“EVALUATION OF SOIL TEST BASED FERTILIZER PRESCRIPTION EVOLVED FOR MUSTARD (*BRASSICA JUNCEA*) CROP IN *VERTISOL”*

M.Sc. (Ag.) THESIS

BY

ONKAR SINGH

DEPARTMENT OF SOIL SCIENCE

AND AGRICULTURAL CHEMISTRY

FACULTY OF AGRICULTURE

COLLEGE OF AGRICULTURE

INDIRA GANDHI KRISHI VISHWAVIDYALAYA

RAIPUR (Chhattisgarh)

2020

"EVALUATION OF SOIL TEST BASED FERTILIZER PRESCRIPTION EVOLVED FOR MUSTARD (*BRASSICA JUNCEA*) CROP IN *VERTISOL*"

Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)

by

ONKAR SINGH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Science

in

Agriculture

(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)U.E.

ID. No. 20181930025 **ID No. 120118210**

JULY, 2020

CERTIFICATE - I

This is to certify that the thesis **"Evaluation of soil test based fertilizer prescription evolved for mustard (*Brassica juncea*) crop in *vertisol.*"** submitted in partial fulfillment of the degree of **Master of Science in Agriculture** of the Indira Gandhi Krishi Vishwayidyalaya, Raipur, is a record of the bonafide research work carried out by **Onkar Singh** under my guidance and supervision. The subject of the thesis has been approved by student s Advisory Committee and Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or certificate course. All the assistance and help received during the course of the investigations have been duly acknowledged.

Chairman

Date: 7/7/20

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Chairman (Dr.L.KSrivastava)

Member (Dr. V.N. Mishra)

Member (Dr. H.L. Sonboir)

Member (Dr. R.R. Saxena)

CERTIFICATE- II

This is to certify that the thesis entitled **"Evaluation of soil test based fertilizer prescription evolved for mustard (*Brassica juncea*) crop in *vertisol*"** submitted by **Onkar Singh** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfilment of the requirements for the degree of Master of science in Agriculture in the Department of Soil Science and Agricultural Chemistry has been approved by the external evaluator and Student's Advisory Committee after oral examination, ***under the chairmanship of Head of the Department.***

Major Advisor

Date 13/7/20

Signature of Head of the Department

(Name Kaushlendra Tekia**)**

Faculty Dean _____

Approved/ Not approved

Director of Instruction _____

ACKNOWLEDGEMENT

I avail this golden opportunity to express my heartfelt sense of gratitude to those who helped me to complete my research possible. These words wouldn't be enough to compensate for their great help and co-operation.

I would like to acknowledge my indebtedness and render my warmest thanks to my learned and revered advisor Dr. L.K.Srivastava*, Senior Scientist, Indira Gandhi Krishi Vishvavidyalaya, Raipur and Chair Person of my Advisory Committee, who made this work possible. His friendly guidance, keen interest and expert advice have been invaluable throughout all stages of the work.*

I express my sincere gratitude to the worthy members of my advisory committee, Dr. V.N. Mishra, *Professor and Scientist, Department of Soil Science,* Dr. H.L. Sonboir*, Scientist, Department of Agronomy*, Dr. R.R. Saxena, *Associate professor, Department of Statistics for their inspiring guidance and critical assessment of the manuscript.*

My sincere thanks also goes to Hon'ble Vice-Chancellor Dr. S.K. Patil, Dr. S.S. Rao, Dean, COA, Raipur, Dr. M.P. Thakur, Director of Instructions, Dr.(Major) G.K. Shristava, Dean Students Welfare, IGKV, Raipur for providing necessary facilities and help during the course of investigation.

I express my gratification and venerable regards to Dr. K. Tedia, Head of the Department of Soil Science for extending necessary facilities as and when required. Financial assistance in the form of stipend provided by the university is fully acknowledged.

I heartily thank Dr. R.N. Singh (Professor and Scientist),Dr.Anurag (Professor and Scientist),Shri Vinay Bachkaiya (Scientist) and Shri.

Gourav Jatav (Scientist) for his valuable guidance and support. Without his precious support it would not be possible to finish my research.

I can hardly overlook the co-operation, timely help, moral support extended by the my seniors Miss. Shambhavi Dubey, Miss. Anusuiya Panda, and classmates Riya Swati, Vivek, Param, Rajesh, Arun, and Chhaviraj who boosted me up in periods of mental stress & strain.

The person with the greatest indirect contribution to this work is my Grandparents Shri.Vishwanath Singh and Late Shrimati Shyamvati Singh, my parents Sshri. Rakesh Raman Singh and Shrimati Rita Singh. I am extremely indebted to them. Heartfelt thanks to my beloved brother Shri Krishna Pratap Singh, Late Shri Ashish Kumar Singh, Shri Chandra Pratap Singh, Shri Ajeet Singh, Shri Mayank Singh and sister Mrs. Pratibha Singh , my beloved children Ayan, Nayan, Rishiraj, Pulkeet, Pratyush, Aradhaya, Saurya, Pankhudi, Yashika, and Abhiyuddh for their constant support and love.

Onkar Singh

Department of soil Science & Agricultural chemistry, IGKV, Raipur

Date-

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LIST OF ABBREVIATIONS

ABBREVIATIONS	DESCRIPTIONS
%	Per cent
@	At the rate of
BGA	Blue green algae
dS/m	Deci Simens per meter
et al	Et alii (and other)
Fig	Figure
FYM	Farmyard manure
GM	Green manure
Ha	Hectare
i.e.,	id est (that is)
Kg	Kilogram
Kg/ha	kilogram per hectare
Mg/kg	Milligram per kilogram
min.	Minimum
max.	Maximum
Cm	Centimeter
P	Page
t/ha	Tonne per hectare
^{o}C	Degree Celsius
SOC	Soil organic carbon
INM	Integrated nutrient management
LTFE	Long term fertilizer experiment
OM	Organic matter
Viz.	Namely
GM	Green manure

THESIS ABSTRACT

a)	Title of the Thesis	: **Evaluation of soil test based fertilizer prescription evolved for mustard (*Brassica juncea*) crop in *Vertisol***
b)	Full Name of the Student	: Onkar Singh
c)	Major Subject	: Soil Science & Agricultural Chemistry
d	Name and address of the Major Advisor	: Dr. L. K. Srivastava Department of Soil Science and Agricultural Chemistry, IGKV, Raipur(C.G.)
e)	Degree to be awarded	: M.Sc. (Ag.) Soil Science & Agricultural Chemistry

Signature of the Student

Signature of the Major Advisor

Date 7/7/20

Signature of the Head of the Department

ABSTRACT

Field experiment was carried out for **"Evaluation of soil test based fertilizer prescription evolved for mustard (*Brassica juncea*) crop in *Vertisol*"** during *Rabi* season, 2019. The objectives of the study were (i) To test the validity of the fertilizer equation derived for mustard. (ii) To monitor the efficiencies of soil test and fertilizer nutrients applied with FYM. The experiment was laid out in factorial randomize block design having sixteen treatments with replicated thrice. The each treatments, T_1 - Control; T_2 - N_{120} P_{60} K_0; T_3 - N_{120} P_0 K_{40}; T_4 - N_0 P_{60} K_{40}; T_5 - N_{120} P_{60} K_{40}; T_6 - YT 14 q/ha; T_7 - YT 18 q/ha and T_8 - YT 22 q/ha were applied alone and with FYM @ 5 t/ha. Fertilizer prescription equation for mustard developed in previous under STCR project as FN = 12.86 Y - 0.58 SN - 0.30 FYM, FP_2O_5 = 4.09 Y – 2.51 SP – 0.33 FYM and FK_2O = 4.50 Y – 0.08SK – 0.07 FYM were used to calculating the fertilizer doses for yield targeted treatments. The soil of experimental field comes in the soil's order of *Vertisols*, locally known as *Kanhar*. The soil of experimental field is clay in texture, having pH 7.4, EC 0.18 dSm-1, OC 0.58 percent and available N, P and K as 200, 16.2 and 308 kg ha^{-1}, respectively.

The grain and straw yield was recorded significantly higher (21.79 q/ha) with the treatment T_8 (that received the STCR based fertilizer dose to achieve yield target of 22q/ha) followed by T_5 (N_{120} P_{60} K_{40}), T_7 (YT 18 q/ha), T_3 ($N_{120}P_0K_{40}$). The N P K uptake in grain, straw and total by mustard crop were significantly higher under treatment T_8 (Yield target of 22 q/ha). Soil test based fertilizer dose for yield target of 22 q/ha found higher response and response ratio as compare to T_5 treatment (N_{120} P_{60} K_{40}). Higher efficiency of applied fertilizer nutrients were found under STCR based fertilizer application. The average values for fertilizer efficiencies of N, P and K were estimated as 33.83, 18.86 and 76.46 percent respectively. Similarly, the nutrient contributions from soil were estimated for N, P and K as 22.07, 55.22

and 8.47 percent, respectively. The efficiencies of organic source (FYM) were observed as 17.21 % N, 8.12 % P and 8.42 % K.

The higher cost of cultivation was calculated with the treatment T_5 (N_{120} P_{60} K_{40}) followed by highest yield target treatment T_8 (YT 22 q/ha) due to higher application of fertilizer doses. Gross return and B:C ratio from mustard was recorded higher with the treatment T_8 (YT 22.0 q/ha). followed by treatment T_5 (N_{120} P_{60} K_{40}) and T_7 (YT 18 q/ha). Application of FYM also showed higher gross return and B:C ratio over sole application of inorganic fertilizers.

शोध सारांश

अ)	शोध का शीर्षक	:	कन्हार मृदा में सरसो (ब्रैसिका जंसिया) की फसल के लिए विकसित मृदा परीक्षण आधारित उर्वरक समीरकण का मूल्यांकन
ब)	छात्र का पूरा नाम	:	ओंकार सिंह
स)	मुख्य विषय	:	**मृदा विज्ञान एवं कृषि रसायन**
द)	मुख्य सलाहकार का नाम एवं पता	:	डॉ.एल.के.श्रीवास्तव वरिश्ठ वैज्ञानिक, मृदा विज्ञान एवं कृशि रसायन विभाग इं.गा.कृ.वि., रायपुर (छ.ग.)
इ)	उपाधि का नाम	:	स्नातकोत्तर (कृषि), **मृदा विज्ञान एवं कृषि रसायन**

छात्र के हस्ताक्षर

मुख्य सलाहकार के हस्ताक्षर

दिनॉकः 7/7/20

विभागाध्यक्ष के हस्ताक्षर

सारांश

कन्हार मृदा में सरसो (ब्रैसिका जंसिया) की फसल के लिए विकसित मृदा परीक्षण आधारित उर्वरक समीकरण का मूल्यांकन करने के लिए वर्श 2019 में रबी के मौसम में क्षेत्र प्रयोग किया गया। अध्ययन का मुख्य उद्देश्य – i. सरसो के लिए व्युत्पन्न उर्वरक समीरकण की वैधता का परीक्षण करना। ii. गोबर की खाद् (FYM) के साथ लागू मृदा परीक्षण और उर्वरक पोशक तत्वों की क्षमता की निगरानी करना था। प्रयोग को तीन प्रतिकृति के साथ कुल सोलह उपचारों वाले गुटीय याद्च्छिक ब्लाक डिजाईन (Factorial Randomized block design) में रखा गया था। प्रत्येक उपचार टी1 नियंत्रण, टी2 (N120 P60 K0) टी–3 (N120 P0 K40), टी4 (N0 P60 K0), टी5 (N120 P60 K40), टी6 (लक्षित उपज 14 क्विं/हेक.), टी7 (लक्षित उपज 18 क्विं/हेक.), टी8 (लक्षिंत उपज 22 क्विं/हेक.) अकेले उर्वरक के साथ (कुल उपचार –8) और गोबर की खाद् (FYM) @ 5. टन/हेक. के साथ (कुल उपचार–8) लगाए गये थे। प्रयोग में STCR परियोजना के तहत् पूर्व में सरसों के लिए विकसित उर्वरक समीकरण ((FN=12.86Y-0.58SN-0.30FYM, FP=4.09Y-2.51SP-0.33FYM, FK=4.50Y-0.08SK-0.07FYM) का

K40), टी6 (लक्षित उपज 14 क्विं/हेक.), टी7 (लक्षित उपज 18 क्विं/हेक.), टी8 (लक्षित उपज 22 क्विं/हेक.) अकेले उर्वरक के साथ (कुल उपचार –8) और गोबर की खाद् (FYM) @ 5. टन/हेक. के साथ (कुल उपचार–8) लगाए गये थे। प्रयोग में STCR परियोजना के तहत् पूर्व में सरसों के लिए विकसित उर्वरक समीकरण ((FN=12.86Y-0.58SN-0.30FYM, FP=4.09Y-2.51SP-0.33FYM, FK=4.50Y-0.08SK-0.07FYM) का उपयोग उर्वरकों की गणना करने के लिए किया गया था। प्रायोगिक क्षेत्र मृदा कन्हार (*Vertisol*) थी। प्रयोगात्मक क्षेत्र की मिट्टी बनावट में चिकनी (Clay) थी। जिसका P^H=7.4, विद्युत चालकता=0.18dSm^{-1}, कार्बनिक कार्बन– 0.58 प्रतिशत और उपलब्ध नत्रजन, स्फुर व पोटाश क्रमशः 200,16.2 और 308 किलोग्राम प्रति हेक्टेयर थे।

21.79 क्विं/हेक्टेयर दानो की उपज के साथ अधिकतम उपज उपचार टी8 जो कि STCR आधारित उर्वरक मात्रा 22 क्विं/हे. के उपज लक्ष्य को प्राप्त करने के लिए दिया गया था प्राप्त हुआ। इसके बाद उपचार टी5 (N120 P60 K40), उपचार टी7 (लक्षित उपज 18 क्विं/हेक.), उपचार टी3 (N120 P0 K40), में अधिकतम उपज प्राप्त हुआ। सरसो की फसल में कुल नट्रोजन, स्फुर, पोटाश का ग्रहण उपचार टी8 (लक्षित उपज 22 क्वि./हे.) में उच्च स्तर पर प्राप्त हुआ। उपचार टी8 (लक्षित उपज 22 क्वि./हे.) प्रतिकिया और प्रतिकिया अनुपात (Response & Response Ratio) उपचार टी5 (N120 P60 K40), की तुलना में सकारात्मक रूप से अधिक प्राप्त हुआ। उपयोग किये गये उर्वरक की दक्षता STCR आधारित उर्वरक अनुप्रयोग के अंतर्गत उच्च प्राप्त हुई। नइट्रोजन, स्फूर व पोटाश तत्वों की उर्वरक दक्षता का औसत मान क्रमशः 33.83, 18.86 और 76.46 प्रतिशत प्राप्त हुआ। इसी प्रकार मिट्टी से पोषक तत्वों के योगदान का आकलन क्रमशः नाइट्रोजन, स्फूर व पोटाश के लिए क्रमशः 22.07,55.22 और 8.47 प्रतिशत प्राप्त हुआ। कार्बनिक स्त्रोत की दक्षता नाइट्रोजन के लिए 17.21 प्रतिशत, स्फुर के लिए 8.12 प्रतिशत और पोटाश के लिए 8.42 प्रतिशत देखी गई।

खेती की लागत की गणना उपचार टी5 (N120 P60 K40), के साथ उच्च प्राप्त हुई। इसके बाद उर्वरक की अधिक उच्चतम लक्षित उपज में मात्रा देने के कारण उपचार टी8 (लक्षित उपज 22 क्वि./हे.) में प्राप्त हुई। सरसो में सकल आय और लाभ : लागत (B:C) अनुपात टी8 (लक्षित उपज 22 क्वि/हे.) के साथ उच्च दर्ज किया

गया। इसके बाद उपचार टी5 (N120 P60 K40), और टी7 (लक्षित उपज 18 क्विं/हेक.), में उच्च लाभ : लागत अनुपात प्राप्त हुआ। केवल अकार्बनिक उर्वरकों के उपभोग की अपेक्षा गोबर की खाद (FYM) के साथ उपचारों में भी सकल आय और लाभ : लागत अनुपात उच्च प्राप्त हुआ।

CHAPTER I

INTRODUCTION

To enhance profitability from a crop under different soil-climate conditions, it is necessary to have knowledge of applying fertilizer in right element, right amount, right methods and right time. Soil testing based fertilizer recommendation is the best tools for balance nutrition to a crop. Troug (1960) was first given the concept to calculating the optimum fertilizer recommendations for yield targets and Ramamoorthy et al., (1967) were further modified that the targeted yield model, it is possible only through the fertility gradient field experimental technique which is the most comprehensive approach of fertilizer application for fixing yield targets by including soil test values, nutrient requirement of the crop, contribution of nutrients from soil, fertilizers and manures. A definite amount of nutrients must be applied to achieving a definite targeted yield of a crop and these nutrient requirements can be estimated by consideration the contribution of native soil available nutrients and applied fertilizer nutrients (Subba Rao and Srivastava, 2001).

