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मृदा परीक्षण फसल अनुक्रिया सह–सम्बन्ध (एस.टी.सी.आर.) पर अखिल भारतीय समन्वित अनुसंधान परियोजना से सम्बंधित परीक्षणों का नियोजन, अभिकल्पना और विश्लेषण

Planning, Designing and Analysis of Experiments Relating to AICRP on Soil Test Crop Response Correlations

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प्राक्कथन

फसल उत्पादन बढ़ाने के लिए विस्तारित सिंचाई सुविधाओं के तहत उच्च उपजशील किस्मों और गहन बहु फसल प्रणाली के आने से मृदा परीक्षण मानों पर आधारित संतुलित उर्वरक के महत्व को भारतीय किसानों ने भली–भांति समझा है । संतुलित उर्वरक की सिफारिशों के लिए मृदा परीक्षण मानों और फसल अनुक्रिया के बीच एक सम्बन्ध विकसित करने के विचार से भारतीय कृषि अनुसंधान परिषद ने सन् 1967–68 के दौरान मृदा परीक्षण फसल अनुक्रिया सहसम्बन्ध (Soil Test Crop Response Correlations) पर एक अखिल भारतीय समन्वित अनुसंधान परियोजना (All India Coordinated Research Project) शुरू की । इस परियोजना द्वारा विगत 35 वर्षों में लक्षित उपज प्राप्त करने के उद्देश्य से भिन्न–भिन्न फसलों की उर्वरक अनुसूचियां निर्धारित करने के लिए अनेक उर्वरक समायोजन समीकरण(fertilizer adjustment equations) तैयार किए जाते रहे हैं । विगत वर्षों में यह देखा गया है कि किसी एक अनुसंधान केन्द्र पर किसी एक फसल की उर्वरक समायोजन समीकरण पर आधारित सिफारिशें संगत(consistent) नहीं हैं । इसके अलावा अधिकांश मामलों में बहु–समाश्रयण (multiple regression) विधि की सहायता से उर्वरक पोषकों की अनुकूल खुराकें प्राप्त नहीं की जा सकीं हैं ।

मृदा परीक्षण फसल अनुक्रिया सहसम्बन्ध पर अखिल भारतीय समन्वित अनुसंधान परियोजना के परियोजना समन्वयक(Project Coordinator), भारतीय मृदा विज्ञान संस्थान (I.I.S.S.) भोपाल, इन समस्याओं के साथ भारतीय कृषि सांख्यिकी अनुसंधान संस्थान, नई दिल्ली में आए और एक लम्बे विचार–विमर्श के बाद आपस में सहमति हुई कि भारतीय कृषि सांख्यिकी अनुसंधान संस्थान में एक परियोजना शुरू की जाएगी ताकि इन समस्याओं के समाधान की संभावनाओं को तलाशा जा सके और नई विश्लेषणात्मक तकनीकों का विकास करने के साथ–साथ परीक्षण करने की नई डिज़ाइनों को सुझाया जा सके । परिणाम स्वरूप दिनांक 01 मार्च, 2000 को भा.कृ.सां.अ.सं. में मृदा परीक्षण फसल अनुक्रिया सहसम्बन्ध पर अखिल भारतीय समन्वित अनुसंधान परियोजना से सम्बंधित परीक्षणों का नियोजन, डिज़ाइनिंग और विश्लेषण (Planning, designing and analysis of experiments relating to AICRP on Soil Test Crop Response Correlations) नामक एक सहयोगी परियोजना शुरू की गई तथा समाप्ती पर इसकी रिपोर्ट का प्रकाशन 2003 मे किया गया।

इस रिपोर्ट में विभिन्न डिजाइन बिन्दुओं वाली अनेक नई डिज़ाइनों का प्रस्ताव रखा गया था । कुछ ऐसी डिजाइनें भी तैयार की गईं जिनके उपचार संयोजनों में कार्बनिक और अकार्बनिक उर्वरक शामिल हैं । इन डिज़ाइनों मे से एक डिज़ाइन जो (3x3x3) Factorial पर आधारित है वो एस.टी.सी.आर. परियोजना के 2005 के वार्षिक सम्मेलन मे परीक्षणों के लिए स्वीकृत किया गया। एस.टी.सी.आर. परियोजना के सभी केन्द मे परीक्षण के लिए तथा भारतीय कृषि सांख्यिकी अनुसंधान संस्थान मे उन परीक्षणों के आंकडो का विश्लेषण करने कि सहमति हो गई।

अतः 01 मार्च, 2007 से मृदा परीक्षण फसल अनुक्रिया सह–सम्बन्ध पर अखिल भारतीय समन्वित अनुसंधान परियोजना से सम्बंधित परीक्षणों का नियोजन, डिजाइनिंग और विश्लेषण (Planning, designing and analysis of experiments relating to AICRP on Soil Test Crop Response Correlations) नामक एक परियोजना भारतीय कृषि सांख्यिकी अनुसंधान संस्थान में शुरू की गई । इस परियोजना के तहत अनुक्रिया अन्तरापृष्ठ (response surface) पद्धति की सहायता से उर्वरक पोषकों के अनुकूलतम मानों को प्राप्त करने के लिए विश्लेषणात्मक तकनीक विकसित की गई है । इस पद्धति को किसी एक विशेष स्थान के मृदा परीक्षण मानों के नियत सैट के लिए उर्वरक पोषकों की अनुकूलतम जरूरत प्राप्त करने के लिए लागू किया जा सकता है । मैं, भारतीय कृषि सांख्यिकी अनुसंधान संस्थान, नई दिल्ली और भारतीय मृदा विज्ञान संस्थान, भोपाल के वैज्ञानिकों के प्रयासों की सराहना करता हूं जिन्होंने बड़े ही मनोयोग से इसे तैयार किया है । आशा करता हूं कि इस परियोजना के परिणामों से मृदा परीक्षण फसल अनुक्रिया सहसम्बन्ध के क्षेत्रा में काम कर रहे कृषि कर्मियों को लाभ मिलेगा । मैं, यह भी कामना करता हूं कि यह सहयोग भविष्य में और सुदृढ़ होगा ।

वि कु भाटिया

(विजय कुमार भाटिया)
निदेशक

FOREWORD

With the introduction of high yielding varieties and intensification of multiple cropping under expanded irrigation facilities, the importance of balanced fertilization based on soil test values was well recognized by the Indian farmers for increased crop production. With a view to develop a relationship between soil test values and crop response to fertilizer for balanced fertilizer recommendations, the Indian Council of Agricultural Research launched the All India Coordinated Research Project on Soil Test Crop Response Correlation during the year 1967-68. This project over the last 35 years has generated numerous Fertilizer Adjustment Equations and calibration charts for prescribing fertilizer schedules for different crops for obtaining targeted yields. However, these fertilizer equations vary widely over the years for a crop at a particular centre. Moreover at most of the time the optimal doses of the fertilizer nutrients could not be obtained using multiple regression method.

The Project Coordinator AICRP on STCR, Indian Institute of Soil Science, Bhopal approached IASRI, New Delhi with these problems. It was mutually agreed that a project would be taken up at IASRI to explore the possibility of solving these problems and to develop new analytical techniques and suggest new designs for carrying out experiments. As over the years, large amount of data have been gathered under the project, the creation of a database under the project was also solicited. Consequently a Collaborative project entitled "Planning, Designing and Analysis of experiments relating to AICRP on soil test crop response correlation" was under taken at IASRI with effect from 1st March 2000 and its report was published in July 2003.

A number of new designs have been proposed with various design points. Also some designs were generated in which the treatment combinations included organic and inorganic fertilizers. One of the designs was accepted for experimentation during the annual workshop of STCR in January 2005.

As a consequence to this, a new project was launched in March 2007 titled " Planning, designing and analysis of experiments relating to AICRP on Soil test crop response correlations", to analyze the data of the experiments conducted at all the cooperating centres and also to develop new methodology to obtain optimal fertilizer doses.

Under the project, an analytical technique has been developed for obtaining the optimal values of the fertilizer nutrients using Response Surface Methodology. This methodology can be applied usefully for obtaining optimal requirement of fertilizer nutrients for a given set of soil test values of a particular site.

I appreciate the efforts of the Scientists of IASRI, New Delhi and IISS, Bhopal for bringing out this report. It is hoped that the agriculture workers in the field of Soil Test Crop Response Correlation shall be benefited by the findings of the project. I also wish that this collaboration would be strengthened in future.

(V.K. Bhatia)
DIRECTOR

आमुख

भारतीय कृषि अनुसंधान परिषद द्वारा 1967–68 के दौरान फसलों की उच्च पैदावार देने वाली किस्मों के साथ–साथ गहन खेती की दशाओं के लिए मृदा परीक्षण अंशांकन का विकास करने के उद्देश्य से मृदा परीक्षण फसल अनुक्रिया सहसंबंध (Soil Test Crop Response Correlations) पर एक अखिल भारतीय समन्वित अनुसंधान परियोजना (All India Coordinated Research Project)शुरू की गई थी । फिलहाल, देश के विभिन्न सस्य जलवायवीय क्षेत्रो (agro climatic zones) में इसके 17 केन्द्र है । गत 35 सालों के दौरान इस परियोजना में आंकड़ों का बृहत् खण्ड तैयार किया गया है । विगत वर्षों में यह देखा गया कि किसी खास केन्द्र पर किसी एक फसल की उर्वरक समायोजन समीकरण (fertilizer adjustment equation) पर आधारित सिफारिशें संगत (consistent) नहीं हैं । इसके अलावा, बहु समाश्रयण विधि (multiple regression) से निकाले गए पोषक तत्वो (nutrients) के इष्टतम मान (optimal dose) हर समय सफल नहीं होते हैं । इसलिए यह जरूरी था कि अपनाई गई डिज़ाइन के हर पहलू की ओर इष्टतम मानों के निर्धारण के साथ–साथ सांख्यिकीय विश्लेषण (statistical analysis) करने की जरूरी परिस्थितियों की समीक्षा की जाए ।

