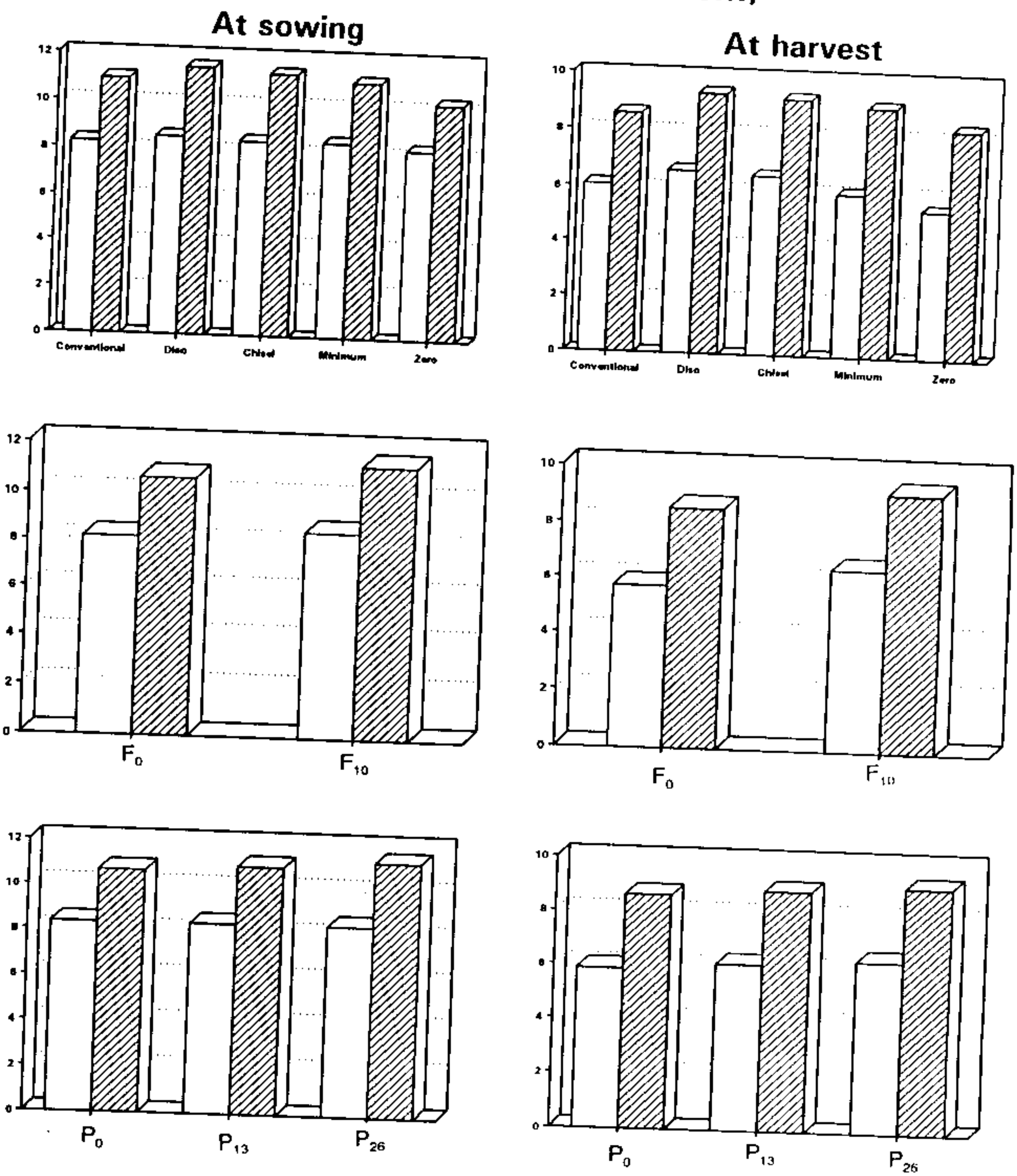
Moisture content in soil profile :

Perusal of data on soil moisture content in soil profile (0-45 cm) presented in Table 4.1.6.5 and Fig. 4.8 revealed that like that of individual soil layer, the soil moisture content in the soil profile as a whole at sowing was highest in the treatment receiving disc ploughing during both the years of experimentation. Similarly an increase in soil moisture content was also evident as a consequence of farmyard manuring during both the years and phosphate fertilization in the second year of experimentation.

Table 4.1.6.5 Effect of tillage, FYM and levels of phosphorus on moisture content (cm) of soil profile (0-45 cm)

Treatment	At sowing		At harvest	
	1989	1990	1989	1990
Tillage				
Conventional	8.26	10.94	6.06	8.58
Disc	8.51	11.45	6.59	9.33
Chisel	8.38	11.26	6.47	9.21
Minimum	8.39	10.98	5.91	8.98
Zero	8.16	10.17	5.38	8.25
FYM (t ha^{-1})				
F_0	8.16	10.65	5.70	8.54
F_{10}	8.49	11.27	6.44	9.20
Phosphorus levels (kg P ha^{-1})				
P_0	8.33	10.68	5.86	8.63
P_{13}	8.34	10.94	6.09	8.87
P26	8.35	11.26	6.29	9.11

FIG. 4.8 Effect of Tillage, FYM and levels of Phosphorus on moisture content (cm) of Soil profile (0-45 cm)



4.1.6b At harvest

Tillage : Perusal of data on soil moisture content in the samples drawn at harvest (Table 4.1.6) revealed that when compared with zero tillage treatment various tillage treatments recorded significantly higher moisture content in all the three layers of soil examined during both the years of investigation. Further, disc ploughing treatment recorded the highest moisture content except the sample drawn from deeper layer (30-45 cm) in the first year and from all the three layers in the second year when compared with chisel ploughing treatment, where the two values recorded remained statistically at par, like the soil moisture content in the sample drawn at sowing the moisture content examined at harvest after second year of experimentation also show a higher value as compared to the value recorded for the samples drawn after the harvest of crop in the first year.

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased the soil moisture content in all the three soil layers examined at harvest during both the years of experimentation.

Phosphorus : Examination of data on soil moisture content in the soil sample drawn at harvest revealed that with a consequent increase in level of phosphate applied distinctly increase in soil moisture content has occurred however, significance of such increase was apparent in all the three layers examined during first year of experimentation and in deeper layer samples drawn during second year of experimentation. Further, phosphate fertilization at 26 kg ha^{-1} has also recorded a significant increase over no-phosphate application in the samples drawn from surface and subsurface layer at harvest of the crop in the second year of experimentation.

Interaction effect of tillage and FYM on soil moisture content :

A perusal of data on interaction between tillage treatment and farmyard manuring (Table 4.1.6.6) revealed that when compared with zero tillage treatment application of farmyard manuring as well as various tillage treatments with or without farmyard manuring resulted in a significant increase in the moisture content of the soil in surface and subsurface soil layer at the harvest of crop in the first year of experimentation. Further, the significantly highest value of soil moisture content was recorded from the plot receiving disc ploughing treatment in conjunction with farmyard manuring. The magnitude of difference in soil moisture recorded over that of minimum value (zero tillage with no-FYM) was in the tune of 44.3 and 53.2 per cent in surface and subsurface soil layer respectively. The moisture content in the plot receiving chisel treatment in conjunction with FYM was the second highest and the magnitude of increase recorded over the minimum value in the two soil layer under reference was in the tune of 30.1 and 47.2 per cent respectively.

4.1.6.6 Interaction effect of tillage and FYM on per cent soil moisture content (volume basis) at harvest (1989)

Tillage→ FYM (t ha^{-1})↓	Conven-tional	Disc	Chisel	Minimum	Zero
			0-15		
F_0	9.45	10.39	10.10	9.75	8.85
F_{10}	10.77	12.77	11.51	11.13	10.11
			15-30		
F_0	12.10	12.84	12.11	11.63	10.05
F_{10}	13.59	15.40	14.79	13.06	11.34

Soil depths (cm)	0-15	15-30
S Em ±	0.170	0.170
C.D. 5%	0.479	0.480

Interaction effect of FYM and levels of phosphorus on soil moisture content :

It is apparent from the data on interaction between FYM and phosphate fertilization (Table 4.1.6.7) that application of farmyard manure as well as phosphate fertilization has significantly increased the moisture content in deeper layer of the soil when examined after the harvest of crop in first year. However, the response to phosphate fertilization was only upto 13 kg ha^{-1} where no-FYM was applied as against the response observed to the phosphorus application upto 26 kg P ha^{-1} under situations where farmyard manuring was done.

Table 4.1.6.7 **Interaction effect of FYM and levels of phosphorus on per cent soil moisture content (volume basis) at harvest (1989)**

FYM (t ha^{-1})	P levels (kg P ha^{-1})		
	P_0	P_{13}	P_{26}
		30-45 cm	
F_0	16.17	16.82	16.90
F_{10}	17.23	17.87	19.17
S Em ±		0.215	
C.D. 5%		0.604	

Moisture Content in Soil Profile :

Perusal of data on moisture content in soil profile (0-45) revealed that (Table 4.1.6.5) Fig. 4.8 the treatment receiving disc ploughing recorded the highest level of residual soil moisture left in the soil after the harvest of the crop in the two years of experimentation. Disc ploughing was followed by chisel ploughing in retaining the moisture content in the profile at harvest. Like that at sowing minimum residual moisture content was apparent from the plot receiving zero tillage treatment. Further, the farmyard manuring and phosphate fertilization have definitely improved the residual moisture level left in the soil profile after the harvest of the crop during both the years of investigation.

4.2 Physico-Chemical Properties of the Soil

4.2.1 Soil pH

Data on soil pH as influenced by various treatments are presented in Table 4.2 and analysis of variance appended in appendix II.

Table 4.2 Effect of tillage, FYM and levels of phosphorus on pH and electrical conductivity of the soil

Treatment	pH	EC (dSm^{-1})
Tillage		
Conventional	7.31	0.13
Disc	7.30	0.14
Chisel	7.30	0.15
Minimum	7.31	0.15
Zero	7.30	0.14
S Em ±	0.011	0.010
C.D. 5%	NS	NS
FYM (t ha^{-1})		
F_0	7.33	0.15
F_{10}	7.28	0.15
S Em ±	0.007	0.005
C.D. 5%	0.019	NS
Phosphorus levels (kg P ha^{-1})		
P_0	7.32	0.13
P_{13}	7.30	0.14
P26	7.29	0.16
S Em ±	0.008	0.006
C.D. 5%	0.022	0.016

Tillage : It is obvious from data on pH of the soil that different tillage treatments did not affect this parameter to any significant level and the values of soil pH ranged between 7.30 to 7.31 under different set of tillage operations.

FYM : Data on soil pH when compared with no-FYM treatment, incorporation of farmyard manure at 10 tons ha^{-1} had significantly decreased the pH of the soil, though the difference in two values recorded was hardly of 0.05 unit.

Phosphorus : Like FYM, phosphate fertilization has also decreased the pH of the soil under study, however, the significance of such changes in pH value was only apparent when the values observed under the plots receiving no-phosphorus treatment was compared with the plots receiving the highest level of P application (26 kg P ha^{-1}).

4.2.2 Electrical conductivity of the soil

Data on Electrical conductivity of the soil as influenced by different treatments are presented in Table 4.2 and their analysis of variance appended in appendix III.

Tillage : An examination of the data from Table 4.2 indicate that different tillage treatments have no any significant effect on electrical conductivity of the soil.

FYM: Like tillage treatment the incorporation of FYM in the soil also had no any significant effect on the electrical conductivity of soil measured after two years of experimentation.

Phosphorus : Unlike tillage and FYM treatments application of phosphorus at 26 kg P ha^{-1} level significantly increased the electrical conductivity of the soil when compared with phosphate fertilization upto 13 kg P ha^{-1}.

Interaction effect of tillage and levels of phosphorus on electrical conductivity of the soil:

An over all examination of data on interaction between tillage treatments and phosphate fertilization (Table 4.2.2.1) indicated that the lowest value of electrical conductivity was observed under zero tillage treatment with no phosphorus fertilization. Though treatment receiving chisel ploughing in conjunction with 26 kg P ha^{-1} level of phosphorus fertilization resulted in the highest value of electrical conductivity, however, there was no definite trend with phosphate fertilization in conjunction with various tillage treatments.

Table 4.2.2.1 Interaction effect of tillage and levels of phosphorus on electrical conductivity (dSm^{-1}) of the soil

Tillage→ P levels (kg P ha^{-1})↓	Conven-tional	Disc	Chisel	Minimum	Zero
P_0	0.15	0.12	0.14	0.16	0.09
P_{13}	0.13	0.14	0.11	0.15	0.17
P_{26}	0.12	0.16	0.21	0.15	0.15
S Em ±			0.012		
C.D. 5%			0.023		

Interaction effect of FYM and levels of phosphorus on electrical conductivity of the soil:

It is evident from the data presented in Table 4.2.2.2 that the minimum electrical conductivity value was observed in treatment combination where no-FYM and no-phosphorus was applied. Application of phosphorus under no-FYM treated plots significantly increased the electrical conductivity of the soil. Though sole application of FYM has also significantly increased the electrical conductivity of the soil but when applied in conjunction with phosphatic fertilizer a definite decrease in electrical conductivity of the soil has occurred.

Table 4.2.2.2 Interaction effect of FYM and levels of phosphorus on EC (dSm^{-1}) of the soil

FYM ($t\ ha^{-1}$)	P levels ($kg\ P\ ha^{-1}$)		
	P_0	P_{13}	P_{26}
F_0	0.12	0.15	0.17
F_{10}	0.15	0.13	0.14
S Em ±		0.008	
C.D. 5 %		0.023	

4.3 Chemical Properties of the Soil :

Data on organic carbon, available soil phosphorus and available soil potassium status of the soil as influenced by different treatments are presented in Table 4.3 and their analysis of variance appended in appendix IV.

4.3.1 Organic carbon content of the soil

Tillage : A critical look on data (Table 4.3) on organic carbon content of the soil indicated that different tillage treatments had significant effect on the organic carbon content of the soil. The organic carbon content decreased with an increase in the depth of tillage operation. The minimum value of organic carbon (0.38 %) was recorded in soils of the plot receiving disc ploughing treatment where the soil was tilled to a maximum level as against the highest value of organic carbon (0.42%) in soils of the plot receiving zero tillage. The other tillage treatments viz., conventional ploughing, chisel ploughing and minimum tillage also recorded significantly higher value of organic carbon when compared with disc ploughing, though remained statistically at par among each other.

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased organic carbon content of the soil and the extent of increase recorded was in tune of 53.6 per cent over no-FYM treatment.

Phosphorus : Further, examination of the data on organic carbon content of the soil revealed that phosphate fertilization significantly increased the organic carbon content of the soil, however, different levels of phosphorus used remained statistically at par in influencing this parameter.

Table 4.3 Effect of tillage, FYM and levels of phosphorus on chemical composition of the soil

Treatment	Organic carbon (%)	Soil available phosphorus (kg ha^{-1})	Soil available potassium (kg ha^{-1})
Tillage			
Conventional	0.40	18.47	399.50
Disc	0.38	20.85	413.67
Chisel	0.40	19.75	409.50
Minimum	0.40	18.97	403.67
Zero	0.42	17.30	406.17
S Em ±	0.005	0.275	2.907
C.D. 5%	0.016	0.844	NS
FYM (t ha^{-1})			
F_0	0.32	17.37	401.33
F_{10}	0.49	20.77	411.67
S Em ±	0.004	0.130	1.820
C.D. 5%	0.011	0.366	5.127
Phosphorus levels (kg P ha^{-1})			
P_0	0.39	13.40	400.00
P_{13}	0.41	20.30	407.00
P26	0.41	23.50	412.50
S Em ±	0.005	0.159	2.229
C.D. 5%	0.013	0.448	6.280

Interaction effect of tillage, FYM and levels of phosphorus on organic carbon content of soil :

A critical examination of third order interaction between tillage, farmyard manure and phosphate fertilization (Table 4.3.1.1) revealed that significantly lowest value of organic carbon was recorded in plot receiving disc ploughing treatment in conjunction with highest level of phosphorus with FYM application, except the plot receiving no-FYM treatment in conjunction with conventional and chisel tillage without phosphorus and minimum tillage with 13 kg P ha^{-1} treatment. Further, it is evident that farmyard manuring in general have significantly improved the organic carbon status of the soil under all the tillage operations over no-FYM treatment, though phosphate application under farmyard manuring have shown no definite trend but a higher value of organic carbon was recorded under conventional, disc and minimum tillage treatments. The highest value of organic carbon (0.53 %) was recorded in plot receiving farmyard manuring with zero tillage treatment, which was followed by minimum, zero and conventional tillage with phosphate application upto 13 kg P ha^{-1}.

Table 4.3.1.1 Interaction effect of tillage, FYM and levels of phosphorus on organic carbon content of the soil (per cent)

Tillage	FYM (t ha^{-1})					
	F_0			F_{10}		
	P levels (kg P ha^{-1})					
	P_0	P_{13}	P_{26}	P_0	P_{13}	P_{26}
Conventional	0.28	0.34	0.33	0.46	0.51	0.51
Disc	0.34	0.31	0.27	0.43	0.45	0.50
Chisel	0.30	0.34	0.32	0.49	0.45	0.50
Minimum	0.31	0.30	0.34	0.45	0.52	0.50
Zero	0.32	0.33	0.34	0.53	0.52	0.49
S Em ±	0.015					
C.D. 5%	0.041					

4.3.2 Soil Available Phosphorus :

Tillage : A perusal of data in (Table 4.3) revealed that all the tillage treatments significantly increased the available phosphorus status of the soil when compared with phosphorus status observed in the plot receiving zero tillage treatment. Among the different tillage treatment disc ploughing was found to be the best where the soil available phosphorus status recorded was in the tune of 20.85 kg P ha^{-1} (maximum) as against 17.30 and 18.47 kg P ha^{-1} recorded for the soils of the plots receiving zero and conventional tillage treatment, respectively. Further, the treatment disc ploughing was followed by chisel ploughing and minimum tillage treatments in influencing the available soil phosphorus status, where the respective values recorded were 19.75 and 18.97 kg P ha^{-1}. The magnitude of increase in soil available phosphorus due to disc ploughing, chisel ploughing and minimum tillage was of the order 20.5, 14.2 and 9.6 per cent respectively over zero tillage treatment.

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased the available phosphorus status of the soil by 3.4 kg P ha^{-1} over no-FYM treatment and the extent of increase recorded was in tune of 19.57 per cent.

Phosphorus : It is apparent from data presented in Table 4.3 that phosphate fertilization had also significantly affected the available phosphorus status of the soil. Phosphorus applied at 26 and 13 kg P ha^{-1} significantly increased the soil available phosphorus by 10.10 and 6.9 kg P ha^{-1} over no-phosphorus treatment. The corresponding increases recorded were of the order 75.37 and 51.49 per cent over no-phosphorus application.

Interaction effect of tillage and FYM on soil available phosphorus :

Perusal of data on interaction between tillage treatments and incorporation of farmyard manure (Table 4.3.2.1) revealed that significantly higher values of soil available phosphorus were recorded under the treatment receiving disc and chisel ploughing in conjunction with farmyard manuring. Further, application of FYM significantly increased the available phosphorus content of the soil irrespective of the tillage treatment examined (Fig. 4.9). The disc ploughing proved to be definitely superior over rest of other tillage treatment as is evident from the higher levels soil available phosphorus recorded even under no-FYM treatment. However, treatment receiving zero tillage without farmyard manuring recorded significantly lowest value of soil available phosphorus.

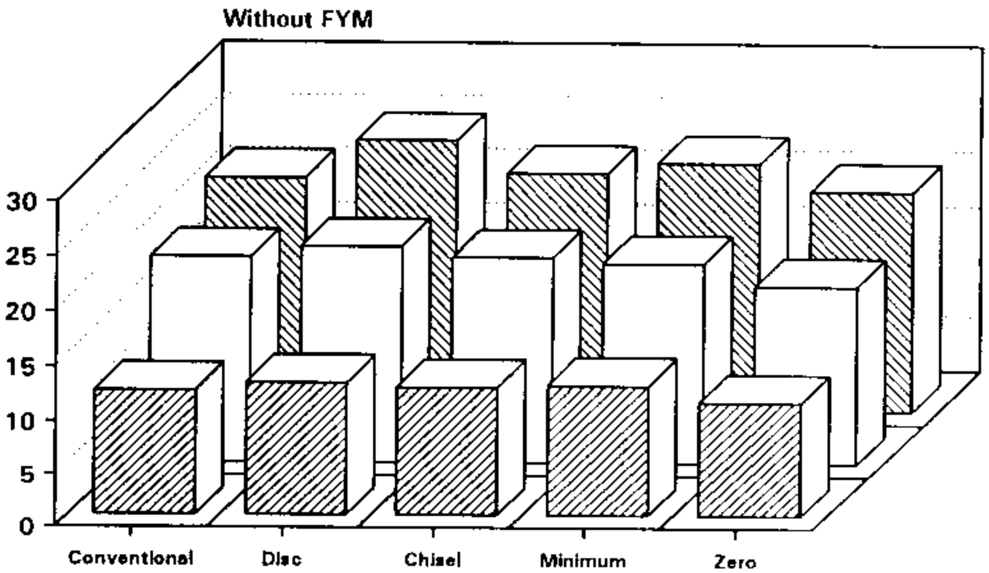
Table 4.3.2.1 Interaction effect of tillage and FYM on soil available phosphorus (kg ha^{-1})

Tillage→ FYM (t ha^{-1})↓	Conven- tional	Disc	Chisel	Minimum	Zero
F_0	17.17	18.90	17.43	17.67	15.67
F_{10}	19.77	22.80	22.07	20.27	18.93
S Em ±			0.290		
C.D. 5%			0.817		

Interaction effect of tillage, FYM and levels of phosphorus on soil available phosphorus:

Perusal of data on third order interaction between tillage treatment, farmyard manure and phosphate fertilization (Table 4.3.2.2) revealed that plot receiving disc ploughing in conjunction with farmyard manuring and phosphate fertilization at 26 kg P ha^{-1} have recorded significantly higher values of soil available phosphorus (27 kg P ha^{-1}) as compared to all other treatment combinations except the plot receiving chisel ploughing under the same set of treatment combination, which remained statistically at par with disc ploughing. Further, there was an improvement in soil available phosphorus with the application of FYM and a subsequent increase in phosphate fertilization whether applied alone or in combination under all the tillage treatments. However, a significantly higher value of soil available phosphorus was recorded when phosphate was applied in conjunction with farmyard manuring under all the tillage treatments.