The deficiency of a particular nutrient is identified with help of soil test based application of plant nutrients and the correction of the nutrients imbalance in soil helps to harness the synergistic effects of balanced fertilization (Rao and Srivastava, 2000). The higher response ratio and benefit: cost ratio is also found with help of soil test based application of plant nutrients applied in desired proportion. Balanced fertilization does not only mean the application of right quantity of fertilizers for crop growth to mitigate this anomaly but it is also the right time, mode and sources of application. The nutrient management strategies involving the use of chemical fertilizers but also supplemented with organic manure and bio fertilizers.

The expected crop yield response to nutrient application is must required for fertilizer recommendations. It is a function of crop nutrient needs, supply of

nutrients from indigenous sources, and the fate of the fertilizer applied (Dobermann et al., 2003). The fertilizers cost has increase up, so, there is need to use of other options for supply of required quantity mainly based on resources available of farmers. Soil properties; enhance nutrient recovery, productivity of crops and optimum biological activities were improved due to use of organics. The maximum utilization of the genetic potential of a crop is restricted in lower nutrient use efficiency due to imbalanced use of chemical fertilizers.

Soil test based fertilizer application is popular among the farming community because it is the highly suitable method for balance fertilization. Targeted yield approach provides the balance crop nutrient management on basis of optimum resources utilization. Soil test gives a correct evaluation of fertility status and predicts fertilizer required for a definite yield goals or maximum return. Fertilizer prescription equation is a useful tool to appropriate need based fertilizer application. In this technique, the fertilizers are recommended separately for different field to a definite yield targets on the basis of soil-test depending upon the availability of fertilizer inputs. The fertilizer application on the soil test based eliminates over or under usage of fertilizer inputs therefore, fertilizer use efficiency and crops yield is increase and maintenance of soil fertility.

After soybean and palm oil, rapeseed and mustard is most important oilseed crop in the world and it comes in third position. Rapeseed and mustard (*Brassica spp*.) contributes 28.6% in the total production of oilseeds out of the seven edible oilseeds cultivated in India. In India, Rapeseed-mustard after groundnut comes in second important crop which is sharing 27.8% under edible oilseed economy in the India's. The rapeseed-mustard is grown in about 3% area out of 14.1% of the total oilseeds cropped area in India. The rapeseed-mustard group broadly includes Indian mustard, yellow sarson, brown sarson, raya, and toria crops. Indian mustard (*Brassica juncea* (L.) Czernj. & Cosson) is predominantly cultivated in Rajasthan, UP, Haryana, Madhya Pradesh, and Gujarat. It is also grown in some area of South India including Andhra Pradesh, Tamil Nadu and Karnataka and its come under

non-traditional areas. Rapeseed and mustard can be also raised well under both irrigated and rainfed conditions.

Fertilizer consumption in India was 89.8 thousand tons in 1950-51 which has become 25.53 mt in 2012-2013 (Agricultural Statistics at a Glance, 2014) in future the problem will aggravate as more grain has to be produced dew to continuously increasing population. Therefore, the application of nutrients needs to be increased to keep the soil fertile. The high yield is sustained when soil must have adequate supply of nutrients. The nutrient supplying capacity of soil is becoming a limited factor due to continuous intensive cultivation and use of high nutrients demands. This declining factor productivity is largely due to imbalanced fertilization along with fertilizer cost growing up. This needs to be supplied very carefully to maintain the soil fertility and obtain maximum yield. Soil testing as a tool for judicious fertilizer use is well recognized practices all over the world which take care of too little, too much or disproportionate application of nutrients.

Keeping this in view, it may be quite worthy to study on "**Evaluation of soil test based fertilizer prescription evolved for mustard (*Brassica juncea*) crop in *Vertisol***" derived during previous season with the following objectives:

1. To test the validity of the fertilizer equation derived for mustard.
2. To monitor the efficiencies of soil test and fertilizer nutrients applied with FYM.

CHAPTER- II
REVIEW OF LITRATURE

Fertilizer is one of the costliest inputs in agriculture and the use of right amount of fertilizer is fundamental for firm profitability and environmental protection. To enhance firm profitability under different soil conditions, it is necessary to have information on optimum doses for the crops. Soil testing as a diagnostic tool, the value of soil testing both in general and specific term is to identify soil fertility problem and constraint in an area and to give specific fertilizer recommendation base on soil analysis of a farm holding. Soil test crop response (STCR) studies help to generate fertilizer adjustment equations and calibration charts for recommending fertilizers on the basis of soil test and achieving targeted yield of crops (Singh and Biswas, 2000).

Soil test crop response approach is based on the three basic requirements i.e. quantity of nutrients required in kg per quintal of economic yield, the percentage contribution of nutrients by the soil and fertilizers to optimize the yield. Another added advantage is the estimation of fertilizer nutrients required to be added for different soil test values of nutrients to achieve a particular targeted yield. This approach is based on the principle of Leibig's law of minimum.

Rao and Srivastava (2000) reported that the cooperating centres of Soil Test Crop Response Correlation (STCR) project had generated numerous fertilizer adjustment equations for prescribing uses of fertilizer to obtaining yields targets of crops on a variety of Indian soils during the last three decades. For Prescriptions derived of the adjustment equations have been tested in numerous follow-up and front-line demonstrations in several states. Post-harvest soil test prediction equations were also generated in the project for generate precise fertilizer recommendations to the cropping systems. The project had also derived useful equations to arrive at the appropriate targeted yields which not only help to realize higher benefit:cost ratios and response ratios but also maintain soil fertility.

In this chapter, the present brief review of the available literature to study on **"Evaluation of soil test based fertilizer prescription evolved for mustard (*Brassica juncea*) crop in *Vertisol.*"** carried out by various researchers with different aspects like; validity of the fertilizer equation, Nutrients requirements, contribution from soil test, efficiencies of fertilizers with or without FYM, nutrients response and benefit cost ratio.

Ramamoorthy *et al* (1967) established the theoretical basis for Leibig;s law of minimum operates equally well for N,P and K and experimental proof the fact. Troug (1960) first advocated this forms for targeted yields on the basis of fertilizer application. The yield targeting method is not only indicates soil test based fertilizer dose but also the farmer can hope to achieve yield level if good agronomical practices are followed in raising the crop. The following basic data are essentially required for formulating fertilizer recommendation for targeted yield:

- Nutrient requirement in kg/q of grain or other economic produce.
- The percent contribution from the soil available nutrient.
- The percent contribution from the applied fertilizer nutrient.

The above mentioned three parameters are calculated as:

A) Nutrient requirement of N, P and K for grain production

Kg of nutrient/q of grain or other economic produce = Total uptake of nutrients (kg)/ Grain yield (q)

$$\text{kg nutrient per quintal grain production (NR)} = \frac{\text{Uptake of nutrient (kg /ha)from grain + straw}}{\text{Grain yield in q/ ha}}$$

b) Contribution of nutrient from soil

$$\text{b) Contribution of Nutrient from soil (Es)} = \frac{\text{Uptake of Nutrient (kg ha}^{-1}\text{) from grain + straw from control plot}}{\text{Soil test value for available Nutrient (kg ha}^{-1}\text{) from control plot}}$$

c) Contribution of nutrient from fertilizer

$$\text{(c) Percent Contribution of Nutrient from fertilizer } (E_f) = \frac{\text{Total uptake Of nutrient In kg ha}^{-1} - \text{Soil test values of fertilizer treated plots} \times \text{Contribution of nutrient from soil}}{\text{Fertilizer nutrient applied}} \times 100$$

Sonar et al. (1982) conducted experiment to work out NR (kg q^{-1}), CS (%) and CF (%) for development of fertilizer adjustment equations using these parameters for sorghum crop under a Vertic Ustropepts soil at Rahuri during kharif 1976. These developed fertilizer adjustment equations were tested at four locations under field conditions. They reported that fertilizers were applied by using fertilizer adjustment equations for yield targets of 40, 50, and 60 q ha-1 and results showed that the higher yields and benefit cost ratio were obtained than the application of general recommended fertilizer dose.

Milapchand *et al.* (1984) trailed on farmer's field to test the validity of yield target concept for rice crop and resulted that the actual yields within ± 5 and ± 10 per cent range for 70 and 23 per cent of the cases, respectively were obtained against different targets.

Dev *et al.* (1985) obtained the mean grain yield of 35.0, 37.5 and 43.3 q ha^{-1} against the target of 35, 40 and 45 q ha^{-1}, respectively of wheat using STCR approach and they also reported that the average yield of 56 experiments was 39.6 q ha^{-1}under general recommended doses of fertilizers. These results showed that targeted yield of wheat were achieved with in ±10 per cent of the deviations under soil test based fertilization in majority of the experiments. After these results, therefore, they could be advice to farmers that fertilizer adjustment equations for knowing soil test based were good and safe to used fertilizer in wheat.

Tamboli *et al.* (1996) conducted a field experiment on a Typic Chromustert with wheat (Kalyansona) and fertilizer prescription equations were evolved. The fertilizers Applied to achieved yields target of 30, 35, 40 and 45 q ha^{-1} were gave higher returns per rupee investment of fertilizer. The verification field trials were conducted at different locations and results showed in majority of the trials that yield targets of 30 and 40 q ha^{-1} were achieved (± 10% variation). A significant positive relationship between actual and targeted yields of wheat was obtained (r = 0.749**). The higher returns per rupee investment of fertilizer were observed under fertilizers Applied to achieved yields target of 30, 35, 40 and 45 q ha^{-1}.

Pranab (2010) conducted an experiment to estimate the fertilizer requirement for specific target yields of rice and yellow sarson under rice-yellow sarson cropping system in old alluvial zone of West Bengal. The nutrient requirements for produce of one tonne of grain yield were 20.14, 17.32 and 11.90 kg in rice and 52.07, 35.16 and 25.97 kg in yellow sarson N, P_2O_5 and K_2O, respectively. The fertilizer adjustment equations were developed for fertilizer recommendation for a desired yield targeted of rice and yellow sarson in the old alluvial soils of West Bengal

Ray et al (2000) were conducted the field experiments with different fertility gradients to development of fertilizer prescription equation for jute, rice and wheat crops in Gangetic alluvial soil (Typic Ustochrept), Nilgary series. The soil was neutral in the reaction, low in N, low to very high in P and medium in K. The individual crop wise basic data, nutrient requirement for one quintal fibre/grain production, per cent contribution of nutrients from fertilizer and soil sources were evaluated for jute, rice and wheat crops. Targeted yield equations were evolved for individual crop under jute-based cropping system. The fertilizer prescription equation were tested with yield targets were 25 to 30 q ha^{-1} for jute (cv. JRO 7835), 35 to 50 q ha^{-1} for coarse rice (cv. Pankaj) and 30 to 35 q ha^{-1} for wheat (cv. Sonalika) and revealed that the desired yield targets were achieved with ±10% variation. Validity of the targeted yield equations were also tested at farmers' fields through follow-up trials as frontline demonstrations which showed that

prescription-based fertilizer application on soil test based was found profitable as compared to general recommendation. Application of phosphorus fertilizer to jute crop could be skipped if soils having available P above 10.5 kg ha^{-1} evaluated as critical limit.

Sharma and Singh (2000) evolved the fertilizer adjustment equations from basic data to achieved yield target of wheat crop; FN = 4.86 T - 0.47 SN, FP2O5 = 2.92 T - 4.37 SP and FK2O = 2.20 T - 0.26 SK where, T denote targeted yield in q ha^{-1}. A replicated follow-up field trial were conducted at IARI farm and applied fertilizer dose 103, 53 and 43 kg ha^{-1} N, P_2O_5 and K_2O respectively, were calculated by using targeted yield equations for the soil to achieved the yield target of 42.53 q ha^{-1} of wheat grain. The yield under targeted yield treatment was obtained 44.17 q ha-1 as against the yield target of 42.53 q ha^{-1}.

Bera et al., (2006) conducted a soil test crop response (STCR) correlation studies taking IR-36 as test crop to quantify rice production using variable balanced fertilization based on targeted yield concept. Soil had moderate variation in different properties like; texture (loamy to clay), organic carbon content (4.4 to 9.8 g/kg), CEC (10.2 to 22.4 cmol (p+)/kg) and pH (5.3 to 6.4). Soil fertility status for N is low to medium (224 to 348 kg/ha), P is medium to high (87 to 320 kg/ha) and K ranges from medium to high (158 to 678 kg/ha). Database regarding nutrient requirement (NR), the percent contribution of available nutrients [CS (%)] from the soil and the percent contribution of the applied fertilizer nutrients [CF (%)] were computed for formulating fertilizer recommendations. Validity of the formulated fertilizer recommendations were tested in farmers' fields for yield target for 7 and 8 t/ha and yields targets was achieved with variation as less than 10% in more than 90% at different level. The viability in uniform cropping practices was found economically within the agro-ecological zone and socio-economic conditions under soil test based fertilizer recommendation.

Benbi *et al*. (2006) conducted a study on soil test crop response correlations with mustard and rapeseed in a Typic Haplustept soil at Punjab Agricultural University farm, Ludhiana provided highly predictable correlations

between grain yield and soil available nutrients status and fertilizer nitrogen. The fertilizer adjustment equations for yield target and site-specific fertilizer recommendations were evolved for mustard and rapeseed for situation. These recommendations were tested for reproducibility and verified by undertaking follow-up trials under farmers' field conditions. They reported that yields, net benefit and B/C ratio under yield target based fertilizer application were higher over the farmers' practice.

Srinivasan *et al*. (2008) conducted a field experiment on soil test crop response (STCR) correlation studies were using rice (ADT-36) at Annamalai University, Annamalainagar, Tamil Nadu, India. The field were divided in four strips (I, II, III & IV), and the variation in soil fertility were deliberately created. After the harvest, each gradient strip was divided into 24 plots which received 5 levels of N (0, 50, 100, 150 and 200 kg ha^{-1}), four levels of P (0, 30, 60 and 90 kg ha^{-1}), three levels of K (0, 40 and 80 kg ha^{-1}), two levels of farmyard manure (FYM; 0.1 and 2.5 t/ha^{-1}) and *Azospirillum* (0 and 2 kg ha^{-1}). At harvest, grain yield, K uptake, initial soil available K status and fertilizer K_2O applied were noted plot-wise. The nutrient requirement (kg q^{-1}), percent nutrient contribution from soil and fertilizer values for K were 1.50, 10.67 and 54.05, respectively. The percent contributions of K from FYM and FYM + Azospirillum were found to be 28.79 and 29.72, respectively. These data have been transformed in the form of simple equations. The results revealed that at an initial soil available K status of 350 kg ha^{-1}, the FK_2O requirement to get a yield target of 70 q ha^{-1} of rice was 111 kgh^{-1} with fertilizer alone, whereas the FK_2O requirement reduced to 86 kg ha^{-1} with fertilizer + FYM + *Azospirillum* application.

Santhi *et al*. (2010) documented in a handbook on soil test and yield target based integrated fertilizer prescriptions, for a range of 41 crop situations in Tamil Nadu. One such example from this hand book, for integrated nutrient management for rice on Noyyal soil series was gave as FN = 4.39 T – 0.52 SN – 0.80 ON, FP2O5 = 2.22 T – 3.63 SP – 0.98 OP, FK2O = 2.44 T – 0.39 SK – 0.72 OK; where ON, OP and OK are the N, P&K nutrients supplied through organic source.

Brajendra *et al*. (2012) celebrated the fertilizer adjustment equations and a ready reckoner for optimum fertilizer doses based on the targeted yield concept to achieved yield target of 40 and 50 q ha-1 of maize yield at varying soil test values. The four field experiments of farmer's fields were conducted with maize during *Kharif* 2006 at different locations by using of developed fertilizer equations for fertilizers application and result indicated that it is possible to achieve the yield target of maize up to 45 q ha^{-1}.

Deshmukh *et al*. (2012) conducted a field study to evaluate the effect of soil test crop response technology on productivity and economics of major crops in four locations of Seoni district of Madhya Pradesh during the year 2007-2009. The fertilizer adjustment equations derived by the All India Coordinated Research Project, JNKVV, Jabalpur Centre were tested for four major crops. Results revealed that yield target of paddy (40 q ha^{-1}), soybean (15 q ha^{-1}), wheat (40 q ha^{-1}) and gram (15 q ha^{-1}) were achieved by using the fertilizer doses on the basis of targeted yield concept (soil test crop response Technology). The maximum net returns were found Rs.15450/-, Rs.20000/-, Rs.29506/- and Rs.13940/- from paddy, soybean, wheat and gram respectively in treatment where plant nutrients applied as per soil test value (STCR treatment). Wheat crop was gave more net return (Rs.29506/-) and B:C ratio 3.10 among the these major crops. They also reported that the maximum gain and soil fertility were maintained due application of plant nutrients as per Soil Test value (STCR Technology).