मृदा परीक्षण फसल अनुक्रिया सह–सम्बन्ध पर अखिल भारतीय समन्वित परियोजना के परियोजना समन्वयक (Project Coordinator) भारतीय मृदा विज्ञान संस्थान, भोपाल द्वारा भारतीय कृषि सांख्यिकी अनुसंधान संस्थान, नई दिल्ली, के परीक्षण अभिकल्पना (design of experiments) प्रभाग के वैज्ञानिकों के साथ विचार–विमर्श के दौरान इन समस्याओं पर प्रकाश डाला गया और आपसी सहमति हुई कि भारतीय कृषि सांख्यिकी अनुसंधान संस्थान में एक परियोजना शुरू की जाए ताकि इन समस्याओं के समाधान की संभावनाएं तलाशी जा सकें और नई डिज़ाइन विकसित करने के साथ–साथ आंकड़ों का विश्लेषण तो किया ही जाए साथ ही उनकी व्याख्या भी की जाए तथा मृदा परीक्षण अंशांकन (soil test calibration) में सुधार लाया जाए । इसके फलस्वरूप मृदा परीक्षण फसल अनुक्रिया सह–सम्बन्ध पर अखिल भारतीय समन्वित अनुसंधान परियोजना से सम्बंधित परीक्षणों का नियोजन, डिजाइनिंग और विश्लेषण (Planning, designing and analysis of experiments relating to AICRP on Soil Test Crop Response Correlations) नामक एक परियोजना 01 मार्च, 2000 से भारतीय कृषि सांख्यिकी अनुसंधान संस्थान में शुरू की गई थी तथा समाप्ति पर इस रिपोर्ट का प्रकाशन 2003 मे किया गया। इस रिपोर्ट में एस.टी.सी. आर. परियोजना की जरूरतों के आधार पर भिन्न–भिन्न डिज़ाइन बिन्दुओ (Design points) सहित (5x4x3), (4x4x3), (4x4x4) इत्यादि डिज़ाइनों की किस्म से अनेक डिजाइनों का प्रस्ताव रखा गया है ।

इन डिज़ाइनों मे से एक डिज़ाइन जो (3x3x3) Factorial पर आधारित है वो एस.टी.सी.आर. परियोजना के 2005 के वार्षिक सम्मेलन मे परीक्षणों के लिए स्वीकृत किया गया । एस.टी.सी.आर. परियोजना के सभी केन्द मे परीक्षण के लिए तथा भारतीय कृषि सांख्यिकी अनुसंधान संस्थान मे उन परीक्षणों के आंकडो का विश्लेषण करने कि सहमति हो गई ।

अतः 01 मार्च, 2007 से मृदा परीक्षण फसल अनुक्रिया सह–सम्बन्ध पर अखिल भारतीय समन्वित अनुसंधान परियोजना से सम्बंधित परीक्षणों का नियोजन, डिजाइनिंग और विश्लेषण (Planning, designing and analysis of experiments relating to AICRP on Soil Test Crop Response Correlations) नामक एक परियोजना भारतीय कृषि सांख्यिकी अनुसंधान संस्थान में शुरू की गई ।

अनुक्रिया अन्तरापृष्ठ (response surface) पद्धति पर आधारित एक विश्लेषणात्मक विधि विकसित की गई है । इस विधि में यदि मृदा परीक्षण मान उपलब्ध हों तो किसी एक खास स्थान के लिए नाईट्रोजन, फासफोरस और पोटैशियम उर्वरक पोषकों के इष्टतम मान निकाले जा सकते हैं । विभिन्न सहयोगी केन्द्रों के आंकड़ों का विश्लेषण करते समय यह देखा गया कि सभी मामलों में जहां अनुक्रिया अन्तरापृष्ठ पद्धति से पल्याण बिन्दु (saddle point) के रूप में एक स्तब्ध बिन्दु (stationary point) बना यानि यह न तो अधिकतम था और न ही न्यूनतम था । इन मामलों में स्तब्ध बिन्दु के परिवेश (vicinity) में अनुक्रिया अन्तरापृष्ठ की संभावना का पता लगाया गया है । लक्षित उपज विधि के माध्यम से उर्वरक पोषकों नाईट्रोजन, फॉस्फोरस और पोटैशियम के इष्टतम मानों को अनुक्रिया अन्तरापृष्ठ पद्धति के परिप्रेक्ष्य में सत्यापित किया गया ।

लेखकगण, भारतीय कृषि सांख्यिकी अनुसंधान संस्थान, नई दिल्ली के निदेशक, डा. विजय कुमार भाटिया, के अत्यंत आभारी हैं कि उन्होंने इस परियोजना में गहरी दिलचस्पी लेते हुए लगातार हमारा उत्साहवर्धन तो किया ही साथ ही सुझाव देने के साथ–साथ हमें सभी सुविधाएं भी उपलब्ध की हैं ।

हम, परीक्षण अभिकल्पना के प्रधान वैज्ञानिक डा. पी.के. बत्रा के बड़े ऋणी हैं जिन्होंने रिपोर्ट की गुणवत्ता में सुधार लाने के लिए सृजनात्मक सुझाव दिए और बहुमूल्य टिप्पणियां कीं ।

हम, श्री उदयवीर सिंह, तकनीकी अधिकारी, टी–6 का भी हार्दिक आभार व्यक्त करते हैं जिन्होने इस रिपोर्ट को तैयार करने के दौरान पूरे लगन और निष्ठा से कार्य किया और अपना अमूल्य योगदान दिया ।

लेखकगण

PREFACE

All India Coordinated research project on Soil Test Crop Response Correlation was initiated by ICAR during 1967-68 to develop soil test calibration for conditions of intensive agriculture with high yielding varieties of crops. Presently there are 17 centres in different agro climatic zones of the country. Over the last 35 years a large volume of data has been generated under the project. It was observed that the recommendations based on the Fertilizer Adjustment Equations are not consistent over the years for a crop at a particular centre. Moreover, the optimal values of the nutrients as derived by the method of multiple regression are not successful every time. Therefore, it was necessary to review the overall aspects of the design adopted, determination of the optimal values, and the conditions necessary for carrying out the statistical analysis.

The Project Coordinator AICRP on Soil Test crop Response Correlations, Indian Institute of Soil Science, Bhopal highlighted these problems in a discussion with the Scientists of Division of Design of Experiments, IASRI, New Delhi and it was mutually agreed that a project would be taken up at IASRI, to explore the possibility of solving these problems and to develop new designs and the analysis of data, their interpretation and improvement in soil test calibration. Consequently, a project entitled "Planning, Designing and analysis of experiments relating to AICRP on Soil test Crop Response Correlations" was initiated at IASRI w.e.f. 1st March 2000 and the report was published in July 2003.

One of the designs suggested in the report, which minimizes the number of experimental strips from 4 to 3 and also the number of levels of factors from 5x4x3 to 3x3x3, was accepted for experimentation in the annual workshop of AICRP on STCR at IISS at Bhopal in January 2005. It was decided that experiments on this new design would be conducted at all the cooperating centres of STCR in the country.

As a consequence of the acceptance and conduct of experiments on this design at all the cooperating centres of STCR and subsequent reporting of the data from these experiments, the present project titled " Planning, designing and analysis of experiments relating to AICRP on Soil test crop response correlations" was initiated on 01-03-2007, in order to analyze the data to be received from the cooperating centres and development of new methodology for obtaining soil test based fertilizer recommendations.

An analytical technique has been developed based on Response surface methodology. In this method, the optimal values of Nitrogen, Phosphorus and Potassium fertilizer nutrients to be applied, could be derived for a particular site if the soil test values of that site are available. While analyzing the data of different cooperating centres, it was observed that in almost all the cases the response surface methodology produced the stationary point as saddle point i.e. neither maxima nor minima. In such cases exploration of the response surface in the vicinity of the stationary point has been attempted. The optimal values of the fertilizer nutrients Nitrogen, Phosphorus and Potassium derived through Targeted Yield Approach were verified in the light of Response Surface Methodology.

We express our deep sense of gratitude to Dr. V.K. Bhatia, Director, IASRI, New Delhi for his keen interest in the project, constant encouragement, suggestions and for the facilities provided.

We are greatly indebted to Dr. P.K. Batra, Principal Scientist, Division of Design of experiments for offering constructive suggestions and valuable comments in improving the quality of the report.

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AUTHORS

CONTENTS

CHAPTER-I

1. Introduction

Green Revolution in India started in late sixties with the introduction of high yielding fertilizer responsive varieties of the food grain crops. Increase in the use of fertilizers and cropping intensity made India self sufficient in food production. With the increase in the cost of fertilizers, crop production system is becoming more and more expensive. Simultaneously, indiscriminate and imbalanced use of chemical fertilizers has negative effect on soil fertility and productivity. Growth rate for productivity of major crops is not only stagnant but also showing declining trends. The population of India is estimated to touch 1.4 billion by the year 2025. With total food grain production hovering around 200-210 MT for the last few years, it may not be possible to achieve a target of 300 MT by 2025 without improvement in soil health (Sharma B.M. et al. 2007). Decline in soil fertility is more alarming in intensively cultivated regions wherein nutrient withdrawals by crops are high and replenishment is not only inadequate but also unbalanced in favour of N. This, therefore, requires extensive research to provide a scientific basis for enhancing and sustaining food production as well as soil productivity with minimum environmental degradation.

Balanced nutrition does not mean the application of nitrogen, phosphorus and potassium alone in certain proportion through fertilizer, but it should ensure that the nutrients in available forms are in adequate quantity and in required proportion in the soil to meet the requirement of the crops for obtaining the desired levels of yield. Nutrients available in the soil are rarely present in adequate amounts and in balanced proportion to meet the nutrient requirement of the crops. This requires intervention by application of external sources of nutrients i.e. fertilizers and nutrients. Soil test provides the requisite information about the amounts of nutrients available in the soil and their imbalances, while fertilizer recommendations aim at correcting the imbalances in nutrients to crop requirements. The fertilizer recommendations based on quantitative / semi- quantitative approaches or methods do not give expected yield responses. Therefore it needs a more comprehensive approach for fertilizer use, incorporating components like soil test, field research and economic evaluation of the results.

Soil test calibration in India is intended to establish a relationship between the levels of soil nutrients determined in the laboratory and crop response to fertilizers in the field permits balanced fertilization through right kind and amount of fertilizers.

1.1 All India Coordinated Research Project on Soil Test Crop Response Correlations

Soil test crop-response studies has been going on for a quite a long period of time both in India and abroad. With the introduction of high yielding varieties and intensification of multiple cropping under expanded irrigation facilities, the importance of balanced fertilizer use for increased crop production was well recognized by the Indian farmers.

Since the fertilizer recommendations for crops based on simple field trials did not give the expected yield response; a need arose for the refinement of fertilizer prescription for varying soil test values for economic crop production. Against this background, the All India Coordinated Research Project on Soil Test Crop Response Correlation (STCR) was initiated during the year 1967-68.