FIG. 4.9 Interaction effect Tillage, FYM and levals of Phosphorus on Soil available phosphorus (Kg/ha)



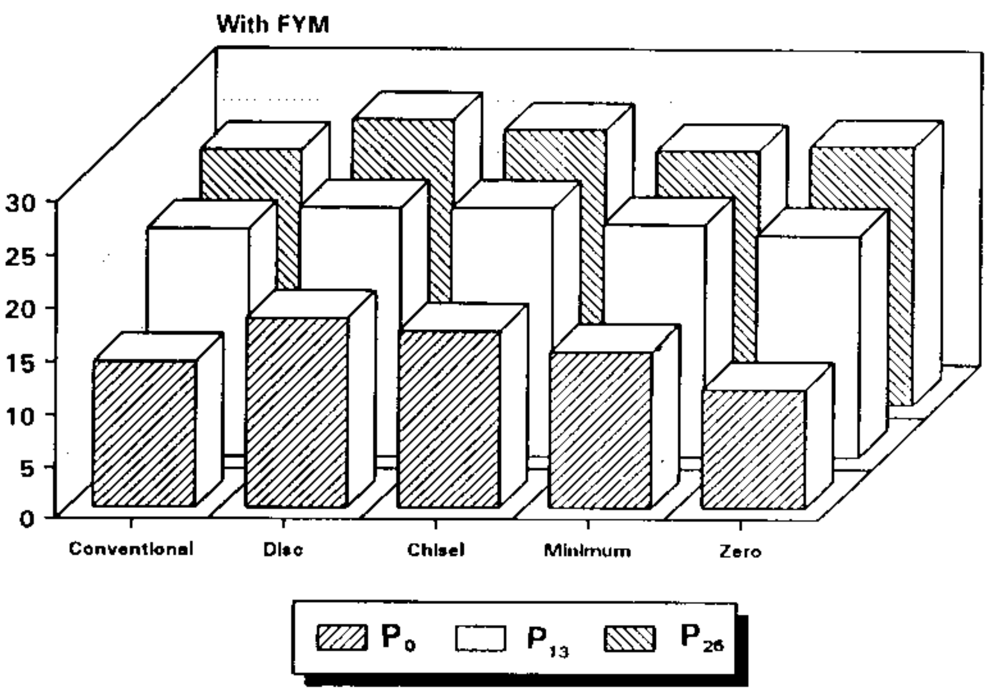


Table 4.3.2.2 Interaction effect of tillage, FYM and levels of phosphorus on soil available phosphorus (kg ha^{-1})

Tillage	FYM (t ha^{-1})					
	F_0			F_{10}		
	P levels (kg P ha^{-1})					
	P_0	P_{13}	P_{26}	P_0	P_{13}	P_{26}
Conventional	11.70	18.80	21.00	13.90	21.40	24.00
Disc	12.40	19.80	24.50	18.00	23.40	27.00
Chisel	12.00	18.80	21.50	16.80	23.40	26.00
Minimum	12.20	18.30	22.50	14.90	21.90	24.00
Zero	10.70	16.30	20.00	11.40	20.90	24.50
S Em ±			0.502			
C.D. 5%			1.414			

4.3.3 Soil Available Potassium :

Tillage : An examination of data (Table 4.3) on soil available potassium status indicated that, different tillage treatments did not influence the available potassium status of the soil, however, the value of soil available potassium recorded under different tillage treatments ranged between 399.50 to 413.7 kg ha^{-1}.

FYM : Incorporation of farmyard manuring at 10 tons ha^{-1} significantly increased the available potassium status of the soil as compared to no-FYM treatment. The value recorded of available potassium in FYM treated plot was 411.7 kg K ha^{-1} as against 401.3 kg K ha^{-1} in no-FYM treated plot.

Phosphorus : Like that of FYM, phosphorus fertilization had also significantly increased the level of available potassium in the soil. Phosphorus applied at 13 and 26 kg P ha^{-1} increased the potassium status of the soil by 7.0 and 12.5 kg K ha^{-1} over no-phosphorus treatment. However, the available potassium of the soil recorded from the soil of the plots receiving 13 and 26 kg P ha^{-1} remained statistically at par.

Interaction effect of tillage and FYM on soil available potassium :

A critical examination of data on interaction between tillage treatments and farmyard manuring on available potassium status (Table 4.3.3.1) of the soil revealed that though highest value of soil available potassium was recorded in the plot receiving disc ploughing in conjunction with farmyard manuring, but the value remained statistically at par with those recorded from the plots receiving minimum, chisel and zero tillage with FYM treatment and disc ploughing in conjunction with no-FYM treatment. Further, incorporation of farmyard manure though definitely increased the soil potassium status under disc, chisel, minimum and zero tillage treatments but , the differences recorded were only statistically significant for the last two tillage treatments.

4.3.3.1 Interaction effect of tillage and FYM on soil available potassium (kg ha^{-1})

Tillage→ FYM (t ha^{-1})↓	Conven- tional	Disc	Chisel	Minimum	Zero
F_0	401.67	408.33	405.00	391.67	400.00
F_{10}	397.33	419.00	414.00	415.67	412.33
S Em ±			4.070		
C.D.5%			11.465		

4.4 Crop Yield :

4.4.1 Sorghum

Data on grain and stover yield of sorghum are presented in Table 4.4.1 and their analysis of variance appended in appendix V.

Tillage : Perusal of data on grain and stover yield of sorghum revealed that tillage treatments had significant effect on grain and stover yields of sorghum during both the years of research except stover yield during 1990. The various tillage practices, disc ploughing, ploughing with chiseller as well as minimum and conventional tillage during both the years recorded significantly higher grain yield over zero tillage. Mean data for the two consecutive years show that ploughing with disc gave the highest grain yield of 28.73 q ha^{-1} which was followed by chiseller (28.67 q ha^{-1}), minimum tillage (28.51 q ha^{-1}) and conventional practice (28.11 q ha^{-1}). The corresponding magnitude of increases recorded over zero tillage were in the tune of 12.31, 12.08, 11.45 and 9.89 per cent. Like grain yield in sorghum the stover yield also dictated the similar trend in the yield responses under different tillage treatments examined. However, responses were statistically significant only for the year 1989. The highest stover yield of 119.44 q ha^{-1} was recorded under disc ploughing which was followed by minimum tillage (117.25 q ha^{-1}), chisel ploughing (116.95 q ha^{-1}) and conventional tillage (113.80 q ha^{-1}). Yield under these treatment were significantly higher over zero tillage treatment where minimum, stover yield of 94.06 q ha^{-1} was recorded in *Kharif*, 1989. Further, it is evident from mean stover yield that the highest yield of 98.10 q ha^{-1} was recorded from the plot receiving treatment of disc ploughing which was followed by chisel, minimum and conventional tillage treatments where the respective yield recorded were 95.98, 95.40 and 94.25 q ha^{-1}. These mean stover yields were distinctly higher than the stover yield recorded under the plot receiving zero tillage 83.54 q ha^{-1}.

FYM : Incorporation of farmyard manuring at 10 tons ha^{-1} significantly increased the grain and stover yields of sorghum during both 1989 and 1990 (Table 4.4.1). The per cent increase in grain and stover yield recorded was 13.49 and 9.84 and 9.05 and 7.51 in the year 1989 and 1990 respectively. Further, the magnitude of increase in mean stover yields for the two years recorded was of the order 11.48 per cent for grain and 8.43 per cent for stover.

Table 4.4.1 Effect of tillage, FYM and levels of phosphorus on sorghum yield (q ha^{-1})

Treatment	Grain			Stover		
	1989	1990	Mean	1989	1990	Mean
Tillage						
Conventional	25.54	30.68	28.11	113.80	74.71	94.25
Disc	26.28	31.18	28.73	119.44	76.76	98.10
Chisel	26.19	31.16	28.67	116.95	75.02	95.98
Minimum	26.04	30.98	28.51	117.25	73.55	95.40
Zero	22.68	28.48	25.58	94.06	73.02	83.54
S Em ±	0.619	0.278		3.670	2.033	
C.D. 5%	1.905	0.857		11.305	NS	
FYM (t ha^{-1})						
F_0	23.75	29.06	26.40	107.44	71.91	89.67
F_{10}	26.94	31.92	29.43	117.16	77.31	97.23
S Em ±	0.479	0.357		1.935	1.303	
C.D. 5%	1.352	1.005		5.448	3.671	
Phosphorus levels (kg P ha^{-1})						
P_0	23.60	29.05	26.32	110.96	73.25	92.10
P_{13}	26.92	31.72	29.32	111.76	74.93	93.34
P26	25.52	30.71	28.11	114.18	75.67	94.92
S Em ±	0.587	0.437		2.369	1.596	
C.D. 5%	1.652	1.228		NS	NS	
C.V.(%)	14.66	9.06		13.35	13.53	

Phosphorus : Application of phosphorus definitely improved the grain as well as stover yield of sorghum, though the differences recorded were statistically significant for grain yield only during both the years of investigation. Application of 13 kg P ha^{-1} recorded a significant increase in grain yield over no phosphorus treatment and the differences recorded were in the tune of 14.07 and 9.19 for 1989 and 1990. However, phosphate fertilization of sorghum beyond 13 kg P ha^{-1} remained in effective in boosting up of the yield during both the years. On reviewing the mean grain yield of sorghum, P fertilization at 13 and 26 kg p ha^{-1} recorded an increase of 11.4 and 6.8 per cent over no-phosphate fertilization.

The mean data for two years indicate that the highest stover yield of 94.92 q ha^{-1} was recorded in plots receiving 26 kg P ha^{-1} as against 92.10 q ha^{-1} recorded from the plot receiving no-phosphorus treatment.

4.4.2 Green gram

The data on seed and stover yield of green gram as influenced by various treatments under study are presented in Table 4.4.2 and analysis of variance appended in appendix VI.

Tillage : An examination of data in Table 4.4.2 revealed that tillage treatment significantly affected the seed and stover yields of green gram during both the years of investigation. The highest seed yield of green gram was recorded from plots receiving disc ploughing, which was followed by chisel ploughing, minimum tillage and conventional practice during both the years of investigation. Significantly lowest seed yield was recorded in plot receiving zero tillage treatment when compared with all other tillage treatments examined. The mean data for two years show that the highest seed yield of 2.68 q ha^{-1} was recorded from the plot receiving disc ploughing which was closely followed by chiseller (2.60 q ha^{-1}), minimum tillage (2.59 q ha^{-1}) and conventional practice (2.53 q ha^{-1}). The magnitude of increase in the mean seed yield under disc ploughing treatment was 17.03 per cent over the yield recorded from the plot receiving zero tillage treatments.

Table 4.4.2 Effect of tillage and levels of phosphorus on green gram yield (q ha^{-1})

Treatment	Grain			Stover		
	1989	1990	Mean	1989	1990	Mean
Tillage						
Conventional	2.205	2.857	2.53	8.250	8.780	8.51
Disc	2.362	2.995	2.68	8.470	11.620	10.04
Chisel	2.271	2.938	2.60	7.730	8.760	8.24
Minimum	2.290	2.895	2.59	7.390	8.440	7.91
Zero	1.957	2.624	2.29	7.280	7.450	7.36
S Em ±	0.059	0.072		0.220	0.324	-
C.D. 5%	0.181	0.219		0.681	0.995	-
FYM (t ha^{-1})						
F_0	1.981	2.705	2.34	7.430	8.580	8.00
F_{10}	2.457	3.019	2.74	8.220	9.440	8.83
S Em ±	0.051	0.089		0.124	0.253	
C.D. 5%	0.143	0.252		0.348	0.709	
Phosphorus levels (kg P ha^{-1})						
P_0	2.038	2.524	2.28	6.870	7.940	7.40
P_{13}	2.295	3.248	2.77	8.390	10.260	9.32
P26	2.314	2.814	2.56	8.220	8.840	8.53
S Em ±	0.063	0.110		0.152	0.309	
C.D. 5%	0.176	0.309		0.428	0.871	
C.V.(%)	17.91	24.28		12.28	21.73	

Like seed yield, the highest stover yield was also recorded from the plot receiving disc ploughing treatment which was significantly higher over all other treatments during both the years except the yield recorded from the plot receiving conventional tillage during 1989, which remained statistically at par with the former. Further, the chisel ploughing and conventional tillage in *Kharif*, 1990 also recorded significantly higher yield over zero tillage treatment. The mean data for two years show that the highest stover yield of 10.04 q ha^{-1} was recorded from the plot receiving disc ploughing treatment which was 36.41 per cent higher than the yield recorded from the plot receiving zero tillage treatment.

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased the seed and stover yields of green gram during both 1989 and 1990. The respective increases in yield recorded for the two years was 24.03 and 11.61 per cent for seed and 10.63 and 10.02 per cent for stover as compared to no-FYM treatment.

Phosphorus : Application of phosphatic fertilizers significantly increased the seed and stover yield of green gram during either year of research. When compared with no-phosphorus application, treatment receiving 13 kg P ha^{-1} resulted in significantly higher seed and stover yields during both the years. However, application of phosphorus beyond 13 kg P ha^{-1} did not give any yield response, rather a decrease in these yield parameters was recorded in *Kharif*, 1990.

The mean data for two years also revealed that application of 13 kg P ha^{-1} resulted in the highest seed and stover yields of green gram and the magnitude of increase recorded over no-phosphorus treatment was 21.49 and 25.94 per cent respectively for seed and stover

4.4.3 Sorghum Equivalent Yield :

Data on sorghum equivalent and pooled equivalent yield as influenced by different treatments under study are presented in Table 4.4.3 and their analysis of variance appended in appendix VII.

Tillage : Perusal of data on sorghum equivalent yield revealed that when compared with zero tillage, application of different tillage treatments significantly increased the sorghum equivalent yield during both 1989 and 1990 (Fig. 4.10). The treatment disc and chisel ploughing gave the highest equivalent yield during 1989 and 1990, respectively. Further, the yield recorded under these two treatments also remained statistically at par with minimum and conventional tillage treatments during both the years of investigation. An examination of pooled data for two consecutive years indicated that the highest sorghum equivalent yield of 34.85 q ha^{-1} was recorded from the plot receiving disc ploughing treatment which was closely followed by chisel, minimum and conventional tillage treatment where the equivalent yields of 34.75, 34.56 and 34.07 q ha^{-1} were recorded which were statistically at par. The pooled equivalent yields recorded under these treatments were significantly higher than those recorded from the plot receiving zero tillage treatment. The respective increase in pooled sorghum equivalent yield recorded over zero tillage were 12.71, 12.39, 11.77 and 10.19 per cent under disc, chisel, minimum and conventional tillage treatments applied.

FYM : Incorporation of farmyard manuring at 10 tons ha^{-1} significantly increased the sorghum equivalent yield during either year of investigation and pooled as well. The per cent increases recorded were in the tune of 15.16 and 10.30 and 12.46 for 1989 and 1990 and pooled respectively.

Phosphorus : It is further evident from the data that phosphorus fertilization has significantly increased sorghum equivalent yield during both the years of research. However, increasing response was only apparent upto 13 kg P ha^{-1} level of application. Application of phosphorus beyond 13 kg P ha^{-1} rather decreased the sorghum equivalent yield during both years when compared with lower level of P applied. The pooled data recorded over two years of experimentation for the treatment receiving 13 kg P ha^{-1} was 12.95 per cent higher than the value recorded under no-phosphorus treatment.

FIG. 4.10 Effect of Tillage, FYM and levels of Phosphorus on Sorghum equivalent yield (q/ha)

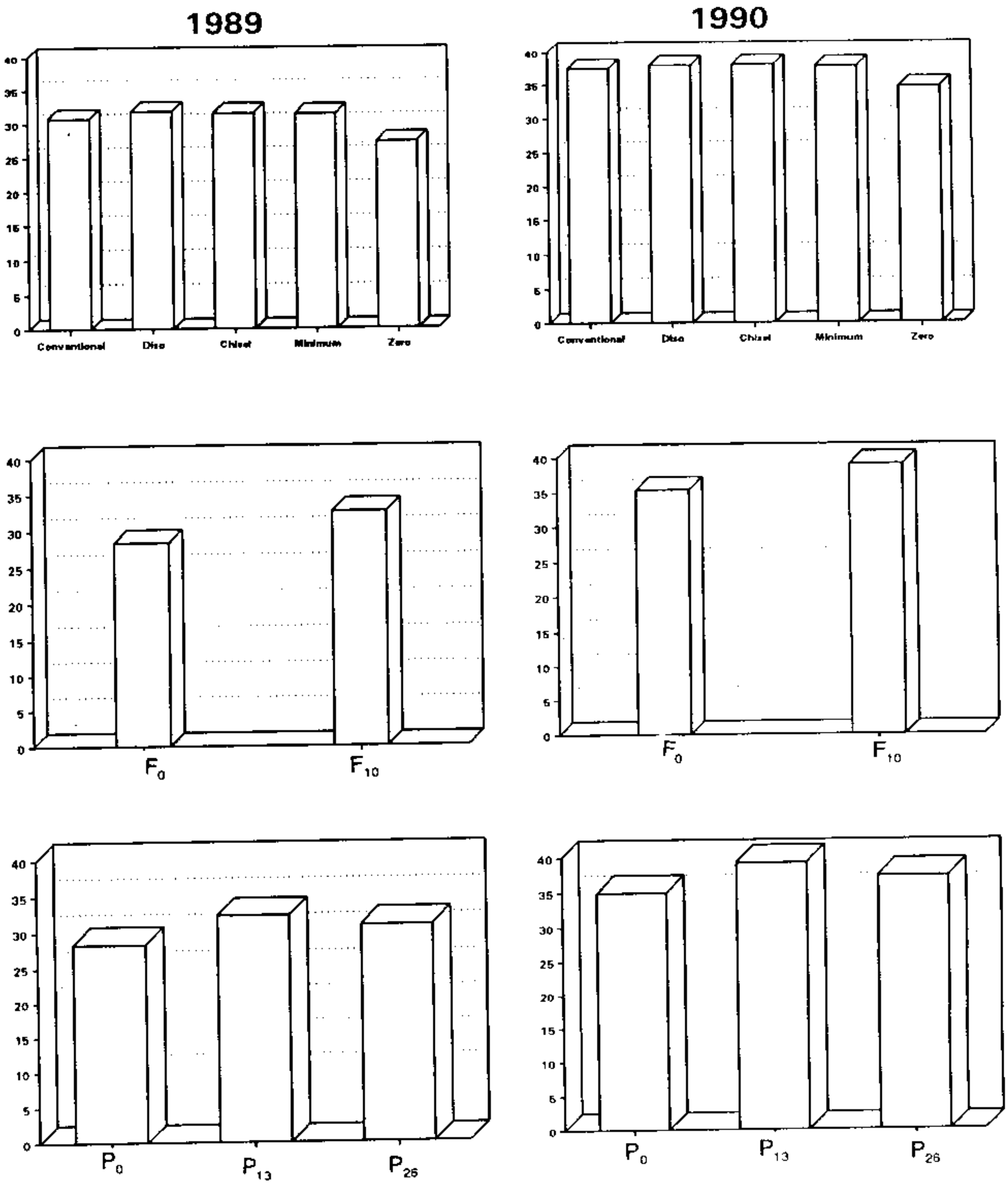


Table 4.4.3 Effect of tillage, FYM and level of phosphorus on sorghum equivalent yield (q ha⁻¹)

Treatment	1989	1990	Pooled Sorghum equivalent yield
Tillage			
Conventional	30.68	37.47	34.07
Disc	31.79	37.91	34.85
Chisel	31.49	38.02	34.75
Minimum	31.38	37.74	34.56
Zero	27.25	34.60	30.92
S Em ±	0.539	0.368	0.326
C.D. 5%	1.659	1.135	0.951
FYM (t ha^{-1})			
F_0	28.37	35.33	31.85
F_{10}	32.67	38.97	35.82
S Em ±	0.497	0.429	0.328
C.D. 5%	1.401	1.208	0.909
Phosphorus levels (kg P ha^{-1})			
P_0	28.36	34.94	31.65
P_{13}	32.28	39.23	35.75
P26	30.92	37.28	34.10
S Em ±	0.609	0.525	0.402
C.D. 5%	1.717	1.479	1.114
C.V. (%)	12.63	8.94	

4.4.4 Effect on root growth

Root density and root dry weight :

Perusal of data on root density and of root dry weight of sorghum as influenced by different tillage treatments (Table 4.4.4) revealed that tillage treatments recorded a definite variations in these two root parameters examined. The highest root mean density (1.23 g/cc) and mean dry weight (16.86 g/plant) was recorded from the plot receiving disc ploughing treatment which was closely followed by the plots receiving chisel ploughing and minimum tillage where a mean value of 0.98 and 0.90 g/cc and 14.89 and 13.43 g/plant were recorded for the root density and root dry weight, respectively. A further, evaluation of data indicated that the respective increase in the mean value recorded under the treatment receiving disc, chisel and minimum tillage over zero tillage were of the order 70.8, 36.1 and 25.0 per cent for root density and 45.90, 28.8 and 16.2 per cent for root dry weight.

Table 4.4.4 Effect of tillage on root growth of sorghum

Treatment	Root density/plant g /cc			Root dry weight/plant (g)		
	1989	1990	Mean	1989	1990	Mean
Tillage						
Conventional	0.85	0.82	0.83	13.35	12.31	12.83
Disc	1.19	1.27	1.23	17.77	15.95	16.86
Chisel	0.98	0.98	0.98	17.35	12.43	14.89
Minimum	0.96	0.85	0.90	14.50	12.36	13.43
Zero	0.72	0.73	0.72	12.39	10.73	11.56

4.5 Uptake Studies :

4.5.1 Uptake of nitrogen by sorghum :

Data on uptake of nitrogen through grain, stover and total harvest by sorghum are presented in Table 4.5.1 and their analysis of variance appended in appendix VIII.

(a) Grain :

Tillage : It is apparent from the data that various tillage treatments have significant effect on nitrogen uptake by sorghum grain during either year of research. The maximum uptake of nitrogen by grain was recorded in disc ploughing plot which was statistically significant over minimum, conventional and zero tillage treatments. However, the N-uptake recorded by grain from the plot receiving chisel ploughing remained statistically at par during both the years of investigation. The treatment disc and chisel ploughing were compared with zero tillage recorded on increase in nitrogen uptake through grain by 34.5 and 26.2 per cent in 1989 and 16.6 and 14.2 per cent in 1990. Further, examination of data revealed that minimum tillage and conventional tillage treatments also resulted in significant increase in nitrogen uptake over zero tillage during either year of research, however, uptake recorded under these two tillage treatments did not differ significantly.

FYM : Incorporation of farmyard manure significantly increased the uptake of nitrogen through grain during both the years. Application of FYM at 10 ton ha^{-1} increased the nitrogen uptake by 24.0 and 19.6 per cent over no-FYM treatment during 1989 and 1990 respectively.

Phosphorus : Examination of data from Table 4.5.1 revealed, that phosphorus fertilization had significantly affected the nitrogen uptake through grain during either year of research. The phosphorus treatment at 13 kg P ha^{-1} level significantly increased the nitrogen uptake by 22.09 and 18.02 per cent during 1989 and 1990, respectively over no-phosphorus treatment. However, the uptake of nitrogen recorded under plot receiving 26 kg p ha^{-1} remained statistically at par with the value recorded for the treatment receiving at 13 kg P ha^{-1} during both the years of examination.

Table 4.5.1 Effect of tillage, FYM and levels of phosphorus on nitrogen uptake ($kg\ ha^{-1}$) by sorghum

Treatment	1989			1990		
	Grain	Stover	Total	Grain	Stover	Total
Tillage						
Conventional	32.302	42.276	74.579	40.974	30.256	71.230
Disc	35.423	47.418	82.841	43.219	31.044	74.263
Chisel	33.233	43.848	77.081	42.345	29.943	72.287
Minimum	30.799	40.789	71.589	40.629	28.502	69.131
Zero	26.337	31.944	58.281	37.077	27.838	64.916
S Em ±	0.786	1.423	1.634	0.469	0.837	1.116
C.D. 5%	2.422	4.382	5.032	1.446	NS	3.438
FYM ($t\ ha^{-1}$)						
F_0	28.234	35.147	63.381	37.196	26.385	63.581
F_{10}	35.004	47.363	82.367	44.501	32.648	77.150
S Em ±	0.600	0.748	0.891	0.521	0.555	0.748
C.D. 5%	1.691	2.107	2.511	1.468	1.563	2.106
Phosphorus levels ($kg\ P\ ha^{-1}$)						
P_0	27.471	36.934	64.405	36.509	27.027	63.536
P_{13}	33.593	41.925	75.518	43.090	30.227	73.318
P26	33.793	44.906	78.699	42.947	31.296	74.243
S Em ±	0.735	0.916	1.092	0.638	0.680	0.916
C.D. 5%	2.071	2.580	3.075	1.799	1.915	2.579

Interaction effect of tillage and FYM on nitrogen uptake by sorghum grain (1990):

Perusal of data on interaction between tillage treatments and farmyard manuring on uptake of nitrogen by sorghum grain during 1990 (Table 4.5.1.1) revealed that application of farmyard manure has significantly increased the uptake of nitrogen under all the tillage treatments. However, the difference in uptake recorded under minimum tillage treatment was statistically not significant. Further, the highest value of nitrogen uptake (47.94 kg ha^{-1}) was recorded under the plot receiving chisel ploughing, which was closely followed and remained statistically at par with the uptake recorded from the plot receiving disc ploughing, (47.31 kg ha^{-1}) both in conjunction with farmyard manuring. The uptake of nitrogen recorded under plot receiving chisel treatment was significantly higher than the value recorded under conventional, minimum and zero tillage treatment, all under the set of treatments receiving farm yard manuring. Significantly lowest value of N-uptake (32.99 kg ha^{-1}) was recorded from the plot receiving zero tillage with no-FYM treatment. However, the uptake recorded under the plots receiving disc, chisel, minimum and conventional tillage under no-FYM treatment remained statistically at par.