Keram et al (2012) conducted a field experiment on soil test crop response with rice-wheat cropping sequence on a *Typic Haplustert* at J.N. Krishi Vishwa Vidhyalaya, Jabalpur (M.P.) during 2007-08. The targeted yield equations were developed by using grain yield, soil available nutrients, inorganic fertilizer contribution with and without organic manure (FYM) and validated. The results showed that inorganic fertilizer application based on targeted yield along with organic manure (FYM) that consisted of application of 98 N: 103 P_2O_5: 27 K_2O kg ha^{-1} through chemical fertilizers+46 N: 36 P_2O_5: 45 K_2O kg ha^{-1} through 5 t FYM ha^{-1} as organic manure was gave higher grain yield 4.04 t ha^{-1} of rice. Similarly, higher grain yield 6.94 t ha^{-1} of wheat was also found with IPNS approach that

consisted of application of 150 N: 174 P_2O_5: 104 K_2O kg ha^{-1} through chemical fertilizers+46 N: 36 P_2O_5: 45 K_2O kg ha^{-1} through 5 t FYM ha^{-1} as organic manure. The yield response of fertilizers along with manure application (4800 kg ha^{-1}) and profit (37233 Rs ha^{-1}) under IPNS approach were more while the B:C ratio (5.71) and yard stick value (9.55 kg of grain kg^{-1} of nutrient applied) were higher in STCR approach in wheat over general recommended dose and control. Thus, the fertilization on the basis of yield targets to a crop is precise, meaningful and eco-friendly which requires to be popularized among farmers to enhance the balanced fertilization through the integrated nutrient management system.

Bhaduri and Gautam (2013) conducted a field trial to response of wheat with twenty four selected treatment combinations of four levels of N, P, K and three levels of FYM with simultaneous variation in initially available nutrients status under soil-test-crop-response calibration in Aquic Hapludoll during 2005–07. They reported that 2.72, 0.49, 2.67 kg of N, P, K were required to produce 100 kg of grain. Per cent contribution of nutrients from soil, chemical fertilizer and FYM were also computed and used along with yield and soil analysis data to formulate prescription equations for varying yield targets. Significant R2 (0.914) correlation was observed between yield, soil test values and fertilizer nutrients. Verification trial was also conducted in next season and revealed that the yield target 4.5 t/ha + FYM @ 10 t/ha was achieved with a targeted yield variation of -2.78 to +0.9% along with highest response and benefit: cost ratio.

Sharma *et al*. (2013) were conducted twenty-six frontline demonstrations (2008-11) to popularize the targeted yield equations using two varieties of *toria* (Bhawani and DK-1) at the farmers' fields in sub-humid sub-tropical zone of Himachal Pradesh . The initial soils properties were moderately acidic to slightly alkaline in reaction, medium in organic carbon, low in available N, medium to high in available P and low to medium in available K status. *Toria* was grown as a catch crop between maize and wheat cropping system. The average fertilizer additions for yield targets of 10 q/ha were lower for N and either almost equal or lower for P_2O_5 but in case of K_2O even for15 q/ha yield target was low in comparison to general recommended dose (GRD). The actual yields were obtained

agreed very well with yield targeted. The yield levels were obtained high when fertilizer dose was applied as per prescription basis compared to either under control or under farmers' practice and which was clearly indicated the importance of balanced nutrition for getting higher returns in *toria*

Singh *et al*. (2014) reported that the fertilizer adjustment equations derived by the All India Coordinated Research Project, Institute of Agricultural Science, B.H.U., Varanasi centre were tested the effect of soil test crop response technology on productivity and economics of rice crop in four locations of Varanasi district during the year 2013. They revealed that targeted yield of rice (45 q ha^{-1}) and (50 q ha^{-1}) were achieved by using the plant nutrients on the basis of targeted yield concept (soil test crop response technology). The yield was increased with 44.50 - 48.00, 44.33 -48.66, 44.63 - 47.10 and 45.50 and 47.66 percent in first, second, third and fourth location over farmers practice which were 33.33, 29.50, 31.00 and 30.00 q ha^{-1}, respectively. The maximum net returns were found from rice first location (Rs.18947.75 and Rs.21539.49), second location (Rs.16873.25 and Rs.18956.09), third location (Rs.19623.10 and Rs.21206.20) and fourth location (Rs.19843.10 and Rs.21085.20) in treatment where plant nutrients applied as per soil test value (STCR treatment). The application of plant nutrients as per soil test value (STCR technology) was maintained the soil available plant nutrients and also gave maximum return and sustain the soil fertility.

Ahmed et al (2015) were conducted a study on Soil Test Crop Response (STCR) for autumn rice under integrated plant nutrition system (IPNS) in Inceptisols (Aeric Endoaquepts) at Jorhat district of Assam during 2010–11. The nutrient requirement (NR) was found 2.40 kg, 0.84 kg and 2.25 kg of N, P_2O_5 and K_2O, respectively for producing one quintal of autumn rice. The estimation percent contribution of nutrients were 12.49, 45.31 and 32.92 for N, 13.42, 28.52 and 11.84 for P_2O_5 and 21.99, 47.58 and 29.76 for K_2O from soil (CS), fertilizer (CF) and FYM (CO), respectively. The fertilizer prescription equations for recommending fertilizer doses for autumn rice were developed by using these basic

parameters computed from the Soil Test Crop Response study. The validation trials of equations were conducted in farmers' fields during 2012 and the result showed that variation between actual yield and targeted yield ranged from +1.36 to +5.33. The response ratio and economic benefit were recorded maximum in fertilizer applied under STCR-IPNS for targeted yield 3 and 4 t ha^{-1} in the field trial and these result confirmed that the proposed fertilizer prescription equations were valid for autumn rice.

Gogoi *et al.* (2015) conducted a field experiment for formulate the fertilizer prescription equation based on targeted yield of pumpkin under rice-pumpkin cropping system in a Vertic Ustochrepts soils of Orissa. Nutrient requirement was found 1.75, 0.56, and 1.74 kg N, P_2O_5, and K_2O respectively, for production of one quintal of pumpkin. Nutrient contribution from soil were 45%, 57% and 47% while fertilizer efficiency 36%, 21%, and 86% N, P_2O_5, and K_2O respectively. The multiple regression equations was showed that initial soil phosphorus, uptake of N & P and fertilizers N, P, K made significant contribution towards the fruit yield of pumpkin.

Parihar *et al.* (2015) Studied on Soil test Crop Response based Integrated Plant Nutrient Management System (STCR - IPNMS) for the desired yield targets of maize in *Inceptisol* at Agricultural Research Farm, Banaras Hindu University, Varanasi during *kharif* 2012. It is necessary to demonstrated and tested the developed fertilizer prescription equation for effectiveness before delivery of technology to the stake holders in need. A series of experiment were conducted for assessment and validation of fertilizer prescription in four location of eastern plain zone of Utter Pradesh. Initial soils of the selected location were analyzed for available N, P and K. Treatments control, farmer practices, general recommended dose of fertilizer and STCR based fertilizer dose for yield target of 30 and 35 q ha^{-1} with 5 t ha^{-1} FYM were included. The results showed that yield target were achieved within±10% variation in all the four locations and it's proved that the equations for prescribing integrated fertilizer doses for maize was valid. The per cent yield increment was highest in the yield target of 35 q ha^{-1} (51.27 percent)

followed by 30 q ha^{-1} (31.43 percent) over farmer's practice. The highest benefit: cost ratio (4.44) was recorded in STCR-IPNMS 30 q ha-1 is followed by STCR-IPNMS 35 q ha^{-1} (3.58). The fertilizer prescription equations developed for maize under IPNMS can be recommended for alluvial *Inceptisol* of eastern Utter Pradesh for achieving a yield target of 30 q ha^{-1} with higher economic return.

Saren et al (2015) conducted a field experiment to study the response of cabbage (Brassica oleraceay to soil test based fertilizer application for targeted yield of cabbage under rice-cabbage cropping system in an *Inceptisol* of Odisha during *rabi*, 2011-12. Three fertility gradient strips (B-1, B-II & B-III) were created in *kharif* season by application of no fertilizer, recommended dose (80:40:40 kg N: P_2O_5: K_2O ha^{-1}) and twice of the recommended dose (160:80:80 kg N: P_2O_5: K_2O ha^{-1}) for rice, respectively. Rice (cv. Lalat) was grown in these three fertility gradient strips in *kharif* season. After harvest of rice crop, each of these fertility gradient strips was divided into 24 sub-plots and super imposed with 19 different combinations of N, P, K and rest five were kept absolute control during *Rabi* season. Cabbage (cv. Pragati) was grown as a test crop with different combinations of N (0, 60, 120 &180); P (0, 30, 60 & 90) and K (0, 30, 60 & 90) levels. Plant uptake of N, P & K by cabbage was determined after harvest of crop. The initial soil test values, nutrients uptake data, the nutrient requirement (NR), the soils efficiency (Cs) and the fertilizer efficiency (Cf) was determined and with these basic parameters, the fertilizer prescription equation for cabbage was formulated for *Inceptisols* of Odisha. The highest yield of cabbage (315. q ha^{-1}) was achieved with application of 180:60:90 kg of N: P: K ha^{-1}.

Sharma et al (2015) conducted an experiment on soil-test crop-response with rice in the Bastar Plateau Agroclimatic Zone of Chhattisgarh during 2009–2011. To calibrated optimum fertilizer doses for attaining yield targets by using relationships among the yield, plant uptake, soil and fertilizer nitrogen (N), phosphorus (P) and potassium (K). Soil nutrients was poor to medium for N (194–283 kg ha^{-1}) and P (7.53–19.66 kg ha^{-1}), and medium to good for K (226–320 kg ha^{-1}). Fertilizer prescription equations were derived based on nutrient

requirements (NR, kg q^{-1}), contributions from soil (CS, %), fertilizer (CF, %), and farmyard manure (CFYM, %). The fertilizer prescription equations were validated with yield targets of 50 and 60 q ha^{-1} in farmer's fields and revealed that rice yield target was achieved within 10% deviation and its indicated that soil-test-based fertilizer dose was superior.

Pogula *et al.* (2016) studied the response of French bean (Phaseolus vulgaris) to graded doses of fertilizer and to formulate soil test based fertilizer recommendation for targeted yield of french bean under rice-french bean cropping system in a lateritic soils of Odisha during 2014–2015. As per detailed morphological and physico-chemical properties of the experimental soil comes under a typifying pedon. Three fertility gradient strips were created (B-I, B-II & B-III) in *kharif* season by application of no fertilizer, recommended dose of fertilizer and twice of the recommended dose in rice. Each fertility gradient strips were divided into 21 plots as treated with different treatment combinations of N, P, K and three plots as control where 0, 2.5 and 5.0 t ha^{-1} FYM were received. In the investigation the french bean (cv. Anupam) was grown as a test crop in all 24 sub-plots during *Rabi* season. Mean pod yield and N, P, K uptake were found the range from 57.6 to 75.0 q ha^{-1} , 67.9 to 75.0, 49.0 to 56.6 and 69.9 to 84.9 kg ha^{-1} respectively. Using the Ramamoorthy's targeted yield approach the fertilizer prescription equations for french bean were developed under site specific integrated nutrient management.

Sellamuthu et al (2016) conducted a field experiment to refine the existing fertilizer prescription equation for rainfed maize using inductive-cum-targeted yield model in a Typic Ustropept (Irugur soil series) soil of Western Zone of Tamil Nadu. The fertilizer requirements were quantified for rainfed maize based on soil test and yield target. The basic parameters viz., nutrient requirement (NR), contributions of nutrients from soil (C_s), fertilizer (C_f) and farm yard manure (C_{fym}) were found out from the field experimental data. The fertilizer prescription equations based on integrated plant nutrition system (IPNS) were developed by using these basic parameters and formulated fertilizer doses for the desired yield target of rainfed maize for the given soil test values. The fertilizer prescription

equations developed for rainfed maize under IPNS were validated in three locations during 2013–15. The results of all the three verification trials showed that the desired yield target was achieved within ±10% variation and proving that the equations for prescribing integrated fertilizer doses were valid for rainfed maize.

Singh et al (2017) demonstrated effectiveness of fertilizer prescription equations on the basis of soil test value of farmer field at Bhojpur to evaluate the model through field experiments in Eastern zone of Uttar-Pradesh. The treatments included control, general recommendation dose, farmer practice, soil test based fertilizer dose for a yield target of 4.5 and 5.0 t ha^{-1}. The fertilizer doses applied for STCR and STCR-INM treatments for the respective yield targets were calculated on based of the initial soil test values of available N, P, K and the quantities of N, P, K contributed through farm yard manure (FYM). The cultivation practices carried out periodically and treatments were imposed and the grain yield was recorded at harvest. The results of in the entire three farmer's field were indicated that the per cent achievement of the targeted yield was within ±5% variation and it's proved that the equations for prescribing integrated fertilizer doses for rice were valid. The per cent achievement of desired target was higher in the targeted yield of 4.5 t ha^{-1} (99.96 %) than yield target of 5.0 t ha^{-1} (98.36 %). The mean average yield was recorded higher under treatment STCR-NPK+FYM 5.0 t ha^{-1} (4918 kg ha^{-1}) and it was increased by 30.93% over farmer's practice along with highest benefit: cost ratio (3.32). The result showed that the post-harvest soil available N, P and K was also the build up and maintenance of soil fertility under soil test and yield target based fertilizer recommendation under STCR-INM treatments. The fertilizer prescription equations developed for rice under STCR-INM system can be recommended for achieving a yield target of 4.5 and 5.0 t ha-1 with maintain the soil fertility of Alluvial soil of Pratapgarh, Uttar-Pradesh and it can be also tested to similar and allied soil types of other agro-climatic zones of Uttar Pradesh.

Verma *et al.* (2017) studied the soil test based fertilizer recommendation for mustard crop on grain and straw yield, nutrient uptake and soil test data were used for obtaining basic parameter viz., Nutrient requirement, contribution of

nutrients from soil, fertilizer and organic manure. The nutrient requirements for producing one quintal of grain were 5.22 kg N, 0.99 kg P_2O_5 and 4.25 kg K_2O. The per cent contribution of soil and applied fertilizer were 23.94, 70.45, 22.14 and 42.53, 21.44, 90.52 per cent of nitrogen, phosphorus and potassium respectively. Using these basic data, the fertilizer adjustment equation were developed for mustard (var. Ashirwad) and estimated the fertilizer doses for a range of soil test values to achieved desired yield targets under NPK alone and with FYM.

Sahu et al.,(2017) studied to calibrate the soil test based balanced fertilizer doses with farm yard manure for wheat under high density planting system during *Rabi* season 2016-17. The soil test values before planting were ranged between 197.6-257.2, 10.2-35.0 and 307.4-467.5 kg ha-1 for available nitrogen, phosphorus and potash, respectively. The nutrient requirement for produce one quintal of grain was found to be 2.00 kg N, 0.54 kg P and 1.91 kg K. The fertilizer and soil test efficiencies of N, P and K for high density wheat crop were estimated as 34.4, 22.0, 72.1 and 13.08, 65.02, 7.98 per cent, respectively. The per cent contributions of farm yard manure were observed as 13.7, 5.6, and 8.0 for N, P and K, respectively. The fertilizer adjustment equations and a readyreconer were evolved by using of these basic parameters viz. nutrient requirement, efficiencies of fertilizer, soil test and farm yard manure, which is useful for those farmers , they grow the wheat crop under high density planting system to achieve a definite yield goal in similar soil and agro-climatic conditions.

Singh et al (2017) studied a field experiments to investigate soil test crop response under integrated plant nutrient system (STCR-IPNS) for *Bt* cotton *in Inceptisols* by using Ramamoorthy's inductive approach of fertility gradients at CCS Haryana Agricultural University, Hisar during 2011–12 and 2012–13. The experiments were carried out on well developed fertility gradients and available N, P and K status of soil in the preceding season before sowing of *Bt* cotton were having wide variability of N (105 to 175 kg ha^{-1}), P (10 to 32 kg ha^{-1}) and K (208 to 392 kg ha^{-1}). The nutrient requirement was recorded 3.58, 1.20 and 3.50 of N, P_2O_5 and K_2O, respectively, for producing one quintal of cotton seed. The per cent contribution from soil, fertilizer and FYM were found t 50.65, 26.00 and 3.70for

N, 55.50, 26.60 and 3.32 for P_2O_5 and 29.50, 45.79 and 4.35 for K_2O, respectively. These data were using for development of soil test based fertilizer prescription equations under IPNS to achieve for desired yield targets of *Bt* cotton. The ready reckoner was also computed for fertilizer recommendations for attaining yield targets of 28, 30 and 32 q ha^{-1} at varying soil test values for *Bt* cotton prepared.

Singh et al (2017) demonstrated effectiveness of fertilizer prescription equations on the basis of soil test value of farmer field at Bhojpur to evaluate the model through field experiments in Eastern zone of Uttar-Pradesh. The treatments included control, general recommendation dose, farmer practice, soil test based fertilizer dose for a yield target of 4.5 and 5.0 t ha^{-1}. The fertilizer doses applied for STCR and STCR-INM treatments for the respective yield targets were calculated on based of the initial soil test values of available N, P, K and the quantities of N, P, K contributed through farm yard manure (FYM). The cultivation practices carried out periodically and treatments were imposed and the grain yield was recorded at harvest. The results of in the entire three farmer's field were indicated that the per cent achievement of the targeted yield was within ±5% variation and it's proved that the equations for prescribing integrated fertilizer doses for rice were valid. The per cent achievement of desired target was higher in the targeted yield of 4.5 t ha^{-1} (99.96 %) than yield target of 5.0 t ha^{-1} (98.36 %). The mean average yield was recorded higher under treatment STCR-NPK+FYM 5.0 t ha^{-1} (4918 kg ha^{-1}) and it was increased by 30.93% over farmer's practice along with highest benefit: cost ratio (3.32). The result showed that the post-harvest soil available N, P and K was also the build up and maintenance of soil fertility under soil test and yield target based fertilizer recommendation under STCR-INM treatments. The fertilizer prescription equations developed for rice under STCR-INM system can be recommended for achieving a yield target of 4.5 and 5.0 t ha-1 with maintain the soil fertility of Alluvial soil of Pratapgarh, Uttar-Pradesh and it can be also tested to similar and allied soil types of other agro-climatic zones of Uttar Pradesh.