1.2 Objectives of AICRP on STCR

The project has the following objectives.

(i) To develop relationships between soil test values and crop response to fertilizers in order to provide calibration for fertilizer recommendations based on soil testing.

(ii) To obtain a basis for making fertilizer recommendations for targeted yields.

(iii) To evaluate various soil test methods for their suitability under field conditions.

(iv) To evaluate the joint use of chemical fertilizers and organic manures for enhanced nutrient use efficiency.

(v) To derive a basis for making fertilizer recommendations for a whole cropping system on initial soil test values.

1.3 Cooperating Centres, location, soil type and agro-eco region

There were eight centers under the project to begin with. During 1970-71, five more centres were added. One centre (Raipur) was added during the year 1981-82. Currently, STCR project is having 17 cooperating centres. The location, year of start, their agro-eco region etc. are shown in Table 1.1

1.4 Statistical design and conduct of experiments under STCR

1.4.1 Statistical design used by STCR prior to 2005

The main objective of STCR consists of developing a relationship between soil test and crop response to fertilizer in order to provide a calibration for balanced fertilizer recommendations based on soil testing. Since different levels of uncontrollable variables e.g. Soil fertility, cannot be expected to occur at one place, different sites have to be selected to represent different levels of soil fertility. In order to tide over the management problem conducting a field experiment at different sites differing from each other in the extent of uncontrolled variables, artificial fertility gradients in 4 adjoining plots are created by applying different amounts of fertilizers to a preceding non-experimental crop. Under the four large plots (strips) first strip receives no fertilizer, while second, third and fourth strips receives half, one and two times the standard dose (X) of N, P, and K respectively.

The standard dose (X) being: N_1=150 Kg/ha^{-1}, P_1=Phosphorus equivalent to the critical point in the P fixation studies of that field and K_1=enough to give 150 Kg/ha^{-1} of exchangeable K.

Then a preparatory crop (or exhaust crop) has to be grown so that the fertilizers undergo reactions with the soil, plant and microbiological agencies. After the harvest of the preliminary crop, the field is ready for laying out the experiment with test crop for soil test-crop response correlation studies. Next the main experiment is conducted by selecting 21 treatments (a sub-set of treatment combinations from a 5 x 4 x 3 factorial experiment design). In each of the 4 strips, these selected 21 treatment combinations were applied randomly along with 6 controls (no fertilizer). Thus there were 27 treatments in each strip. This experiment was being conducted since 1967 at all the cooperating centres on various crops suitable to the region.

The main aim of these experiments was to derive optimal fertilizer doses for recommendation to the farmers. To get these optimal values, initially the analysis was carried out using multiple regression method. But it is not always possible to get optimal values using multiple regression method.

It has been observed that in order to derive optimum rates of fertilizer for recommendation, the multiple regression equation should fulfil certain basic criteria (Annual report, AICRP on STCR, 1993-98,) like (i) high and significant value of R^2, (ii) follow the law of diminishing returns and (iii) the partial regression coefficients should be significant and should be of appropriate signs and lastly (iv) the signs of the coefficients of the linear, quadratic and interaction terms of the parameters in the multiple regression equation should be '+ ve', '-ve' and '-ve' respectively. However, these criteria are satisfied in limited number of cases.

To overcome these problems, instead of multiple regression, the STCR project makes use of Fertilizer adjustment equations based on a Targeted yield to get calibrated equations for the farmer's field for different nutrients. Among the various methods of fertilizer recommendation, the one based on yield targeting is unique in the sense that this method not only indicates soil test based fertilizer dose but also the level of yield the farmer can hope to achieve if recommended agronomic practices are followed in raising the crop.

Targeted yield concept strikes a balance between 'fertilizing the crop' and 'fertilizing the soil'. The procedure provides a scientific basis for balanced fertilization and balance between applied nutrients and soil available nutrients. In the targeted yield approach, it is assumed that there is a linear relationship between grain yield and nutrient uptake by the crop, as for obtaining a particular yield, a definite amount of nutrients are taken up by the plants. Once this requirement is known for a given yield level, the fertilizer needs can be estimated taking into consideration the contribution from soil available nutrients.

Once these optimal doses are derived from the fertilizer adjustment equations, these are then used for follow up trials in the farmers' field for a yield target, to confirm the adequacy of the doses.

Although the derived optimal doses with fertilizer adjustment equations are fairly good enough for recommendation to farmer but it is generally seen that the optimum doses of fertilizer nutrients derived from these calibrated equations and also the signs and magnitudes of their coefficients change over the years.

Over the years, a large volume of data has been generated under the AICRP on STCR project. Therefore with a view to investigate these specific problems and to see the possibility of a new design setup which would give better results along with minimizing the resources, the project co-ordinator (STCR) IISS, Bhopal and Director, IASRI, New Delhi decided to collaborate in this respect and for planning, designing and analysis of experiments to be taken up in future and to provide the statistical analysis and interpretation of the data generated by the experiments conducted under the STCR project. The collaborating team, which consisted of scientists from IASRI, New Delhi as well as IISS, Bhopal have brought out a report on the first phase of the project which covered the period from 01.03.2000 to 28.02 2003.

In this project report entitled " Planning, designing and analysis of data relating to AICRP on Soil Test Crop response Correlations" Lahiri et al. (2003) investigated some of the problems as mentioned in the earlier sections. Some of them is given in brief (given under Chapter-II, review of literature).

- Reviewed the whole design structure of the experiments conducted at various cooperating centres and suggested some appropriate treatment structures for different situations

- Also various regression diagnostics were used to see the causes of variation in the data and the results.

- The optimum doses of fertilizer N,P and K to be applied to a site with given soil test values were obtained using the response surface methodology exploring the response surface in the vicinity of stationary point. This methodology has an advantage over the targeted yield approach in the sense that year effect may also be incorporated in the model which is not possible in targeted yield approach.

1.4.2 New Statistical design structure used by STCR from 2005 onwards

The problems identified in the earlier project were tackled in the light of Response Surface methodology. Various Regression Diagnostics were also applied to see the causes of such variations in the results obtained from the experimental data. Besides the problems faced by the STCR project, which have been discussed already in the last section, another important problem was the treatment structure of the design with which the experiment was being conducted for over 35 years. This was discussed at length at the Kalyani Workshop in 2002 and then at IASRI in the same year. At IASRI meeting, the team from division of design of experiments, IASRI, New Delhi presented a number of alternate designs with different treatment structures and situations with different design points. These have been presented in the report of Lahiri et al.(2003). During the meeting at IASRI in the year 2002, it was felt that having run the experiment for so many years, the results obtained from the experiments should give enough evidence about the optimum levels of N, P and K and so there is no need to have five levels of any factor.

Therefore, the experiment should be run with only three levels of N, P and K. which may be
(i) The optimum level,
(ii) One level below optimum level and
(iii) One level above optimum level.
Also the number of strips may be taken as three instead of four.

Based on the considerations above, one of the designs which also include treatments of Organic manures was proposed by IASRI, New Delhi, and was accepted by the QRT of STCR and later on was accepted at the annual workshop of STCR workshop held in 24-25,January 2005 at Bhopal. This experiment is being conducted at all the 17 cooperating centres of STCR. The data generated under the experiments are analyzed at IASRI.

Moreover, there are still some questions, which remain to be answered. For example, the derivation of optimal doses of fertilizer nutrients by creating fertilizer adjustment equations has been found to be effective and optimal. But the main concern is that the coefficients of the nutrients in the fertilizer-adjusted equations vary widely over the years. Whether these coefficients could be pooled to give a consolidated and consistent fertilizer doses over the years? More importantly, the method for the derivation of the optimum doses of fertilizers in combination with organic matter is to be worked out.

The experiments with the design (with new treatments structure as suggested by IASRI) are being conducted at all the co-operative centres of STCR. Thus there is a continuous flow of data from these cooperating centres of the STCR project and received at IASRI, New Delhi. These are analyzed as per the design and the results are being sent to the respective cooperating centres (Appendix-I). These results would also be utilized for the development of future designs. These in turn would add more knowledge about the mechanism of the system. Further, some modifications in the treatment structure, if required, would be suggested. Some new considerations have cropped up since then. Of late, soil scientists have been stressing on the use of organic manures and bio- fertilizers, in a big way. Therefore under this project the design suggested by IASRI consists of treatment combinations involving organic manures besides the inorganic fertilizers.

Keeping in view of the above the present study was proposed with the following objectives:

(1) To develop suitable methodology for the analysis of data of past experiments conducted under STCR

(2) To plan, design and analyze the data of experiments relating to AICRP on Soil test crop response correlations (STCR).

CHAPTER -II

2.0 Review of literature

2.1 Early work done on Soil-Test Crop Response

The yield response to application of most nutrients follows the law of diminishing returns. Each added fertilizer increment produces a progressively smaller yield increase, finally reaching an asymptote. The economic benefit of fertilization is a function of yield response in relation to fertilizer cost. The law of diminishing returns can be approximated by a curvilinear equation i.e. Mitscherlich equation (1909)

$$\log A - \log(A-Y) = Cx$$

$$\text{or, in the form } Y = A(1 - e^{-Cx}) + \varepsilon \qquad (2.1)$$

where Y is yield expressed on a relative basis as obtained in proportion to a limiting factor, x., “A” is the maximum yield, and "C" is a constant describing the shape of the curve (generally between 0.1 and 1, the higher the value the sooner the curve reaches maximum). Thus as the value of x increases, Y increases but at ever diminishing amounts.

The first approach towards the establishment of a soil test calibration was attempted by Bray (1948) which is a modification of Mitscherlich equation and known as Mitscherlich-Bray model as follows:

$$(A-Y)/A = \exp(b_1 x + b_2 t) + \varepsilon \qquad (2.2)$$

In this method, the yield is converted to relative yield, which is then correlated with soil test and fertilizer rate by the equation. Where, A is the maximum yield, Y is the relative yield, x the fertilizer rate and t the soil test value. This method suffers from the drawback that in order to have a reasonable estimate of fertilizer requirements, the maximum yield has to be some desirable proportion of the yield (e.g. 95%) and the maximum is approached only as fertilizer rate approaches infinity.

The Mitscherlich-Bray equation was modified by Mombiela et al (1981)

$$Y = A\{1 - e^{-C[x + f(t)]}\} + \varepsilon \qquad (2.3)$$

Where, Y is a predicted yield obtained by application of x units of Nutrient (fertilizer), say P, to a soil with a soil test value ‘t’. The parameter A is defined as maximum yield and C is proportionality constant related to the efficiency of soil and fertilizer P. The function f(T) relates to an amount of plant available P in the soil.