Table 4.5.1.1 Interaction effect of tillage and FYM on nitrogen uptake (kg ha^{-1}) by sorghum grain (1990)

Tillage→ FYM (t ha^{-1})↓	Conventional	Disc	Chisel	Minimum	Zero
F_0	37.46	39.13	36.75	39.65	32.99
F_{10}	44.49	47.31	47.94	41.60	41.17
S Em ±			1.166		
C.D. 5%			3.284		

(b) Stover :

Tillage : A perusal of data on uptake of nitrogen (Table 4.5.1) revealed that when compared with zero tillage, various tillage treatments though increased the uptake of nitrogen by sorghum stover but the differences recorded were statistically significant for the sorghum stover harvested during 1989. The maximum nitrogen uptake, by sorghum stover recorded in plot receiving disc ploughing, which was significantly higher than the value recorded under the plots receiving conventional, minimum and zero tillage treatments in the year 1989.

However, the uptake recorded from the plot receiving chisel ploughing treatment closely followed the value recorded under disc ploughing as well as remained statistically at par with the data recorded for the treatment receiving conventional and minimum tillage. The treatment disc ploughing and chisel ploughing when compared with zero tillage recorded an increase in nitrogen uptake through stover by 48.44 and 37.26 per cent. Further, examination of data revealed that conventional and minimum tillage treatment also resulted in significant increase in nitrogen uptake over zero tillage. On the other hand in the year 1990 though the differences recorded for the nitrogen uptake by stover were statistically not significant but the highest value of nitrogen uptake was also observed under the treatment where ploughing was done with disc plough. When compared with zero tillage treatment disc ploughing has recorded an increase in the nitrogen uptake through stover by 11.52 per cent.

FYM : Incorporation of farmyard manure increased the uptake of nitrogen through stover and the differences recorded were statistically significant for both the years of investigation. Application of farmyard manure at 10 tons ha^{-1} increased the nitrogen uptake by 34.76 and 23.74 per cent over no-FYM treatment during 1989 and 1990, respectively.

Phosphorus : A critical look on data from Table 4.5.1 revealed that phosphorus fertilization had a significant effect on nitrogen uptake through stover during both the years of research. The phosphorus treatment at 26 kg P ha^{-1} level significantly increased the nitrogen uptake by 21.58 and 15.79 per cent during 1989 and 1990 when compared with no-phosphorus treatment. It is further evident from the data that a subsequent increases in the phosphate level used under study resulted in a consecutive increase in the nitrogen uptake by stover, though the differences in uptake under two levels of phosphate used were statistically not significant in *Kharif* 1990.

Interaction effect of tillage and FYM on nitrogen uptake by sorghum stover (1990):

It is apparent from the data on interaction between tillage treatment and farmyard manuring on nitrogen uptake by sorghum stover (Table 4.5.1.2) that application of farmyard manure though resulted in an increase in nitrogen uptake under all the tillage treatments but the differences recorded over no-FYM treatment were statistically significant for chisel ploughing, disc ploughing and minimum tillage only. The increase in nitrogen uptake recorded under the above referred three tillage treatments remained statistically at par but the value recorded from the plot receiving chisel ploughing was significantly higher than the value recorded under the plot receiving conventional and zero tillage even when accompanied with farmyard manuring. However, the uptake value recorded under no-FYM treatment for conventional, disc and zero tillage treatments were significantly higher than those recorded from the plot receiving chisel and minimum tillage.

4.5.1.2 Interaction effect of tillage and FYM on nitrogen uptake (kg ha^{-1}) by sorghum stover (1990)

Tillage→ FYM (t ha^{-1})↓	Conven- tional	Disc	Chisel	Minimum	Zero
F_0	29.42	27.83	23.45	23.80	27.44
F_{10}	31.10	34.26	36.44	33.21	28.24
S Em ±			1.241		
C.D. 5%			3.496		

Interaction effect of tillage and levels of phosphorus on nitrogen uptake by sorghum stover (1989 & 1990):

An examination of data on nitrogen uptake as influenced by the interaction between tillage and phosphate fertilization (Table 4.5.1.3) revealed that phosphate fertilization has definitely increased the nitrogen uptake by sorghum stover during both the years of investigation. The maximum value of nitrogen uptake was recorded from the plot receiving phosphorus at 26 kg P ha^{-1} in conjunction with disc ploughing in 1989 and conventional tillage in 1990.

The nitrogen uptake by sorghum stover recorded at highest level of phosphorus application under disc ploughing during 1989 were statistically at par, although the value recorded under disc ploughing treatment was significantly higher than the value observed for rest of all other treatment combinations. A critical examination of data on above interaction during 1990 revealed that when compared with no-phosphorus treatment under respective tillage, application of phosphorus at 26 kg P ha^{-1} recorded significantly higher uptake of nitrogen under the plots receiving conventional chisel and minimum tillage treatment.

The nitrogen uptake recorded under the treatment combination receiving conventional tillage and phosphorus at 26 kg P ha^{-1} recorded a significantly higher uptake than the plots receiving phosphorus at 13 kg P ha^{-1} in conjunction with minimum tillage and even upto 26 kg P ha^{-1} in conjunction with zero tillage.

Table 4.5.1.3 Interaction effect of tillage and levels of phosphorus on nitrogen uptake (kg ha^{-1}) by sorghum stover

Tillage→ P levels (kg P ha^{-1})↓	Conven- tional	Disc	Chisel	Minimum	Zero
			1989		
P_0	37.10	43.33	35.98	38.13	30.13
P_{13}	40.00	46.28	46.02	43.14	34.18
P_{26}	49.72	52.64	49.55	41.10	31.52
			1990		
P_0	25.11	30.02	25.86	25.21	28.93
P_{13}	31.76	30.75	32.76	29.41	26.45
P_{26}	33.90	32.36	31.20	30.88	28.13
Year		1989		1990	
S Em ±		2.048		1.520	
C.D. 5%		5.770		4.282	

Interaction effect of FYM and levels of phosphorus on nitrogen uptake by sorghum stover (1989):

Perusal of data on nitrogen uptake by sorghum stover in 1989 as influenced by interaction between farmyard manuring and phosphate fertilization (Table 4.5.1.4) revealed that significantly lowest value (28.69 kg ha^{-1}) was recorded from the treatment combination receiving no-FYM and no-phosphate treatment indicating that farmyard manuring as well as phosphate fertilization has significantly increased the nitrogen uptake by sorghum stover. A subsequent increase in phosphate fertilization upto 26 kg P ha^{-1} under the situations where no-FYM was given has significantly increased the nitrogen uptake by sorghum stover. However, in situation where farmyard manuring was practised the uptake recorded under the two levels of phosphate used remained statistically at par, though the highest value of nitrogen uptake (49.36 kg ha^{-1}) was apparent in plot receiving the highest level of phosphorus.

Table 4.5.1.4 Interaction effect of FYM and levels of phosphorus on nitrogen uptake (kg ha^{-1}) by sorghum stover (1989)

FYM (t ha^{-1})	P levels (kg P ha^{-1})		
	P_0	P_{13}	P_{26}
F_0	28.69	36.31	40.45
F_{10}	45.18	47.54	49.36
S Em ±		1.295	
C.D. (%)		3.649	

(c) Total Uptake :

Tillage : An examination of data on total uptake of nitrogen (Table 4.5.1) revealed that various tillage treatments have significant effect on cumulative nitrogen uptake by sorghum during both 1989 and 1990. The maximum nitrogen uptake was recorded from the harvest received from disc ploughed plot which was statistically significant over the value recorded for rest of all other tillage treatments in 1989, and minimum and zero tillage treatments in 1990. The total nitrogen uptake recorded in the harvest from the plot receiving disc ploughing was closely followed by the value recorded from the plot receiving chisel ploughing which was though distinctly higher than the value recorded under the plot receiving minimum tillage but significance was observed only during 1989. Further, the total uptake of nitrogen recorded from the plot receiving chisel ploughing and conventional tillage though remained statistically at par but were significantly higher than the value recorded from the plot receiving zero tillage treatment during both the years of investigation. Further, the total uptake of nitrogen during both the years recorded from the plot receiving minimum tillage treatment also remained statistically higher when compared with the value recorded from zero tillage treatment, but was at par with the values recorded from the plots receiving conventional tillage treatment. Disc ploughing when compared with zero tillage treatment recorded an increase in total nitrogen uptake through sorghum by 42.14 and 14.40 per cent in 1989 and 1990. The magnitude of increase recorded for the total uptake of nitrogen under chisel ploughing when compared with zero tillage was of the order of 32.26 and 11.35 per cent during 1989 and 1990.

FYM : Incorporation of farmyard manure significantly increased the total uptake of nitrogen through sorghum during either year of research. Application of FYM at 10 tons ha^{-1} increased the nitrogen uptake by 29.95 and 21.34 per cent over no-FYM treatment during 1989 and 1990 respectively.

Phosphorus : An examination of data from Table 4.5.1 revealed that phosphate fertilization had a significant effect on the total nitrogen uptake by sorghum during either year of study. The phosphorus treatment at 26 kg P ha^{-1} level recorded the maximum, uptake and the magnitude of increase recorded over no-phosphorus treatment was statistically significant and was of the order 22.19 and 16.85 per cent during 1989 and 1990. A subsequent increase in phosphate levels though resulted in a consecutive increase in the total uptake of nitrogen by sorghum, however, the significance in difference observed for the two levels of phosphorus used was only apparent in *Kharif* 1989.

Interaction effect of tillage and FYM on total nitrogen uptake by sorghum (1989 & 1990):

An examination of data on interaction between tillage and farmyard manuring on total nitrogen uptake by sorghum (Table 4.5.1.5) revealed that farmyard manuring has significantly increased the total nitrogen uptake by sorghum under all the tillage treatments examined during both the year of investigation. The significantly highest value of total nitrogen uptake (92.46 kg ha^{-1}) was observed under the plot receiving disc ploughing in conjunction with farmyard manuring in *Kharif* 1989. Tillage treatment receiving chisel ploughing, minimum and conventional tillage though remained statistically at par in recording the total nitrogen uptake by sorghum but were significantly higher when compared with zero tillage, all in conjunction with farmyard manuring in *Kharif* 1989. Further, examination of the data on total nitrogen uptake recorded for *Kharif* 1990 revealed that maximum value was apparent from the plot receiving chisel ploughing (84.38 kg ha^{-1}) and was closely followed by the uptake value recorded from the plot receiving disc ploughing (81.57 kg ha^{-1}) both in conjunction with farmyard manuring. The total nitrogen uptake recorded under these two treatment combinations were statistically significant over rest of other treatment combinations examined. The plot receiving conventional and minimum tillage have also recorded a significantly higher total nitrogen uptake over zero tillage treatment, all when practised in conjunction with farmyard manuring.

Interaction effect of tillage and levels of phosphorus on total nitrogen uptake by sorghum (1989) :

Perusal of data on interaction between tillage treatment and phosphate fertilization on total nitrogen uptake by sorghum (Table 4.5.1.6) indicate that phosphorus fertilization up to 13 kg P ha^{-1} has significantly increased the total nitrogen uptake by sorghum under all the tillage treatment examined. Application of phosphorus beyond 13 kg P ha^{-1} has only responded under the tillage treatments receiving disc ploughing and conventional tillage. However, significantly highest (92.28 kg ha^{-1}) value of total nitrogen uptake was recorded from the plot receiving disc ploughing in conjunction with phosphorus fertilization at 26 kg p ha^{-1}. Further, conventional tillage when practiced in conjunction with 26 kg P ha^{-1} level of phosphate application also recorded a significant increase in total nitrogen uptake when compared with 13 kg P ha^{-1} application under the vary same tillage treatment and upto 26 kg P ha^{-1} application under minimum and zero tillage treatments. Further, zero tillage treatment even with phosphate fertilization recorded a lower value of total nitrogen uptake when compared with all the tillage treatments applied in conjunction with phosphate fertilization.

Table 4.5.1.5 Interaction effect of tillage and FYM on total nitrogen uptake (kg ha^{-1}) by sorghum

Tillage→ FYM (t ha^{-1})↓	Conven- tional	Disc	Chisel	Minimum	Zero
			1989		
F_0	66.75	73.22	68.17	58.32	50.44
F_{10}	82.41	92.46	85.99	84.85	66.12
			1990		
F_0	66.88	66.96	60.19	63.46	60.43
F_{10}	75.59	81.57	84.38	74.81	69.40

Year	1989	1990
S Em ±	1.993	1.672
C.D. 5%	5.614	4.709

Table 4.5.1.6 Interaction effect of tillage and levels of phosphorus on total nitrogen uptake (kg ha^{-1}) by sorghum (1989)

Tillage→ P levels (kg P ha^{-1})↓	Conventional	Disc	Chisel	Minimum	Zero
P_0	65.15	73.00	65.61	65.66	52.62
P_{13}	73.72	83.25	81.77	76.37	62.49
P_{26}	84.87	92.28	83.87	72.74	59.74
S Em ±			2.441		
C.D. 5%			6.876		

4.5.2 Uptake of phosphorus by sorghum :

Data on uptake of phosphorus through grain, stover and total harvest by sorghum are presented in Table 4.5.2 and their analysis of variance appended in appendix IX.

(a) Grain :

Tillage : Perusal of data on uptake of phosphorus revealed that when compared with zero tillage treatment different tillage treatments had significant effect in increasing the phosphorus uptake through grain during both 1989 and 1990 (Table 4.5.2). The maximum phosphorus uptake was recorded in plot receiving disc ploughing during both the years though the value recorded under this treatment remained statistically at par with the values observed from the plots receiving chisel, minimum and conventional tillage in *Kharif* 1989 but was significantly higher than those recorded from all other treatments in *Kharif* 1990.

The mean phosphorus uptake by sorghum grain recorded under disc, chisel and minimum tillage treatments were 10.07, 9.67 and 9.65 kg ha^{-1} respectively as against 9.38 and 8.03 kg ha^{-1} from the plot receiving conventional and zero tillage treatments. The mean per cent increase in phosphorus uptake due to disc and chisel ploughing treatments over zero tillage were of the order 25.4 and 20.70, respectively.

Table 4.5.2 Effect of tillage, FYM and levels of phosphorus on phosphorus uptake (kg ha^{-1}) by sorghum

Treatment	1989			1990		
	Grain	Stover	Total	Grain	Stover	Total
Tillage						
Conventional	8.734	18.668	27.402	10.025	12.520	22.546
Disc	9.184	20.772	29.956	10.957	13.337	24.295
Chisel	9.001	18.739	27.740	10.375	12.430	22.805
Minimum	9.134	19.209	28.343	10.163	12.731	22.894
Zero	7.119	15.244	22.363	8.939	11.960	20.898
S Em ±	0.321	0.669	0.790	0.183	0.349	0.438
C.D. 5%	0.988	2.061	2.435	0.563	NS	1.348
FYM (t ha^{-1})						
F_0	7.659	16.601	24.260	9.458	11.285	20.743
F_{10}	9.610	20.452	30.062	10.725	13.906	24.631
S Em ±	0.179	0.344	0.375	0.144	0.225	0.249
C.D. 5%	0.505	0.968	1.057	0.405	0.633	0.702
Phosphorus levels (kg P ha^{-1})						
P_0	6.770	15.755	22.525	8.518	10.830	19.347
P_{13}	9.727	19.051	28.778	10.817	12.788	23.605
P26	9.407	20.773	30.180	10.941	14.169	25.110
S Em ±	0.220	0.421	0.459	0.176	0.275	0.305
C.D. 5%	0.619	1.185	1.294	0.496	0.775	0.860

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased the phosphorus uptake by sorghum grain to the extent of 1.9 and 1.3 kg ha^{-1} during 1989 and 1990, respectively over the value recorded from the plot receiving no-FYM treatment. The corresponding increases recorded were of the order 25.5 and 13.4 per cent over no-FYM treatment.

Phosphorus : It is obvious from data in Table 4.5.2 that application of phosphorus up to 13 kg P ha^{-1} significantly increased the phosphorus uptake by sorghum grain during both the years, however, phosphorus fertilization beyond 13 kg P ha^{-1} has no significant effect on phosphorus by grain. The magnitude of increase in uptake of phosphorus recorded to 13 kg P ha^{-1} level of application was of the order 43.7 and 27.0 per cent during 1989 and 1990 over no-phosphorus application.

Interaction effect of tillage and levels of phosphorus on phosphorus uptake by sorghum grain (1989) :

Perusal of data on interaction between tillage treatment and phosphate fertilization (Table 4.5.2.1) revealed that phosphate fertilization up to 13 kg P ha^{-1} level significantly increased the phosphorus uptake by sorghum grain under all the tillage treatments. However, response to phosphate fertilization beyond 13 kg P ha^{-1} in increasing the phosphorus uptake by sorghum grain was only apparent under the plot receiving chisel ploughing. The maximum value of phosphorus uptake was recorded from the plot receiving minimum tillage in conjunction with 13 kg P ha^{-1} application and was significantly higher than the values observed under the plots receiving phosphorus fertilization upto 26 kg P ha^{-1} in conjunction with conventional and zero tillage and 13 kg P ha^{-1} in conjunction with chisel ploughing.

Table 4.5.2.1 Interaction effect of tillage and levels of phosphorus on P uptake (kg ha^{-1}) by sorghum grain (1989)

Tillage→ P levels (kg P ha^{-1})↓	Conven- tional	Disc	Chisel	Minimum	Zero
P_0	6.291	6.951	7.241	7.611	5.751
P_{13}	10.081	10.271	8.981	11.501	7.801
P_{26}	9.831	10.341	10.780	8.29	7.81
S Em ±			0.491		
C.D. 5%			1.384		

(b) Stover :

Tillage : Perusal of data on phosphorus uptake by sorghum stover as influenced by various tillage treatments (Table 4.5.2) indicated that the maximum value of phosphorus uptake was recorded from the plot receiving disc ploughing treatment but the increase recorded was statistically significant for the observation recorded during *Kharif* 1989. The phosphorus uptake recorded from the plot receiving disc ploughing treatment was maximum (20.77 kg ha^{-1}) and significantly higher than the values recorded from the plots receiving conventional and zero tillage. The phosphorus uptake recorded under the plot receiving zero tillage treatment was significantly lowest when compared with all other tillage treatments. Further, the phosphorus uptake recorded under chisel ploughing and minimum tillage remained statisticallyat par with the values recorded from the plots receiving disc ploughing as well as those receiving conventional tillage treatment. The highest mean phosphorus uptake of 17.05 kg ha^{-1} was recorded from the plot receiving disc ploughing treatment as against 13.60 kg ha^{-1} from the plot receiving zero tillage.

The treatments chisel ploughing, minimum and conventional tillage also increased the phosphorus uptake by sorghum stover during both the years. The corresponding increases in mean phosphorus uptake was 14.5, 17.4 and 14.6 per cent over zero tillage.

FYM : Incorporation of farmyard manure significantly increased the phosphorus uptake to the extent of 3.8 and 2.6 kg ha^{-1} over no-FYM treatment during 1989 and 1990. The magnitude of increase in phosphorus uptake recorded was to the tune of 23.2 per cent during both the years of investigation.

Phosphorus : Application of phosphorus resulted in significant increase in phosphorus uptake by sorghum stover during both the years of research. The phosphorus uptake significantly increased with a subsequent increase in dose of phosphorus upto 26 kg P ha^{-1} in either year of research. The magnitude of increase in phosphorus uptake by sorghum stover recorded was of the order by 20.9 and 31.8 per cent during 1989 and 18.10 and 30.8 during 1990 under the treatment receiving 13 and 26 kg P ha^{-1} over no-phosphorus treatment.

Interaction effect of tillage and FYM on phosphorus uptake by sorghum stover (1990):

A critical look at the data on interaction between tillage treatments and farmyard manuring in *Kharif* 1990 presented in Table 4.5.2.2 clearly indicated that farmyard manuring has significantly increased the phosphorus uptake by sorghum stover under all the tillage treatments examined. Further, farmyard manuring under disc, chisel and minimum tillage treatments recorded significantly higher phosphorus uptake when compared with zero tillage even when accompanied with farmyard manuring. However, the phosphorus uptake recorded from the stover harvested from the plot receiving farmyard manuring in conjunction with conventional and zero tillage did not differ statistically.

Table 4.5.2.2 Interaction effect of tillage and FYM on phosphorus uptake (kg ha^{-1}) by sorghum stover (1990)

Tillage→ FYM (t ha^{-1})↓	Conventional	Disc	Chisel	Minimum	Zero
F_0	11.680	12.351	10.501	10.661	11.231
F_{10}	13.361	14.321	14.361	14.801	12.691
S Em ±			0.502		
C.D 5%			1.415		

Interaction effect of FYM and levels of phosphorus on phosphorus uptake by sorghum stover (1990):

An examination of data from interaction between farmyard manuring and phosphate fertilization on phosphorus uptake by sorghum stover in *Kharif* 1990 (Table 4.5.2.3) revealed that application of phosphorus has a definite impact in increasing the phosphorus uptake whether farmyard manuring was done or not. However, the increase in phosphorus uptake recorded over no-phosphorus treatment was statistically significant with phosphorus fertilization at 26 kg P ha^{-1} under farmyard manuring and upto 26 kg p ha^{-1} under situation where no-FYM was used.

Table 4.5.2.3 Interaction effect of FYM and levels of phosphorus on phosphorus uptake (kg ha^{-1}) by sorghum stover (1990)

FYM (t ha^{-1})	P levels (kg P ha^{-1})		
	P_0	P_{13}	P_{26}
F_0	10.01	13.11	14.84
F_{10}	10.73	11.65	15.23
S Em ±		0.389	
C.D. 5%		1.096	

(c) Total Uptake

Tillage : Like grain and stover the total phosphorus uptake by sorghum was significantly affected by different tillage treatments during both the years 1989 and 1990 (Table 4.5.2). The maximum value of total phosphorus uptake was recorded from the plot receiving disc ploughing treatment during both the years of investigation. The value recorded was significantly higher than those recorded from conventional and zero tillage treatments in *Kharif* 1989 and all other tillage treatments examined in *Kharif* 1990. Further, significantly lowest value of phosphorus uptake was recorded from the plot receiving zero tillage treatment when compared with all other tillage treatment examined in either year of research. In *Kharif* 1989 the total phosphorus uptake recorded from the plot receiving chisel ploughing and minimum tillage remained statistically at par with those recorded from the plots receiving disc ploughing treatment. The magnitude of increase in total phosphorus uptake under disc ploughing was 33.9 and 16.2 per cent,respectively during 1989 and 1990 when compared with values recorded from plot receiving zero tillage. The mean of two years data shows that highest total phosphorus uptake was observed from the plot receiving disc ploughing (27 kg ha^{-1}) and the lowest was observed from the plot receiving zero tillage (21.6 kg ha^{-1}) treatment.

FYM : Application of farmyard manure also significantly affected the total phosphorus uptake during either year of research. Incorporation of FYM at 10 tons ha^{-1} increased the total phosphorus uptake to the extent of 5.8. and 3.9 kg ha^{-1} during 1989 and 1990, respectively over the value recorded from the plot receiving no-FYM treatment.