Ranjan *et al.* (2018) conducted an experiment using integrated plant nutrient management system on the basis of STCR approach in *Inceptisol* at

Agricultural Research Farm, Banaras Hindu University, Varanasi during rabi 2016. Soil test values, grain yield of pea and NPK uptake by pea crop were used for celebration of four important basic parameters viz., nutrients required to produce one quintal of pea grain (NR), contribution of nutrients from fertilizers (%CF), soil (%CS) and organic matter-FYM (%OM). Nutrient required for producing one quintal pea grain yield were found 5.56, 0.79 and 3.08 kg of N, P_2O_5 and K_2O, respectively. The per cent contribution of nutrients were 36.2, 133.7 and 12.6 for N; 51.7, 24.8 and 3.04 for P2O5 and 23.0, 71.4 and 10.0 for K_2O from soil, fertilizer and FYM, respectively. The ready reckoner of fertilizer NPK alone and NPK + FYM doses were evolved for various soil test values to achieving desired grain yield targets of pea by using these basic parameters.

CHAPTER - III

MATERIALS AND METHODS

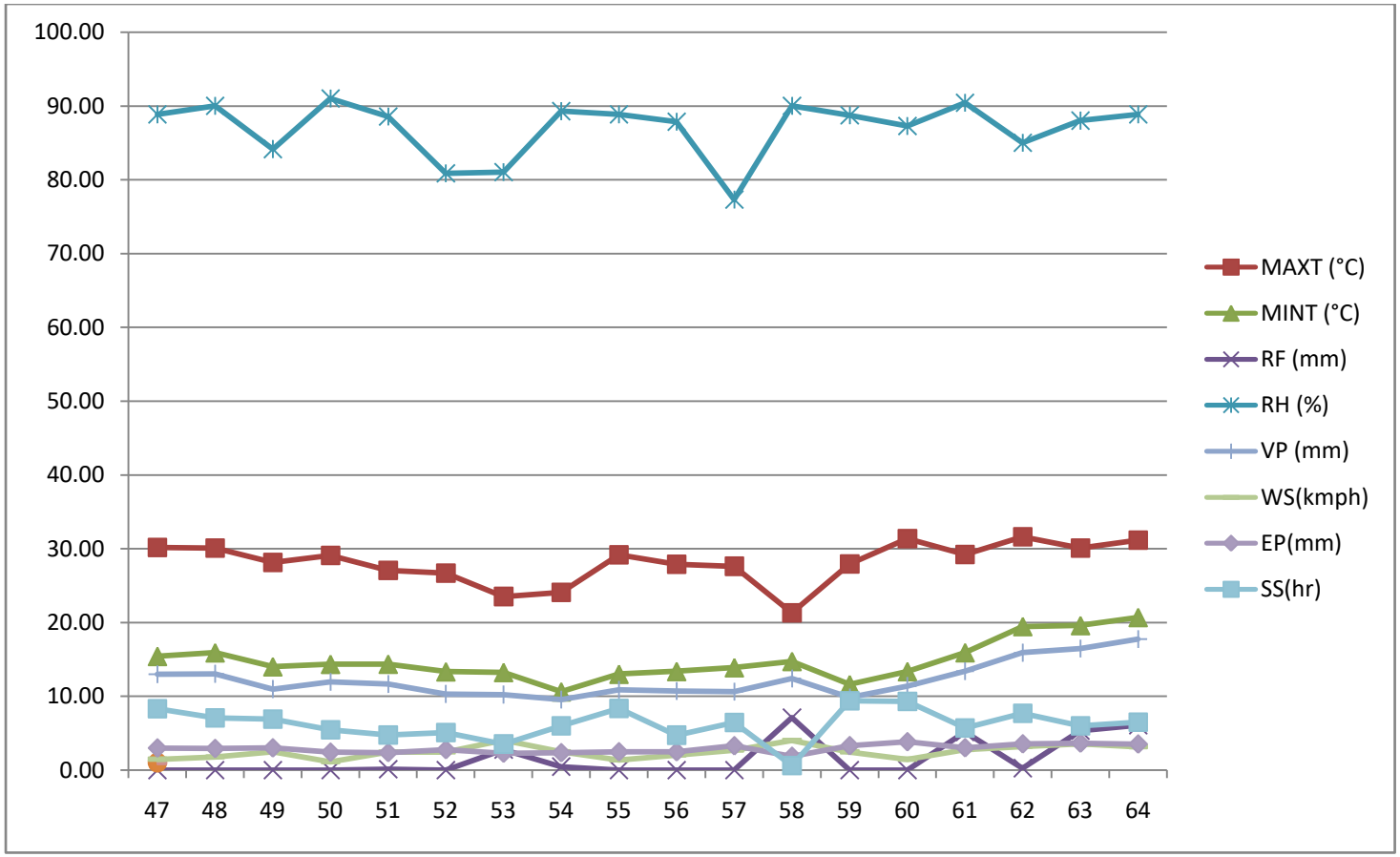
This chapter deals with the concise description of the materials used and the techniques adopted during the course of investigation. The present investigation entitled **"Evaluation of soil test based fertilizer prescription evolved for mustard (*Brassica juncea*) crop in *Vertisol*"** was conducted at Instructional farm, IGKV, Raipur.

3.1 Geographical situation

Raipur is the capital of Chhattisgarh state and situated in the center of state and lies between 21^0 16'N latitude and 81^0 60'E longitude with altitude of 289.56 meters from the mean sea level. The Instructional farm of IGKV is situated in the eastern part of Raipur city on NH 6 and located between 20^0 4' North latitude and 81^0 39' East longitude with an altitude of 293 m above from mean sea level.

3.2 Climatic and Weather Condition

The experimental site is comes under Chhattisgarh plains agro climatic zone, it is one agro climatic zone of the three agro climatic Zones of the Chhattisgarh state. The climatic condition of zone is comes under sub-humid. The average annual rainfall of the area is 1250 mm and major amount of precipitation receives from the month of June to September (about 3-4 Months). May is the hottest month whiles the coolest month is December, respectively. The detail weekly meteorological data recorded from meteorological observatory during the crop period presented in Fig.3.1.



Source: Department of Agrometerology, I.G.K.V., Raipur

Fig.3.1 Meteorological data during the crop growth period (weekly) in *Rabi* 2019

3.3 Soil properties of the experimental site

The experiment was conducted at the Instructional Farm IGKV, Raipur. Composite soil samples were collected randomly in the experimental area from 0-15 cm depth before laying out the field. The collected samples were processed and analyzed for various soil properties and the detail results are presented in table 3.1

Table 3.1 Initial physical and chemical properties of soil.

S. No.	Parameter	Values
1.	Sand (%)	26.4
2.	Silt (%)	28.8
3.	Clay (%)	44.8
4.	Particle Density (gm/cc)	2.36
5.	Water Holding Capacity (%)	39.48
6.	Porosity %	41.32
7.	pH	7.4
8.	EC (dS/m)	0.18
9.	Organic Carbon (%)	0.58
10.	Available Nitrogen (kg ha^{-1})	200
11.	Available phosphorus (kg ha^{-1})	16.2
12.	Available potassium (kg ha^{-1})	308
13.	DTPA Fe (ppm)	10.88
14.	DTPA Zn (ppm)	1.61
15.	DTPA Mn (ppm)	4.95
16.	DTPA Cu (ppm)	2.12

3.4 Experimental details, STCR prescription equation and layout Plan

The experiment was laid out as per the factorial randomized block design with three replication and 16 treatments during *Rabi* season of 2019-20. The layout plan given in fig: 3.2. Details of treatments as presented in Table 3.2. STCR prescription equation for mustard developed in previous under STCR project used for validation or calculating the fertilizer doses for yield targeted treatments as given in table 3.3.

Table 3.2 Treatment details

S. No.	Treatment	Treatment details
1	T_1	Control ($N_0P_0K_0$)
2	T_2	Control ($N_0P_0K_0$) + FYM
3	T_3	$N_{120}P_{60}K_0$
4	T_4	$N_{120}P_{60}K_0$ + FYM
5	T_5	$N_{120}P_0K_{40}$
6	T_6	$N_{120}P_0K_{40}$ + FYM
7	T_7	$N_0P_{60}K_{40}$
8	T_8	$N_0P_{60}K_{40}$ + FYM
9	T_9	$N_{120}P_{60}K_{40}$
10	T_{10}	$N_{120}P_{60}K_{40}$ + FYM
11	T_{11}	Yield target 14.0 t/ha ($N_{64}P_9K_{38}$)
12	T_{12}	Yield target 14.0 t/ha + FYM($N_{63}P_7K_{38}$)
13	T_{13}	Yield target 18.0 t/ha($N_{115}P_{25}K_{56}$)
14	T_{14}	Yield target 18.0 t/ha + FYM($N_{114}P_{24}K_{56}$)

15	T_{15}	Yield target 22.0 t/ha($N_{166}P_{42}K_{74}$)
16	T_{16}	Yield target 22.0 t/ha + FYM($N_{165}P_{40}K_{74}$)

Table 3.3 STCR prescription equation

Fertilization	Fertilizer adjustment equation
NPK + FYM	FN = 12.86 Y - 0.58 SN - 0.30 FYM
	FP = 4.09 Y – 2.51 SP – 0.33 FYM
	FK = 4.50 Y – 0.08SK – 0.07 FYM

Design : Factorial Randomized Block Deign (FRBD)

Replications : Three

Plot size : 4 x 4m (16m

No. of treatments : 16

Crop and Variety : Mustard (*Brassica juncea*) ; var (Pusa bold)

Date of sowing : 18th November 2019

Date of harvesting : 18th March 2020

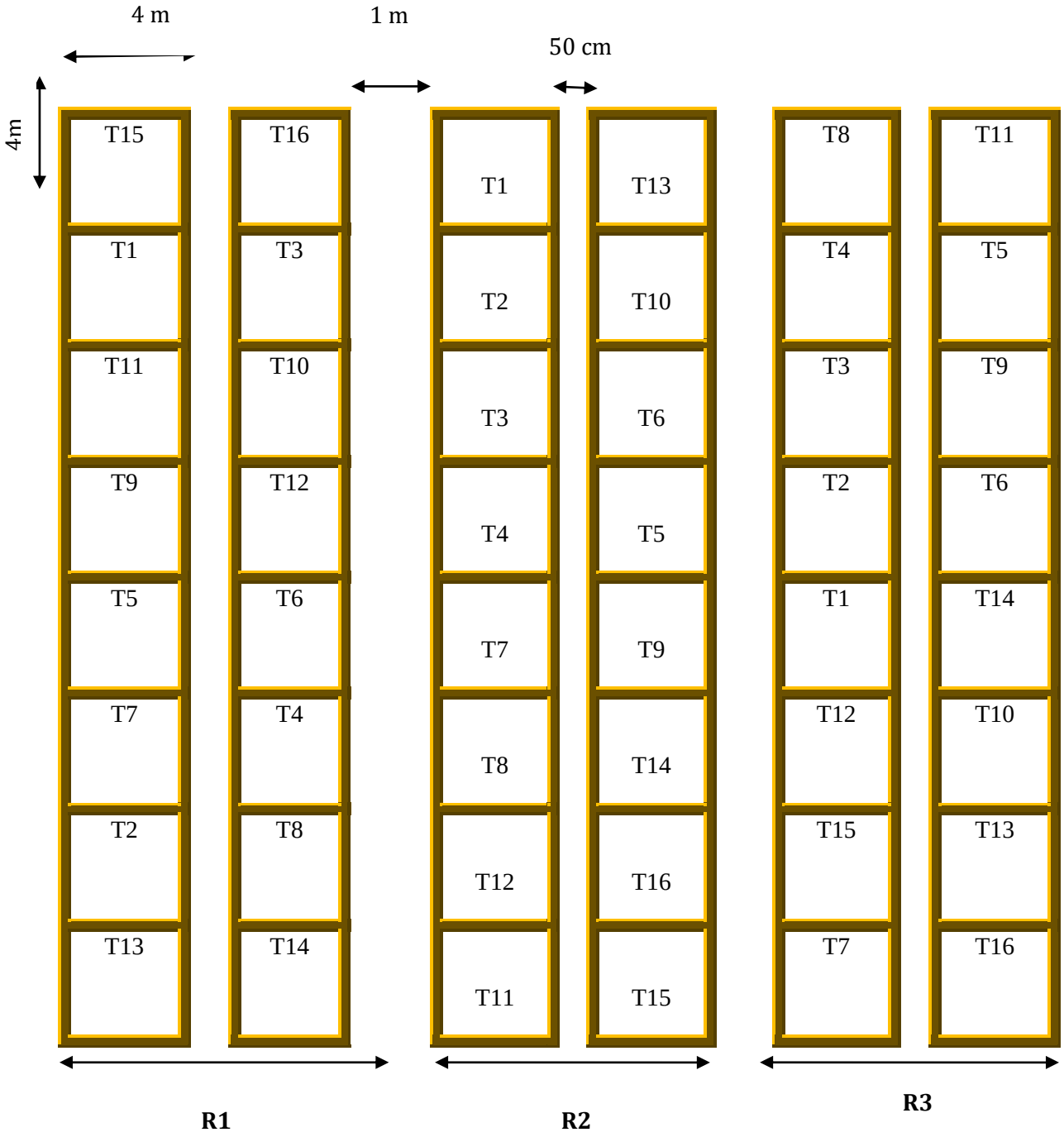


Fig. 3.2: The Layout plan of experiment.

3.5. Land Preparation

The experimental field was ploughed two times by tractor drawn cultivator and leveled by using leveler (pata) then individual plot was prepared.

3.6 Application of fertilizers

As per Treatment, the total amount of P and K were applied as basal dose through SSP and MOP respectively. N was applied in three split doses through urea.

3.7 Method of Soil and Plant Analysis

3.7.1 Soil Analysis

3.7.1.1 Soil reaction

Soil reaction (pH) was determined in 1:2.5 soil to water suspension using pH meter (Systronic Digital pH meter 335) after shaking the sample with water for 30 minutes (Jackson, 1967).

3.7.1.2 Electrical conductivity

Electrical conductivity was determined by taking supernatant liquid of soil water suspension prepared for pH determination by using electrical conductivity meter (Black, 1965).

3.7.1.3 Soil bulk density

Bulk density was determined by using core method given by Black and Hartge, (1986).

3.7.1.4 Soil Texture

Analysis of soils for different textural fractions was carried out by International pipette method (Piper, 1966).

3.7.1.5 Water holding capacity

Water holding capacity was determined by keen Rackzowski brass cup as described by Sankaram (1966).

3.7.1.6 Organic carbon

Organic carbon was determined by Walkley and Black's rapid titration method as described by Walkley and Black, (1934).

3.7.1.7Available nitrogen

Available nitrogen was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956).

3.7.1.8 Available phosphorus

Available phosphorus was extracted from soil with 0.5 M sodium bicarbonate (pH 8.5) as described by Olsen *et al.*, (1954).

3.7.1.9 Available potassium

Neutral (pH 7) normal (1N) ammonium acetate (Muhr *et al*. 1965) was used for extraction of available K from soil and was measured by using Flame photometer.

3.7.1.10 DTPA extractable micronutrients

Available zinc, copper, manganese and iron in the soils were determined in DTPA extract, using atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

3.7.2 Plant chemical analysis

3.7.2.1 Sample preparation

Dried straw and grain were grinded and used for following chemical analysis

3.7.2.2 Total Nitrogen content

Nitrogen content was determined by KEL plus unit methods as described by Chapman and Pratt, (1961).

3.7.2.3 Total Phosphorus

Phosphorus in the diacid extract of plant samples was estimated by vanadomolybdo phosphoric yellow colour method using spectrophotometer at 420 nm wave length as described by Jackson (1973).

3.7.2.4 Total Potassium

Potassium in the diacid extract of plant samples was determined using flame photometer as per the method described by Jackson (1973).

3.8 Statistical analysis

All the field and laboratory experiment results were recorded and tabulated in systematic manner. The final observations were statistically analyzed by Factorial Randomized Block Deign. For significant treatment effects, standard error of means (SEm) and critical differences were calculated at 5% of probability.

CHAPTER- IV

RESULTS AND DISCUSSION

This chapter presents the results of experiment conducted on **"Evaluation of soil test based fertilizer prescription evolved for mustard (*Brassica juncea*) crop in *Vertisol.*"**at the Instructional Farm, Indira Gandhi Krishi Vishwavidhyalaya, Raipur (CG) during, *Rabi* season,2019. The results obtained over the season on various parameters have been presented and discussed under the following heads:

4.1: Grain and straw yield response to fertilizer application

Table 4.1.1: Average grain and straw yield (q/ha) of mustard in relation to different fertilizer treatments with and without FYM application.