Colwell (1974) suggested a method of calculating optimal fertilizer P by the following equation:

$$P_R = (1/C)\log(CA/p(1+R)) - bt + \varepsilon \qquad (2.4)$$

Where, P =price of fertilizer/price of crop, R=marginal rate of return (or interest rate), and other terms are as previously defined under the modified Mitscherlich equation.

A number of different yield functions have been proposed and used in the past, representing the relationship between crop response and fertilizer application. Heady, Pesek and Brown (1955), Heady (1961), Abraham and Rao (1966) etc., have studied the suitability of a number of such relationships.

Heady et al. (1955) favoured the model.

$$Y_{ij}=A_i + B_i X_{ij}^{1/2} + C_i X_{ij} + D_i X_{ij}^{3/2} + \ldots + \varepsilon \tag{2.5}$$

where A_i , B_i , C_i etc. are the parameters to be estimated, ε is the random error distributed as $N\sim(0,\sigma^2)$. While Abraham and Rao preferred the model,

$$Y_{ij}=A_i+B_iX_{ij}+C_i X_{ij}^2 + \ldots + \varepsilon \tag{2.6}$$

because of their simplicity in comparison to the traditional exponential growth function.

$$Y_{ij}=\alpha_i+ \beta_i \exp(\gamma_i X_{ij}) + \varepsilon \tag{2.7}$$

where α_i , β_i and γ_i are site parameters. These authors showed that the polynomials (2.5) & (2.6) give on an average a better regression fit of yield data. Also the polynomials have an additional advantage that they can accommodate a maximum yield, which the exponential models cannot.

Colwell (1967) developed a method wherein he used orthogonal polynomials to fit the data of n sites of a region at each of which a Randomized fertilizer experiment has been carried out with same r treatments (rates of fertilizer applications). He described the calibration equation as below:

$$Y=P_0\xi_0+P_1\xi_1+P_2\xi_2+P_3\xi_3+\ldots+\varepsilon \tag{2.8}$$

where Y is the yield, ξ_0 , ξ_1 , ξ_2 and so on are orthogonal polynomials of fertilizer application rates and P_0 ,P_1 , P_2 and so on are site parameters and ε as defined earlier. The regression of the form given above were fitted to the data of each site and coefficients for each site were then used as dependent variables to solve simultaneous regression of the form

$$p_{ki} = q_{ki}+ r_{ki} + T_i^{1/2} + s_{ki} T_i +\ldots+ \varepsilon' ;k = 0, 1, 2,\ldots,(r-1) ;\ i = 1, 2,\ldots , n. \tag{2.9}$$

where, T_i is the soil test measurements of the i^{th} site and k corresponds to the order of the polynomial in (2.8). The coefficients q_{ki} , r_{ki} and s_{ki} may be regarded as the regional parameters that provide a generalization of (2.8) by a function relating yield to fertilizer rate and soil test values. With appropriate substitution from (2.9) for the coefficients of p_{ki} in (2.8) and the expansion of the orthogonal polynomials, a generalized function may be obtained in the form of polynomials of soil test T_i and fertilizer rate X_i , in the square root scale, namely,

$$Y_{ij} = (\alpha_0 + \alpha_1T_i^{1/2} + \alpha_2 T_i)+(\beta_0 +\beta_1T_i^{1/2} +\beta_2T_i)X_{ij}^{1/2} + (\gamma_0 +\gamma_1T_i^{1/2} +\gamma_2T_i) X_{ij} + (\delta_0+\delta_1T_i^{1/2}+\delta_2T_i)X_{ij}^{3/2} + \ldots + \varepsilon \tag{2.10}$$

Alternatively, an average regional yield function

$$Y_i = a + b\, X_i^{1/2} + c\, X_i + d\, X_i^{3/2} + \ldots + \varepsilon \qquad (2.11)$$

may be obtained without soil test regression, by averaging the coefficients of (2.8) over sites and again by expanding and collecting terms. In both cases the coefficients may be regarded as regional parameters of generalized yield function.

Alternative to the derivation of (2.10) or (2.11) from (2.8) and (2.9), these equations may be estimated directly by a least square fit of regression to the yield, fertilizer and soil test data. It can be shown that the coefficients obtained by this direct method are identical with those derived from equations (2.8) and (2.9) for the same data. Colwell found square root scale to be somewhat better fit to the data as compared to the corresponding quadratic expression in natural scale. Yield response, profit and fertilizer requirements can be calculated by appropriate substitution in equation (2.10) and (2.11). Mead and Pike (1975) have given an exhaustive review of various response surface models.

Colwell (1978) brought out a comprehensive report based on his studies on soil test – crop response, titled "Computation for studies of soil fertility and fertilizer requirement". The work on soil test – crop response studies had been taken up elsewhere also, to name a few, the government soil testing agencies of Netherlands and U.S.A. in the last forty years conducted thousands of field experiments with different crops and on different types of soils under various climatic conditions.

With regard to choosing a model, Colwell (1978) noted that the model can be chosen for their:
(a) Computational convenience
(b) Statistical estimation of functions from data and
(c) The calculation of optimal rates.

Keeping this in view, the polynomial models are popular because:
1. They are easily fitted to data using standard multiple regression procedure
2. They can be made flexible enough to describe most smooth trends and rigid enough to smooth out aberrations or "errors" in data by appropriate choice of scale and degree
3. They are implicit in many standard methods of statistical analysis of variance in the form of orthogonal polynomial trends and
4. They can easily accommodate interaction effects.

2.2 Modified Colwell approach

Lahiri et al (1998) applied a modification to the Colwell's approach (discussed under section 2.1) in a study conducted at IASRI, New Delhi. In this approach, step wise multiple regression (backward elimination) method was applied in two stages. Let a district be divided into 'v' zones, 'b' blocks in each zone and 'm' villages in each block. Thus we have (v × b × m) sites or say 'n' sites for each district. At each site an experiment has been conducted using randomised block design, with the same set of treatments. Also, at each of these sites, s soil test measurements have been carried out. Then the problem is to relate these s soil tests to the yield data obtained by conducting the experiment at each site and testing the statistical significance of their relationship. The yield data from each of the site may be represented by a polynomial function of the fertilizer rate.

$$Y_{ij} = b_{0j} + b_{1j} X_{i1} + b_{2j} X_{i2} + b_{3j} X_{i3} + b_{4j} X_{i1}^2 + b_{5j} X_{i2}^2 + b_{6j} X_{i3}^2 + b_{7j} X_{i1} X_{i2} + b_{8j} X_{i1} X_{i3} + b_{9j} X_{i2} X_{i3} + \varepsilon_{ij} \quad (2.13)$$

Where 'i' denotes the fertilizer treatment (i = 1,2,…,p) and 'j' denotes the site (j = 1,2,…,n), b's are regression co-efficients of linear, quadratic and interaction effects of fertilizer nutrients X_{i1}, X_{i2} and X_{i3} respectively and ε_{ij}'s are randomly distributed with zero mean and variance σ^2. The whole set up of 'n' experiments can be written as simultaneous set of regression

$$Y = X\beta + \varepsilon \quad (2.14)$$

where Y is a matrix of order (p x n) (row corresponds to fertilizer treatments and columns to sites), X is a (p x r) matrix of polynomial terms of the fertilizer treatments and β is a matrix of regression co-efficients which may be regarded as site parameters, representing linear and quadratic trends of yield response to fertilizers.β is estimated by the usual least square procedure.

$$\hat{\beta} = (X'X)^{-1} X'Y \quad (2.15)$$

The site parameters of matrix $\hat{\beta}$ can as such be treated as function of the 's' site measurements (soil test values), the relationship being represented also by the simultaneous regression

$$\beta' = T'D \quad (2.16)$$

where **T′** is the n x (s+1) matrix of the soil test variables for the n sites.

$$T = \begin{bmatrix} 1 \ldots 1 \ldots\ldots\ldots\ldots\ldots\ldots 1 \\ t_{11} t_{12} \ldots\ldots\ldots\ldots\ldots\ldots t_{1n} \\ t_{21} t_{22} \ldots\ldots\ldots\ldots\ldots\ldots t_{2n} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ t_{s1} t_{s2} \ldots\ldots\ldots\ldots\ldots\ldots t_{sn} \end{bmatrix} \quad (2.17)$$

D is the matrix of regression co-efficients estimated by

$$\mathbf{D} = \mathbf{(T'T)^{-1} TB'} \quad (2.18)$$

From the relationships of (2.14) and (2.16), yield may be expressed as a function of fertilizer treatments and soil tests as

$$Y = X'D'T \quad (2.19)$$

The equation (2.19) may be expanded, rearranged and written in the form as follows:-

$$Y_j = \sum_{m=0}^{s} a_m t_m + \sum_{m=o}^{s} b_m t_m X_{j1} + \sum_{m=o}^{s} c_m t_m X_{j2} + .------+ \sum_{m=o}^{s} k_m t_m X_{j2} X_{j3} \quad (2.20)$$

where Y_j is yield estimated for a particular site with the soil test values t_1, t_2,--- t_s and X_j 's are the fertilizer polynomial terms.

The above equation (2.20) was worked out taking the linear and quadratic terms of applied fertilizer and that of soil test values. The regression analysis was carried out by the method of stepwise multiple regression (backward elimination method). This method is only possible if the number of sites is more, so as to give greater error degrees of freedom for the analysis.

2.3 The All India Coordinated Research Project on Soil-Test Crop-Response Correlations

Consequent upon the introduction of high yielding varieties, the importance of fertilizer application for higher crop production was very well recognized by the farmers. With the fast expanding soil testing advisory service in India, the Indian Council of Agricultural Research felt the need to generate information on soil test crop response calibration and fertilizer recommendation based on soil test values. In the first phase, work on soil test crop response correlation in the country was carried out at the Indian Agricultural Research Institute, New Delhi under field and pot culture conditions using limited number of soils collected from less than 20 locations in the country using the then existing tall varieties of wheat and paddy in the early sixties.

In order to provide a refinement in the scientific basis in fertilizer use suited for the modern agricultural technology, consequent upon Green Revolution, the second phase of soil test–crop response work in the country was initiated under All India Co-ordinated Research Project on Soil Test–Crop Response Correlations by the Indian Council of Agricultural Research from 1967 onwards initially at eight centres. In 1970-71 five more centres were sanctioned. At present there are seventeen centres across the country.