Phosphorus : A further examination of data in Table 4.5.2 show that a subsequent increase in phosphorus application resulted in a significant increase in total phosphorus uptake by sorghum. The maximum phosphorus uptake was recorded from the plot where phosphorus was applied at 26 kg P ha^{-1} during both the years of research. The mean increase in total phosphorus uptake by sorghum with the application of 26 kg P ha^{-1} was to the tune of 32 per cent over no-phosphorus treatment.

Interaction effect of tillage and FYM on total phosphorus uptake by sorghum (1990):

Perusal of data on interaction between tillage treatments and farmyard manuring in *Kharif* 1990 (Table 4.5.2.4) revealed that incorporation of farmyard manure has significantly increased the total phosphorus uptake by sorghum under all the tillage treatments. However, the phosphorus uptake recorded from the plots receiving disc ploughing in conjunction with farmyard manuring recorded significantly higher value than those recorded from the plot receiving conventional and zero tillage treatments in conjunction with farmyard manuring (Fig. 4.11). The value of total phosphorus uptake by the harvest recorded under the plots receiving chisel and minimum tillage treatments remained statistically at par with those recorded from the harvest of the plots receiving disc ploughing in conjunction with FYM.

FIG. 4.11 Interaction effect of tillage and FYM on total phosphorus uptake (kg/ha) by Sorgham (1990)

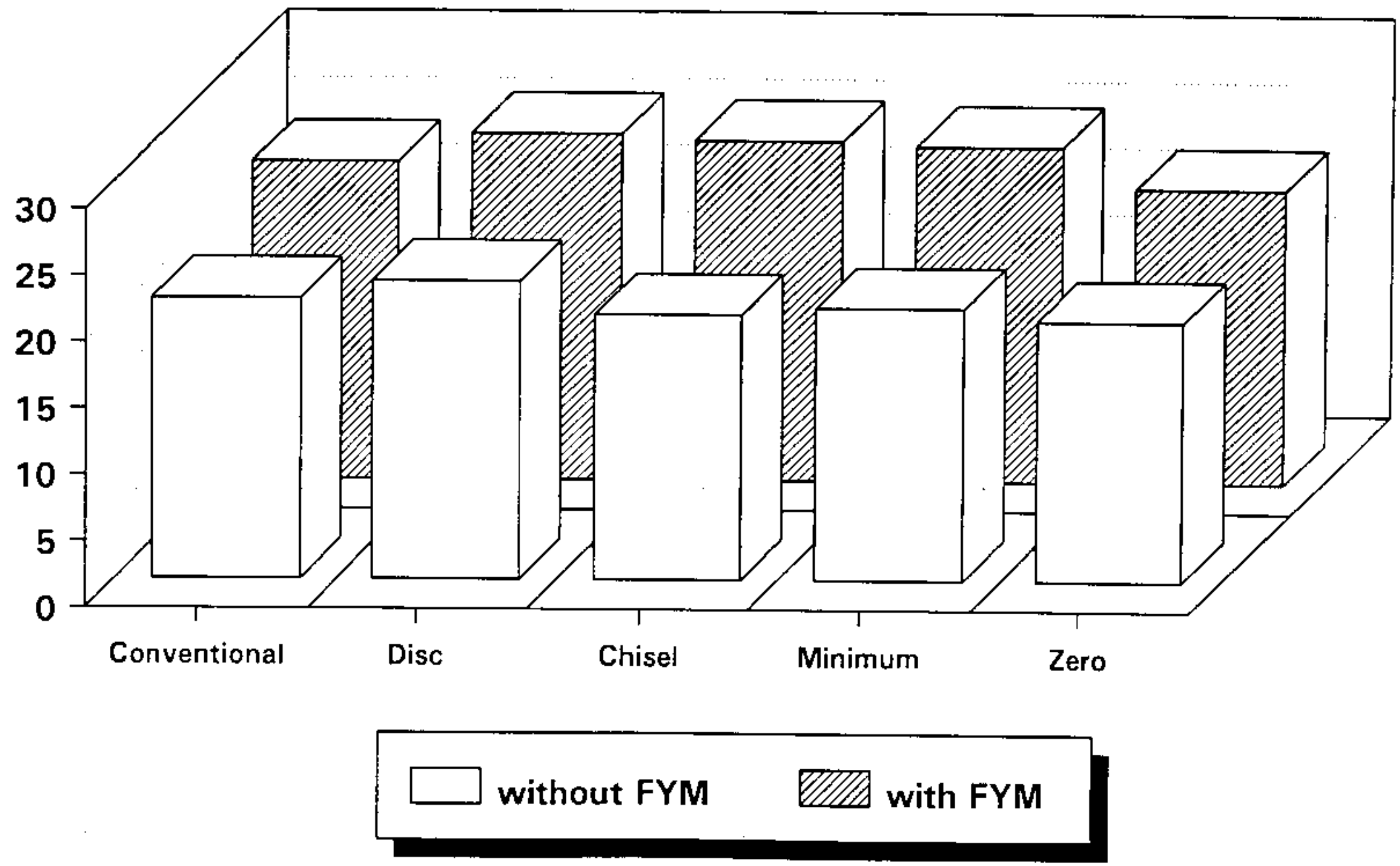


Table 4.5.2.4 Interaction effect of tillage and FYM on total phosphorus uptake (kg ha^{-1}) by sorghum (1990)

Tillage → FYM (t ha^{-1}) ↓	Conventional	Disc	Chisel	Minimum	Zero
F_0	21.12	22.47	19.99	20.53	19.60
F_{10}	23.97	26.12	25.62	25.26	22.19
S Em ±			0.558		
C.D.5%			1.570		

Interaction effect of tillage and levels of phosphorus on total phosphorus uptake by sorghum (1989):

A critical examination of data on total phosphorus uptake by sorghum as influenced by interaction between tillage treatments and phosphate fertilization (Table 4.5.2.5) indicated that application of phosphorus upto 13 kg P ha^{-1} level has significantly increased the total phosphorus uptake by sorghum under all the tillage treatments examined. Application of phosphorus beyond 13 kg P ha^{-1} although recorded an increase in total phosphorus uptake under the plots receiving disc, chisel and conventional tillage treatments but the significance was observed only for the treatment receiving disc and chisel ploughing. Further, the total phosphorus uptake recorded under the treatment receiving phosphorus application even at 26 kg P ha^{-1} under zero tillage treatment was significantly lower than the values recorded under the treatment receiving 13 and 26 kg P ha^{-1} in conjunction with all other tillage treatments tested.

Table 4.5.2.5 Interaction effect of tillage and levels of phosphorus on total phosphorus uptake (kg ha-1) by sorghum (1989)

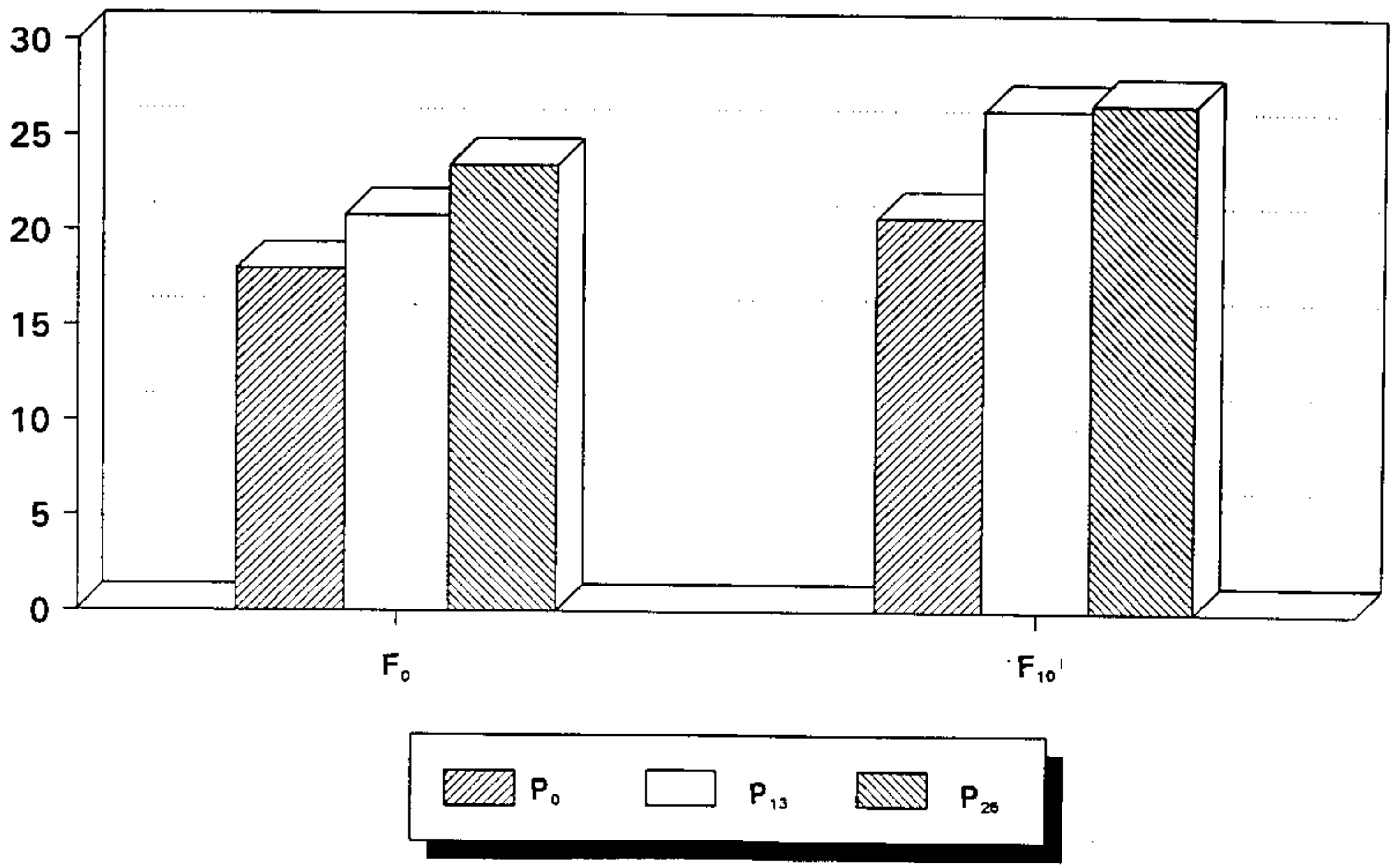
Tillage→ P levels (kg P ha^{-1})↓	Conventional	Disc	Chisel	Minimum	Zero
P_0	22.46	24.63	22.75	24.17	18.62
P_{13}	28.65	30.64	28.40	31.91	24.29
P_{26}	31.10	34.60	32.07	28.95	24.18
S Em ±			1.027		
C.D.5%			3.164		

Perusal of data on interaction between farmyard manuring and phosphate fertilization on total phosphorus uptake by sorghum during *Kharif* 1990 (Table 4.5.2.6) revealed that phosphate fertilization and farmyard manuring alone as well as in combination significantly increased the total phosphorus uptake by sorghum. However, phosphorus fertilization upto 26 kg P ha^{-1} under no-FYM treatment and 13 kg P ha^{-1} under farmyard manuring was effective in increasing the total phosphorus uptake by sorghum (Fig. 4.12).

Table 4.5.2.6 Interaction effect of FYM and levels of phosphorus on total phosphorus uptake (kg ha^{-1}) by sorghum (1990)

FYM (t ha^{-1})	P levels (kg P ha^{-1})		
	P_0	P_{13}	P_{26}
F_0	17.98	20.79	23.46
F_{10}	20.72	26.42	26.76
S Em ±		0.432	
C.D.5%		1.217	

FIG. 4.12 Interaction effect of FYM and Phosphorus levals on Total phosphorus uptake (Kg/ha) by Sorghum (1990)



4.5.3 Uptake of potassium by sorghum

Data on uptake of potassium through grain, stover and total harvest by sorghum are presented in Table 4.5.3 and their analysis of variance appended in appendix X.

(a) Grain :

Tillage : It is obvious from the data (Table 4.5.3) that different tillage treatments have significant effect on potassium uptake by grain during both 1989 and 1990. The maximum potassium uptake by grain was recorded from the plot receiving disc ploughing treatment during either year of research and was closely followed by the value recorded under the treatment receiving chisel ploughing, minimum and conventional tillage. Further, it was observed that the potassium uptake by grain under disc ploughing treatment was statistically at par with those recorded from the plots receiving chisel and minimum tillage and superior over that recorded from conventional and zero tillage treatments during 1989, however, was significantly superior over those recorded from all other tillage treatments during 1990. Further, the value of potassium uptake by grain recorded in 1990 under the plots receiving chisel, minimum and conventional tillage though remained statistically at par but were significantly higher than the value recorded from the treatment receiving zero tillage. The mean value of potassium uptake by sorghum grain was 27.10 kg ha^{-1} in disc ploughing as against 22.50 kg ha^{-1} in zero tillage treatment. The magnitude of mean increase in potassium uptake due to disc, chisel, minimum and conventional tillage treatments were of the order of 20.2, 14.7, 12.4 and 12.2 per cent over the value recorded from the plot receiving zero tillage treatment.

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased the potassium uptake through sorghum grain and the extent of increase recorded was in the tune of 3.7 and 3.6 kg ha^{-1} over no-FYM treatment during 1989 and 1990,respectively. The corresponding increase observed over no-FYM treatment were 18.0 and 13.7 per cent.

Phosphorus : Data in Table 4.5.3 further show that application of phosphorus had significant effect on potassium uptake by sorghum grain. Application of phosphorus up to 13 kg P ha^{-1} has significantly increased the potassium uptake by sorghum grain. However, phosphorus application beyond this level did not gave any response during either year of research. When compared with no-phosphorus treatment the per cent increase in potassium uptake recorded due to application of 13 kg P ha^{-1} treatment was 22.5 and 17.4 during 1989 and 1990, respectively.

(b) Stover :

Tillage : It is evident from the data on potassium uptake by sorghum stover that different tillage treatments definitely increased the potassium uptake during both the years of research (Table 4.5.3) however, the differences observed were found significant only during 1989. Further, analysis of data on potassium uptake show that the treatments disc ploughing,chisel ploughing, minimum and conventional tillage though found statistically at par but were significantly higher than those recorded from the plot receiving zero tillage treatment during 1989. Mean values of two years data for potassium uptake by grain revealed that the maximum potassium uptake was recorded in chisel ploughing treatment (115.45 kg ha^{-1}) which was followed by minimum tillage, disc ploughing and conventional tillage treatments where the mean values observed were 114.28, 112.88 and 107.04 kg ha^{-1} as against the minimum value of 94.46 kg ha^{-1} recorded under the plot receiving zero tillage. The treatments chisel ploughing minimum tillage, disc ploughing and conventional tillage recorded mean increase in potassium uptake through stover to the tune of 22.2, 21.0, 19.5 and 13.3 per cent over the minimum value recorded in grain harvested from the plot receiving tillage treatment.

FYM : It was observed that application of farmyard manure at 10 tons ha^{-1} significantly increased the potassium uptake by sorghum stover. The incorporation of farmyard manure increased the potassium uptake to the magnitude of 20.7 and 17.4 per cent during 1989 and 1990 over no-FYM treatment.

Phosphorus : Application of phosphorus upto 13 kg P ha^{-1} recorded a definite increase in the potassium uptake through stover during either year of research, however, the differences recorded over no-phosphorus treatment was significant only during 1990. The mean data of two years research show that application of phosphorus at 13 kg P ha^{-1} increased the potassium uptake by 10.06 per cent over no-phosphorus treatment.

(c) Total uptake :

Tillage : Like stover the total potassium uptake by sorghum was significantly affected by different tillage treatments only during 1989. Further, a critical look on data (Table 4.5.3) of potassium uptake by sorghum during 1989 show that the value observed under the treatment receiving disc ploughing, chisel ploughing and minimum tillage, though found statistically at par but were significantly higher than those observed under conventional tillage was also significantly superior to those recorded under zero tillage but was significantly lower than those recorded under disc ploughing treatment. Mean value of the two years data show that the maximum potassium uptake of 141.28 kg ha^{-1} was recorded in chisel ploughing treatment which was followed by disc ploughing minimum and conventional tillage where the value observed were of the order 139.96, 139.58 and 132.31 kg ha^{-1} respectively. The magnitude of mean increase in total potassium uptake under the treatment chisel, disc, minimum and conventional tillage were in the tune of 20.8, 19.6, 19.3 and 13.1 per cent over the value recorded for zero tillage treatment.

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased the total potassium uptake by sorghum. Application of farmyard manure increased the potassium uptake to the extent of 20.3 and 16.5 per cent during 1989 and 1990 over no-FYM treatment.

Phosphorus : It was observed that application of phosphorus significantly increased the total potassium uptake during either year of research. However, application of phosphorus beyond 13 kg P ha^{-1} did not give any response. The mean data of two years show that application of phosphorus at 13 kg P ha^{-1} increased the total potassium uptake by 11.8 per cent over no-phosphorus treatment.

Table 4.5.3 Effect of tillage, FYM and levels of phosphorus on potassium uptake (kg ha^{-1}) by sorghum

Treatment	1989			1990		
	Grain	Stover	Total	Grain	Stover	Total
Tillage						
Conventional	22.670	123.041	145.710	27.864	91.046	118.909
Disc	24.268	135.358	159.626	29.895	90.409	120.304
Chisel	23.476	134.436	157.912	28.196	96.463	124.659
Minimum	23.145	131.003	154.148	27.469	97.549	125.018
Zero	19.373	101.336	120.709	25.672	87.576	113.249
S Em ±	0.518	4.466	4.376	0.396	3.198	3.285
C.D. 5%	1.597	13.755	13.477	1.221	NS	NS
FYM (t ha^{-1})						
F_0	20.722	113.282	134.005	26.034	85.207	111.241
F_{10}	24.450	136.787	161.238	29.604	100.010	129.615
S Em ±	0.479	2.985	3.010	0.506	2.169	2.148
C.D. 5%	1.350	8.409	8.478	1.425	6.110	6.051
Phosphorus levels (kg P ha^{-1})						
P_0	19.806	118.341	138.147	24.962	84.558	109.520
P_{13}	24.264	128.485	152.748	29.313	94.832	124.144
P26	23.689	128.279	151.968	29.183	98.435	127.619
S Em ±	0.587	3.656	3.686	0.619	2.656	2.631
C.D. 5%	1.653	NS	10.384	1.745	7.483	7.411

4.5.4 Uptake of nitrogen by green gram :

Data on uptake of nitrogen seed, stover and total harvest by green gram are presented in table 4.5.4 and their analysis of variance appended in appendix XI.

(a) Seed :

Tillage : A critical look at the Table 4.5.4 indicated that all the tillage treatments significantly increased the nitrogen uptake through seed when compared with zero tillage treatment during either year of research. The treatment disc ploughing though resulted in maximum nitrogen uptake but was statistically at par with chisel ploughing in 1989 and chisel, minimum and conventional tillage in 1990. Further, the nitrogen uptake recorded under the plots receiving chisel, minimum and conventional tillage were also remained statistically at par during 1989. The mean nitrogen uptake in disc ploughing treatment was 9.58 kg ha^{-1} as against 7.90 kg ha^{-1} in zero tillage. The per cent increase in nitrogen uptake through grain by disc ploughing recorded over the value for zero tillage was in the tune of 25.2 and 17.7 during 1989 and 1990. When compared with zero tillage treatments viz; chisel ploughing, minimum tillage and conventional tillage also recorded a significant increase in nitrogen uptake through seed in the tune of 17.0, 15.7, 15.0 per cent during 1989 and 13.4, 12.3 10.2 per cent during 1990, respectively.

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased the nitrogen uptake through seed and the magnitude of increase recorded was to the tune of 42.3 and 24.2 per cent over no-FYM treatment during 1989 and 1990,respectively.

Phosphorus : It is apparent from the data in table 4.5.4 that phosphorus application significantly increased the nitrogen uptake through seed over no-phosphorus application during 1989 as well as 1990. However, the response to phosphorus was only upto 13 kg P ha^{-1} level of application. The corresponding increases recorded were of the order 17.30 and 33.45 per cent over no-phosphorus treatment. An examination of the mean increases in nitrogen uptake recorded under phosphorus fertilization at 13 kg P ha^{-1} over no-phosphorus treatment indicated an increase to the extent of 26 per cent.

(b) Stover :

Tillage : Like seed, nitrogen uptake by green gram stover was also affected significantly due to different tillage treatments during both 1989 and 1990 (Table 4.5.4). The nitrogen uptake through green gram stover was significantly higher under the plot receiving disc ploughing treatment as compared to the values recorded for all other tillage treatmentsexamined during both the years of research. Further, the uptake value recorded from the plots receiving chisel, conventional and minimum was also significantly higher than those recorded under zero tillage treatment, however, the value of nitrogen uptake recorded under these treatments remained statistically at par when compared among each other during both the years of research except the treatment receiving minimum tillage when compared with conventional tillage in *Kharif*, 1989. The mean nitrogen uptake by stover averaged for the two years indicated that the maximum value (15.0 kg N ha^{-1}) was observed under the plot receiving disc ploughing treatment as against a minimum value of 10.2 kg N ha^{-1} recorded under the plot receiving zero tillage treatment. Further, the treatments conventional tillage, chisel ploughing and minimum tillage were also found significantly superior over zero tillage treatment in influencing the nitrogen uptake through stover and the respective mean increases recorded were of the order 18.51, 14.30 and 11.07 per cent.

FYM: It is evident from the data in Table 4.5.4 that application of farmyard manure at 10 tons ha^{-1} gave significantly more nitrogen uptake through stover than no-FYM treatment during either year of research. The value observed for nitrogen uptake from FYM treated plots were 12.10 and 14.25 kg ha^{-1} as against 10.15 and 11.74 kg ha^{-1} in no-FYM treatment during 1989 and 1990 respectively. The corresponding per cent increase recorded over no-FYM treatment were of the order 19.2 and 21.3.

Phosphorus : A perusal of data from Table 4.5.4 show that phosphorus application upto 13 kg P ha^{-1} significantly increased the nitrogen uptake through stover over no-phosphorus application in either year of research. However, phosphorus when applied beyond 13 kg P ha^{-1} gave no response on nitrogen uptake, rather a decrease was observed in 1990. Data on mean of the two years when compared with mean value recorded under no-phosphorus treatment, application of 13 kg P ha^{-1} recorded an increase of the magnitude 31.14 per cent.

(c) Total uptake :

Tillage : Like seed and stover, the total nitrogen uptake through green gram was also significantly influenced by different tillage treatments during both the years of investigation (Table 4.5.4). Perusal of data on total nitrogen uptake by green gram revealed that significantly highest value was observed under the plot receiving disc ploughing treatment. Further, the treatment receiving conventional, chisel and minimum also recorded a significantly higher value of total nitrogen uptake over those observed under zero tillage treatment. However, these three tillage treatments remained statistically at par for the total nitrogen uptake by green gram. The magnitude of increase in total nitrogen uptake recorded under disc ploughing when compared with zero, conventional, chisel and minimum tillage treatments were of the order 24.90, 9.16, 9.5 and 14.5 per cent during 1989 and 44.9, 23.9, 20.0 and 25.9 per cent during 1990. Conventional, chisel and minimum tillage when compared with zero tillage treatment recorded an increase in total nitrogen uptake by green gram of the magnitude 14.56, 14.09, and 9.11 per cent during 1989 and 16.90, 15.02 and 15.12 per cent during 1990. The mean of two years data shows that the highest total nitrogen uptake of 24.55 kg N ha^{-1} was recorded from the plot receiving disc ploughing treatment, while the lowest value of 18.12 kg N ha^{-1} was recorded from the plot receiving zero tillage treatment.

FYM : Application of farmyard manure also significantly affected the total nitrogen uptake during either year of research. When compared with no-FYM treatment the farmyard manure at 10 tons ha^{-1} increased the total nitrogen uptake to the extent of 4.78 and 4.60 kg ha^{-1} during 1989 and 1990, respectively.