Grain & straw yield (q/ha)						
Treatments (T)	**Grain**			**Straw**		
	Without FYM	**With FYM**	**Mean**	**Without FYM**	**With FYM**	**Mean**
T_1 -Control ($N_0P_0K_0$)	6.71	8.62	7.66h	13.10	17.10	15.10h
T_2 -N_{120} $P_{60}K_0$	16.67	18.77	17.72cd	24.25	25.19	24.72de
T_3 -N_{120} P_0K_{40}	14.50	15.60	15.05e	25.46	25.50	25.48cd
T_4 -N_0 $P_{60}K_{40}$	10.21	12.73	11.47g	17.69	21.10	19.40g
T_5 -N_{120} $P_{60}K_{40}$	18.44	19.92	19.43b	26.25	27.19	26.72c
T_6-Yield Target 14.0 q/ha	13.94	14.46	14.20ef	23.25	25.04	24.14ef
T_7-Yield Target 18.0 q/ha	18.08	18.73	18.15c	29.71	30.63	30.17b
T_8-Yield Target 22.0 q/ha	21.73	21.85	21.79a	34.23	35.02	34.62a
Mean	**15.03**	**16.33**	**15.68**	**24.24**	**25.85**	**25.04**
CD at 5% level			**Grain**	**= T =** 1.08**, F =** 0.54**, FT =** NS		
			Straw	**= T =** 1.68**, F =** 0.84**, FT =** NS		

In a column, means with a common small letter and in a row with a common capital letter are not significantly different

Results presented in Table 4.1.1 and depicted in Fig. 4.1.1 show the mean grain and straw yields of mustard significantly affected by fertilizer and FYM application however, the interaction effect (FT) showed a non-significant result. The grain yield was recorded significantly higher (21.79 q/ha) with the treatment T_8 (that received the STCR based fertilizer dose to achieve yield target of 22q/ha) followed by T_5 (N_{120} P_{60} K_{40}), T_7 (YT 18 q/ha), T_3 ($N_{120}P_0K_{40}$). Application of FYM also showed significantly higher grain yields over sole application of inorganic fertilizers. Significant effect of potassium application on grain yield of mustard was noticed between the yield data of the treatments T_2 (N_{120} P_{60} K_0) and T_5 (N_{120} P_{60} K_{40}). Straw yield of mustard also affected significantly with fertilizer and FYM application. The highest straw yield of mustard was recorded significantly with the T8 (YT 22 q/ha) on STCR based fertilizer dose. Straw yields followed almost the similar trends as with the grain yields. The grain and straw yields of mustard were drastically reduced when fertilizer N was omitted in T_4 ($N_0P_{60}K_{40}$) that indicates the importance of N for mustard yield. FYM application enhanced the grain and straw yields over without FYM as it induced the nutrients availability and efficiencies.

The treatments on fertilizer application based on STCR concept to achieve the yield targets of 14, 18 and 22 q/ha resulted 14.20, 18.15 and 21.79 q/ha, respectively. These results showed that yield targets of mustard were achieved with in ±10 per cent of the deviations under soil test based fertilizers applied alone or with FYM in the experiment. This result confirms the derivation of soil test based fertilizer prescription equations evolved for mustard crop to achieve a definite yield target in *Vertisol* of Chhattisgarh. Other workers like Sonar et al. (1982), Dev et al. (1985) and Milapchand et al. (1984) also confirmed their findings.

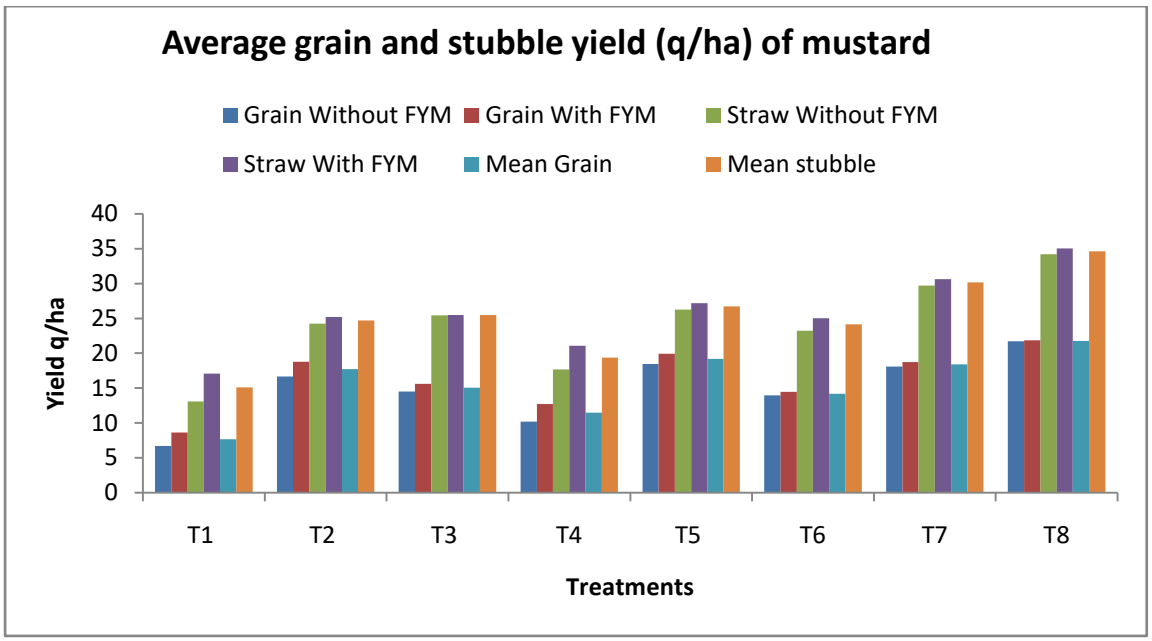


Fig. 4.1.1 Average grain and straw yield (q/ha) of mustard

4.2: Nutrients uptake

Uptake of N P and K by mustard grain, straw and their total were analyzed and data on these parameters have been presented in the following Tables.

4.2.1: Nitrogen uptake

Results presented in Table 4.2.1 and depicted in Fig. 4.2.1 show the N uptake in grain, straw and total by mustard crop significantly affected by fertilizer application only and FYM and the interaction effect (FT) were statistically non-significant. The N uptake is a multiple of N content and dry matter yield hence in most of the cases, the trends in N uptake by grain, straw as well as their total also indicate in a similar trends. The N uptake in grain, straw and total were recorded significantly higher under treatment T_8 (that received the STCR based fertilizer dose to achieve yield target of 22 q/ha). Application of FYM did not show any significant variations over sole application of inorganic fertilizers.

The mean value of total N uptake under T_8 (YT 22 q/ha) showed significantly higher over all other treatments. However, T_5 ($N_{120}P_{60}K_{40}$) showed non-significant variations with T_7 (Yield Target 18.0 q/ha). The availability of nitrogen enhanced by its application of and had a higher N uptake due to good crop response to its application. Crop yields badly affected when no N was applied due to lower N uptake. High crop responses due to high N uptake in high dose of fertilizer N application were reported by many researchers like Bhandari and Gautam (2013) and Pranab (2010).

4.2.2: Phosphorus uptake

Results presented in Table 4.2.2 and depicted in Fig. 4.2.2 show the P uptake in grain, straw and total by mustard crop significantly affected by fertilizer application. FYM and its interaction effect with fertilizer (FT) were statistically non-significant. The total phosphorous uptake under treatment T_8 (YT 22 q/ha) was significantly higher (21.94 kg/ha) followed by T_5 (N_{120} $P_{60}K_{40}$) and T_7 (Yield Target 18.0 q/ha). However difference between T_5 and T_7 was at par. Total P uptake in T_2 and T_3 did not differed significantly even if with and without P application. P uptake by grain showed in the similar trends as with the total P uptake where in straw P uptake T_8 treatment had significantly higher P uptake and remaining treatment did not show any definite trends. Application of FYM did not show any significant variations. Similar type of response was also reported by Ahmed et al.

4.2.3: Potassium uptake

Results presented in Table 4.2.3 and depicted in Fig. 4.2.3 show the total potassium uptake by mustard crop differed significantly by fertilizer treatments. However, FYM application and the interaction effect (FT) showed non-significant results. The mean total K uptake was significantly higher with T_8 (YT 22 q/ha) followed by T_7 and T_5 treatments. However, the treatment T_5 showed non-significant variation with T_2 and T_3. Application of FYM over sole application of inorganic fertilizers had no statistical difference on potassium uptake. Potassium uptake was higher in straw part of the crop than grain part. Similar type of

response was also reported by Bhandari and Gautam (2013) Ahmed et al. (2015) and Pranab (2010).

Table 4.2.1: Nitrogen uptake in mustard grain, straw and their total in relation to different fertilizer treatments with and without FYM application

N uptake (kg/ha)									
Treatments (T)	**Grain**			**Straw**			**Total**		
	Without FYM	**With FYM**	**Mean**	**Without FYM**	**With FYM**	**mean**	**Without FYM**	**With FYM**	**Mean**
T1 -Control ($N_0P_0K_0$)	26.02	30.41	28.22 h	11.55	13.70	12.63 gh	37.57	44.12	40.84 h
T2 -N_{120} $P_{60}K_0$	61.02	63.74	62.38 d	17.68	17.93	17.80 ef	78.70	81.67	80.18 d
T3 -N_{120} P_0K_{40}	52.28	53.68	52.98 e	18.79	19.09	18.94 c	71.07	72.77	71.92 e
T4 -N_0 $P_{60}K_{40}$	36.55	42.94	39.75 g	13.47	13.77	13.62 g	50.02	56.71	53.37 g
T5 -N_{120} $P_{60}K_{40}$	67.68	69.34	69.38 b	18.62	18.82	18.72 de	86.30	88.16	88.10 bc
T6-Yield Target 14.0 q/ha	46.43	46.84	46.64f	18.83	19.03	18.93 cd	65.26	65.87	65.56f
T7-Yield Target 18.0 q/ha	66.52	69.67	67.16bc	21.09	21.44	21.27 b	87.61	91.11	88.43b
T8-Yield Target 22.0 q/ha	75.62	75.87	75.75a	25.33	25.57	25.45 a	100.95	101.44	101.20a
Mean	**54.01**	**56.56**	**55.29**	**18.17**	**18.67**	**18.42**	**72.18**	**75.36**	**73.70**
CD at 5% level	**Grain = T =** 3.76, **F =** NS, **FT** = NS, **Straw = T =** 1.39, **F =** NS, **FT =** NS **Total = T = 5.26, F =** NS, **FT =** NS								

In a column, means with a common small letter and in a row with a common capital letter are not significantly different.

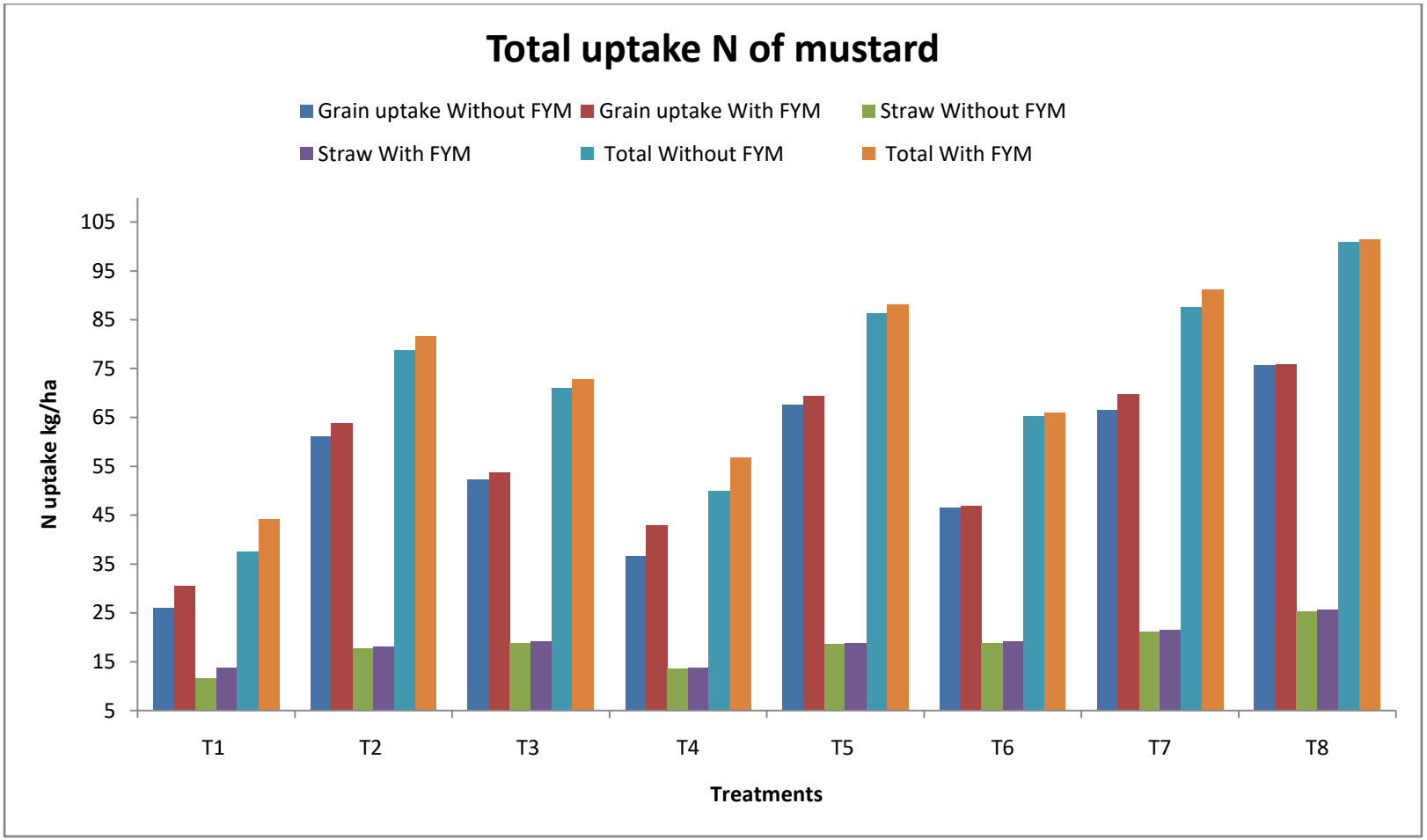


Fig 4.2.1 Total N uptake of mustard

Table 4.2.2: Phosphorus uptake in mustard grain, straw and their total in relation to different fertilizer treatments with and without FYM application

Treatments (T)	P uptake (kg/ha)								
	Grain			Straw			Total		
	Without FYM	With FYM	Mean	Without FYM	With FYM	mean	Without FYM	With FYM	Mean
T1 -Control ($N_0P_0K_0$)	5.39	6.06	5.72f	2.36	2.91	2.64d	7.75	8.97	8.36 f
T2 -N_{120} $P_{60}K_0$	10.67	11.98	11.32d	3.37	3.78	3.57c	14.04	15.76	14.90 c
T3 -N_{120} P_0K_{40}	11.88	12.57	12.22d	3.31	3.57	3.44c	15.19	16.14	15.67 c
T4 -N_0 $P_{60}K_{40}$	7.45	8.13	7.79e	2.48	3.38	2.93d	9.93	11.50	10.71e
T5 -N_{120} $P_{60}K_{40}$	14.75	14.81	14.97b	5.25	5.44	5.35 a	20.00	20.25	20.13b
T6-Yield Target 14.0 q/ha	8.87	8.49	8.68e	4.88	4.51	4.69b	13.76	13.00	13.38d
T7-Yield Target 18.0 q/ha	13.56	14.04	13.61c	5.35	5.51	5.43a	18.91	19.55	19.04b
T8-Yield Target 22.0 q/ha	16.03	16.42	16.23a	**5.48**	5.95	5.72 a	21.50	22.38	21.94 a
Mean	**11.07**	**11.72**	**11.40**	**4.06**	**4.44**	**4.25**	**15.14**	**16.16**	**15.65**

CD at 5% level **Grain = T =** 1.01**, F =** NS**, FT =** NS , **Straw = T =** 0.56**, F =** NS**, FT =** NS
Total = T = 1.36**, F** = 0.70**, FT** = NS

In a column, means with a common small letter and in a row with a common capital letter are not significantly different.