The Methodology for conducting the experiment as per the design adopted by AICRP on STCR since 1967 to 2005 has been discussed in the section 1.4.1 in the introduction chapter.

2.3.1 The general soil test- crop response model

The general soil test- crop response model for yield which was in use, earlier can be given in terms of soil and fertilizer variables as:

$$Y = a + b_1\, SN + b_2\, SP + b_3\, SK + b_4\, FN + b_5\, FN^2 + b_6\, FP + b_7\, FP^2 + b_8\, FK + b_9\, FK^2 + \\ + b_{10}\, (FN \times SN) + b_{11}\, (FP \times SP) + b_{12}\, (FK \times SK) + \varepsilon \qquad (2.12)$$

where, SN, SP and SK are soil available nutrients and FN, FP and FK are added fertilizer nutrients and ε is the error term which is assumed to be independently and identically distributed normally with zero mean and constant variance σ^2.

For soil test calibration, the multiple regression equation that has a high predictability ($R^2 >$ 0.67) is used for making both yield prediction and optimization of chemical fertilizer requirements (Annual report, AICRP on STCR, 1993-98). This equation is differentiated with respect to the nutrient concerned.. The derivative will give the desired optimum fertilizer dose for varying soil test values of a nutrient for maximum yield. Inclusion of economic parameters will enable calculation of soil test based fertilizer dose for maximum profit and any desired rate of return on the investment made on fertilizers.

The method of multiple regression for obtaining the optimal values of the nutrients is not always successful as the coefficients of linear, quadratic and interaction effects should have positive, negative and negative signs (+, -, -) respectively for each of N, P and K ,which is not so in general. More over the R^2 value is also not so high.

2.3.2 The Targeted yield approach

To derive the fertilizer prescriptions, the method given by Truog (1960) was adopted, which although has no statistical theory behind, but is a mathematical derivation of certain indices. The basic data of the indices were generated by calculating the Nutrient requirement, Soil use efficiency and Fertilizer use efficiencies obtained from the nutrient uptake values of nutrients

N, P and K. Then these values were fed into separate formula for obtaining separate equations for obtaining optimal doses for N, P and K respectively. Based on soil test values of a particular a site, the corresponding doses of N, P and K are calculated from these equations. Then follow up trials is conducted with these doses. Although the results of the follow up trials show good results but the coefficients of the parameters of the equations for generating the fertilizer doses vary widely from year to year. Different centres conduct experiments by choosing the number of treatments from the set defined earlier and could take any of the treatment combinations of their choice. Over the years, numbers of experiments were conducted at various centers of the AICRP on Soil Test Crop Response project by the application of various designs with different treatment combinations.

As described earlier, the process of multiple regression does not always provide desired results. The method of Targeted yield equations although provide some close results, but it is not statistically sound as it is based on some mathematical indices.

As mentioned earlier, in order to investigate the problems faced by the STCR project, a project was taken up at IASRI, New Delhi (during 2000-2003) . In this project report entitled " Planning, designing and analysis of data relating to AICRP on Soil Test Crop response Correlations" Lahiri et al. (2003) investigated some problems faced by the AICRP on STCR:

- Reviewed the whole design structure of the experiments conducted at various cooperating centres and suggested some appropriate treatment structures for different situations.

- One of the treatment structures has been accepted in the National workshop and is currently being used by all the research centres under AICRP on STCR.

- Also various regression diagnostics were used to see the causes of variation in the data and the results. This was done for a few centres only. This requires further study.

- The optimum doses of fertilizer N,P and K to be applied to a site with given soil test values were obtained using the response surface methodology exploring the response surface in the vicinity of stationary point. This methodology has an advantage over the targeted yield approach in the sense that year effect may also be incorporated in the model which is not possible in targeted yield approach.

- However, for studying the year effect, over the years data for about 7/8 years is required and hence once the data become available, more in depth study needs to be done.

CHAPTER- III

3.0 Methodology:

3.1 About the experiment conducted by the STCR project

In this approach all the needed variation in soil fertility level is obtained not by selecting soils at different locations but deliberately creating it in one and the same field experiment in order to ensure homogeneity in the soil population studied, management practices adopted and prevailing climatic conditions. This is achieved by selecting a large area for the experiment in which there will be some variation in soil fertility level.

In the present experiment, conducted since 2005 with the new design structure, the chosen field is divided into three strips length wise. The first strip receives no fertilizer, the second receives full standard dose(X) of N, P and K and the third strip receives twice the standard dose. The standard dose (X) is follows:N_1 = 150 kg./ha., P_1 = Phosphorus equivalent to the critical value in the P fixation studies of that field and K_1 = enough to give 150 kg/ha of exchangeable K.

Then a preparatory crop (or exhaust crop) is grown so that the fertilizers undergo reactions with the soil, plant and microbiological agencies. After the harvest of the preliminary crop, the field is ready for laying out the main experiment with test crop for soil test- crop response correlation studies. Under this each of the strips is subdivided into 24(or 21) subplots which receive various combinations of the levels of Nitrogen, Phosphorus and Potassium, using the new design structure set up (as described in section 3.2). Before the main experiment, initial soil test values are recorded from all the plots. The soil samples from all these plots under the experiment are to be collected from different soil layers. The package of cultural practices recommended for the test crop is followed for the experimental crop. The yield of the crop and uptake of the nutrients N, P and K, on harvest are recorded from each plot.

The general soil test- crop response model with yield as dependent variable and the soil and fertilizer variables as independent variables is described as:

$$\begin{aligned} Y = {} & b_0 + b_1\,SN + b_2\,SP + b_3\,SK + b_4\,FN + b_5\,FN^2 + b_6\,FP + b_7\,FP^2 + \\ & + b_8\,FK + b_9\,FK^2 + b_{10}\,FNFP + b_{11}\,FNFK + b_{12}\,FPFK + b_{13}\,FNSN + b_{14}\,FPSP + \\ & + b_{15}\,FKSK + \varepsilon \end{aligned}$$

where, SN, SP and SK are soil available nutrients and FN, FP and FK are added fertilizer nutrients and ε is the error term which is assumed to be independently and identically distributed normally with zero mean and constant variance σ^2.

For soil test calibration the multiple regression equation, which has a high predictability is used for making both yield prediction and optimization of chemical fertilizer requirements (Annual report, AICRP on STCR, 1993-98,). From this equation, the desired optimum fertilizer dose for varying soil test values of a nutrient for maximum yield could be obtained. Inclusion of economic parameters will enable calculation of soil test based fertilizer dose for maximum profit and at any desired rate of return on the investment made on fertilizers.

Over the years, a large volume of data has been generated in the STCR project. While using multiple regression approach, it has been observed that in order to derive optimum rates of fertilizer for recommendation, the multiple regression equation should fulfil certain basic criteria like (i) high and significant value of R^2, (ii) to follow the law of diminishing returns and (iii) the partial regression coefficients should be significant.

These criteria are satisfied in limited number of cases. Moreover, sometimes optimum doses of fertilizer nutrients are not derivable from the fitted functions.
Therefore, the **Targeted yield approach (**Ramamoorthy, et al.1967) and fertilizer adjustment equations was adopted by the STCR project. Among the various methods of fertilizer recommendation, the one based on yield targeting is unique in the sense that this method not only indicates soil test based fertilizer dose but also the level of yield the farmer can hope to achieve if recommended agronomic practices are followed in raising the crop. The essential basic data required for formulating fertilizer recommendation for targeted yield are :

(i) Nutrient requirement (NR) in kg/q of produce, grain or other economic produce
(ii) Percent contribution (CS) from the soil available nutrients and
(iii) Percent contribution (CF) from the applied fertilizer nutrients
(Ramamoorty et al 1967)

The above mentioned three parameters are calculated as follows:

(i) Nutrient Requirement of Nitrogen, Phosphorus and Potassium for grain Production (NR)

$$\text{Kg of nutrient/ q of grain} = \frac{\text{Total uptake of nutrient (kg)}}{\text{Grain yield (q)}}$$

(ii) Percent contribution of nutrient from soil (CS)

$$\text{Percent contribution from soil} = \frac{\text{Total uptake in control plots (kg ha}^{-1}) \times 100}{\text{Soil test values of nutrient in control plots (kg ha}^{-1})}$$

(iii) Percent contribution of nutrient from fertilizer (CF)

Contribution from fertilizer = (total uptake of nutrients in treated plots) – (soil test values of nutrients in fertilizer treated plots× CS)

$$\text{Percent contribution from Fertilizer} = \frac{\text{Contribution from fertilizer}}{\text{fertilizer dose (kg ha}^{-1})} \times 100$$

Calculation of fertilizer dose (Fertilizer Adjustment Equation)

The above basic data are transformed into workable adjustment equation as follows:

$$\text{Fertilizer dose} = \frac{\text{Nutrient requirement in kg/q of grain}}{\%\ \text{CF}} \times 100 \times T - \frac{\%\ \text{CS}}{\%\ \text{CF}} \times \text{Soil test value}$$

$$= \text{a constant} \times \text{yield target(q ha}^{-1}) - \text{b constant} \times \text{soil test value(kg/ha}^{-1})$$

where T is the targeted yield

Targeted yield concept strikes a balance between 'fertilizing the crop' and 'fertilizing the soil'. The procedure provides a scientific basis for balanced fertilization and balance between applied nutrients and soil available nutrients. In the targeted yield approach, it is assumed that there is a linear relationship between grain yield and nutrient uptake by the crop, as for obtaining a particular yield, a definite amount of nutrients are taken up by the plants. Once this requirement is known for a given yield level, the fertilizer needs can be estimated taking into consideration the contribution from soil available nutrients.

These equations give fairly good recommendations but in fact they vary over the years for the same place and site. Moreover, there is variation in the coefficients of the nutrients of the fertilizer adjustment equations from year to year and these equations cannot be pooled statistically.

In such cases Response Surface Methodology has been used. This methodology has an advantage over the targeted yield approach in the sense that year effect may also be incorporated in the model which is not possible in targeted yield approach. However, for studying the year effect, over the years, 7/8 years data is required and hence once the data become available, more in depth study would be taken up.