Phosphorus : It was observed that phosphorus application had a significant effect on total nitrogen uptake by green gram. However, the response to phosphorus fertilization was only apparent up to 13 kg P ha^{-1} level of application. The mean increase in nitrogen uptake under 13 kg P ha^{-1} treatment was 28.9 per cent over no-phosphorus treatment.

Table 4.5.4 Effect of tillage, FYM and levels of phosphorus on nitrogen uptake (kg ha^{-1}) by green gram

Treatment	1989			1990		
	Grain	Stover	Total	Grain	Stover	Total
Tillage						
Conventional	8.136	11.437	19.572	9.639	12.757	22.395
Disc	8.858	12.486	21.345	10.295	17.463	27.759
Chisel	8.273	11.220	19.493	9.914	12.119	22.034
Minimum	8.185	10.456	18.642	9.824	12.228	22.052
Zero	7.072	10.013	17.085	8.744	10.411	19.156
S Em ±	0.214	0.306	0.347	0.244	0.485	0.643
C.D. 5%	0.659	0.942	1.069	0.752	1.493	1.979
FYM (t ha^{-1})						
F_0	6.691	10.146	16.837	8.636	11.744	20.380
F_{10}	9.519	12.099	21.618	10.730	14.247	24.978
S Em ±	0.196	0.178	0.267	0.306	0.374	0.471
C.D. 5%	0.551	0.501	0.752	0.861	1.054	1.327
Phosphorus levels (kg P ha^{-1})						
P_0	7.186	9.370	16.555	8.311	11.055	19.366
P_{13}	8.429	11.913	20.342	11.091	14.877	25.968
P26	8.700	12.085	20.785	9.648	13.056	22.704
S Em ±	0.240	0.218	0.327	0.374	0.458	0.577
C.D. 5%	0.675	0.614	0.921	1.055	1.292	1.625

4.5.5 Uptake of phosphorus by green gram :

Data on uptake of phosphorus through seed, stover and total harvest by green gram are presented in Table 4.5.5 and their analysis of variance appended in appendix XII.

Seed :

Tillage : It is obvious from the data (Table 4.5.5) that different tillage treatments had significant effect in increasing the phosphorus uptake through seed when compared with zero tillage treatment during 1989 as well as 1990. The treatment disc ploughing resulted in maximum phosphorus uptake by green gram seed during both the years and the value recorded was significantly higher than all other tillage treatments examined except the plot receiving chisel ploughing in *Kharif* 1989 where the value observed remained statistically at par. The phosphorus uptake recorded under the plots receiving chisel and conventional tillage also recorded significantly higher value as compared to those recorded from the plot receiving minimum tillage in 1990. Further, the phosphorus uptake recorded under the plots receiving chisel and minimum as well as minimum and conventional tillage during 1989 and chisel and conventional tillage during 1990 were found statistically at par. The maximum phosphorus uptake recorded in disc ploughing treatment had increased the phosphorus uptake through seed by 26.9 and 41.3 per cent during 1989 and 1990 over these recorded from zero tillage respectively. A further look on the mean values computed from the data for the two years revealed that the treatment disc ploughing (1.03 kg P ha^{-1}) was followed by chisel ploughing (0.92 kg P ha^{-1}), conventional tillage (0.90 kg P ha^{-1}) and minimum tillage (0.89 kg P ha^{-1}) treatments. The treatment chisel ploughing, conventional and minimum tillage increased the mean phosphorus uptake through seed by 25.5, 22.4 and 21.9 per cent over zero tillage.

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased the phosphorus uptake through seed and the magnitude of increase recorded was in the tune of 30.5 and 32.8 per cent over no-FYM treatment during 1989 and 1990, respectively.

Table 4.5.5 Effect of tillage, FYM and levels of phosphorus on phosphorus uptake (kg ha^{-1}) by green gram

Treatment	1989			1990		
	Grain	Stover	Total	Grain	Stover	Total
Tillage						
Conventional	0.767	1.778	2.545	1.036	1.946	2.981
Disc	0.872	2.059	2.931	1.190	2.656	3.845
Chisel	0.824	1.729	2.553	1.024	1.990	3.014
Minimum	0.800	1.691	2.492	0.995	1.900	2.895
Zero	0.631	1.465	2.095	0.842	1.634	2.476
S Em ±	0.018	0.048	0.047	0.024	0.087	0.010
C.D. 5%	0.056	0.147	0.145	0.074	0.267	0.307
FYM (t ha^{-1})						
F_0	0.676	1.437	2.113	0.874	1.595	2.469
F_{10}	0.882	2.052	2.933	1.161	2.455	3.616
S Em ±	0.020	0.029	0.036	0.031	0.058	0.864
C.D. 5%	0.057	0.082	0.100	0.086	0.163	0.181
Phosphorus levels (kg P ha^{-1})						
P_0	0.641	1.171	1.813	0.689	1.274	1.963
P_{13}	0.818	1.943	2.761	1.249	2.509	3.758
P26	0.878	2.118	2.996	1.113	2.292	3.405
S Em ±	0.025	0.036	0.043	0.038	0.071	0.079
C.D. 5%	0.070	0.100	0.123	0.106	0.200	0.221

Phosphorus : On examining the data in Table 4.5.5 show that application of phosphorus had significantly increased the phosphorus uptake through seed over no-phosphorus treatment during either year of research. However, the response to phosphorus fertilization was only up to 13 kg P ha^{-1} level of application. The corresponding increases over no-phosphorus treatment were in the order 27.6 and 81.3 per cent during 1989 and 1990. However, an examination of the mean increase in phosphorus uptake recorded under phosphorus fertilization at 13 kg P ha^{-1} over no-phosphorus treatment indicated an increase to the extent of 55.4 per cent.

Stover :

Tillage : Like seed, phosphorus uptake by green gram stover was also significantly affected due to different tillage treatments when compared with zero tillage during either year of research (Table 4.5.5). The treatment disc ploughing gave significantly higher phosphorus uptake through stover over rest of all other tillage treatments during both 1989 and 1990. Further, the phosphorus uptake recorded under the plots receiving chisel ploughing, conventional and minimum tillage remained statistically at par during either year of research. The mean data of two years of research show that the treatment disc ploughing gave a maximum phosphorus uptake of 2.357 kg P ha^{-1} followed by conventional tillage (1.862 kg P ha^{-1}), chisel ploughing (1.859 kg P ha^{-1}) and minimum tillage (1.795 kg P ha^{-1}) treatment as against 1.549 kg P ha^{-1} from the plot receiving zero tillage treatment. The per cent, increases recorded in mean phosphorus uptake due to disc ploughing, chisel ploughing, conventional and minimum tillage were of the order 52.2, 20.0, 20.2 and 15.9 per cent respectively over the value recorded for stover harvested from the plot receiving zero tillage treatment.

FYM : Application of farmyard manure significantly increased the phosphorus uptake by stover during both the years. Incorporation of farmyard manure at 10 tons ha^{-1} increased the phosphorus uptake over no-FYM treatments and the magnitude of difference recorded was of the order 42.8 and 53.9 per cent during 1989 and 1990,respectively.

Phosphorus : It is apparent from the data (Table 4.5.5) on phosphorus uptake by green gram stover that phosphorus application at 13 and 26 kg P ha^{-1} significantly increased the phosphorus uptake through stover over no-phosphorus treatment. However, the response to phosphorus fertilization beyond 13 kg P ha^{-1} was only apparent in *Kharif* 1989. The corresponding increases recorded for the uptake of phosphorus by stover were to the tune of 65.9 and 80.9 per cent in 1989 and 81.3 and 61.5 per cent in 1990, respectively.

Interaction effect of tillage and phosphorus uptake by green gram stover (1989 & 1990):

A critical examination of data on phosphorus uptake by green gram stover as influenced by interaction between tillage treatments and phosphate fertilization presented in Table 4.5.5.1 revealed that phosphorus fertilization upto 13 kg P ha^{-1} level has significantly increased the phosphorus uptake under all the tillage treatments in either year of research. However, the response to the phosphorus fertilization beyond 13 kg P ha^{-1} was only apparent in the treatment receiving conventional tillage and chisel ploughing in *Kharif* 1989. Further, the maximum value of phosphorus uptake was observed under the treatment combination receiving disc ploughing in conjunction with phosphorus fertilization at 13 kg P ha^{-1}, which was significantly higher over the phosphorus fertilization even upto 26 kg P ha^{-1} in conjunction with rest of all other tillage treatment during both the years of investigation.

Interaction effect of FYM and levels of phosphorus on phosphorus uptake by green gram stover (1989 & 1990):

A look at the interaction between farmyard manure and phosphate fertilization on phosphorus uptake by green gram stover (Table 4.5.5.2) indicated that phosphorus fertilization up to 13 kg P ha^{-1} has significantly increased the phosphorus uptake under both the situations whether farmyard manuring was practised or not in either year of research. Further, a significant increase in phosphorus uptake due to farmyard manuring was only apparent when it was applied in conjunction with phosphorus fertilization. The response to phosphorus fertilization beyond 13 kg P ha^{-1} was only apparent in *Kharif* 1989 that too under the situations where farmyard manuring was done.

Table 4.5.5.1 Interaction effect of tillage and levels of phosphorus on phosphorus uptake (kg ha^{-1}) by green gram stover

Tillage→ P levels (kg P ha^{-1})↓	Conventional	Disc	Chisel	Minimum	Zero
			1989		
P_0	1.27	1.26	1.31	1.12	0.90
P_{13}	1.89	2.51	1.74	1.90	1.69
P_{26}	2.18	2.41	2.15	2.05	1.81
			1990		
P_0	1.25	1.38	1.28	1.26	1.21
P_{13}	2.45	3.60	2.34	2.21	1.95
P_{26}	2.15	2.99	2.35	2.23	1.74
Year		1989		1990	
S Em ±		0.080		0.159	
C.D. 5%		0.224		0.447	

Table 4.5.5.2 Interaction effect of FYM and levels of phosphorus on phosphorus uptake (kg ha^{-1}) by green gram stover

FYM (t ha^{-1})	P levels (kg P ha^{-1})		
	P_0	P_{13}	P_{26}
		1989	
F_0	1.12	1.53	1.66
F_{10}	1.23	2.35	2.58
		1990	
F_0	1.18	1.90	1.71
F_{10}	1.37	3.12	2.87
Year	1989		1990
S Em ±	0.050		0.100
C.D. 5%	0.142		0.283

4.5.5 Total Uptake :

Tillage : Like seed and stover the total phosphorus uptake through green gram was also affected significantly by different tillage practices over zero tillage treatment (Table 4.5.5) during both the years of investigation. The treatment disc ploughing gave significantly maximum total phosphorus uptake through green gram over rest of all other tillage treatments during both 1989 and 1990. Further, the total phosphorus recorded under the plots receiving chisel ploughing, conventional and minimum tillage also remained statistically at par during both the years of research. The mean value computed from the data for the two years of investigation show that the highest total phosphorus uptake was obtained from the plot receiving disc ploughing treatments (3.39 kg ha^{-1}), while the lowest was obtained from the plot receiving zero tillage (2.28 kg ha^{-1}). The magnitude of increase in total phosphorus uptake recorded under the plot ploughed with disc plough over zero tillage was of the order 39.9 and 55.3 per cent, respectively during 1989 and 1990.

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased the total phosphorus uptake during both the years. The extent of increase in total phosphorus uptake recorded was to tune of 42.8 and 46.4 per cent over no-FYM treatment in 1989 and 1990, respectively.

Phosphorus : It was also observed that phosphorus application had a significant effect on total phosphorus uptake by green gram (Table 4.5.5). The maximum phosphorus uptake recorded during 1989 was from the plot receiving 26 kg P ha^{-1} whereas during 1990 was from the plot receiving 13 kg P ha^{-1} only. The mean increase in phosphorus uptake recorded for 13 and 26 kg P ha^{-1} levels of phosphorus application over no-phosphorus treatment computed from the data for the two years was of the order 72.7 and 69.5 per cent.

Interaction effect of tillage and levels of phosphorus on total phosphorus uptake by green gram (1989 & 1990):

A critical look at the data on interaction between tillage treatment and phosphate fertilization on total phosphorus uptake by green gram presented in Table 4.5.5.3 indicated that phosphorus fertilization up to 13 kg P ha^{-1} has significantly increased the total phosphorus uptake by green gram during both the years of investigation. However, response beyond 13 kg P ha^{-1} was only apparent in *Kharif* 1989 under the plots receiving conventional, chisel and minimum tillage. Further, a significantly highest value of total phosphorus uptake was recorded from the plot receiving disc ploughing in conjunction with 13 kg P ha^{-1} of phosphate fertilization, when compared with phosphate fertilization even upto 26 kg P ha^{-1} in rest of all other tillage treatments during either years of research. The zero tillage treatment without phosphate fertilization recorded the lowest value of total phosphorus uptake during both the years of research.

Table 4.5.5.3 Interaction effect of tillage and levels of phosphorus on total phosphorus uptake (kg ha-1) by green gram

Tillage→ P levels (kg P ha^{-1})↓	Conventional	Disc	Chisel	Minimum	Zero
			1989		
P_0	1.88	1.98	1.93	1.82	1.44
P_{13}	2.70	3.44	2.67	2.66	2.33
P_{26}	3.05	3.37	3.06	2.99	2.52
			1990		
P_0	1.94	2.25	1.94	1.89	1.79
P_{13}	3.67	4.99	3.74	3.40	3.00
P_{26}	3.34	4.29	3.36	3.40	2.64

Year	1989	1990
S Em ±	0.098	0.176
C.D. 5%	0.275	0.495

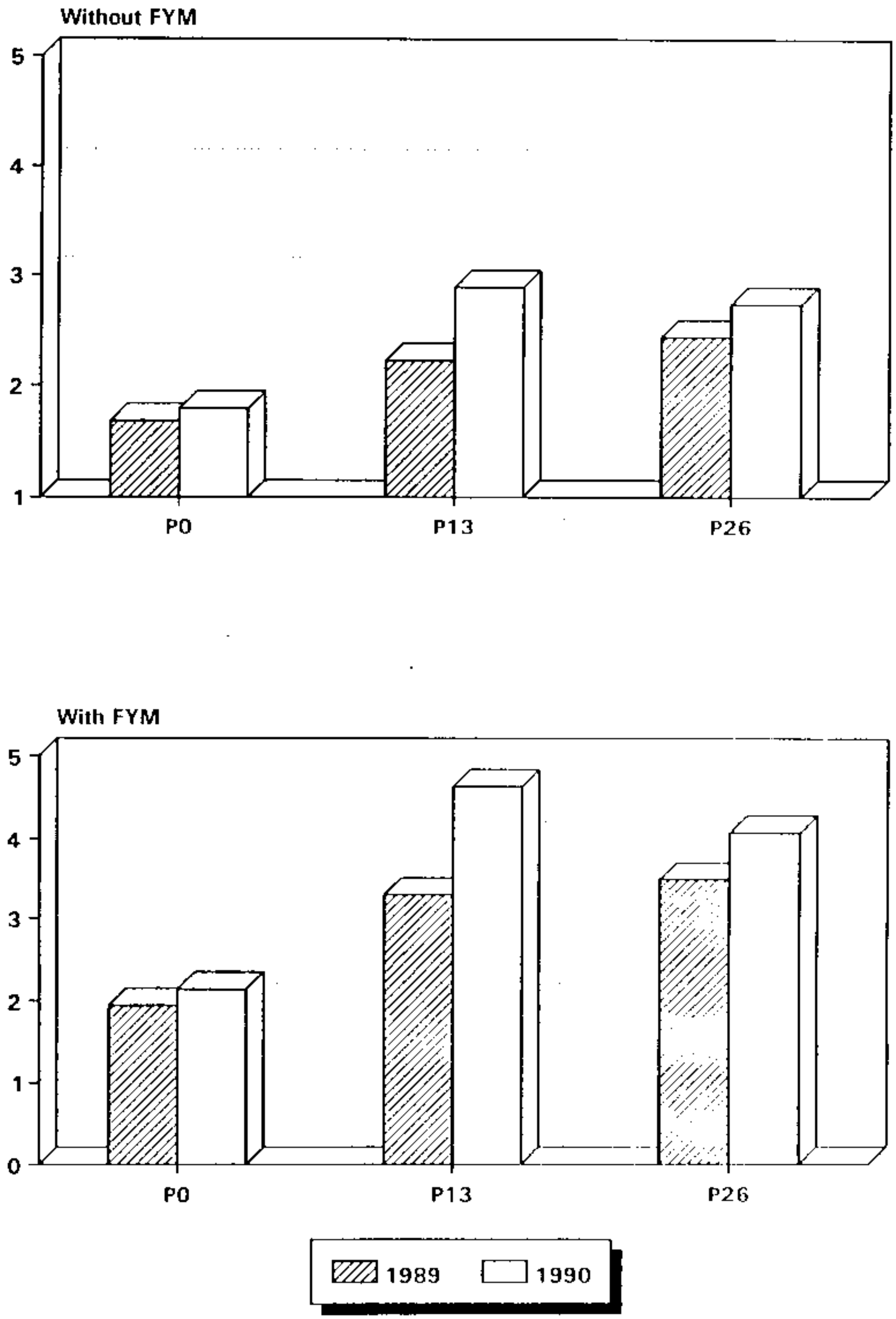
Interaction effect of FYM and levels of phosphorus on total phosphorus uptake by green gram (1989 & 1990):

A look at the data on interaction between farmyard manuring and phosphate fertilization on total phosphorus uptake by green gram (Table 4.5.5.4) revealed that phosphorus fertilization and farmyard manuring alone as well as in combination have significantly increased the total phosphorus uptake by green gram (Fig. 4.13). However, the response to phosphorus beyond 13 kg P ha^{-1} was only apparent in *Kharif* 1989. Further, examination of data revealed that the significantly highest total phosphorus uptake was observed in plot receiving farmyard manure in conjunction with 26 kg P ha^{-1} in *Kharif* 1989 whereas in the subsequent year of research the significantly highest value was apparent in the plot receiving farmyard manuring with phosphate fertilization only at 13 kg P ha^{-1}.

Table 4.5.5.4 Interaction effect of FYM and levels of phosphorus on total phosphorus uptake (kg ha^{-1}) by green gram

FYM (t ha^{-1})	P levels (kg P ha^{-1})		
	P_0	P_{13}	P_{26}
		1989	
F_0	1.68	2.22	2.44
F_{10}	1.94	3.30	3.56
		1990	
F_0	1.79	2.89	2.74
F_{10}	2.14	4.63	4.07
Year	1989		1990
S Em ±	0.062		0.111
C.D. 5%	0.174		0.313

FIG. 4.13 Interaction effect of FYM and Phosphorus levals on Total phosphorus uptake (Kg/ha) by Grean Gram



4.5.6 Uptake of potassium by green gram

Data on uptake of potassium through seed, stover and total harvest by green gram are presented in Table 4.5.6 and their analysis of variance appended in appendix XIII.

Seed :

Tillage : Perusal of data on potassium uptake presented in Table 4.5.6 revealed that all the tillage treatments significantly increased the potassium uptake through seed over zero tillage during both the years except from the plot receiving minimum and conventional tillage in *Kharif* 1990. A critical look on data presented on potassium uptake by green gram seed indicated that the treatment receiving disc, chisel, minimum and conventional tillage in 1989 and disc, chisel and minimum tillage in 1990, remained statistically at par. Further, the disc and chisel ploughing treatment during *Kharif* 1990 also recorded a significant increase in the potassium uptake through seed over conventional tillage. The disc ploughing treatment recorded the maximum value of potassium uptake over all other tillage treatment during either year of research. When compared with zero tillage treatment, per cent increase in potassium uptake through seed under disc ploughing treatment recorded was of the order 26.7 an 15.1 per cent during 1989 and 1990, respectively. The mean value computed from data for two years show that the treatment disc ploughing, chisel and minimum tillage recorded an increase in the total potassium uptake through seed by 19.9, 14.4 and 14.0 per cent, respectively over the value derived for the plot receiving zero tillage.

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} had significantly increased the potassium uptake through seed over no-FYM treatment. The magnitude of increase recorded over no-FYM treatment was in the tune of 35.6 and 27.0 per cent in 1989 and 1990, respectively.

Phosphorus : It is obvious from the data (Table 4.5.6) that phosphorus application at 13 kg P ha^{-1} significantly increased the potassium uptake through seed over no-phosphorus application in either year of research. The magnitude of increase under this treatment was of the order 23.7 and 42.8 per cent in 1989 and 1990,respectively over no-phosphorus treatment. However, an examination of the mean increases in phosphorus uptake recorded under phosphate fertilization at 13 kg P ha^{-1} over no-phosphorus treatment indicated an increase to the extent of 34.25 per cent.

Table 4.5.6 Effect of tillage, FYM and levels of phosphorus on potassium uptake (kg ha^{-1}) by green gram

Treatment	1989			1990		
	Seed	Stover	Total	Seed	Stover	Total
Tillage						
Conventional	1.579	3.782	5.361	1.947	3.959	5.906
Disc	1.728	3.994	5.722	2.189	5.467	7.656
Chisel	1.607	3.652	5.259	2.130	4.117	6.247
Minimum	1.667	3.483	5.150	2.056	3.980	6.036
Zero	1.364	3.385	4.750	1.901	3.470	5.371
S Em ±	0.058	0.124	0.128	0.055	0.195	0.225
C.D. 5%	0.179	0.380	0.394	0.168	0.601	0.694
FYM (t ha^{-1})						
F_0	1.349	3.318	4.666	1.801	3.908	5.710
F_{10}	1.830	4.001	5.831	2.288	4.489	6.776
S Em ±	0.043	0.062	0.073	0.068	0.146	0.151
C.D. 5%	0.121	0.174	0.204	0.192	0.411	0.426
Phosphorus levels (kg P ha^{-1})						
P_0	1.349	3.045	4.394	1.667	3.451	5.118
P_{13}	1.669	3.977	5.646	2.380	4.877	7.257
P26	1.750	3.956	5.706	2.086	4.267	6.354
S Em ±	0.052	0.076	0.089	0.084	0.179	0.185
C.D. 5%	0.148	0.213	0.251	0.236	0.503	0.522

Stover :

Tillage : Perusal of data on potassium uptake by green gram stover presented in Table 4.5.6 revealed that the plot receiving disc and conventional tillage in *Kharif* 1989 and disc and chisel ploughing in *Kharif* 1990 have significantly increased the potassium uptake through green gram stover over zero tillage treatment. However, the potassium uptake recorded under the plots receiving conventional, chisel and minimum tillage in 1989 and 1990 were found statistically at par. The potassium uptake by stover was maximum in disc ploughing treatment during both the years. When compared with zero tillage treatment, an increase to the extent of 18.0 and 57.5 per cent in potassium uptake was apparent in the values recorded for *Kharif* 1989 and 1990 from the plot receiving disc ploughing treatment.

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased the potassium uptake through stover over the treatment receiving no-FYM. The per cent increase in potassium uptake recorded over no-FYM treatment was of the order 20.6 and 14.9 in 1989 and 1990, respectively.

Phosphorus : On examining the data from Table 4.5.6 show that application of phosphorus at 13 kg P ha^{-1} had significantly increased the potassium uptake over no-phosphorus treatment during both the years. However, the response to phosphorus application beyond 13 kg P ha^{-1} level was not evident. The corresponding increases in potassium uptake recorded for the year 1989 and 1990 due to phosphorus application at 13 kg P ha^{-1} was 30.6 and 41.3 per cent over no-phosphorus treatment. An examination of mean increases in potassium uptake recorded under phosphorus fertilization at 13 kg P ha^{-1} over no-phosphorus treatment indicated an increase to the extent of 36.3 per cent.