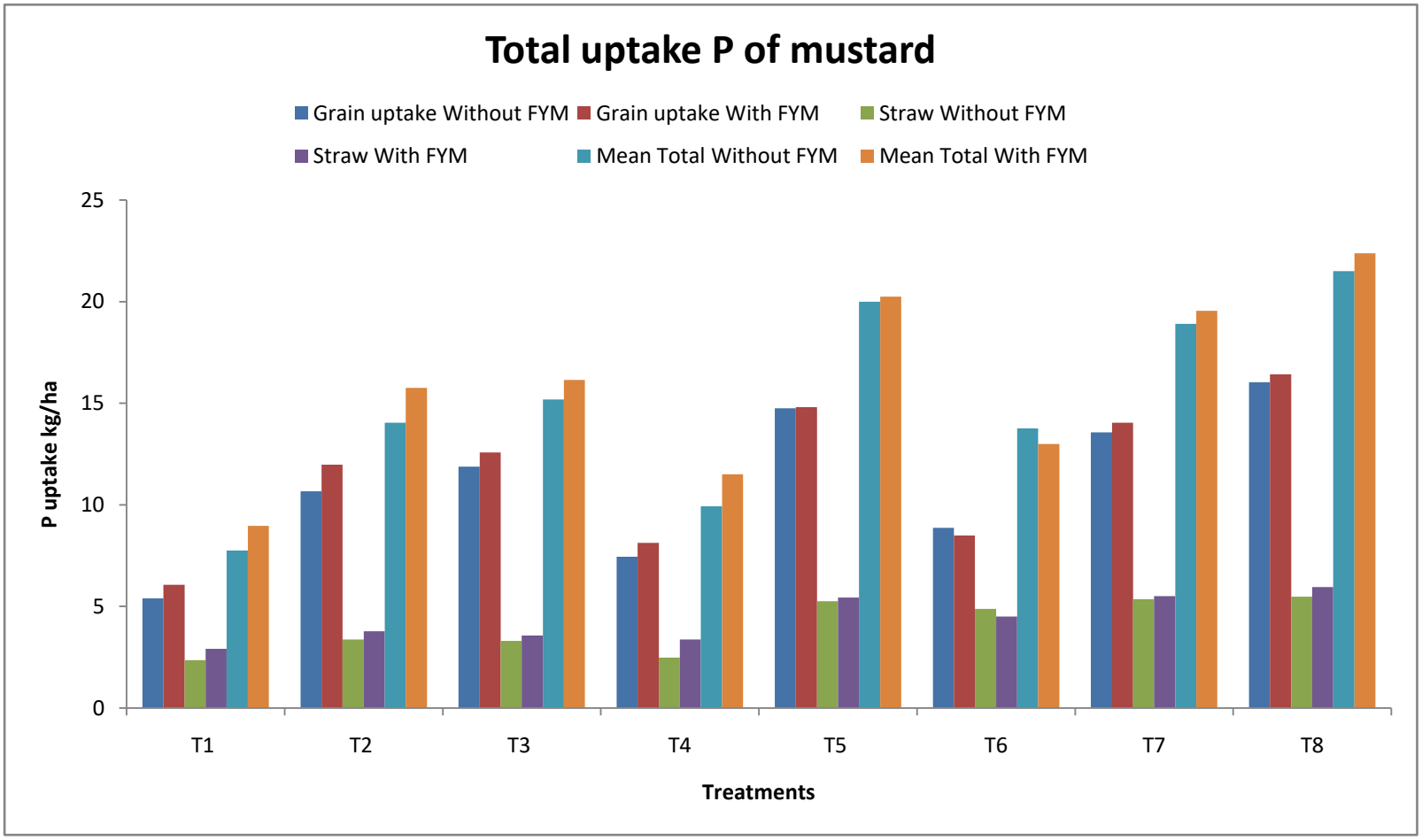


Fig. 4.2.2 Total P uptake of mustard

Table 4.2.3: Potassium uptake in mustard grain, straw and their total in relation to different fertilizer treatments with and without FYM application

Treatments (T)	K uptake (kg/ha)								
	Grain			Straw			Total		
	Without FYM	With FYM	Mean	Without FYM	With FYM	mean	Without FYM	With FYM	Mean
T1 -Control ($N_0P_0K_0$)	5.28	6.73	6.00h	21.96	27.10	24.53h	27.24	33.83	30.54 h
T2 -N_{120} $P_{60}K_0$	14.04	14.42	14.23b	44.52	44.80	44.66cde	58.56	59.22	58.89 cd
T3 -N_{120} P_0K_{40}	10.59	11.41	11.00e	45.20	45.73	45.47c	55.80	57.14	56.47cde
T4 -N_0 $P_{60}K_{40}$	8.03	9.49	8.76g	31.60	36.15	33.87g	39.63	45.64	42.63g
T5 -N_{120} $P_{60}K_{40}$	13.81	13.59	13.87bc	43.98	46.10	45.04cd	57.79	59.69	58.91c
T6-Yield Target 14.0 q/ha	10.03	10.07	10.05ef	40.69	42.82	41.75ef	50.72	52.89	51.80f
T7-Yield Target 18.0 q/ha	13.21	13.58	13.22bcd	52.88	53.29	53.08b	66.09	66.87	66.29b
T8-Yield Target 22.0 q/ha	16.29	16.64	16.46a	59.21	59.54	59.38a	75.50	76.17	75.84a
Mean	**11.41**	**11.99**	**11.70**	**42.50**	**44.44**	**43.47**	**53.92**	**56.43**	**55.17**
CD at 5% level	**Grain = T =** 1.09**, F =** NS**, FT =** NS , **Straw = T =** 3.06**, F =** NS**, FT =** NS **Total = T** = 4.12**, F** = NS**, FT** = NS								

In a column, means with a common small letter and in a row with a common capital letter are not significantly different.

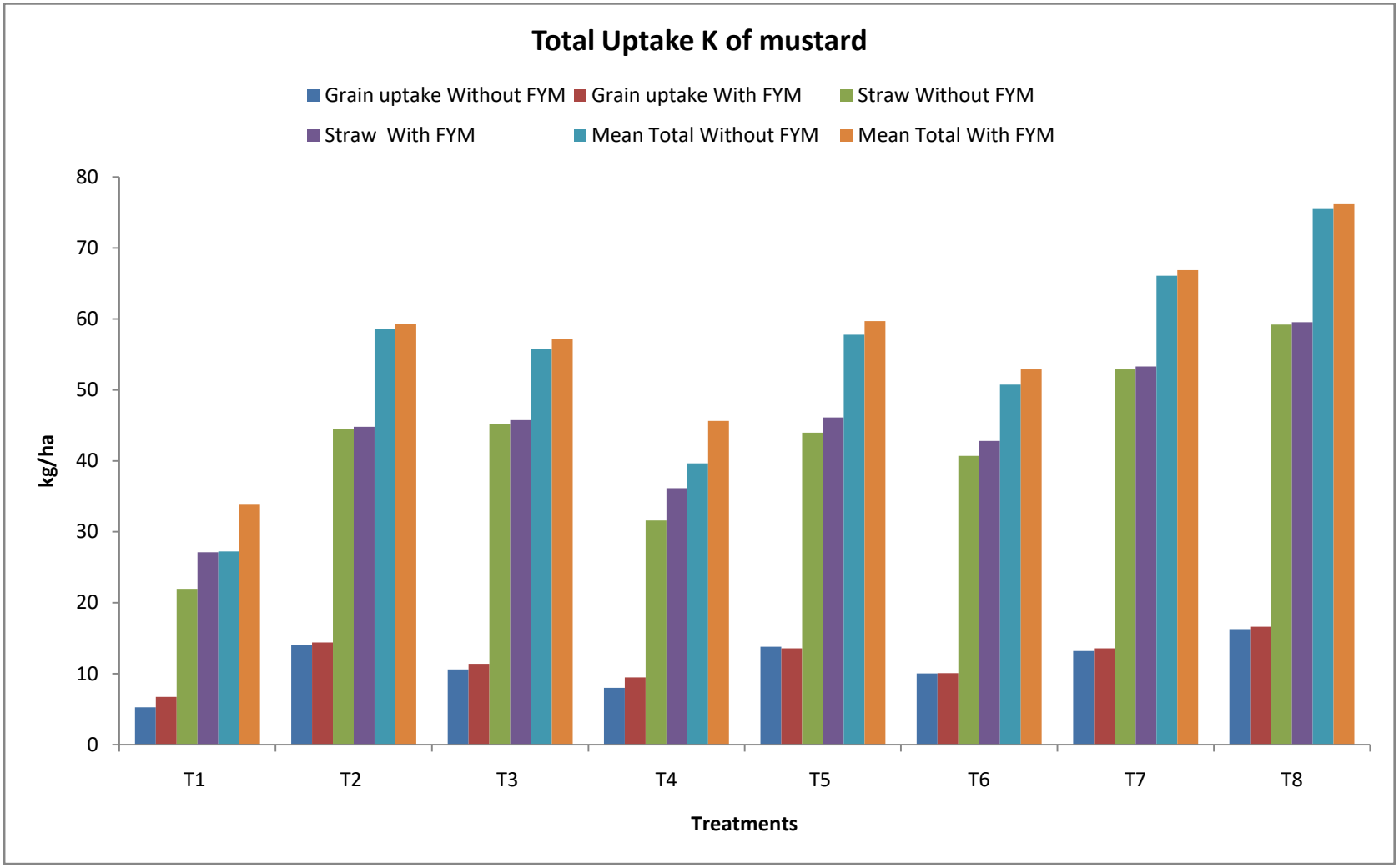


Fig. 4.2.3 Total K uptake of mustard

4.3: Yield response and response ratio of mustard

Yield response and response ratio of mustard were analyzed and data on these parameters have been presented in the Table 4.3.1.

Table 4.3.1: Yield response and response ratio of mustard in relation to different fertilizer treatments with and without FYM application

Treatment	Yield Response			Response ratio		
	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean
T1 -Control ($N_0P_0K_0$)	-	-	-	-	-	-
T2 -N_{120} $P_{60}K_0$	996	1206	**1101**	5.53	6.70	**6.12**
T3 -N_{120} P_0K_{40}	779	890	**834**	4.87	5.56	**5.21**
T4 -N_0 $P_{60}K_{40}$	350	602	**476**	3.50	6.02	**4.76**
T5 -N_{120} $P_{60}K_{40}$	1173	1320	**1246**	5.33	6.00	**5.66**
T6-Yield Target 14.0 q/ha	723	775	**749**	6.08	7.36	**6.72**
T7-Yield Target 18.0 q/ha	1137	1202	**1169**	5.55	6.29	**5.92**
T8-Yield Target 22.0 q/ha	1502	1514	**1508**	5.17	5.47	**5.32**
Mean	**951**	**1073**	**1012**	**5.14**	**6.02**	**5.58**

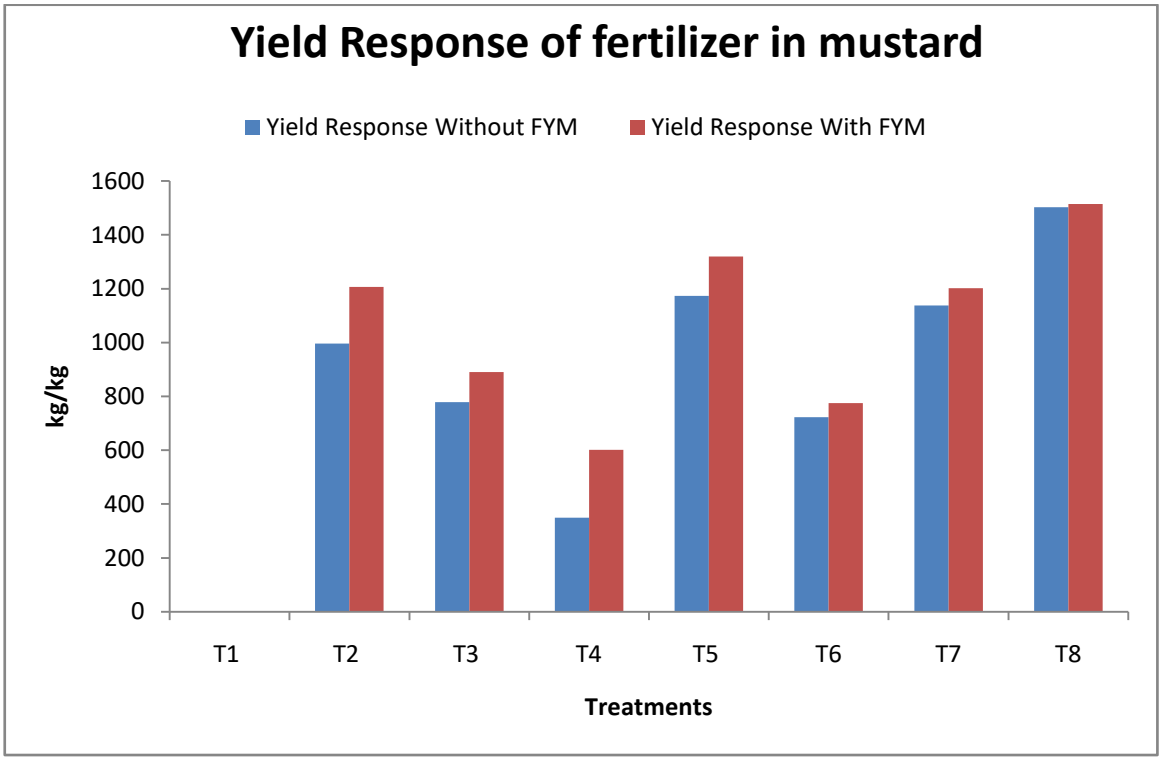


Fig 4.3.1 Yield Response of fertilizer in mustard

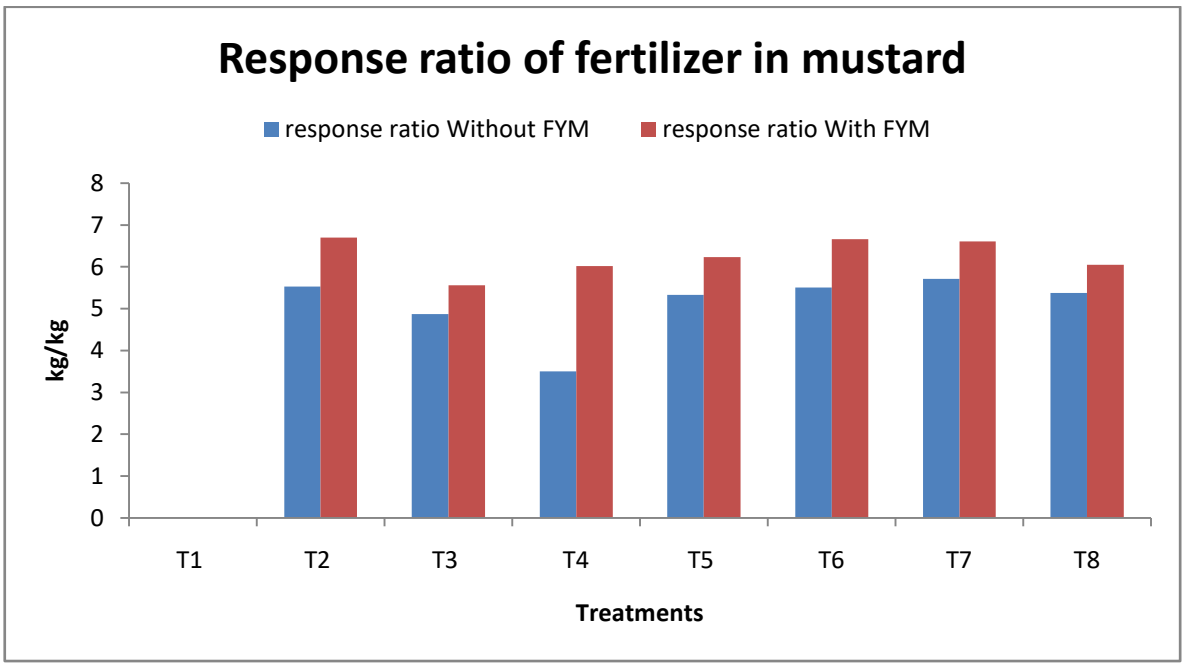


Fig 4.3.2 Response ratio of fertilizer in mustard

Response of mustard to fertilizers and FYM application as presented in Table 4.3.1 and Fig 4.3.1 show that higher response was recorded with the treatment T_8 (YT 22 q/ha) followed by T_5 (N_{120} P_{60} K_{40}), T_7 (YT 18 q/ha), T_2 (N_{120} P_{60} K_0) and T_3 (N_{120} P_0 K_{40}). STCR based fertilizer dose for yield target of 22 q/ha found higher response as compare to T_5 treatment which received recommended dose of fertilizer (N_{120} $P_{60}K_{40}$). High crop response was observed which received the soil test based fertilizer application. Fertilizer application with FYM recorded higher grain yield response as compared to sole application. This result is supported by other workers like Bhaduri and Gautam (2013), Ahmed et al.(2015), and Keram et al. (2012)

Response ratio in mustard (Table 4.3.1 and Fig 4.3.2) affected by fertilizer treatment and FYM application. The nutrient response and response ratio were found higher with FYM applications over fertilizer alone. This result confirms that application of FYM helps to enhance the crop yields by enhancing the nutrients utilization. Response ratio is expressed in terms of kg grain per kg of nutrients applied. The higher response ratio was recorded with the treatment T_7 (YT 18 q/ha) followed by T_2 (N_{120} P_{60} K_0), T_5 (N_{120} $P_{60}K_{40}$), T_8 (YT 22 q/ha) and T_6 (YT 14 q/ha). STCR based fertilizer dose for yield target of T_7 (YT 18 q/ha) was higher than T_8 (YT 22 q/ha) and RDF T_5. The yield and nutrients response ratio was higher in treatment T_8 (YT 22 q/ha) but response ratio was lower than RDF due to application of higher dose of fertilizer. Ahmed et al (2015) reported that the response ratio was recorded maximum in fertilizer applied under STCR-IPNS for targeted yield of rice at 3 and 4 t ha^{-1} in the field trial and this result confirmed that the proposed fertilizer prescription equations were valid for autumn rice.