3.2 The experiment with the new design structure :

Experiments on the new design structure involving organic manures and major nutrients N, P and K in a 3^3 factorial setup are being conducted since 2005-06 at the different centres of AICRP on STCR project. Accordingly the data from these centres were received at IASRI, New Delhi as per the collaborative program. These data were analyzed statistically and the results with interpretations were sent to the respective centres and also to the Project coordinator at IISS, Bhopal. Some centres did not follow the design suggested (namely, Hyderabad and Bhubaneswar). Also no data was reported from Coimbatore centre.

Earlier (prior to 2005-06) the design which was followed by STCR for its experimentation was a fractional factorial design 5×4×3 with 21 treatment combinations besides 6 controls.

During a workshop of STCR held on 2002 at IASRI, the experts, who attended, felt that having run the experiment for so many years, the results obtained from the experiments should give enough evidence about the optimum levels of N, P and K and so there is no need to have 5 levels of any factor. Therefore, the experiment should be run with only three levels of N, P and K. The three levels being, the optimum level, one level below optimum level and one level above optimum level.

Based on the considerations above, one of the designs proposed by IASRI, which also include treatments of Organic manures, was accepted at the STCR workshop at IISS, Bhopal held in January 2005. This design has 24(or 21) treatments including controls. This experiment is being conducted at the cooperating centres of STCR project in the country since 2005. It is being conducted using only three strips of fertility gradient (0, 1, and 2) which has been formed by applying fertilizer nutrients of Nitrogen, Phosphorus and Potassium. The first strip has no fertilizer, second has the standard dose (which is fixed earlier as determined in the laboratory) and third has twice the standard dose.

The following treatment structure was accepted for experimentation

S.No.	N	P	K	S.No.	N	P	K
1	1	2	2	**15**	3	**2**	**3**
2	2	2	2	**16**	0	0	0
3	3	2	2	**17**	0	0	0
4	2	1	2	**18**	0	0	0
5	2	3	2	**19**	3	2	1
6	2	2	1	**20**	3	3	1
7	2	2	3	**21**	3	1	1
8	1	1	1	And			
9	2	1	1	**19$**	2	2	0
10	1	2	1	**20$**	2	0	2
11	1	1	2	**21$**	0	2	2
12	2	3	3	The runs Sl.No. 19$, 20$, 21$ have been suggested by IISS, Bhopal			
13	3	3	3				
14	3	3	2				

For organic manure, 3 levels of OM and 3 strips:

	Strip 1	Strip 2	Strip 3
OM1	A	B	C
OM2	B	C	A
OM3	C	A	B

Where A, B,C comprise of 8(or 7) design points each according to the choice of the experimenter. The composition of A, B,C, is the following:

A	B	C
0 0 0	0 0 0	0 0 0
321 and 220	331 and 202	311 and 022
Any of the 5 points from 1 to 15	Any of the 5 points from the remaining 10 points (of 1-15)	Remaining 5 points

Randomization of the chosen treatment combinations is carried out in each strip and within each group A, B and C.

The main features of the above design are:

- This arrangement is a Latin Square type arrangement.
- All treatment combinations are tried on each level of OM.
- All treatment combinations are tried on all the strips.
- All the three groups viz. A, B, C are appearing with every level of OM and also in all the strips precisely once.

3.3 Extent of data received and analyzed

Experiments with the design given above were conducted at the centres of STCR in the country and the data were sent to IASRI for analysis. The extent and details of data received from various cooperating centres and analyzed at IASRI is given in Appendix -II

3.4 Methodology for the Analysis of data

The data received from various centres, were subjected to statistical analysis which is described below:

(1) To see whether the fertility gradient is created overall the strips

As mentioned in the earlier sections that all the needed variation in soil fertility is created deliberately in the experimental field. Therefore, it is necessary to see whether the fertility gradient has been created in the experiment.

For this the analysis of variance of the data was carried out by taking the soil available Nitrogen (SN) as dependent variable over all the strips (replications). If the strips are found to be significantly different with respect to Soil available Nitrogen (SN), then it could be said that the fertility gradient has been created in respect of SN. Likewise the same procedure was followed for soil phosphorus (SP) and soil Potassium (SK).

Example: Centre : BARRACKPORE Crop: JUTE 2007-08

Dependent Variable	Prob. > F	R.Square	Co-eff. of Variation	Mean
SN	**0.003****	**0.233310**	**6.513566**	**278.9048**
SP	**0.0001****	**0.255891**	**20.74176**	**86.10000**
SK	**<.0001****	**0.691315**	**7.257004**	**219.7619**

It is seen that in all the three cases SN, SP and SK as dependent variable, the effect of the strip is **highly significant**. This indicates that the fertility gradient was created in respect of Nitrogen, Phosphorus and Potassium.

(2) To see whether the fertility gradient is created at FYM level wise

Next it is to be seen whether the fertility gradient has been created in the experiment at each of the FYM levels. For this the analysis of variance of the data was performed using the Soil nutrients, SN, SP and SK separately as dependent variables (as said before) for each level of FYM.

Example: Centre : BARRACKPORE Crop: JUTE 2007-08

For FYM Level at 0 t/ha

Dependent Variable	Prob. > F	R. Square	Co-eff. of Variation	Mean
SN	**0.0071****	**0.423333**	**4.266925**	**281.6667**
SP	**0.1323^{NS}**	**0.201288**	**24.45992**	**81.96190**
SK	**0.0002****	**0.622061**	**8.347610**	**216.0000**

It is seen that in case of SN and SK as dependent variable, the effect of the strip under 0 t/ha is **highly significant**. This indicates that the fertility gradient was created only in respect of N and K.

For FYM Level at 5 t/ha

Dependent Variable	Prob. > F	R. Square	Co-eff. of Variation	Mean
SN	0.1252^{NS}	0.206157	5.231388	271.9048
SP	0.0700**	0.255869	21.04713	85.18571
SK	<.0001**	0.819740	5.617003	219.5714

The effect of the strips is found to be **Highly significant** only in the case of SP and SK as dependent variable. This indicates that the fertility gradient was created in respect of only P and K at FYM at 5 t/ha.

FYM at Level 10 t/ha

Dependent Variable	Prob. > F	R. Square	Coeff. of Variation	Mean
SN	0.0525*	0.279241	8.702985	283.1429
SP	0.0161**	0.367733	18.35575	91.15238
SK	<.0001**	0.680549	8.019919	223.7143

*The effect of the strips is found to be **significantly different in all the cases .** This indicates that the fertility gradient was created in respect of N, P and K at FYM at 10 t/ha

(3) To find the best level of FYM

For finding the best level of FYM, the analysis of variance was carried out taking yield as the dependent variable and the factors as Treatment, FYM and interaction of (FYM and Treatment) as independent variables.

Example: Centre : BARRACKPORE Crop: JUTE 2005-06

ANOVA for Treatment, FYM and their interaction without covariates

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treatment	**18**	**7600055.778**	**422225.321**	**17.92**	**0.0009****
FYM	**2**	**126689.238**	**63344.619**	**2.69**	**0.1467 ^{NS}**
Treat*FYM	**36**	**790686.984**	**21963.527**	**0.93**	**0.6034 ^{NS}**
Error	**6**	**141408.000**	**23568.000**		
Corrected Total	**62**	**8658840.000**			
	R-Square	**Coeff Var**	**Root MSE**	**Yield Mean**	
	0.983669	**8.757486**	**153.5187**	**1753.000**	

**-Highly Significant
NS-Not Significant

Here it is observed that the effect of Treatment is highly significant whereas the effects of FYM and the interaction (Treatment* FYM) are not significant. So it is not possible to identify the best level of FYM here.

Next, we perform analysis of variance for treatment, FYM and their interaction along with SN, SP and SK as covariates

ANOVA for Treatment, FYM and their interaction with covariates

Example: Centre : BARRACKPORE Crop: JUTE 2005-06

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treatment	**18**	**7600055.778**	**422225.321**	**90.79**	**0.0016****
FYM	**2**	**126689.238**	**63344.619**	**13.62**	**0.0312****
Treat*FYM	**36**	**790686.984**	**21963.527**	**4.72**	**0.1124NS**
SN	**1**	**45040.626**	**45040.626**	**9.69**	**0.0528****
SP	**1**	**79535.324**	**79535.324**	**17.10**	**0.0257****
SK	**1**	**2880.748**	**2880.748**	**0.62**	**0.4887NS**
Error	**3**	**13951.303**	**4650.434**		
Corrected Total	**62**	**8658840.000**			
	R-Square	**Coeff Var**	**Root MSE**	**Yield Mean**	
	0.998389	**3.890136**	**68.19409**	**1753.000**	

Here it is observed that the effects of Treatment and FYM are highly significant whereas the effect of the interaction is not significant. Moreover, the covariates SN and SP are also highly significant. Therefore, by performing analysis of variance with covariates, the effects which were not significant earlier have been found to be significant. The coefficient of variation has also reduced from 8.76 to 3.89. Now therefore it would be possible to identify the best level of FYM by preparing the marginal mean tables and comparing the treatment means with the critical difference..

(4) Analysis using the design as Resolvable block design

This design may be viewed alternatively as a reinforced resolvable block design with three replications (or resolvable groups). Each group is a complete replicate.

- The 3 levels of OM are the 3 replications or the 3 resolvable groups.
- There are three blocks within each replication. The three strips on each level of OM are the 3 blocks. In all there are 9 blocks.
- There are 6(or7) treatment combinations in each block.
- Each block is reinforced with a control treatment.

Thus the resolvable design has the following parameters:

❖ Number of treatments, v=18(or21) + 1 (control),
❖ Number of replications = 3,
❖ Number of blocks per replication = 3,
❖ Total number of blocks = 9,

- Number of treatment combinations per block or the block size = 7(or 8),
- Replication of treatment combinations= 3,
- Replication of the control treatment = 9.

The analysis of the data generated can be presented in the following ANOVA:

Source	D.F.
Replications (OM)	**2**
Blocks within replication [Strips within levels of OM]	**6**
Treatments	**18**
Error	**36**
Total	**62**

Example: Centre : BARRACKPORE Crop: JUTE 2005-06

(a) ANOVA for Treatment, FYM and Strips without interactions and covariates (Taking strips within FYM levels)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
FYM	2	126689.238	63344.619	3.78	0.0325**
Strip (FYM)	6	400017.048	66669.508	3.97	0.0038**
Treat	18	7528062.036	418225.669	24.92	<.0001**
Error	36	604071.678	601.824		
Corrected Total	62	8658840.000			
	R-Square	Coeff Var	Root MSE	Yield Mean	
	0.930236	7.389432	129.5367	1753.000	

Here it is observed that the effects of TREATMENT, FYM and STRIPS within FYM levels are highly significant. So here it is also possible to identify the best level of FYM.