Interaction effect of tillage and levels of phosphorus on potassium uptake (kg ha^{-1}) by green gram stover (1989):

It is obvious from the data on interaction between tillage treatment and phosphate fertilization on potassium uptake by green gram stover recorded in *Kharif* 1989 (Table 4.5.6.1) revealed that phosphate fertilization upto 13 kg P ha^{-1} has significantly increased the potassium uptake under all the tillage treatments examined; however, the phosphorus application beyond 13 kg ha^{-1} had given response only in the treatment where zero tillage was practised. The treatment receiving disc ploughing in conjunction with phosphorus fertilization at 13 kg P ha^{-1} recorded the highest value of potassium uptake which was significantly higher than those recorded at this level of phosphorus under the plots where chisel, minimum and zero tillage was given, however, was statistically at par with the value observed from the plots receiving conventional tillage in conjunction with 13 kg P ha^{-1}.

Table 4.5.6.1 Interaction effect of tillage and levels of phosphorus on potassium uptake (kg ha^{-1}) by green gram stover (1989)

Tillage→ P levels (kg P ha^{-1})↓	Conventional	Disc	Chisel	Minimum	Zero
P_0	3.02	3.44	3.13	3.01	2.62
P_{13}	4.34	4.48	3.70	3.88	3.49
P_{26}	3.98	4.06	4.13	3.56	4.05
S Em ±			0.169		
C.D.5%			0.477		

Total uptake

Tillage : Like seed and stover the total potassium uptake through green gram Table 4.5.6 when compared with value recorded from the plot receiving zero tillage, application of various tillage treatments during both the years of research recorded as significant increase except for the plot receiving conventional tillage in *Kharif* 1990. The treatment disc ploughing recorded the highest value of total potassium uptake by green gram, which was significantly higher when compared with all other tillage treatments except the value recorded from the plot receiving conventional tillage in *Kharif* 1989. Further, the plot receiving conventional, chisel and minimum tillage remained statistically at par in recording the total potassium uptake by green gram and were significantly superior to the treatment receiving zero tillage during either year of research except the value recorded from the plot receiving conventional tillage in *Kharif* 1990. The treatment disc ploughing was found to be superior over all other tillage treatments and when compared with zero tillage treatment recorded an increase in total potassium uptake to the extent of 20.5 and 42.5 per cent during 1989 and 1990, respectively.

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased the total potassium uptake during both the years. The increase in total potassium uptake recorded over no-FYM treatment was of the order 25.0 and 18.7 per cent during 1989 and 1990, respectively.

Phosphorus : It is obvious from the data in Table 4.5.6 that phosphorus application had a significant effect on total potassium uptake by green gram. However, the significant response to phosphorus fertilization in increasing the total potassium uptake was only apparent when phosphorus was applied upto 13 kg P ha^{-1} during both the years of investigation. The mean value computed from data for two years revealed that the treatment 13 kg P ha^{-1} increased the total potassium uptake to the extent of 35.6 per cent over no-phosphorus application.

4.6 Protein Content of Sorghum and Green gram :

Data on protein content of sorghum and green gram are presented in Table 4.6.1 and 4.6.2 respectively and their analysis of variance appended in appendix XIV.

4.6.1 Sorghum :

Tillage : It is apparent from the data on protein content of sorghum grain that different tillage treatments did not affect the protein content during either year of research (Table 4.6.1). The maximum protein content of 9.03 per cent in *Kharif* 1989 and 8.83 per cent in *Kharif* 1990 was recorded from the plot receiving disc ploughing as against a minimum value of 8.82 and

8.74 per cent observed from the plot receiving zero tillage treatment in 1989 and 1990, respectively.

Table 4.6.1 Effect of tillage, FYM and levels of phosphorus on protein content (%) by sorghum grain

Treatment	1989	1990	Mean
Tillage			
Conventional	8.812	8.762	8.787
Disc	9.030	8.828	8.929
Chisel	8.892	8.822	8.857
Minimum	8.911	8.741	8.826
Zero	8.822	8.740	8.781
S Em ±	0.059	0.049	
C.D. 5%	NS	NS	
FYM (t ha^{-1})			
F_0	8.761	8.665	8.713
F_{10}	9.026	8.892	8.959
S Em ±	0.041	0.030	
C.D. 5%	0.114	0.086	
Phosphorus levels (kg P ha^{-1})			
P_0	8.738	8.671	8.704
P_{13}	8.902	8.785	8.843
P_{26}	9.040	8.879	8.959
S Em ±	0.050	0.037	
C.D. 5%	0.140	0.105	

FYM : Incorporation of farmyard manure at 10 tons ha^{-1} significantly increased the protein content in sorghum grain. The increases in protein content due to application of FYM was to the tune of 3.0 and 2.6 per cent during 1989 and 1990, respectively over no-FYM treatment.

Phosphorus : Fertilization of phosphorus also significantly affected the protein content of sorghum grain. It was observed that the protein content increases with a subsequent increase in phosphorus level and the maximum value being observed in plot receiving 26 kg P ha^{-1} treatment during either year of research. However, the significance of response to the phosphorus fertilization was observed only upto 13 kg P ha^{-1} level of application. The respective increase in protein content due to 13 and 26 kg P ha^{-1} level of phosphorus application over no-phosphorus treatment was of the order 1.88 and 3.46 per cent during 1989 and 1.31 and 2.40 per cent during 1990.

4.6.2 Green gram :

Tillage : An examination of data on protein content of green gram revealed that different tillage treatments affected the protein content of green gram of seed to a very little extent (Table 4.6.2) and the significance of difference was only apparent during *Kharif* 1990. The protein content recorded under the plots receiving disc, chisel and conventional tillage th ough remained statistically at par but were significantly higher than those recorded from the plots receiving minimum and zero tillage treatments. The mean for the two years research show that the maximum protein content of 22.86 was recorded from the plots receiving disc ploughing treatment which was followed by chisel ploughing (22.79) and conventional tillage (22.74) as against a minimum protein content of 22.61 under plot receiving zero tillage treatment.

FYM : Data in Table 4.6.2 further show that application of farmyard manure significantly affected the protein content in green gram seed during both the years of experimentation. It was observed that farmyard manure when applied at 10 tons ha^{-1} increased the protein content by 13.94 and 10.94 per cent during 1989 and 1990 over no-FYM treatment.

Phosphorus : Like, FYM the phosphorus application also affected the protein content of green gram seed significantly during either year of research. The protein content increased with a subsequent increase in the phosphorus level during both the years. The mean values derived from data show that application of phosphorus at 13 and 26 kg P ha^{-1} increased the protein content by 3.78 and 5.61 per cent, respectively over the value derived from the plot receiving no -phosphorus application.

Table 4.6.2 Effect of Tillage, FYM and levels of Phosphorus on Protein content (%) by green gram seed

Treatment	1989	1990	Mean
Tillage			
Conventional	23.560	21.923	22.741
Disc	23.770	21.960	22.865
Chisel	23.621	21.964	22.792
Minimum	23.595	21.740	22.667
Zero	23.545	21.681	22.613
S Em ±	0.1267	0.072	
C.D. 5%	NS	0.221	
FYM (t ha^{-1})			
F_0	22.079	20.720	21.399
F_{10}	25.158	22.987	24.072
S Em ±	0.104	0.045	
C.D. 5%	0.003	0.126	
Phosphorus levels (kg P ha^{-1})			
P_0	22.81	21.29	22.045
P_{13}	23.70	22.06	22.878
P_{26}	24.350	22.22	23.283
S Em ±	0.127	0.055	
C.D. 5%	0.359	0.154	

Interaction effect of tillage and FYM on protein content of green gram (1989 & 1990):

Perusal of data on interaction between tillage treatments and incorporation of farmyard manure (Table 4.6.2.1) revealed that incorporation of FYM had significantly increased the protein content under various tillage treatments examined during either year of research. Under the situation where the farmyard manuring was done the protein content recorded from the plot receiving disc plough though remained statistically at par with the values recorded from the plots treated with chisel ploughing but was significantly higher than those recorded from the plots receiving minimum, conventional and zero tillage during *Kharif* 1989. However, the protein content recorded in the seed harvested from farmyard manured plots in *Kharif* 1990 the treatments receiving conventional, disc and chisel though remained statistically at par but were significantly superior to those recorded from the plots receiving minimum and zero tillage treatments.

Table 4.6.2.1 Interaction effect of tillage and FYM on protein content (%) of green gram

Tillage→ FYM (t ha^{-1})↓	Conven-tional	Disc	Chisel	Minimum	Zero
			1989		
F_0	22.36	21.78	21.79	22.44	22.02
F_{10}	24.76	25.76	25.45	24.75	25.07
			1990		
F_0	20.47	20.67	20.78	20.95	20.73
F_{10}	23.37	23.25	23.14	22.53	22.63

Year	1989	1990
S Em ±	0.233	0.100
C.D. 5%	0.656	0.281

Interaction effect of tillage and levels of phosphorus on protein content of green gram (1989 & 1990):

An overall examination of data on protein content of green gram seed as influenced by the interaction between tillage treatments and phosphate fertilization (Table 4.6.2.2) indicated that incorporation of phosphorus at 13 kg P ha^{-1} had significantly increased the protein content of green gram seed under all the treatment during both the years of investigation except the chisel treatment in *Kharif* 1989 and minimum tillage in *Kharif* 1990, where the values for protein content recorded remained statistically at par with those recorded from the plots receiving no-phosphorus application. Further, incorporation of 26 kg P ha^{-1} under disc ploughing treatment during *Kharif* 1989 recorded the highest protein content which was though statistically at par with value recorded from the plot receiving the same level of phosphorus under conventional tillage treatment but was statistically superior to all other treatment combinations. Similarly incorporation of phosphorus up to the level of 26 kg P ha^{-1} under zero tillage and at 26 kg P ha^{-1} under minimum tillage in *Kharif* 1990 also recorded significant increase in the protein content of green gram seed. However, phosphorus fertilization beyond 13 kg P ha^{-1} in the plots receiving conventional, disc and chisel treatment gave no response in improving protein content of green gram seed.

Interaction effect of FYM and levels of phosphorus on protein content of green gram

Perusal of data on protein content from the interaction between farmyard manuring and phosphorus fertilization (Table 4.6.2.3) indicated that incorporation of farmyard manure and phosphatic fertilizer alone as well as in combination have significantly increased the protein content of green gram seed during both the years of study. Further, phosphate fertilization upto a level of 26 kg P ha^{-1} was found significant under the situation where no-FYM was incorporated however, the response to phosphate was only limited up to the level of 13 kg P ha^{-1} under situation where farmyard manuring was done.

Table 4.6.2.2 Interaction effect of tillage and levels of phosphorus on protein content (%) of green gram seed

Tillage→ P levels (kg P ha^{-1})↓	Conven-tional	Disc	Chisel	Minimum	Zero
			1989		
P_0	22.33	22.31	23.95	22.80	22.63
P_{13}	23.38	23.87	23.36	23.97	23.91
P_{26}	24.97	25.13	23.55	24.01	24.10
			1990		
P_0	21.44	21.05	21.65	21.31	20.97
P_{13}	22.12	22.47	22.21	21.63	21.86
P_{26}	22.21	22.37	22.02	22.28	22.21
Year		1989		1990	
S Em ±		0.285		0.122	
C.D. 5%		0.803		0.345	

Table 4.6.2.3 Interaction effect of FYM and levels of phosphorus on protein content (%) of green gram seed

FYM (t ha^{-1})	P levels (kg P ha^{-1})		
	P_0	P_{13}	P_{26}
		1989	
F_0	21.17	21.94	23.12
F_{10}	24.44	25.46	25.57
		1990	
F_0	20.01	20.97	21.18
F_{10}	22.56	23.14	23.25
Years	1989		1990
S Em ±	0.180		0.077
C.D.5%	0.508		0.218

Interaction effect of tillage, FYM and levels of phosphorus on protein content of green gram (1989 & 1990)

An examination of data on protein content as influenced by interaction between tillage, farmyard manure and phosphate fertilization (Table 4.6.2.4) revealed that farmyard manuring and phosphate fertilization have significantly increased the protein content of green gram seed under all the tillage treatments. The protein content under FYM treated plots when compared with those receiving no-FYM treatment under specific level of phosphorus used recorded a definite increase during both the years of research. However, the treatment receiving chisel ploughing gave no response to phosphorus application whether farmyard manure was applied or not except the plot receiving 13 kg P ha^{-1} in *Kharif* 1990 which when compared with P levels of phosphorus fertilization gave significantly higher protein content. Though the highest value of protein content was recorded from the plots receiving disc ploughing in conjunction with farmyard manuring and phosphate fertilization at 26 kg P ha^{-1} during both the years but the significance was observed only during *Kharif* 1989 as compared to rest of all the combination. Further, phosphate fertilization gave response to the level of 13 kg P ha^{-1} only under no-FYM treatment receiving conventional, disc, chisel and minimum treatments in *Kharif* 1990. The same was also true under farmyard manured plots receiving conventional and disc ploughing treatments.

4.7 Economics of Treatments :

Data on economics of treatments worked out for sorghum equivalent yield are presented in Table 4.7 and their analysis of variance appended in appendix XV and appendix XVI.

Tillage : A perusal of data presented in Table 4.7 revealed that a significant increase in the net profit per hectare have been recorded from the plots receiving minimum and disc ploughing in the year 1989 and disc ploughing in the year 1990 over the value recorded from the plots receiving zero and conventional tillage treatments. Further, the treatment receiving chisel ploughing in the year 1989 had also recorded a significantly higher net profit over that

Table 4.6.2.4 Interaction effect of tillage, FYM and levels of phosphorus on protein content (%) of green gram seed

Tillage	FYM (t ha^{-1})					
	F_0			F_{10}		
	P levels (kg P ha^{-1})					
	P_0	P_{13}	P_{26}	P_0	P_{13}	P_{26}
			1989			
Conventional	20.55	22.45	24.08	24.11	24.30	25.86
Disc	20.34	21.97	23.03	24.28	25.78	27.22
Chisel	22.83	20.64	21.89	25.08	26.08	25.20
Minimum	21.86	22.15	23.30	23.74	25.80	24.71
Zero	20.28	22.47	23.31	24.97	25.35	24.88
			1990			
Conventional	19.92	20.62	20.87	22.95	23.62	23.54
Disc	19.81	21.25	20.94	22.28	23.68	23.79
Chisel	20.29	20.99	21.06	23.01	23.43	22.98
Minimum	20.46	21.16	21.22	22.17	22.10	23.33
Zero	19.54	20.84	21.81	22.40	22.87	22.61
Years		1989		1990		
S Em ±		0.403		0.173		
C.D.5%		1.136		0.488		

recorded from the plots receiving zero tillage. However, treatments receiving disc, chisel and minimum tillage remained statistically at par in giving the net profit per hectare during either year of research. On reviewing the mean data for the two years of research, it is evident that treatments receiving minimum, disc and chisel tillage recorded an additional profit of Rs. 1753, 1714 and 1201 over that observed for the plot receiving zero tillage treatment.

Table 4.7 Effect of tillage, FYM and levels of phosphorus on net return (Rs ha^{-1}) on equivalent yield basis

Treatment	1989	1990	Mean
Tillage			
Conventional	10735	10459	10597
Disc	11669	11131	11400
Chisel	11136	10639	10887
Minimum	11780	11099	11439
Zero	9208	10165	9686
S Em .±	254.22	184.35	
C.D. 5%	784	568	
FYM (t ha^{-1})			
F_0	10537	10566	10551
F_{10}	11274	10831	11052
S Em ±	174.21	135.56	
C.D. 5%	491.00	NS	
Phosphorus levels (kg P ha^{-1})			
P_0	10373	10149	10261
P_{13}	11430	11416	11423
P_{26}	10913	10531	10722
S Em ±	213.36	166.03	
C.D. 5%	601.00	468.00	

FYM: Incorporation of FYM at 10 tons ha^{-1} though resulted in increased net profit over the treatment receiving no-FYM but the significance in the increase was only observed during first year of examination.

Phosphorus : Like farmyard manuring the phosphate fertilization at 13 kg P ha^{-1} had also significantly increased the net profit ha^{-1} over no-phosphorus application during either year of research. However, phosphorus fertilization beyond 13 kg P ha^{-1} gave no-additional gain. Phosphate fertilization at 13 kg P ha^{-1} gave an additional return of Rs. 1162 ha^{-1} when compared with the net profit received from the plot receiving no-phosphorus application.

5. DISCUSSION

In course of presenting results of the experiments entitled "Interactive effect of tillage and phosphate fertilization in conjunction with farmyard manure on soil physical parameters and yield of sorghum intercropped with green gram under dryland", significant variations in the criteria used for evaluating treatments were observed. Variations found significant or assuming a uniform trend, are discussed to establish the cause and effect relationship *vis-a-vis* existing evidences and literature. For the purpose, the discussion has been divided into four parts, viz.,

5.1 Effect of Environment

5.2 Physical and Chemical Properties of the Soil

5.3 Yield and Uptake of Nutrients

5.4 Crop Quality and Economics

5.1 Effect of Environment :

An overall examination of data for the two years (Table 5.1) indicate that during *Kharif*, 1989 sorghum crop produced higher biomass and stover yield (137.64 and 112.30 q ha^{-1} respectively) as compared to that recorded during *Kharif*, 1990 (105.10 and 74.61 q ha^{-1}, respectively). Unlike stover and biomass production the grain yield of sorghum as well as the sorghum equivalent yield recorded during 1990 was distinctly higher than that recorded during 1989.

Since crop was grown under identical level of management, resources and cultivation practices, the observed variation in crop yields between the years of experimentation seems

Table 5.1 Mean Meteorological Data at different crop growth stages (days) and yield ($q\ ha^{-1}$) during 1989 and 1990

Parameters	Years	
	1989	1990
Temperature (°C)		
30	28.87	31.23
30 - 45	28.25	29.60
45 - 60	27.67	28.80
60 - 75	26.83	29.20
75 - 90	29.44	28.77
Rainfall (mm)		
30	159.30	271.90
30 - 45	125.60	118.60
45 - 60	442.40	57.80
60 - 75	26.30	67.80
75 - 90	NIL	9.30
Total biomass production of sorghum	137.64	105.10
Sorghum seed yield	25.35	30.49
Sorghum equivalent yield	30.52	37.15
Sorghum stover yield	112.30	74.61

to be the resultant of environmental conditions prevailed during the critical crop growth stages. This might have influenced overall growth and development and finally crop yields. The profound influence of climatic conditions on productivity of agricultural crops is well established. In this context, Mistry and Patel (1977) stated that the weather is principal input parameter which bring year to year variation in crop productivity, despite consistency of other input parameters and practices of crop husbandry. The meteorological observations recorded during 1989 (Table 5.1) revealed that right from initial growth stage, crop received adequate well distributed total rainfall of 753.6 mm for crop season of which 442.4 mm was received during 45-60 days of crop growth, whereas, the total rainfall received during 1990 was restricted to 525.4 mm over the total crop life period of which only 57.6 mm was received during 45-60 days of crop growth. Further, the crop experienced comparatively lower mean temperature up to 75 days of crop growth in the year 1989 over that experienced in the year 1990 (Table 5.1). Thus favourable climatic conditions i.e. adequate rainfall and lower mean temperature seem to have improved physiological efficiencies of the crop by virtue of greater availability of nutrients and maintaining optimum turgor. This might have resulted in greater photosynthetic efficiency and effective translocation of photosynthates towards yield formation as evident from increased biomass production and stover yield of sorghum in *Kharif* 1989. Sivakumar *et al.*(1989) have reported that the average air temperature in sorghum belt varies from about 31 °C in the early growing season to 23 °c in the late growing season. Further, the effect of 1^{0}C temperature ranged above its average prove unfavourable for the sorghum crop during most of the crop life period. The lower biomass and stover yield in *Kharif* 1990 is attributed to the prevailing consistant higher temperature throughout the vegetative stage of crop growth.

Besides congenial, edaphic environment brought about through improvement in soil physical conditions (Table 4.1), favourable climatic conditions especially at peak reproductive stage (60 to 75 days of crop growth) receiving 67.8 mm of rainfall (Table 3.1) in the year 1990 possibly contributed towards realization of higher grain and sorghum equivalent yields. While on the other hand a long dry spell (Table 3.1) observed at grain filling to maturity (64 days of crop growth to harvest) resulted in early maturity of sorghum crop in the year 1989 (87 days of crop growth). Further a heavy showers of rains (442.4 mm) at 45 to 60 days of crop growth, extending congenial atmosphere for more vegetative growth lead to lower grain as well as sorghum equivalent yields.

5.2 Physical and Chemical Properties of Soil :

5.2.1 Physical properties

The tillage implements used under dry land condition were intended to bring changes in different physical properties of the soil. When compared with zero tillage, all the tillage treatments, in general lowered the bulk density and increased the total porosity, water holding capacity, hydraulic conductivity and basic infiltration rate of the soil (Table 4.1, Fig 4.1 to 4.5) and also the profile soil moisture at the time of sowing and harvest (Table 4.1.6).

Among various tillage treatments disc ploughing recorded significantly lowest value of bulk density and the highest value of soil porosity which was followed by chisel, minimum and conventional tillage treatments irrespective of depth of soil examined. However, the changes observed were of greater magnitude in surface layer as compared to sub surface layer of soil profile examined. The various tillage treatments based on their degree of influencing these two soil physical parameters can be placed in descending order as disc > chisel > minimum > conventional. Decrease in bulk density to a greater degree as a consequence of disc ploughing is attributable to the change brought in pore geometry.

Bhushan *et al.* (1973) have also reported that deep ploughing results in to more stirring (loosening and mixing) of soil decreasing the larger size aggregates (2 to 5 mm) but improved the granulation of smaller aggregates (1 to 0.1 mm) and there by increased the total pore space of the soil and consequently decreased the bulk density of soil. The findings of present investigation is in agreement with the results of Chaudhary *et al.* (1983), Fernandis *et al.* (1983), El-Gayear *et al.* (1986), Madeiva (1989) and Rahman (1991) .

The differential degree of response to tillage treatments observed in surface and sub-surface layers of soil is because of greater tilling action in the surface layer and is in close confirmity with the findings of Cassel and Nelson (1985) and Ike (1986). Further a higher value of bulk density and lower value of porosity under zero tillage treatment as compared to various tillage operations is attributed to want of loosening and mixing of soil layer (Batra *et al.*, 1972; Ketcheson, 1980; Voorhees and Lindstrom, 1984; Wang *et al.* 1986; Sharma *et al.* 1988; Riley and Ekeberg, 1989; Quiroga and Monsalvo, 1990).

Like porosity the maximum value of water holding capacity, basic infiltration rate and hydraulic conductivity was observed in the plot operated with disc plough which was closely followed by plot receiving chisel ploughing treatment. However, the value recorded for these physical parameters were distinctly superior under all the tillage treatments when compared with values recorded from the plot receiving zero tillage. Subramanian *et al.* (1975) and Jorge *et al* (1984) were also of the opinion that deep tillage leads to an improvement in capillary porosity and hydraulic conductivity of the soil. An improvement in basic infiltration rate and hydraulic conductivity due to disc and chisel ploughing over zero tillage is attributed to a significant change in the soil pore geometry and enhanced root growth in the surface soil layer which is also evident by decreased bulk density and increased porosity (Table 4.1) under these treatments. The observations recorded are in close conformity with the findings of Ambegaonkar *et al.* (1984); Jorge *et al.* (1984), Madeiva *et al.* (1989); Choi *et al.* (1990) and Pelegrin *et al.* (1990). Pelegrin *et al.* (1988 and 1990) have also reported that the differences in infiltration rate by disc ploughing, chisel ploughing and other tillage implements could be caused by a different structure pattern with a different pore system being created by them and to influence of plough pan. Impaired root growth due to absence of proper soil cultivation has also been reported by Prihar *et al.* (1975) and Almound *et al.* (1983), Chaudhary *et al.* (1985).

An improvement in soil physical parameters, bulk density, porosity, infiltration rate, hydraulic conductivity and water holding capacity in turn resulted in an increased soil moisture content in different layers of soil profile (Table 4.1.6) with concommitant increase in the total soil moisture content in the profile (Table 4.1.6.5), are in close cognizance with findings of Chaudhary *et al.* (1985), Adeoye and Mohamed-Saleem (1990), Hill (1990) and Heilman *et al.* (1991).