4.4: Efficiency of fertilizer nutrients for mustard

Efficiencies of fertilizer nutrients for mustard were analyzed and data on these parameters have been presented in the Table 4.4.1.

Table 4.4.1: Fertilizer efficiency of mustard in relation to different fertilizer treatments with and without FYM application

Treatments (T)	FN			FP			FK		
	Without FYM	**With FYM**	**Mean**	**Without FYM**	**With FYM**	**mean**	**Without FYM**	**With FYM**	**Mean**
T1 -Control ($N_0P_0K_0$)	--	--	--	--	--	--	--	--	--
T2 -N_{120} $P_{60}K_0$	0.34	0.37	**0.36**	0.10	0.13	**0.12**	--	--	--
T3 -N_{120} P_0K_{40}	0.28	0.29	**0.29**	--	--	--	0.71	0.75	**0.73**
T4 -N_0 $P_{60}K_{40}$	--	--	--	0.04	0.06	**0.05**	0.31	0.46	**0.38**
T5 -N_{120} $P_{60}K_{40}$	0.41	0.42	**0.42**	0.20	0.21	**0.21**	0.76	0.81	**0.79**
T6-Yield Target 14.0 q/ha	0.43	0.49	**0.46**	0.36	0.45	**0.40**	0.61	0.72	**0.67**
T7-Yield Target 18.0 q/ha	0.43	0.49	**0.46**	0.34	0.42	**0.38**	0.69	0.74	**0.72**
T8-Yield Target 22.0 q/ha	0.38	0.40	**0.49**	0.28	0.33	**0.31**	0.65	0.68	**0.67**
Mean	0.30	0.41	**0.40**	0.26	0.29	**0.28**	0.61	0.66	**0.64**

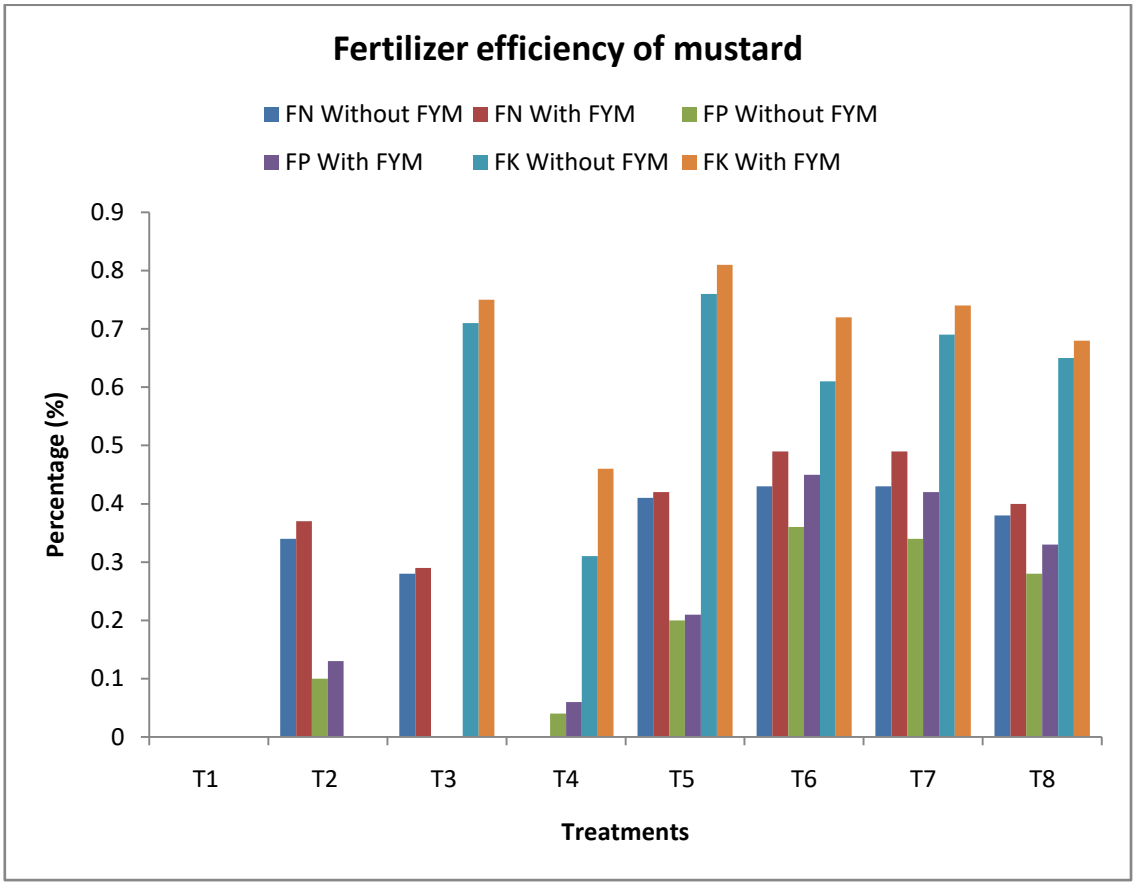


Fig 4.4.1 Fertilizer efficiency of mustard

The efficiencies of applied fertilizer nutrients with and without FYM were estimated as presented in Table 4.4.1 and Fig 4.4.1 for mustard crop. Higher efficiency of applied fertilizer N with and without FYM as well as its mean recorded with soil test based fertilizer application for targeted yield in comparison to other fertilizer treatments including RDF (T_5). This may be due to the fact that STCR based fertilizer application gives actual fertilizer nutrients based on the nutrient requirement and their efficiencies and hence maximum nutrients utilization occurs as compared to blanket fertilizer application and other treatments. In general, FYM application enhanced the nutrients use efficiency as can be seen in this result.

The phosphorus use efficiency recorded in very wide range (0.05 -0.40) which indicates that if imbalanced fertilization is done as in case of T_3 treatment that received full dose of phosphorus without nitrogen then

efficiency of P could not be attained and the treatments which received soil test based fertilizer application for targeted yield utilized maximum P from fertilizer alone as well as with FYM. The higher P use efficiency were recorded due to higher native soil P that enhanced the use of applied P

The potassium use efficiency as recorded in the Table 4.4.1 show that STCR based fertilizer treatments gave higher K use efficiency than the other blanket applications. Potassium use efficiency estimation some time misleads because of low crop response to applied K due to high native soil K status of the experimental field. Sahu et.al (2017) reported that almost the similar results on fertilizer nutrients efficiencies with soil test and organic source to evolved fertilizer prescription equation for high density wheat crop at Raipur, STCR centre.

Table: 4.4.2 Basic parameter for mustard

Nutrients	Nutrient Requirement (kg q-1)	Fertilizer efficiency (%)	Soil test efficiency (%)	FYM efficiency (%)
N	4.78	33.83	22.07	17.21
P	0.99	18.86	55.22	8.12
K	3.57	76.46	8.47	8.42
Nutrient content in FYM	**0.4% N, 0.30 % P and 0.8 % K**			

The average values for fertilizer efficiencies of N, P and K were estimated as 33.83, 18.86 and 76.46 percent respectively. Similarly, the nutrient contributions from soil were estimated for N, P and K as 22.07, 55.22 and 8.47 percent, respectively. The efficiencies of organic source (FYM) were observed as 17.21 % N, 8.12 % P and 8.42 % K. It is well known that some amounts of the applied fertilizer N are lost through leaching, volatilization, de-nitrification and by run-off. Similarly, a large fraction of applied fertilizer P is fixed in soil by reacting with dominant cations present in the soil like Ca, Mg, Fe, Mn etc. High efficiency of applied fertilizer K observed seems to be due to higher uptake of this nutrient as soil K status

was high in experimental field resulted poor response and due to luxury consumption, high K uptake could be misleading the estimation of applied K efficiency hence can be treated as indefinable.

Gogoi *et al.* (2015) reported that Nutrient requirement was found 1.75, 0.56, and 1.74 kg N, P_2O_5, and K_2O respectively, for production of one quintal of pumpkin. Nutrient contribution from soil were 45%, 57% and 47% while fertilizer efficiency 36%, 21%, and 86% N, P_2O_5, and K_2O respectively. Similarly Saren et al (2015) reported the contribution of soil and fertilizer nutrients as 14.13 and 38.28 per cent for N, 35.33 and 56.61 per cent for P2O5 and 14.33 and 70.03 per cent for K2O, respectively for onion bulb yield in Inceptisol of Tamil Nadu.

4.5: Total cost of cultivation and gross return for mustard

Total cost of cultivation and gross return for mustard were analyzed and data on these parameters have been presented in the Table 4.5.1.

Table: 4.5.1: Total cost of cultivation and gross return for mustard crop in relation different fertilizer treatments with and without FYM application

Treatment	Cost of cultivation			Gross Return		
	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean
T1 -Control ($N_0P_0K_0$)	15000	16500	15750	28175	36208	32191
T2 -N_{120} $P_{60}K_0$	19917	21417	20667	70000	78838	74419
T3 -N_{120} P_0K_{40}	17802	19302	18552	60900	65538	63219
T4 -N_0 $P_{60}K_{40}$	19635	21135	20385	42875	53463	48169
T5 -N_{120} $P_{60}K_{40}$	21177	22677	21927	77438	83650	80544
T6-Yield Target 14.0 q/ha	17965	19021	18493	58555	60725	59640
T7-Yield Target 18.0 q/ha	20113	21169	20641	75915	78662	77288
T8-Yield Target 22.0 q/ha	22261	23317	22789	91263	91752	91508
Mean	19234	20567	19900	63140	68604	65872

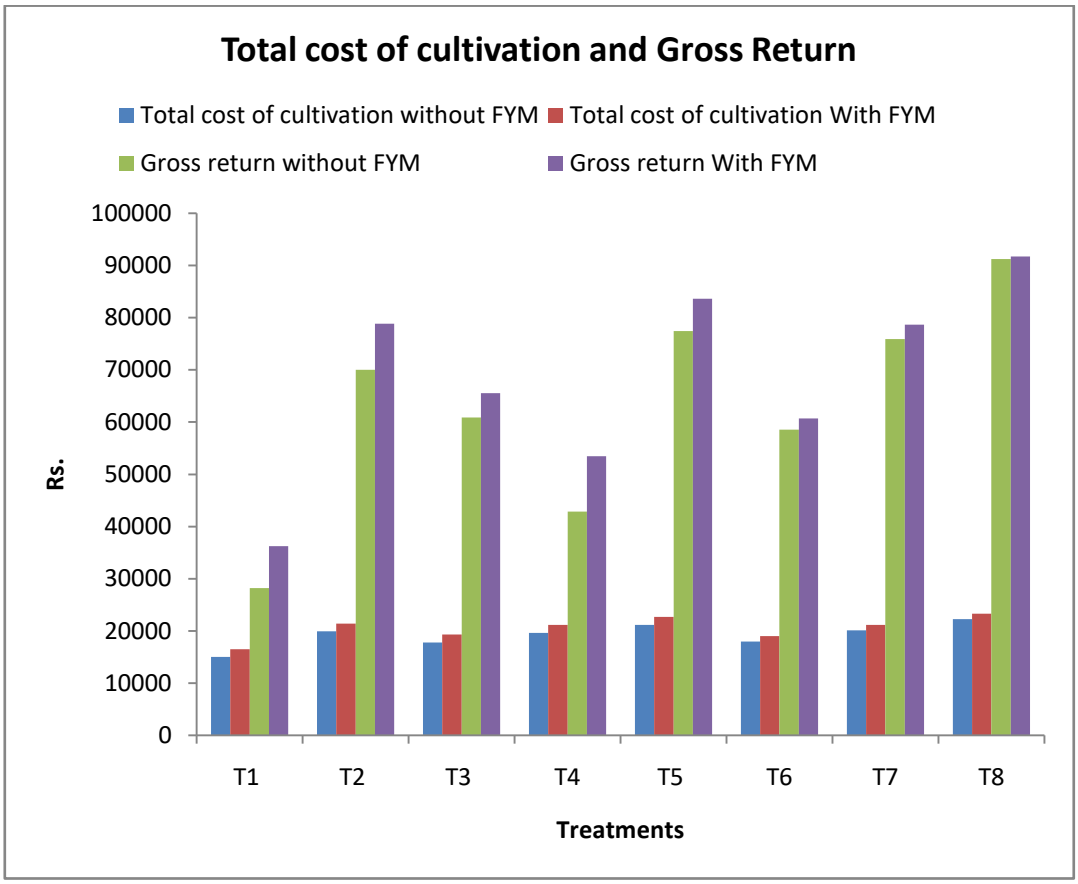


Fig 4.5.1 Total cost of cultivation and gross return

Total cost of cultivation and gross return (Table 4.5.1 and Fig 4.5.1) affected with fertilizer and FYM application. The higher cost of cultivation was calculated with the treatment T_5 (N_{120} P_{60} K_{40}) followed by highest yield target treatment T_8 (YT 22 q/ha) due to higher application of fertilizer doses. Gross return from mustard was recorded higher with the treatment T_8 (YT 22.0 q/ha) followed by treatment T_5 (N_{120} P_{60} K_{40}) and T_7 (YT 18 q/ha). Application of FYM also showed higher gross return over sole application of inorganic fertilizers. Treatment of yield target of 22 q/ha on STCR based fertilizer dose has given highest gross return among all other treatments. Gross return of mustard was drastically affected when N fertilizers did not apply. N is the most essential elements for yield of mustard otherwise yield was severely reduced without nitrogen fertilizer application and so the production cost. The fertilizer

prescription equations developed for maize under IPNS can be recommended for alluvial *Inceptisol* of eastern Utter Pradesh for achieving a yield target of 30 q ha^{-1} with higher economic return, reported by Parihar *et al.* (2015). Similar results were also supported by Ahmed et al. (2015).

Table 4.5.2: Net Return and benefit cost ratio of mustard in relation to different fertilizer treatments with and without FYM application.

Treatments (T)	Net Return			Benefit cost ratio		
	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean
T1 -Control ($N_0P_0K_0$)	13175	19707	**16441**	0.88	1.19	1.03
T2 -N_{120} $P_{60}K_0$	50083	57420	**53751**	2.51	2.68	2.60
T3 -N_{120} P_0K_{40}	43098	46235	**44666**	2.42	2.39	2.40
T4 -N_0 $P_{60}K_{40}$	23240	32327	**27783**	1.18	1.53	1.35
T5 -N_{120} $P_{60}K_{40}$	56261	60973	**58617**	2.66	2.68	2.67
T6-Yield Target 14.0 q/ha	40590	41703	**41146**	2.25	2.19	2.22
T7-Yield Target 18.0 q/ha	55801	57493	**56647**	2.77	2.71	2.74
T8-Yield Target 22.0 q/ha	69001	68434	**68717**	3.09	2.93	3.01
Mean	43906	48036	**45971**	2.22	2.28	2.25