(b) ANOVA for Treatment, FYM and Strips without interactions and With covariates SN, SP and SK (Taking strips within FYM levels)

The ANOVA will be as follows:

Source	D.F.
Replication (OM)	2
Blocks within replication [Strips within levels of OM]	6
Treatments	18
SN	1
SP	1
SK	1
Error	33
Total	62

Example: Centre : BARRACKPORE Crop: JUTE 2005-06

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
FYM	2	126689.238	63344.619	3.52	0.0413**
STRIP (FYM)	6	400017.048	66669.508	3.70	0.0064**
Treatment	18	7528062.036	418225.669	23.22	<.0001**
SN	1	601.824	601.824	0.03	0.8561 NS
SP	1	4521.366	4521.366	0.25	0.6197 NS
SK	1	4522.697	4522.697	0.25	0.6196 NS
Error	33	594425.791	18012.903		
Corrected Total	62	8658840.000			
	R-Square	Coeff Var	Root MSE	Yield Mean	
	0.931350	7.656141	134.2122	1753.000	

**-Highly Signficant, NS- Not significant

Here also, it is observed that the effects of TREATMENT, FYM and STRIPS within FYM levels are highly significant. So here it is possible to identify the best level of FYM. The covariates SN.SP and SK are not significant.

(5) Response at middle doses of Nitrogen, Phosphorus and Potassium

As stated earlier that the experiment should be run with only three levels of N, P and K, the three levels being, the optimum level, one level below optimum level and one level above optimum level. Therefore an attempt was made to find the responses of any nutrient at the middle doses of the other two. For example the response of N was calculated from treatment combinations 022, 122, 222 and 322 where the first level is for N, the second and third levels are the middle doses of P and K. Like wise it was calculated for P at middle doses of N and K and for K at middle doses of N and P.

Example: Centre : BARRACKPORE Crop: JUTE 2007-08

CENTRE: BARRAKPORE CROP: JUTE YEAR: 2007
Response to N at middle doses of P and K (kg/ha) ($N_0 P_{40} K_{40}$)

	OM_0	OM_5	OM_{10}	AVERAGE	OVER N_0	OVER SUCCESSIVE DOSES
N_0	12.4	14.5	15.8	14.2	-	-
N_{40}	16.2	19.8	18	18.0	0.093	0.093
N_{80}	25.7	24.2	24.67	24.8	0.133	0.172
N_{120}	26.2	26.0	27.0	26.4	0.101	0.039
Average	20.1	21.1	21.4	20.9		

Response to P at middle doses of N and K (kg/ha) (N_{80} P_0 K_{40})

	OM_0	OM_5	OM_{10}	AVERAGE	OVER P_0	OVER SUCCESSIVE DOSES
P_0	12.4	14.5	15.8	14.2	-	-
P_{20}	23.7	24.1	23.67	23.8	0.479	0.479
P_{40}	25.7	24.2	24.67	24.8	0.265	0.051
P_{60}	26.2	26.0	27.0	26.4	0.203	0.078
Average	22.0	22.2	22.8	22.3		

Response to K at middle doses of N and P (kg/ha) (N_{80} P_{40} K_0)

	OM_0	OM_5	OM_{10}	AVERAGE	OVER K_0	OVER SUCCESSIVE DOSES
K_0	12.4	14.5	15.8	14.2	-	-
K_{20}	27.8	28.0	30.5	28.8	0.726	0.726
K_{40}	25.7	24.2	24.67	24.8	0.265	-0.196
K_{60}	28.0	27.6	27.97	27.9	0.227	0.151
Average	23.5	23.6	24.7	23.9		

(6) Fitting of response surfaces at various levels of organic manure and also combined over all levels and Testing the Homogeneity of the regression equations,

To study the effect of OM on the relationship of soil test values (SN, SP and SK) and added fertilizers FN, FP and FK the following analysis were carried out.

- A second order response surface was fitted to the 24(21) design points at each level of OM ignoring the effect of strips. The effect of strips may be ignored since we are taking soil parameters into consideration.

$$\begin{aligned} y &= \beta_0 + \beta_1 SN + \beta_2 SP + \beta_3 SK + \beta_4 FN + \beta_5 FP + \beta_6 FK + \beta_7 FN^2 \\ &\quad + \beta_8 FP^2 + \beta_9 FK^2 + \beta_{10} FN \times FP + \beta_{11} FN \times FK + \beta_{12} FP \times FK \\ &\quad + \beta_{13} FN \times SN + \beta_{14} FP \times SP + \beta_{15} FK \times SK + e \end{aligned}$$

- To test the homogeneity of the three regression equations.
- If the regression equations are not homogeneous, then separate recommendations may be made for each level of organic manure otherwise we can pool the data and fit only one response surface.

Example: Centre : BARRACKPORE Crop: JUTE 2005-06

Testing of Homogeneity of Regression Equations

FYM LEVELS	ERROR SUM OF SQUARES	DF
FYM 0	91270	5
FYM 5	29312	5
FYM 10	30928	5
Full	151510	15
Combined(Reduced)	779805	47

$$F = \frac{(SSE_{REDUCED} - SSE_{FULL})/32}{SSE_{REDUCED}/47} = \frac{(779805 - 151510)/32}{779805/47} = \frac{19634.21875}{16591.5957} = 1.1834$$

Prob > F = 0.294855 (Not Significant)

This indicates that the three equations were homogeneous and therefore, we can go for combined regression of the three strips. We put, for any site, its available soil test values of Nitrogen, Phosphorus and Potash(say, mean values for convenience) in the combined regression equation and do the canonical analysis of the response surface.

Response Surface Combined over all FYM levels

Variable	DF	Estimate	S.E	t -Value	Pr > |t|
Intercept	**1**	**-173.66646**	**604.61980**	**-0.29**	**0.7752**
FN	**1**	**29.24176**	**8.58228**	**3.41**	**0.0014***
FP	**1**	**12.66755**	**7.72185**	**1.64**	**0.1076**
FK	**1**	**-20.26425**	**9.74366**	**-2.08**	**0.0430***
FN^2	**1**	**-0.10569**	**0.02458**	**-4.30**	**<.0001***
FP^2	**1**	**-0.06729**	**0.09788**	**-0.69**	**0.4951**
FK^2	**1**	**0.13118**	**0.10413**	**1.26**	**0.2140**
FNFP	**1**	**0.04392**	**0.05779**	**0.76**	**0.4510**
FNFK	**1**	**0.00866**	**0.05840**	**0.15**	**0.8828**
FPFK	**1**	**0.05301**	**0.12452**	**0.43**	**0.6723**
FNSN	**1**	**-0.02508**	**0.02617**	**-0.96**	**0.3427**
FPSP	**1**	**-0.12976**	**0.04519**	**-2.87**	**0.0061***
FKSK	**1**	**0.03499**	**0.03254**	**1.08**	**0.2878**
SN	**1**	**2.31619**	**2.01009**	**1.15**	**0.2550**
SP	**1**	**5.10736**	**1.76728**	**2.89**	**0.0058***
SK	**1**	**0.05092**	**1.17476**	**0.04**	**0.9656**

R-Square	Adj.R-Square	Coeff Var	Root MSE	Yield Mean	Prob. > F
0.9099	**0.8812**	**7.35**	**128.80838**	**1753.00**	**< .0001***

Combined regression equation at given values of SN, SP and SK

Substituting SN=322.84; SP=106.70; and SK=209.65(mean values) gives the reduced complete Second order Response Surface as:

$$\mathbf{Y = 1131.644 + 21.14092 * FN - 1.21677 * FP - 12.9164 * FK - 0.10569 * FN^2 - 0.06729 * FP^2}$$
$$\mathbf{+ 0.13118 * FK^2 + 0.04392 * FNFP + 0.00866 * FNFK + 0.05301 * FPFK}$$

(6) Estimating the optimal values of N, P and K to be applied

Canonical Analysis of Response Surface gave the following results. The stationary point is:

FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
110.174	**41.56531**	**37.19647**

Predicted Value at Stationary Point is: 2030.725 kg/ha
Eigen values and Eigen vectors are:

Eigen values	FN	FP	FK
0.107348	**0.042096**	**0.025551**	**0.998787**
-0.034404	**0.260553**	**0.964801**	**-0.035663**
-0.114218	**0.964541**	**-0.261738**	**-0.033957**

Nature of Stationary Point : Saddle Point (Neither maxima nor Minima)

(8) Exploration of Response Surface in the vicinity of Stationary point

Since the stationary point is a saddle point, the exploration of the response surface in the vicinity of the stationary point was carried out. For this a SAS code (Appendix-III) was developed where by putting the soil test values of a particular site, optimal values of the fertilizer nutrients were generated along with predicted value at the stationary point. Next another SAS code (Appendix-IV) was developed where using the data of the previous SAS code and using a targeted yield (or desired yield), optimal values of fertilizer N, P and K could be generated based on the soil test values of the site with the following result.

Desired Yield (kg/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
2000	109.91	47.95	25.98
	109.84	47.67	23.46
	110.55	50.38	47.26
2100	111.89	53.58	75.26
	111.29	53.21	71.98
	111.24	53.01	70.20
2200	110.78	51.25	54.84
	111.21	52.91	69.32
	110.52	50.28	46.33

(9) Estimation of optimal values of N, P and K with the help of Targeted Yield equations.

The basic data and the targeted yield equations were generated using the MS-Excel programme developed at the unit of the Project director (STCR) at IISS (Bhopal)

BASIC DATA

PARAMETER	N	P_2O_5	K_2O
Nutrient Requirement (kg/q)	2.0448	6.4655	4.8462
Soil efficiency	0.0717	0.2997	0.2240
Fertilizer efficiency	0.1908	1.3486	0.9929

TARGETED YIELD EQUATIONS	SOIL TEST VALUES (kg/ha)	TARGETED YIELD (kg/ha)	OPTIMUM FERTILIZER DOSES		
			FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
FN = 10.72* T - 0.38 SN	323	2000	92	41	41
FP = 4.79* T - 0.51 SP	107	2100	102	46	46
FK = 4.88* T - 0.27 SK	210	2200	113	51	51

Analysis of data by the methodology given above, was carried out for all the data received from the centres and sent to the respective centres as well the project coordinator (STCR) at Indian Institute of Soil Science, Bhopal.