Disc ploughing treatment has significantly improved the soil moisture content in surface, subsurface and deeper soil layers at sowing as well as at harvest during either year of research (Table 4.1.6). Disc ploughing was closely followed by chisel ploughing treatment in improving the soil moisture content. Further, there was a higher soil moisture content in the soil sample drawn at sowing from the different soil layers during second year of experimentation is attributed to the cumulative effect of an improvement in soil physical conditions brought about as a consequence of tillage treatments (Table 4.1.). A comparatively higher moisture content in the soil layers recorded at harvest during *Kharif* 1990 is attributable to the late rains received at dough stage (43.6 mm) and maturity (9.3 mm)i.e. prior to harvest of the sorghum.

Incorporation of farmyard manure at 10 tons ha^{-1} resulted in an improvement in soil porosity, hydraulic conductivity, water holding capacity, basic infiltration rate and ultimately in an increased moisture content in soil profile and total soil moisture held in the profile (Table 4.1.6.5) with a decreased bulk density in surface and subsurface layer .An improvement in hydraulic conductivity, available soil moisture and other soil physical parameters as a consequence of regular addition of farmyard manure have also been reported by a number of workers (Mandal and Pain, 1965; Biswas *et al.*, 1971; Muthval *et al.*, 1973; Singh and Singh, 1974; Weill *et al.*, 1990).

Further, phosphorus fertilization has distinct effect in favourably altering most of the soil physical parameters under study. Application of phosphorus up to 26 kg P ha^{-1} has significantly lowered the bulk density and increased the porosity of soil in surface soil layer, however, such effects were only apparent in the subsurface layer upto the phosphorus level at 13 kg P ha^{-1}. However, phosphorus fertilization has no any significant effect on the water holding capacity of soil.

The lowest value of bulk density and highest value of porosity and basic infiltration rate was observed under the plots receiving disc ploughing in conjunction with farmyard manuring. Disc ploughing when accompanied with farmyard manuring and phosphate fertilization at 26 kg P ha^{-1} recorded a significantly lowest value of bulk density and highest value of soil porosity in surface and subsurface soil layer examined (Table 4.1.1.4 and 4.1.2.4). Like wise the highest hydraulic conductivity was also recorded in the above said treatment in the subsurface soil layer (Table 4.1.5.3). Further, phosphate fertilization when accompanied with farmyard manuring has improved these soil physical parameters under various tillage treatments examined. The additive effect of disc ploughing, farmyard manuring and phosphate fertilization in the betterment of soil physical parameters in the present investigation is attributed to deep penetration and more proliferated roots produced under this treatment combination as is also evident from the highest value of root density and root dry weight recorded under this treatment (Table 4.4.1). Tisdal *et al.* (1984) have reported that adequate fertilization of surface soil and proper management are important in promoting deeper vigourous and extensive rooting system. This stimulation of root development is related to the build of high concentration of nitrogen and phosphorus in the cells that hastens division and elongation favouring branching and an increased growth regulator auxins. Production of more extensive root system in turn might have increased the humus content and improved the aggregate status of the soil because of formation of polymers-bridges between clay particles (Taimurazova, 1967). Betterment in aggregates of soil might have changed the pore geometry leading to improved bulk density, total air space, hydraulic conductivity and water holding capacity of the soil (Subramanian *et al.* 1975).

A highly negative correlation exist between basic infiltration rate and bulk density, hydraulic conductivity and bulk density of the soil and a corresponding value of correlation coefficient (r) observed were -0.738 and - 0.647. Contrary to this a highly positive correlation was observed between water holding capacity and basic infiltration rate (r=0.729), water holding capacity and hydraulic conductivity (r=0.669) and hydraulic conductivity and basic infiltration rate (r=0.785). That these properties are inter-related is evident from the findings of Curtis and Post (1964), Larson (1964), Luts *et al.* (1966) and Kolarkar *et al.* (1974).

5.2.2 Chemical properties

An examination of the data on physico-chemical and chemical properties of the soil (Table 4.2 and 4.3) indicated that different tillage treatments though did not influenced the pH, electrical conductivity and available potassium status of the soil but have significantly altered the organic carbon and available phosphorus status of the soil drawn from the experimental plots. Significantly highest value of organic carbon was observed under the plot receiving zero tillage, while that of soil available phosphorus was recorded from the plots receiving disc ploughing treatments. The soil under various tillage treatments based on their available phosphorus status can be placed in descending order as: disc > chisel > minimum > conventional, where as that for organic carbon status can be placed as: zero > minimum = conventional = chisel > disc.

No change in pH and electrical conductivity of the soil drawn from the experimental plots indicate lack of relationship between these parameters and cultivation techniques which is in close agreement with the findings of Gaykwad and Khuspe (1976); Khiani and More (1979) and Rydberg (1987). The maximum value of organic carbon recorded under zero tillage treatment in the present investigation is attributed to a lesser degree of decomposition of organic matters (Rydberg, 1987; Carter *et al.*, 1988 and Madeiva *et al.*, 1989). Wrucke and Arnold (1985) and Ike (1987) have also reported that direct drilling caused changes in soil macro aggregation, reduced the evaporation rate and increased the microbial biomass C & N, total organic carbon and N and extractable ions at the surface when compared with the treatment receiving mould board ploughing. However, deeper tillage help in improving the level of available phosphorus in the soil (Gaikwad and Khauspe, 1976). Disc ploughing in conjunction with farmyard manuring has resulted in significant increase in available P and K status while decrease in EC of the soil. Further, farmyard manuring and phosphate fertilization alone as well as in combination in the present investigation have decreased the pH and increased the organic carbon, available P and K status of the soil (Table 4.2,4.3,4.3.1.1 & 4.3.2.2).

In general application of phosphorus in conjunction with FYM in all the tillage treatments though significantly increased the soil available phosphorus but the highest value was observed from the plot receiving disc ploughing in conjunction with 26 kg P and 10 tons of FYM per hectare. Application of FYM in general recorded an increased organic carbon and soil available phosphorus under all the tillage treatments though the highest value of organic carbon was apparent from the plot receiving zero tillage.

The favourable effect of farmyard manuring and phosphate fertilization in improving these soil parameters is an outcome of increased proliferation of roots and microbial activity (Kofoed, 1987), which in turn have released the organic acids lowering down the pH of the soil (Maurya and Ghosh, 1972 and Chaudhary *et al.*, 1981) and releasing the native phosphorus and potassium from the soil apart from reduction in fixation of applied phosphorus (Vyas and Motiramani, 1971; Sadanadan and Mahapatra, 1972 and Khaiani and More, 1984). Addition of FYM enhances the solubility of phosphate probably by interfering in some way with the formation of less soluble Octa calcium from dicalcium phosphate (Cooke, 1967). Similarly, Dhillon and Dev (1979) have reported that improvement in available P in soil may be attributed to humic substances secreted by roots, mineralization and solubilizing effect of soil microflora and intense CO_2 produced by the roots and associated microorganisms which may promote the solubilization of native soil P.

An increase in organic carbon status of the soil as a consequence of phosphate and farmyard manure application is attributed to more production of roots and their subsequent decomposition (Sundra Rao and Krishnan, 1963 and Chaudhary *et al.*, (1981). Significant increase in available phosphorus status of the soil with phosphorus and FYM application in the present investigation are in line with those reported by Havanagi and Mann (1970), Maurya and Ghosh (1972) and Chaudhary *et al.* (1981).

Like that of organic carbon and available phosphorus, farmyard manuring and phosphorus application in the present investigation have significantly increased the available potassium status of the soil which is attributed to addition of K through FYM as well as to enhanced mineralization of native K from the soil (Kwakye 1988).

5.3 Yield and Uptake of Nutrients :

An overall examination of data on yield of intercrop (Table 4.4.1, 4.4.2 and 4.4.3) revealed that when compared with zero tillage, all other tillage treatments in general significantly increased the grain/ seed and stover yields of test crops and uptake of N, P and K by them in the course of present study. Among various tillage treatments disc ploughing resulted in highest value of seed and stover yields of sorghum and green gram as well as the uptake of N, P and K by seed/ grain, stover and total harvest during both the years of research. Based on their degree of influencing the sorghum grain yield, sorghum equivalent yield and green gram seed yield, the tillage treatments can be placed in order as: disc ploughing = chisel ploughing = minimum tillage = conventional tillage > zero tillage.

The improvement in soil physical conditions in the present investigation as a consequence of tillage treatments (Table 4.1) lead to more moisture retention in the soil profile (Table 4.1.6.5), higher density of root and root mass production (Table 4.4.4) and better nutritional environment (Table 4.3) which ultimately resulted in higher grain/seed and stover yields of crops under study (Yadav, 1984). A significant positive correlation exist between root density and sorghum yield in 1990 and soil profile moisture at sowing as well as at harvest and sorghum equivalent yield during either year of research (Table 5.2).

Findings of Ram and Mohan (1971), Anderson and Cassel (1984), Rahman and Islam (1986), Hazra (1988), Ekeberg and Riley (1989), Dick *et al.* (1991) and Wielhelm *et al.* (1991) also coroborated the results of present investigation. Unger (1984) and Saxena (1987) have reported that deep ploughing makes the land suitable for maximum absorption of rainwater and exposes the lower layers of the soil to the sun and air as well as lowered the weed population at the initial stage of crop growth, which ultimately increased the crop yields.

Incorporation of farmyard manure and phosphate fertilization independently increased the grain /seed, stover as well as sorghum equivalent yields of intercrops. The application of phosphorus gave highest response only upto 13 kg P ha^{-1} level of fertilization (Table 4.4.1, 4.4.2 and 4.4.3)

Table 5.2 Correlation coefficient between independent variable (X) and dependent variable (Y)

Dependent (Y)	Independent (X)	Correlation Coefficient (r) 1989	1990
Basic infiltration rate (mm/hr^{-1})	Bulk density (mgm^{-3})	-	-0.738**
Hydraulic Conductivity (cm/hr^{-1})	Bulk density (mgm^{-3})	-	-0.647**
Water holding Capacity (%)	Basic infiltration rate ($mm\ hr^{-1}$)	-	0.729**
WHC (%)	Hydraulic conductivity ($cm\ hr^{-1}$)	-	0.669**
Hydraulic Conductivity (cm/hr^{-1})	Basic infiltration rate ($mm\ hr^{-1}$)	-	0.785**
Yield ($q\ ha^{-1}$)	Soil profile moisture (cm/45 cm)		
	At Sowing	0.811**	0.780**
	At harvest	0.838**	0.755**
Sorghum grain yield ($q\ ha^{-1}$)	Root density (g /cc)	0.826	0.931*
Sorghum grain yield ($q\ ha^{-1}$)	Total N uptake ($kg\ ha^{-1}$)	0.854**	0.871**
	Total P uptake ($kg\ ha^{-1}$)	0.827**	0.776**
	Total K uptake ($kg\ ha^{-1}$)	0.880**	0.753**
Green gram seed yield ($q\ ha^{-1}$)	Total N uptake ($kg\ ha^{-1}$)	0.723**	0.767**
	Total P uptake ($kg\ ha^{-1}$)	0.789**	0.704**
	Total K uptake ($kg\ ha^{-1}$)	0.844**	0.738**
Total uptake by sorghum ($kg\ ha^{-1}$)	Soil available phosphorus ($kg\ ha^{-1}$)		
N		0.721**	0.767**
P		0.838**	0.898**
K		0.611**	0.729**
Total uptake by green gram (kg/ha^{-1})	Soil available phosphorus (kg/ha)		
N		0.819**	0.646**
P		0.870**	0.803**
K		0.866**	0.697**
Sorghum yield ($q\ ha^{-1}$)	Soil available phosphorus ($kg\ ha^{-1}$)	0.642**	0.684**
Green gram yield ($q\ ha^{-1}$)	Soil available phosphorus ($kg\ ha^{-1}$)	0.672**	0.518**

* Significant at 5% level ** Significant at 1% level

The Karl Pearson's Coefficient of Correlation was determined which indicate a non significant linear relationship between phosphorus application and grain/seed yield of sorghum and green gram during either year of research. The 'r' values obtained were 0.576 and 0.616 for sorghum and 0.911 and 0.400 for green gram for the year 1989 and 1990, respectively. However, both the grain yield of sorghum and seed yield of green gram found suitable to fit in quadratic nature of regression equation, which represents the crop out put and phosphorus input relationship (Fig 5.1). The response curves indicate that phosphorus application gave quadratic response for both the crops during either year of research. Lack of response to higher level of P application in the present investigation is attributed to the marginally high level of initial available P status in the soil (15 kg P ha^{-1}, Table 3.2).

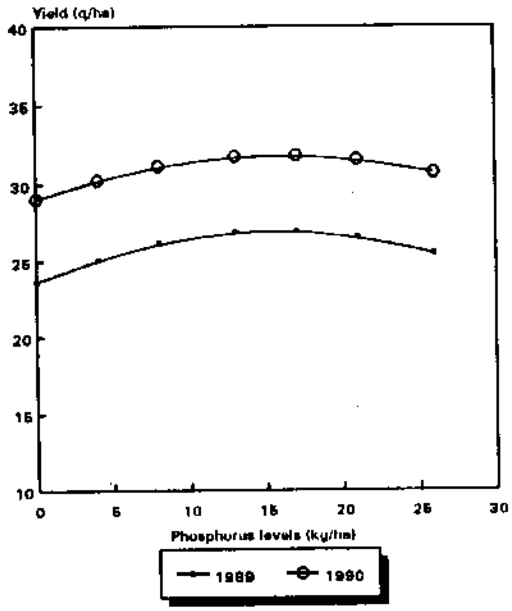
The response equation obtained for sorghum were:
$Y = 23.6001 + 0.4369\ x - 0.0140\ x^2$ $Y = 29.05 + 0.346918\ x - 0.010887\ x^2$ and for green gram were: $Y = 2.04 + 0.022769\ x - 0.000651\ x^2$ $Y = 2.52 + 0.09961\ x - 0.003402\ x^2$ respectively for the year 1989 and 1990.

Under rainfed conditions, plants heavily depend upon profile stored water to overcome moisture stress and the application of farmyard manure in the present study has resulted in enhanced harvesting of rain water which is evident from the increased moisture in the soil profile (Table 4.1.6.5) leading to better crop yields (Grewal *et al.* 1985). An increased yields of crops due to FYM application have also been reported by Bhatia and Shukla (1982), Gupta (1986), Bhoskar and Raikhelkar (1990).

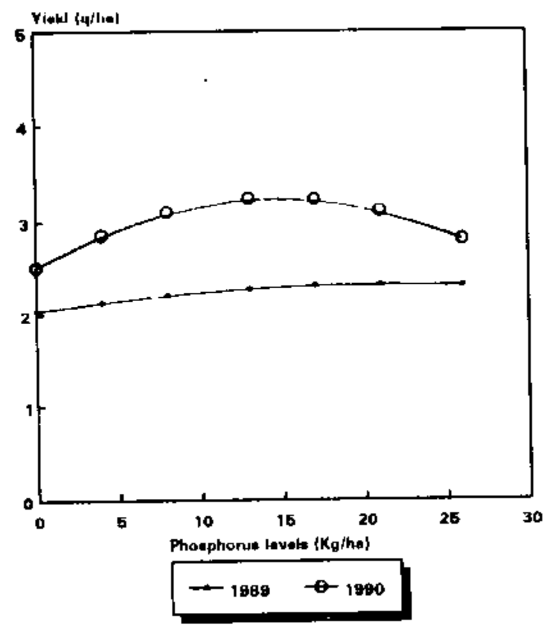
Application of phosphorus has significantly increased the yield of sorghum and green gram which is in agreement with the findings Singh (1982), Patel *et al.* (1984), Kothari and Saraf (1986), Kalira (1989) and Bishnoi and Balwinder Singh (1990). Phosphorus fertilization possibly influenced the vigour of the green gram plant which might have accelerated the nitrogen fixing power of the plant by increasing the activities of nodule bacteria and thus resulted in more dry matter as well as seed yields (Arnon, 1953 and Moolani, 1966). Further, phosphate fertilization have shown definitely beneficial effect in improving the sorghum and sorghum equivalent yields which is attributed to the improvement in nutritional status of the soil (Table 4.3) in addition to some physical parameters (Table 4.1) of the soil (Badanur and

FIG. 5.1 Regression of Sorghum grain and seed yield of Green Gram (y) on Phosphorus levels (x)

Sorghum



Green Gram



Venkata Rao, 1972, Chaudhary *et al.*, 1979). The higher nutrient utilization under the deep ploughing treatments in the present investigation was probably due to enhanced root growth (Table 4.4.4) that could have facilitated greater removal of nutrients and water from the soil apart from higher biomass production (Nielsen and Humphries, 1966; Terman *et al.*, 1976; Chaudhary and Sandha, 1983); Sharma and Ackarya (1987). Rahman and Islam (1986) have also reported that N, P , K uptake was always higher in deep tillage treatments as compared to traditional ploughing. Further, the presence of legumes between sorghum lines also reduced crop weed competition and accentuated uptake of nutrients (Abraham and Singh, 1984).

Incorporation of farmyard manure and phosphate fertilization alone as well as in combination have increased the NPK uptake by grain /seed, stover and total harvest of inter crops during both the years of investigation (Table 4.5.1 to 4.5.6). Increased uptake of NPK as a consequence FYM and phosphorus application is attributed to the favourable nutritional status of the soil (Table 4.3) resulting into increased biomass production of the crops (Table 4.4.1 and 4.4.2). There exist a highly significant positive correlation between yields of intercrops and total uptake of nutrients and coefficient of correlation (r) observed were 0.854 and 0.723 with N, 0.827 and 0.789 with P, and 0.880 and 0.844 with K uptake during kharif 1989 and 0.871 and 0.767 with N, 0.778 and 0.704 with P and 0.753 and 0.738 with K uptake during *Kharif* 1990 by sorghum and green gram,respectively. Similarly, a highly significant positive correlation between soil available phosphorus and total uptake of nutrients and grain/seed yield of sorghum and green gram as well were observed during either year of research (Table 5.5). Such an increased uptake of NPK under these treatments have also been reported by Bassiri *et al.* (1979), Schenk and Barber (1980), Zadode and Padole (1984), Panwar *et al.* (1988) and Balaguravaiah *et al.* (1989). Thus,improvement in soil physical conditions, soil moisture in the profile, nutrients status of the soil have resulted in more proliferated roots and enhanced uptake of nutrients which ultimately lead to increased production of grain/seed and stover of the crops under study in treatments receiving deeper tillage, FYM and phosphorus application in the present investigation.

5.4 Crop Quality and Economics :

Perusal of data on protein content of sorghum and green gram (Table 4.6.1 and 4.6.2) revealed that though tillage treatment in general have no-effect on protein content of the intercrops but FYM and phosphate application independently has increased the protein content of sorghum grain and in combination as well have increased the protein content of green gram seed during both the years of investigation. Further, FYM and phosphorus when applied in conjunction with various tillage systems have increased the protein content in green gram during either year of research (Table 4.6.2.3 and 4.6.2.4) however, the response to phosphate fertilization was only restricted to 13 kg P ha^{-1} level of application in FYM treated plots. An increased protein content in grain/seed of intercrops as a consequence of phosphate fertilization in the present investigation is attributed to the increased soluble carbohydrate content (Nandapuri and Singh, 1966). An increase in protein content as a consequence of phosphorus application is in agreement with the findings of Panwar *et al.* (1976), Zadode and Padole (1984), Ahmed *et al.* (1986) and Patel and Parmar (1986).

The findings of the experiment presented in the preceding chapter indicate that the treatment receiving disc ploughing was superior in improving soil physical and chemical properties, grain/seed and stover yields of inter crops and nutrient uptake and quality of crop as well and was closely followed by chisel ploughing. However, perusal of data on net return (Table 4.7) indicated that disc ploughing treatment remained statistically at par with the treatment receiving minimum and chisel tillage. The higher value of net return recorded under minimum tillage is attributed to a comparatively higher cost of treatment for disc and chisel ploughing. Deep tillage though had favourable effect on soil characteristics but reduces the net profit because of higher operating cost has also been reported by Sheikh *et al.* (1983). The economic consequences of different tillage systems are more difficult to assess, as they depend so much on farm size, investment patterns and fluctuating cost/price relations (Cartee, 1992).

6. SUMMARY AND CONCLUSION

Investigation on "Interactive effect of tillage and phosphate fertilization in conjunction with FYM on soil physical parameters and yield of sorghum intercropped with green gram under dry land" was carriedout for two consecutive years during kharif, 1989 and 1990 at Agricultural Research Substation Arjia Bhilwara.

The experiment consisted of 30 treatment combinations, comparising of 5 tillage practices conventional (desi plough), disc ploughing, chisel ploughing, minimum tillage (Disc harrowing) and zero tillage, 2 farmyard manure levels, 0 and 10 tons ha^{-1} and 3 phosphorus levels 0, 13 and 26 kg P ha^{-1}. The experiment was laid-out in split plot design, allocating tillage operations in main plots and combination of FYM and phosphorus fertilizer in subplots replicating each treatment in quadruple.

The results obtained during the course of investigation are summarized and concluded as follows :

6.1 Effect of Tillage :

Various tillage treatments when compared with zero tillage decreased the bulk density and increased the soil porosity in both surface and subsurface soil layers. However, the minimum value of bulk density and maximum value of soil porosity was recorded from the plot receiving disc ploughing treatment, which was followed by chisel ploughing, minimum tillage and conventional tillage treatment.

Like wise, an appreciable increase in water holding capacity, basic infiltration rate and hydraulic conductivity of the soil was observed under the treatments receiving various tillage operations when compared with zero tillage treatment. Treatment receiving disc ploughing recorded the maximum value of these parameters (37.89 %, 15.10 mm hr^{-1} and 1.92 cm hr^{-1} respectively) and was followed by chisel, minimum and conventional tillage treatments. The extent of increase in hydraulic conductivity was much more pronounced in surface soil than that observed under subsurface soil layers.

Various tillage treatments recorded a increased soil moisture in the samples drawn from different soil layers (0-15, 15-30 and 30-45 cm) at sowing as well as at harvest during either year of research. Among various tillage treatments disc ploughing was found to be the best in harvesting the rain water and water storage in the profile which was closely followed by chisel ploughing treatment.

When compared with zero tillage, various tillage operations decreased the organic carbon and increased the available phosphorus status of the soil though they did not influence the pH, EC and available potassium status of the soil to any significant level. The minimum value of organic carbon (0.38%) and the maximum value of soil available phosphorus (20.85 kg ha^{-1}) was recorded from the plot receiving disc ploughing.

From the view point of positive influence on soil physical and chemical properties various tillage treatments can be placed as disc > chiseller > minimum > conventional.

All the tillage treatments in general significantly increased the grain /seed and stover yields of intercrops over zero tillage treatment. However, disc ploughing resulted in highest grain/seed and stover yields of sorghum and green gram during both the years of investigation. The sorghum equivalent yield recorded under this treatment was 31.79 and 37.91 q ha^{-1} as against 27.25 and 34.60 q ha^{-1} recorded from the plot receiving zero tillage in kharif 1989 and 1990, respectively. Further, the pooled analysis indicated that 12.71 percent increase in sorghum equivalent yield was apparent due to disc ploughing treatment over the treatment receiving zero tillage.

The uptake of nitrogen, phosphorus and potassium by grain/seed, stover and total harvest of intercrops observed under various tillage treatments were significantly higher than that recorded from zero tillage treatment. Disc ploughing showed its superiority in recording the uptake of nutrients (NPK) over rest of other tillage treatment during both the years of investigation.

The highest root density and root dry weight of sorghum was observed in disc ploughing followed by chisel ploughing and minimum tillage treatments. Tillage treatments in general have no-effect on protein content of the intercrops.