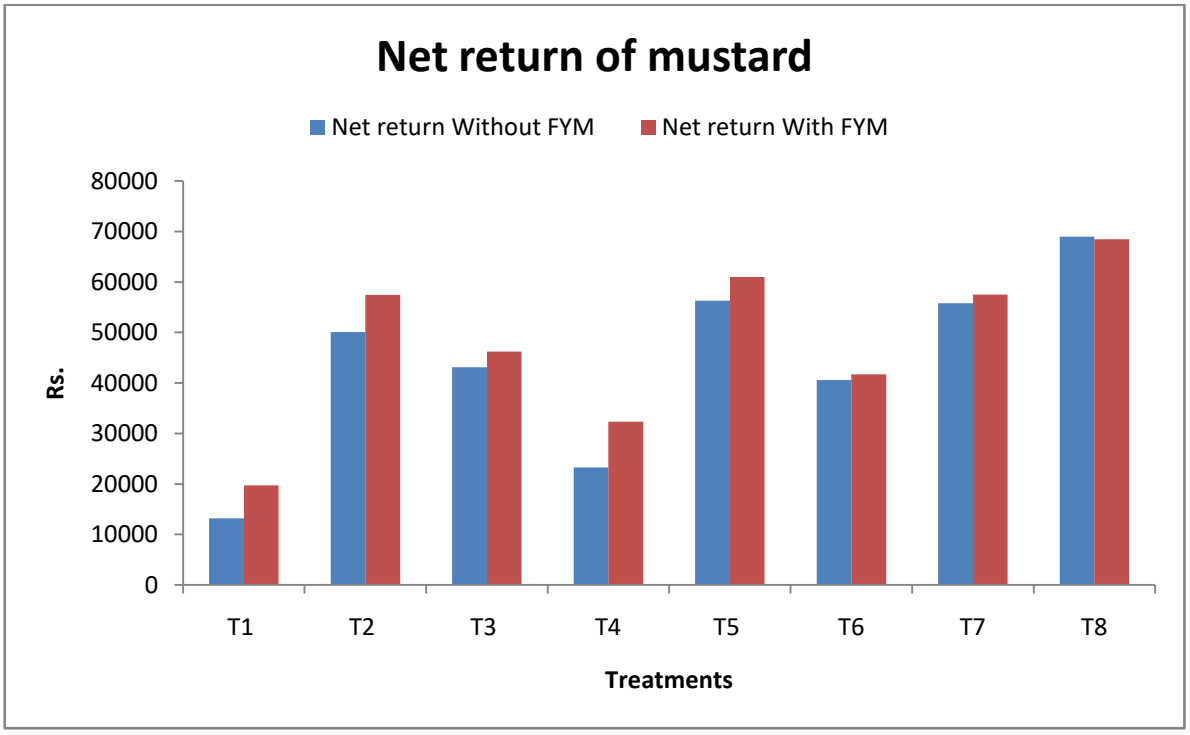


Fig 4.5.2 Net return of mustard

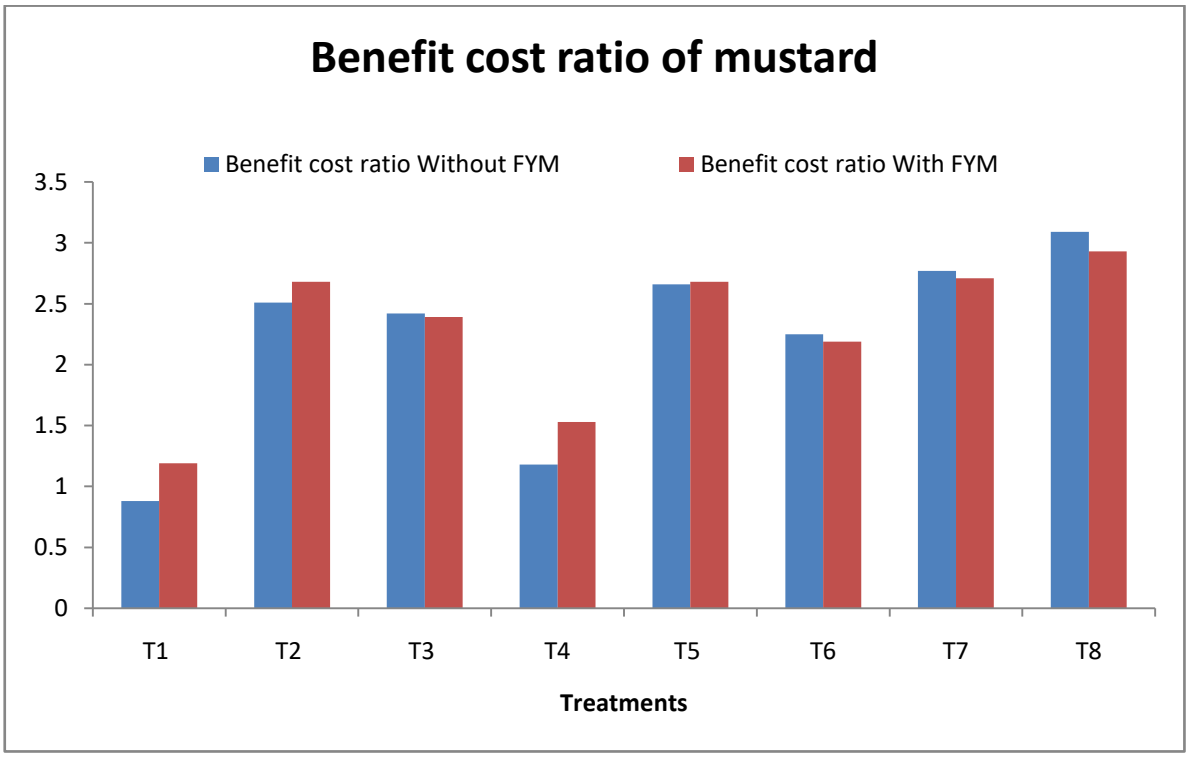


Fig 4.5.3 Benefit cost ratio of mustard

The net Return and cost benefit ratio from mustard as shown in Table 4.5.2 and Fig. (4.5.2.and 4.5.3) The higher net return was recorded with the treatment T_8 (YT 22 q/ha) followed by T_5 (N_{120} P_{60} K_{40}) and T_7 (YT 18.0 q/ha). Application of FYM also showed higher net return as compare to sole application of inorganic fertilizer. The cost benefit ratio under treatment of yield target of 22 q/ha on STCR based fertilizer dose has recorded highest return among all treatments. The mean benefit cost ratio of mustard affected by fertilizer and FYM application. The higher B:C ratio was recorded with the treatment T_8 (YT 22 q/ha) followed by treatment T_7(YT 18 q/ha) and T_5 (N_{120} $P_{60}K_{40}$) whereas B:C ratio was decreased with the fertilizer applied with FYM as compared to fertilizer alone. Benbi *et al*. (2006) reported that yields, net benefit and B/C ratio under yield target based fertilizer application were higher over the farmers' practice. Similar result was also reported by Deshmukh et al. (2012).

CHAPTER - V
SUMMARY AND CONCLUSION

The Experiments were conducted to study **"Evaluation of soil test based fertilizer prescription evolved for mustard (*Brassica juncea*) crop in *Vertisol."*** at the Instructional Farm of Indira Gandhi Krishi Vishwavidhyalaya, Raipur (CG) during, *Rabi* season, 2019 with following objectives:

1. To test the validity of the fertilizer equation derived for mustard.
2. To monitor the efficiencies of soil test and fertilizer nutrients applied with FYM.

The experiment was laid out in factorial randomize block design having sixteen treatments with replicated thrice. The each treatments, T_1 - Control; T_2 - N_{120} P_{60} K_0; T_3 - N_{120} P_0 K_{40}; T_4 - N_0 P_{60} K_{40}; T_5 - N_{120} P_{60} K_{40}; T_6 - YT 14 t/ha; T_7 - YT 18 t/ha and T_8 - YT 22 t/ha were applied alone and with FYM @ 5 t/ha. Fertilizer prescription equation for mustard developed in previous under STCR project as FN = 12.86 Y - 0.58 SN - 0.30 FYM, FP_2O_5 = 4.09 Y – 2.51 SP – 0.33 FYM and FK_2O = 4.50 Y – 0.08SK – 0.07 FYM were used to calculating the fertilizer doses for yield targeted treatments. The soil of experimental field comes in the soil's order of *Vertisols*, locally known as *Kanhar*. The soil of experimental field is clay in texture, having pH 7.4, EC 0.18 dSm-1, OC 0.58 percent and available N, P and K as 200, 16.2 and 308 kg ha^{-1}, respectively.

The mean grain and straw yields of mustard significantly affected by fertilizer and FYM application however, the interaction effect (FT) showed a non-significant result. The grain and straw yield was recorded significantly higher (21.79 q/ha) with the treatment T_8 (that received the STCR based fertilizer dose to achieve yield target of 22q/ha) followed by T_5 (N_{120} P_{60} K_{40}), T_7 (YT 18 q/ha), T_3 ($N_{120}P_0K_{40}$). Application of FYM also showed significantly higher grain and straw yields over sole application of inorganic fertilizers. Significant effect of potassium application on grain yield

of mustard was noticed between the yield data of the treatments T2 (N_{120} P_{60} K_0) and T_5 (N_{120} P_{60} K_{40}). The grain and straw yields of mustard were drastically reduced when fertilizer N was omitted in T4 ($N_0P_{60}K_{40}$) that indicates the importance of N for mustard yield. The treatments on fertilizer application based on STCR concept to achieve the yield targets of 14, 18 and 22 q/ha resulted 14.20, 18.15 and 21.79 q/ha, respectively. These results showed that yield targets of mustard were achieved with in ±10 per cent of the deviations under soil test based fertilizers applied alone or with FYM in the experiment. This result confirms the derivation of soil test based fertilizer prescription equations evolved for mustard crop to achieve a definite yield target in *Vertisol* of Chhattisgarh.

The N, P and K uptake in grain, straw and total by mustard crop were significantly affected by fertilizer application. The N uptake in grain, straw and total were recorded significantly higher under treatment T_8 (that received the STCR based fertilizer dose to achieve yield target of 22 q/ha). The total phosphorous uptake under treatment T_8 (YT 22 q/ha) was significantly higher (21.94 kg/ha) followed by T5 (N_{120} $P_{60}K_{40}$) and T7 (Yield Target 18.0 q/ha). However difference between T5 and T7 was at par. Total P uptake in T2 and T3 did not differed significantly even if with and without P application. P uptake by grain showed in the similar trends as with the total P uptake where in straw P uptake T8 treatment had significantly higher P uptake and remaining treatment did not show any definite trends. The mean total K uptake was significantly higher with T_8 (YT 22 t/ha) followed by T7 and T5 treatments. However, the treatment T_5 showed non-significant variation with T_2 and T_3. Application of FYM did not show any significant variations over sole application of inorganic fertilizers.

The higher response was recorded with the treatment T_8 (YT 22 q/ha) followed by T_5 (N_{120} P_{60} K_{40}), T_7 (YT 18 t/ha), T_2 (N_{120} P_{60} K_0) and T_3 (N_{120} P_0 K_{40}). STCR based fertilizer dose for yield target of 22 q/ha found higher response as compare to T_5 treatment which received recommended dose of fertilizer (N_{120} $P_{60}K_{40}$). High crop response was observed which received the

soil test based fertilizer application. The nutrient response and response ratio were found higher with FYM applications over fertilizer alone. This result confirms that application of FYM helps to enhance the crop yields by enhancing the nutrients utilization. The higher response ratio was recorded with the treatment T_7 (YT 18 t/ha) followed by T_2 (N_{120} P_{60} K_0), T_5 (N_{120} $P_{60}K_{40}$), T_8 (YT 22 t/ha) and T_6 (YT 14 t/ha). STCR based fertilizer dose for yield target of T_7 (YT 18 t/ha) was higher than T_8 (YT 22 t/ha) and RDF T_5. The yield and nutrients response ratio was higher in treatment T_8 (YT 22 t/ha) but response ratio was lower than RDF due to application of higher dose of fertilizer.

Higher efficiency of applied fertilizer N with and without FYM as well as its mean recorded with soil test based fertilizer application for targeted yield in comparison to other fertilizer treatments including RDF (T5). This may be due to the fact that STCR based fertilizer application gives actual fertilizer nutrients based on the nutrient requirement and their efficiencies and hence maximum nutrients utilization occurs as compared to blanket fertilizer application and other treatments. The phosphorus use efficiency recorded in very wide range (0.05 -0.40) which indicates that if imbalanced fertilization is done as in case of T3 treatment that received full dose of phosphorus without nitrogen then efficiency of P could not be attained and the treatments which received soil test based fertilizer application for targeted yield utilized maximum P from fertilizer alone as well as with FYM. The higher P use efficiency was recorded due to higher native soil P that enhanced the use of applied P. The potassium use efficiency under STCR based fertilizer treatments was higher than the other blanket applications. Potassium use efficiency estimation some time misleads because of low crop response to applied K due to high native soil K status of the experimental field. In general, FYM application enhanced the nutrients use efficiency as can be seen in this result. The average values for fertilizer efficiencies of N, P and K were estimated as 33.83, 18.86 and 76.46 percent respectively. Similarly, the nutrient contributions from soil were estimated for N, P and K

as 22.07, 55.22 and 8.47 percent, respectively. The efficiencies of organic source (FYM) were observed as 17.21 % N, 8.12 % P and 8.42 % K.

Total cost of cultivation and gross return were affected with fertilizer and FYM application. The higher cost of cultivation was calculated with the treatment T_5 (N_{120} P_{60} K_{40}) followed by highest yield target treatment T_8 (YT 22 t/ha) due to higher application of fertilizer doses. Gross return from mustard was recorded higher with the treatment T_8 (YT 22.0 t/ha) followed by treatment T_5 (N_{120} P_{60} K_{40}) and T_7 (YT 18 t/ha). Application of FYM also showed higher gross return over sole application of inorganic fertilizers. Treatment of yield target of 22 t/ha on STCR based fertilizer dose has given highest gross return among all other treatments. Gross return of mustard was drastically affected when N fertilizers did not apply. N is the most essential elements for yield of mustard otherwise yield was severely reduced without nitrogen fertilizer application and so the production cost.

The higher net return was recorded with the treatment T_8 (YT 22 t/ha) followed by T_5 (N_{120} P_{60} K_{40}) and T_7 (YT 18.0 t/ha). Application of FYM also showed higher net return as compare to sole application of inorganic fertilizer. Among all treatments, the higher B:C ratio was recorded with the treatment T_8 (YT 22 t/ha) followed by treatment T_7(YT 18 t/ha) and T_5 (N_{120} $P_{60}K_{40}$) whereas B:C ratio was decreased with the fertilizer applied with FYM as compared to fertilizer alone. The mean benefit cost ratio of mustard affected by fertilizer and FYM application.

Conclusion:

1. Fertlizer prescription equation derived for mustard to achieve a definite yield target were validated within ±10 per cent of the deviations. The fertilizer prescription equations developed for mustard can be recommended for *Vertisol* of chhattisgarh plain area.
2. The average values for soil test and fertilizer efficiencies for N, P, K were estimated as 22.07, 55.22, 8.47 and 33.83, 18.86, 76.46 percent

respectively. The efficiencies of organic source (FYM) were observed as 17.21 % N, 8.12 % P and 8.42 % K.

3. The soil test based fertilizer prescription was found profitable as compared to general recommendation.

SUGGESTIONS FOR FUTURE RESEARCH WORK:

1. There is a need to test the fertilizer prescription equations derived for mustard crop under various soil situations for different agro-climatic zones by improving the efficiency factors.
2. Continuous validation and refinement should be performed for improvement over years.
3. The information generated as soil test based fertilizer application with organic source need to be tested on farmer's field in the similar soil situation for its suitability.
4. In our country, state soil testing facilities are limited in number, therefore, linking transferring soil test technology to the farmers.

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APPENDICES

APPENDIX A: WEEKLY METEOROLOGICAL DATA DURING THE CROP GROWTH PERIOD (FROM NOV TOMARCH 2019-20) RECORDED FROM IGKV METEOROLOGICAL SITE, RAIPUR

Weeks	MAXT (°C)	MINT (°C)	RF (mm)	RH I (%)	RH II (%)	VP I (mm)	VP II (mm)	WS(kmph)	EP(mm)	SS(hr)
47	30.14	15.40	0.00	88.86	38.86	12.97	11.86	1.46	2.99	8.30
48	30.06	15.89	0.00	90.00	42.57	13.03	12.74	1.77	2.91	7.06
49	28.11	14.00	0.00	84.14	34.43	10.96	9.49	2.47	3.00	6.89
50	29.09	14.33	0.00	91.00	41.86	11.93	12.24	1.11	2.41	5.44
51	27.04	14.34	0.11	88.57	48.29	11.66	11.79	2.44	2.36	4.74
52	26.66	13.31	0.00	80.86	36.29	10.30	8.93	2.46	2.76	5.07
53	23.50	13.23	2.77	81.00	52.57	10.21	9.86	4.06	2.29	3.51
54	24.07	10.60	0.46	89.29	49.43	9.54	10.00	2.49	2.34	5.99
55	29.17	12.99	0.00	88.86	40.00	10.86	11.37	1.37	2.47	8.33
56	27.89	13.36	0.00	87.86	43.71	10.69	11.59	2.03	2.47	4.71
57	27.60	13.87	0.00	77.29	37.29	10.61	9.93	2.70	3.29	6.43
58	21.29	14.71	7.09	90.00	75.29	12.39	12.77	4.00	1.86	0.60
59	27.91	11.59	0.00	88.71	30.86	9.83	8.99	2.46	3.30	9.37
60	31.37	13.34	0.00	87.29	31.43	11.37	10.57	1.46	3.83	9.29
61	29.19	15.90	5.14	90.43	44.00	13.39	12.13	2.77	3.01	5.70
62	31.60	19.44	0.26	85.00	50.00	15.89	16.26	3.19	3.54	7.69
63	30.06	19.57	5.31	88.00	55.29	16.44	16.74	3.54	3.64	5.97
64	31.15	20.67	6.07	88.86	55.04	17.72	17.76	3.16	3.52	6.48

VITA

Name	: Onkar Singh
Date of birth	: 21 April, 1988
Present Address	: Jal Vihar Colony,Telibandha,Raipur
Phone	: 9827661887
Email	: onkarorsingh@gmail.com
Permanent Address	: Mission chowk, kedarpur,Ambikapur,Surguja,Chhattisgarh.

Academic Qualifications:

Degree	Year	University/ Institute
Board of Secondary Education	2004	CBSE, Delhi
Board of Higher Secondary Education	2007	CGBSE, Raipur
B.Sc. (Agriculture)	2011	IGKV,Raipur
M.Sc. (Ag.) Soil Sc. & Agril. Chemistry	2020	Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G)

Professional Experience :Rural Agricultural Work Experience Programme and 8 year as RAEO,CG Government

Membership of Professional Societies (If any):

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