Though disc ploughing treatment came out to be the best followed by chisel ploughing in influencing the soil physical and chemical parameters, providing more water and nutrients to the intercrops and ultimately in an increased biological and economic yields of crops under study but when compared with minimum tillage based on net return obtained remained statistically at par.

6.2 Effect of FYM :

Incorporation of farmyard manure at 10 tons ha^{-1} resulted in an improvement of soil physical properties viz., bulk density, total porosity, waterholding capacity, basic infiltration rate and hydraulic conductivity and ultimately in an increased moisture content in the soil profile.

FYM application though decreased the soil pH but increased the organic carbon, available phosphorus and potassium status of the soil. The increase in organic carbon content recorded was to tune of 53.6 percent over no-FYM treatment.

An increase in yields of intercrops and sorghum equivalent yield has been recorded as a consequence of farmyard manuring. The percent increase in grain/seed yields recorded was of the order 13.5 and 10.0 for sorghum and 24.0 and 11.6 for green gram during 1989 and 1990, respectively.

Incorporation of farmyard manure significantly increased the uptake of NPK by grain/seed, stover and total harvest of sorghum and green gram during either year of research. Further, FYM application resulted in increased protein content of sorghum and green gram during either year of research though the magnitude of increase was higher in green gram.

6.3 Effect of Phosphorus :

Phosphorus fertilization significantly lowered the bulk density and increased the soil porosity in surface and subsurface layer of soil examined, however, the effect was pronounced up to 26 kg P ha^{-1} in surface and at 13 kg P ha^{-1} in subsurface soil layer.

Phosphate fertilization, has significantly influenced the basic infiltration rate and the maximum value was observed under the highest level of phosphorus (26 kg P ha^{-1}) used. Similarly, phosphorus fertilization had a significant effect on the hydraulic conductivity of the soil and, the highest value was observed under the plot receiving highest level of phosphorus application irrespective of the depth of soil examined.

Application of phosphorus significantly increased the pH, EC, organic carbon and available phosphorus and potassium status of the soil though the response observed was in general at par with two levels of phosphorus applied. The phosphorus application at 13 kg P ha^{-1} significantly increased soil available phosphorus by 75.4 percent over no-phosphorus treatment.

Application of phosphorus significantly increased the grain/seed, stover and sorghum equivalent yields of intercrops though the responses recorded was significant only upto 13 kg P ha^{-1} level of fertilization.

Phosphate fertilization significantly increased the NPK uptake in grain/seed, stover and total harvest of the crops. In general the response obtained was only apparent upto 13 kg P ha^{-1} level of phosphorus applied.

Phosphorus application significantly affected the protein content of grain/seed of sorghum and green gram. The protein content increases with a subsequent increase in phosphorus level in green gram during either year of research.

6.4 Interaction Effect :

Disc ploughing when accompanied with farmyard manuring and phosphate fertilization at 26 kg P ha^{-1} has in general recorded significantly highest value of soil porosity and hydraulic conductivity in surface and subsurface soil layer and the lowest value of bulk density.

Disc ploughing in conjunction with farmyard manure was found to be the best treatment for improvement in soil physical parameters under the course of investigation which was closely followed by chisel operation. Further, the disc ploughing when applied in conjunction with 13 kg P ha^{-1} level of phosphate fertilization has also recorded an increased moisture content in the soil profile.

The highest value of soil available phosphorus (27.0 kg P ha^{-1}) was observed from the plot receiving disc ploughing in conjunction with FYM and highest level of phosphate fertilization which remained statistically at par with the treatment receiving chisel operation under same set of treatments.

Incorporation of farmyard manure in combination with phosphate fertilization increased the NPK uptake by grain/seed, stover and total harvest of intercrops during both the years of investigation.

FYM and phosphorus when applied with various tillage systems increased the protein content of green gram seed during 1989 and 1990, though the response to phosphate fertilization was restricted to 13 kg P ha^{-1} under the situation where farmyard manuring was incorporated, where as under no-FYM treatment, the response was found upto 26 kg P ha^{-1} level of phosphorus fertilization. Thus,the results of present investigation have conclusively indicated that:

1. A definite improvement in soil physical parameters, rain water harvest and chemical properties of the soils can be brought about by the use of deep tillage operations when applied alone or in conjunction with FYM and phosphate fertilization under dry land agriculture.

2. Disc ploughing used as a primary tillage was superior in improving soil physical and chemical properties condusive to better growth of crops under study by providing more moisture and nutrients which ultimately resulted in increased grain/seed and stover yields of intercrops and sorghum equivalent yield during either year of research.

3. Though based on economic analysis disc ploughing stands statistically at par with minimum tillage owing to involvement of higher operational cost but looking to the extent of improvement brought it can prove economically more sound on long run.

4. Maximum yield and better quality of intercrops can only be achieved when disc ploughing treatment was accompanied with incorporation of FYM and phosphorus fertilization at 13 kg P ha^{-1} level apart from application of recommended dose of Nitrogen (60 kg N ha^{-1}).

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APPENDIX I

Analysis of variance (MSS) for bulk density, soil porosity, water holding capacity, basis infiltration rate and hydraulic conductivity

Source of variation	d.f.	Bulk density		Soil porosity		Water holding capacity	Basic infiltration rate	Hydraulic conductivity	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm			0-15 cm	15-30 cm
Replications	3	0.00006	0.00015	0.077	0.213	24.563**	0.0003	0.003	0.001
Tillage (T)	4	0.024**	0.014**	34.736**	19.858**	39.049**	211.227**	2.522**	3.442**
Error (a)	12	0.00036	0.001	0.350	0.755	2.345	0.00025	0.003	0.002
FYM (F)	1	0.166**	0.172**	234.780**	244.645**	107.920**	460.247**	0.333**	0.471**
T X F	4	0.014**	0.002**	20.337**	2.589**	6.566	4.342**	0.012**	0.008
Phosphorus (P)	2	0.026**	0.003**	35.899**	4.169**	4.849	0.205**	0.252**	0.249**
T X P	8	0.003**	0.002**	3.658**	2.791**	6.004	0.006	0.014**	0.006
F X P	2	0.002*	0.003**	3.187*	4.762*	5.912	0.003	0.003	0.002
T X F X P	8	0.001**	0.002**	2.072**	3.272**	5.583	0.004	0.007	0.009*
Error (b)	75	0.001	0.0004	0.738	0.615	5.463	0.003	0.002	0.003

* Significant at 5%   ** Significant at 1%

APPENDIX II

Analysis of variance (MSS) for moisture content in different depth of soil profile

Source of Variation	d.f	At sowing						At Harvest					
		1989			1990			1989			1990		
		0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
Replications	3	0.015	0.358	0.154	0.153	0.145	0.450	0.034	0.081	0.382	0.205	0.598	0.167
Tillage (T)	4	1.854**	3.412**	1.891**	15.035**	31.856**	49.530**	14.737**	40.411**	37.939**	31.696**	24.227**	19.648**
Error (E)	12	0.281	0.166	0.109	0.162	0.166	0.806	0.110	0.119	1.307	0.652	0.485	0.604
FYM (F)	1	17.518**	24.855**	11.864**	52.845**	57.98**	63.288**	72.474**	106.00**	64.239**	76.293**	54.001**	63.544**
T X F	4	0.348	2.569**	0.708**	1.837	1.469*	1.681	1.327**	2.666*	1.441	1.232	1.317	1.653
Phosphorus (P)	2	0.050	0.072	0.091	14.631**	16.099**	17.896**	3.797**	6.684**	17.848**	3.516*	16.397**	17.525**
T X P	8	0.093	0.051	0.038	1.035*	1.056*	1.168	0.091	1.386	0.981	0.099	0.712	1.163
F X P	2	0.015	0.152	0.311	3.276*	4.325*	4.831	0.084	0.018	4.773*	0.162	3.817	5.165
T X F X P	8	0.080	0.055	0.018	0.624	0.457	0.523	0.017	0.044	0.465	0.009	0.591	0.500
Error (b)	75	0.218	0.212	0.141	0.324	0.349	1.638	0.348	0.349	0.923	1.128	1.536	1.785

*Significant at 5% **Significant at 1%

APPENDIX III

Analysis of Variance (MSS) for pH and EC

Source of Variation	d.f	pH	E.C.
Replications	3	0.003	0.001
Tillage (T)	4	0.001	0.002
Error (a)	12	0.003	0.002
FYM (F)	1	0.067**	0.001
T X F	4	0.000	0.001
Phosphorus (P)	2	0.010*	0.005*
T X P	8	0.000	0.008**
F X P	2	0.001	0.008**
T X F XP	8	0.000	0.003
Error (b)	75	0.003	0.001

*Significant at 5%   **Significant at 1%

APPENDIX IV

Analysis of variance (MSS) for O.C., available phosphorus and available potassium in soil

Source of variation	d.f	Organic Carbon	Available Phosphorus	Available Potassium
Replications	3	0.002	0.601	3393.267**
Tillage (T)	4	0.004**	42.830**	705.000
Error (a)	12	0.001	1.821	202.878
FYM (F)	1	0.867**	346.800**	3203.333**
T X F	4	0.001	4.603**	611.667*
Phosphorus (P)	2	0.004**	1065.733**	1570.000**
T X P	8	0.002	1.780	142.500
F X P	2	0.001	1.200	223.333
T X F X P	8	0.005**	4.053**	234.167
Error (b)	75	0.001	1.009	198.769

*Significant at 5%   ** Significant at 1%

APPENDIX V

Analysis of variance (MSS) for grain and stover yields of sorghum

Source of Variation	d.f.	Grain Yield		Stover Yield		Sorghum Equivalent Yield	
		1989	1990	1989	1990	1989	1990
Replications	3	0.480	0.067	22.959	5.530	15.980	3.086
Tillage (T)	4	2.433**	1.387**	114.281**	2.240	84.081**	49.760**
Error (a)	12	0.404	0.082	14.260	4.376	6.965	3.257
FYM (F)	1	13.474**	10.830**	125.011**	38.579**	556.594**	398.508**
T X F	4	0.709	0.396	5.262	12.215	11.779	12.609
Phosphorus (P)	2	4.906**	3.216**	4.962	2.713	158.673**	184.148**
T X P	8	0.088	0.109	10.796	6.657	1.808	2.413
F X P	2	0.036	0.061	5.242	0.774	0.285	12.620
T X F X P	8	0.127	0.091	7.190	5.046	3.959	3.676
Error (b)	75	0.609	0.336	9.906	4.492	14.853	11.025

*Significant at 5%   **Significant at 1% level of significance.

APPENDIX VI

Analysis of variance (MSS) for seed and stover yields of green gram

Source of Variation	d.f.	Seed Yield		Stover Yield	
		1989	1990	1989	1990
Replications	3	0.013	0.008	0.126	0.028
Tillage (T)	4	0.026**	0.022*	0.288**	2.563**
Error (a)	12	0.004	0.005	0.051	0.111
FYM (F)	1	0.302**	0.132*	0.823**	0.986*
T X F	4	0.005	0.004	0.016	0.006
Phosphorus (P)	2	0.042**	0.232**	1.236**	2.417**
T X P	8	0.004	0.021	0.072	0.342
F X P	2	0.008	0.038	0.050	0.026
T X F X P	8	0.006	0.013	0.022	0.020
Error (b)	75	0.007	0.021	0.041	0.169

*Significant at 5% **Significant at 1%

APPENDIX VII

Analysis of variance (MSS) for pooled analysis of equivalent yield (1989 & 1990)

Source of Variation	df	M S S
Year	1	2636.22**
Rep X year	6	9.533
Tillage	4	131.183*
Year X tillage	4	2.658
Error (a)	24	5.111
FYM	1	948.51**
Phosphorus	2	341.05**
FYM X Phosphorus	2	6.97
Year X FYM X Phosphorus	5	4.397
Tillage X FYM	4	4.257
Tillage X Phosphorus	8	1.85
Tillage X FYM X Phosphorus	8	2.18
Year X Tillage X FYM X Phosphorus	20	7.156
Error (b)	150	12.939

* Significant at 5%

** Significant at 1%

APPENDIX VIII

Analysis of variance (MSS) for nitrogen uptake of sorghum

Source of Variation	d.f.	1989			1990		
		Grain	Stover	Total	Grain	Stover	Total
Replications	3	11.667	46.469	86.419	12.086	33.201	16.098
Tillage (T)	4	276.698**	795.995**	2007.410**	132.844**	41.451	305.132**
Error (a)	12	14.839	48.571	64.072	5.292	16.806	29.900
FYM (F)	1	1375.090**	4476.625**	10813.877**	1601.134**	1176.663**	5522.971**
T X F	4	36.267	67.247	120.534*	68.156**	158.920**	245.177**
Phosphorus (P)	2	516.656**	648.884**	2252.899**	565.179**	197.400**	1407.814**
T X P	8	12.407	90.679*	129.504*	12.977	42.212*	27.911
F X P	2	17.802	151.207*	69.813	9.102	52.777	76.200
T X F X P	8	10.610	18.792	43.014	11.457	37.091	43.785
Error (b)	75	21.613	33.562	47.666	16.305	18.483	33.531

*Significant at 5% **Significant at 1%

APPENDIX IX

Analysis of variance (MSS) for phosphorus uptake by grain and stover by sorghum

Source of Variation	d.f.	1989			1990		
		Grain	Stover	Total	Grain	Stover	Total
Replications	3	0.787	16.180	15.500	0.627	2.427	2.303
Tillage (T)	4	17.955**	98.089**	195.749**	13.014**	6.034	35.161**
Error (a)	12	2.469	10.745	14.995	0.801	2.923	4.597
FYM (F)	1	114.190**	444.716**	1009.605**	48.157**	206.092**	453.496**
T X F	4	2.014	10.830	9.878	1.361	9.744*	9.822*
Phosphorus (P)	2	105.345**	260.104**	664.550**	74.507**	112.615**	357.369**
T X P	8	7.848**	6.448	19.596*	0.778	4.028	4.209
F X P	2	0.733	4.004	2.762	0.473	17.250**	23.437**
T X F X P	8	2.791	4.441	11.340	0.181	4.186	3.876
Error (b)	75	1.931	7.082	8.445	1.240	3.027	3.730

*Significant at 5%   **Significant at 1%

APPENDIX X

Analysis of variance (MSS) for phosphorus uptake by grain and stover by sorghum

Source of Variation	d.f.	1989			1990		
		Grain	Stover	Total	Grain	Stover	Total
Replications	3	5.150	446.674	504.560	0.659	73.412	81.669
Tillage (T)	4	85.601**	4776.897**	6123.118**	55.096**	431.208	557.015
Error (a)	12	6.451	478.637	459.530	3.773	245.535	258.954
FYM (F)	1	416.946**	16574.415**	22248.976**	382.363**	6574.330**	10127.674**
T X F	4	15.775	237.026	331.069	5.548	181.909	154.771
Phosphorus (P)	2	235.203**	1344.594	2698.801**	245.113**	2073.972**	3689.877**
T X P	8	1.649	388.447	406.304	7.065	166.520	155.514
F X P	2	4.036	915.582	807.172	1.250	541.314	582.533
T X F X P	8	2.971	291.109	328.178	2.430	352.828	383.561
Error (b)	75	13.776	534.713	543.508	15.348	282.235	276.858

*Significant at 5% **Significant at 1%

APPENDIX XI

Analysis of variance (MSS) for nitrogen uptake by grain and stover by green gram

Source of Variation	d.f.	1989			1990		
		Seed	Stover	Total	Seed	Stover	Total
Replications	3	4.185*	7.102	16.801*	2.076	1.865	1.137
Tillage (T)	4	10.018**	21.864**	57.638**	7.990*	168.322**	234.651**
Error (a)	12	1.101	2.245	2.890	1.429	5.637	9.911
FYM (F)	1	240.046**	114.426**	685.938**	131.599**	187.967**	634.120**
T X F	4	1.620	1.360	1.427	1.844	0.707	2.802
Phosphorus (P)	2	26.066**	92.495**	216.157**	77.305**	146.190**	435.848**
T X P	8	1.512	3.307	2.447	5.211	16.376	11.942
F X P	2	4.782	2.622	10.960	11.454	2.155	16.825
T X F X P	8	1.181	0.631	1.327	4.351	2.917	9.328
Error (b)	75	2.299	1.900	4.281	5.612	8.408	13.314

*Significant at 5%   **Significant at 1%

APPENDIX XII

Analysis of variance (MSS) for phosphorus uptake by green gram

Source of Variation	d.f.	1989			1990		
		Seed	Stover	Total	Seed	Stover	Total
Replications	3	0.038*	0.203*	0.307*	0.028	0.070	0.072
Tillage (T)	4	0.200**	1.087**	2.111**	0.369**	3.442**	5.953
Error (a)	12	0.008	0.055	0.053	0.014	0.181	0.239
FYM (F)	1	1.265**	11.344**	20.185**	2.462**	22.224**	39.479**
T X F	4	0.025	0.126	0.129	0.011	0.312	0.297
Phosphorus (P)	2	0.604**	10.154**	15.699**	3.410**	17.390**	36.166**
T X P	8	0.022	0.192**	0.179*	0.057	0.735**	0.770**
F X P	2	0.028	1.935**	2.353**	0.422**	3.303**	5.104**
T X F X P	8	0.014	0.108	0.107	0.038	0.116	0.211
Error (b)	75	0.025	0.051	0.076	0.057	0.201	0.247

*Significant at 5%　　**Significant at 1%

APPENDIX XIII

Analysis of variance (MSS) for potassium uptake by green gram

Source of Variation	d.f.	1989			1990		
		Seed	Stover	Total	Seed	Stover	Total
Replications	3	0.184	0.977	1.467*	0.137	0.154	0.226
Tillage (T)	4	0.457**	1.399*	2.972**	0.350*	13.515**	17.484**
Error (a)	12	0.081	0.366	0.394	0.072	0.914	1.220
FYM (F)	1	6.942**	14.014**	40.682**	7.094**	10.111**	34.144**
T X F	4	0.101	0.026	0.134	0.016	0.324	0.263
Phosphorus (P)	2	1.798**	11.318**	21.938**	5.133**	20.480**	46.116**
T X P	8	0.073	0.572*	0.410	0.251	1.965	1.121
F X P	2	0.130	0.300	0.548	0.696	0.554	1.883
T X F X P	8	0.098	0.144	0.266	0.249	0.131	0.478
Error (b)	75	0.110	0.229	0.317	0.280	1.276	1.376

*Significant at 5%　　**Significant at 1%

APPENDIX XIV

Ayalysis of variance (MSS) for protein content in sorghum and green gram seed

Source of Variation	d.f.	Sorghum		Green gram	
		1989	1990	1989	1990
Replications	3	0.018	0.111	0.329	0.189
Tillage (T)	4	0.184	0.046	0.194	0.426
Error (a)	12	0.084	0.058	0.387	0.124
FYM (F)	1	2.101**	1.544**	284.500**	154.133**
T X F	4	0.379	0.075	3.320*	1.671**
Phosphorus (P)	2	0.916**	0.433**	24.075**	9.941**
T X P	8	0.055	0.022	3.904**	0.585*
F X P	2	0.185	0.064	3.143*	0.660*
T X F X P	8	0.031	0.013	2.994*	0.681*
Error (b)	75	0.099	0.056	0.650	0.120

*Significant at 5% **Significant at 1%

APPENDIX XV

Analysis of Variance (MSS) for Net Return

Source of Variation	d.f.	1989	1990
Replications	3	3616188	797457
Tillage (T)	4	25873458**	4156186*
Error (a)	12	1551058	815671
FYM (F)	1	16298018**	2095106
T X F	4	1710751	1413189
Phosphorus (P)	2	11165664**	16906512**
T X P	8	1081373	871651
F X P	2	431162	1469600
T X F X P	8	1120376	893837
Error (b)	75	1820976	1102596

*Significant at 5% **Significant at 1%

APPENDIX XVI

Economics of Treatment

Treatment	Gross Returns (Rs) 1989	Gross Returns (Rs) 1990	Cost of Cultivation (Rs)	Net Returns (Rs) 1989	Net Returns (Rs) 1990	Mean	Mean B:C Ratio
$T_1F_0P_0$	15516.75	14893.75	4930	10586.75	9963.75	10275.25	2.08
$T_1F_0P_{13}$	15645.25	16719.25	5193	10452.25	1126.25	10989.25	2.11
$T_1F_0P_{26}$	16151.50	1581.75	5456	10695.50	10358.75	10527.12	1.93
$T_1F_{10}P_0$	16264.75	15622.50	6130	10134.75	9492.50	9813.62	1.60
$T_1F_{10}P_{13}$	17905.75	17281.00	6393	11512.75	10888.00	11200.37	1.75
$T_1F_{10}P_{26}$	17683.75	17180.75	6656	11027.75	10524.75	10776.25	1.62
$T_2F_0P_0$	15533.75	15565.75	4680	10853.75	10885.75	10869.75	2.32
$T_2F_0P_{13}$	16310.25	16099.50	4943	11367.25	11156.50	11261.87	2.28
$T_2F_0P_{26}$	17019.25	16023.75	5206	11813.25	10817.75	11315.80	2.17
$T_2F_{10}P_0$	17232.25	16611.25	5880	11352.25	10731.25	11041.75	1.88
$T_2F_{10}P_{13}$	18475.00	18538.75	6143	12332.00	12395.75	12363.87	2.01
$T_2F_{10}P_{26}$	18702.00	17205.25	6406	12296.00	10799.25	11547.62	1.80
$T_3F_{0P}0$	15522.75	14502.75	4930	10592.75	9572.75	10082.75	2.04
$T_3F_0P_{13}$	16497.50	15924.25	5193	11304.50	10731.25	11017.87	2.12
$T_3F_0P_{26}$	16498.50	15555.50	5456	11042.50	10099.50	10571.00	1.94
$T_{3F}10P_0$	16201.25	16204.00	6130	10071.25	10074.00	10072.62	1.64
$T_3F_{10}P_{13}$	18652.75	19362.00	6393	12259.75	12969.00	12614.37	1.97
$T_3F_{10}P_{26}$	18199.75	17045.50	6656	11543.75	10389.50	10966.62	1.65
$T_4F_0P_0$	1496.50	14289.50	4280	10681.50	10009.50	10345.50	2.42
$T_4F_0P_{13}$	16067.00	16351.25	4543	11524.00	11808.25	11666.12	2.57
$T_4F_0P_{26}$	15518.50	15974.75	4806	10712.52	11168.75	10940.62	2.28
$T_4F_{10}P_0$	17948.00	16270.50	5480	12468.00	10790.50	11629.25	2.12
$T_4F_{10}P_{13}$	18840.75	17497.50	5743	13097.75	11754.50	12426.12	2.16
$T_4F_{10}P_{26}$	18200.00	17065.75	6006	12193.75	11059.75	11626.75	1.93
$T_{5F}0P0$	11646.00	14168.75	4180	7466.00	9988.75	8727.37	2.09
$T_5F_0P_{13}$	14523.00	14559.25	4443	10080.00	10116.25	10098.12	2.27
$T_5F_0P_{26}$	13586.25	14998.75	4706	8880.25	10292.75	9586.50	2.04
$T_5F_{10}P_0$	14907.00	15358.75	5380	9527.00	9978.75	9752.87	1.81
$T_5F_{10}P_{13}$	16012.75	16458.50	5643	10369.75	10815.50	10592.62	1.88
$T_5F_{10}P_{26}$	14828.25	15703.50	5906	8922.25	9797.50	9359.87	1.58

Treatment Cost : Cost of Cultivation : Rs. 4180 ha^{-1}

Tillage : Conventional tillage (*Desi plough*) : Rs 750 ha^{-1}; Disc Ploughing : Rs 500 ha^{-1}; Chisel Ploughing : Rs. 750 ha^{-1}; Minimum tillage (*Disc harrowing*) : Rs. 100 ha^{-1}

FYM : Rs 120/ton **Phosphorus :** Rs.1.40/kg

Cost of byproducts(q ha^{-1}): Grain/Seed:Sorghum Rs 300, Green gram Rs 800, Fodder: (Intercrops) Rs 60