CHAPTER -IV

4. Results and discussions

Experiments with new treatment structure involving organic manures and major nutrients N, P and K in 24 design points were conducted at all the 17 centres of AICRP on STCR using the design suggested by the Institute.

At first, to examine whether the fertility gradient has been created, analysis of variance was carried out using the soil nutrients, SN, SP and SK separately as dependent variables.. Then the following types of analysis were performed:

(1) Evaluation of responses to middle doses of N, P and K, (2) Analysis of variance with and without covariates SN , SP and SK, (3) Fitting of response surfaces at various levels of organic manure and also combined over all levels, (4) Testing of Homogeneity of the regression equations, (5) Exploration of response surface in the vicinity of the stationary point, (6) Estimating the optimal values of N, P and K to be applied and (7) Targeted yield equations.

(1) CENTRE : Bangalore, Crop: Onion, Year: 2005-06

For the STCR experiment on Onion 2005-06 at Bangalore centre it was observed that the fertility gradient has been created only with respect to SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 30 t/ha and 40 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM). It was observed that none of the effect of is significant. So it is not possible to identify the best level of FYM here. When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels) it was observed that the Strips (within FYM level) is highly significant which indicates creation of fertility gradient in the strips within the FYM levels.

The response to N at the middle doses of P and K showed that the response over N_0 increased for N_{75} then decreased for N_{125} and again increase for N_{150}. Same trend was observed in case of P at middle doses of N and K and K at middle doses of N and P respectively.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$
\begin{aligned}
Y= {} & 306.644+ 0.99432*FN- 2.9595*FP - 0.3706*FK - 0.0086*FN^2 - 0.0128*FP^2 + \\
& + 0.00192*FK^2 + 0.01214* FNFP - 0.0055 *FNFK+0.01026*FPFK + \\
& +0.30795*SN - 0.2305*SP - 0.0556*SK+0.00372*FNSN+0.00715*FPSP \\
& - 5E-05*FKSK
\end{aligned}
$$

Substituting **SN=233; SP=201.89; and SK=765.71**, gives the reduced complete Second order Response Surface as:

$$
\begin{aligned}
Y= {} & 289.3147 + 1.86108 *FN – 1.51596* FP – 0.40944* FK – 0.00859* FN^2 – \\
& 0.01284* FP^2 + 0.00192 * FK^2 + 0.01214 * FNFP – 0.00554 * FNFK + \\
& 0.01026 * FPFK
\end{aligned}
$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**87.82** kg/ha, Fertilizer Phosphorus =**31.95** kg/ha and Fertilizer Potash= **138.78** kg/ha and with predicted yield at stationary point as **350** q/ha.

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (Q/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
355	86.27	38.67	159.55
	88.16	30.63	134.28
	90.24	22.46	106.51
360	89.15	26.72	120.99
	90.13	22.86	107.87
	91.40	17.87	90.92

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM (M)
350.00	233.00	201.89	765.71	30

T= Targeted Yield

Targeted Yield Equations			
FN =	2.08*	T - 2.68*	STVN - 0.39* M
FP =	0.30*	T -0.32*	STVP- 0.16* M
FK =	0.95*	T -0.41*	STVK -0.16* M

Targeted Yield (t /ha)	**Optimum fertilizer doses**		
	FN (kg/ha)	**FP (kg/ha)**	**FK (kg/ha)**
350.00	**92.81**	**36.69**	**11.98**
355.00	**103.23**	**38.19**	**16.70**
360.00	**113.65**	**39.69**	**21.43**

(2) Centre : BARRACKPORE CROP: JUTE YEAR: 2005-06

For the STCR experiment on Jute 2005-06 at Barrackpore centre, it was observed that the fertility gradient has been created with respect to SN, SP and SK for overall the strips, but for organic manure level wise it was created only with respect to SP and SK at 0 t/ha, 5t/ha.and 10 t/h of FYM and for SN it was created only at 0t/ha and 10 t/ha.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that only the effect of Treatment is highly significant. When the ANOVA for

Treatment, Organic manure and their interaction (Treatment * OM) with covariates was carried out, it was observed that the effect of Treatment and FYM are highly significant whereas the effect of the interaction is not significant. Moreover, the covariates SN and SP are also highly significant .So here it is possible to identify the best level of FYM.
When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels) it is observed that the effects of TREATMENT, FYM and (STRIPS within FYM levels) are highly significant. So here it is possible to identify the best level of FYM and this also indicates creation of fertility gradient in the strips within the FYM levels.
.
The response to N at the middle doses of P and K showed that there is a gradual downward trend for response over N_0 from N_{40} to N_{80} and then to N_{120}. Same trend was observed in case of P at middle doses of N and K and K at middle doses of N and P respectively.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\mathbf{Y= -173.6665+ 29.2418*FN+12.66755*FP -20.26425*FK -0.10569*FN^2-0.06729*FP^2 +0.13118*FK^2+0.04392*FNFP+0.00866*FNFK+0.05301*FPFK +2.31619*SN + 5.10736*SP + 0.05092*SK - 0.02508*FNSN - 0.12976*FPSP + 0.03499*FKSK}$$

Substituting SN=322.84; SP=106.70; and SK=209.65, gives the reduced complete Second order Response Surface as:

$$\mathbf{Y = 1131.644 + 21.14092 * FN - 1.21677 * FP - 12.9164 * FK - 0.10569 * FN^2 - 0.06729 * FP^2 + 0.13118 * FK^2 + 0.04392 * FNFP + 0.00866 * FNFK + + 0.05301 * FPFK}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**110.174**kg/ha, Fertilizer Phosphorus =**41.56** kg/ha and Fertilizer Potash= **37.20** kg/ha and with predicted yield at stationary point as 2000 kg/ha.

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (kg/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
2000	109.91	47.95	25.98
	109.84	47.67	23.46
	110.55	50.38	47.26
2100	111.89	53.58	75.26
	111.29	53.21	71.98
	111.24	53.01	70.20
2200	110.78	51.25	54.84
	111.21	52.91	69.32
	110.52	50.28	46.33

Optimal doses obtained through Targeted yield equations

Targeted Yield Equations	Soil test values (kg/ha)	Targeted yield (kg/ha)	OPTIMUM FERTILIZER DOSES		
			FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
FN = 10.72* T - 0.38 SN	323	2000	92	41	41
FP = 4.79* T - 0.51 SP	107	2100	102	46	46
FK = 4.88* T - 0.27 SK	210	2200	113	51	51

*** T= Targeted Yield**

(3) CENTRE : BARRACKPORE CROP: JUTE YEAR: 2006-07

For the STCR experiment on Jute 2006-07 at Barrackpore centre, it was observed that the fertility gradient has been created with respect to SN, SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 2.5 t/ha and 5 t/h of FYM.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that only the effect of Treatment is highly significant. When the ANOVA for Treatment, Organic manure and their interaction (Treatment * OM) with covariates was carried out, it was observed that none of the effects were significant .So it is not possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out without interactions and covariates (taking the strips within FYM levels) it is observed that the effects of TREATMENT, FYM and (STRIPS within FYM levels) are highly significant. So here it is possible to identify the best level of FYM and this also indicates creation of fertility gradient in the strips within the FYM levels.

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The response to N at the middle doses of P and K showed that there is an increasing trend for response over N_0 from N_{40} to N_{80} and then decreasing from N_{80} to N_{120}. In case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\begin{aligned} \mathbf{Y} = {} & \mathbf{0.75786 + 0.05219*FN - 0.17311*FP + 0.37354*FK - 0.0008432*FN^2} \\ & \mathbf{+0.00104*FP^2 - 0.00034*FK^2 + 0.000334*FNFP + 0.0000115*FNFK +} \\ & \mathbf{+0.000993*FPFK - 0.032*SN + 0.06473*SP + 0.08627*SK} \\ & \mathbf{0.0005344*FNSN + 0.000864*FPSP - 0.00175*FKSK} \end{aligned}$$

Substituting **SN=291.98; SP=13.42; and SK=214.81**(say, Mean values), gives the reduced complete Second order Response Surface as:

$$\mathbf{Y= 10.82028+ 0.208229*FN -0.16151*FP -0.00238*FK -0.00084*FN^2 +0.00104*FP^2 +0.00034*FK^2 + 0.000334*FNFP + 0.0000115*FNFK+0.000993*FPFK}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**119.82** kg/ha, Fertilizer Phosphorus =**24.06** kg/ha and Fertilizer Potash= **35.28** kg/ha and with predicted yield at stationary point as **2103** kg/ha.

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (kg/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
2500	129.00	8.98	42.63
	129.36	13.82	44.07
	129.39	14.22	44.19
3000	131.96	48.67	54.44
	132.29	53.09	55.76
	134.52	83.04	64.67

Optimal doses obtained through Targeted yield equations

Targeted Yield Equations			T	SN	SP	SK	FYM
			2100	291.98	13.42	214.81	5
FN =	8.76	* T -		0.30	* STVN -	0.59	* M
FP =	2.15	* T -		2.62	* STVP -	0.24	* M
FK =	4.00	* T -		0.20	* STVK -	0.24	* M

*** T= Targeted Yield**

Targeted Yield (kg/ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
2100	93.31	8.88	39.19
2500	128.12	17.43	55.09
3000	171.91	28.19	75.09

(4) CENTRE : BARRACKPORE CROP: JUTE YEAR: 2007-08

For the STCR experiment on Jute 2007-08 at Barrackpore centre, it was observed that the fertility gradient has been created with respect to SN, SP and SK for overall the strips but at organic manure level wise it has been created in respect of (SN and SK)at 0 t/ha, (SP and SK) at 2.5 t/ha and for SN, SP and SK at10 t/h of FYM.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) with and without covariates. It was observed that only the effect of Treatment is highly significant in both cases.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels) it is observed that the effects of TREATMENT and FYM are highly significant. So here it is possible to identify the best level of FYM .

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The response to N at the middle doses of P and K showed that there is an increasing trend for response over N_0 from N_{40} to N_{80} and then decreasing from N_{80} to N_{120}. In case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\begin{aligned}\mathbf{Y=} \; & \mathbf{2.3832+ 0.37059*FN+0.1557*FP -0.27803*FK -0.00196*FN^2} \\ & \mathbf{+0.00193*FP^2+0.00504*FK^2+0.00115*FNFP+0.00080676*FNFK+} \\ & \mathbf{-0.00505*FPFK+0.01085*SN + 0.06563*SP+ 0.01625*SK} \\ & \mathbf{-0.000172*FNSN-0.00187*FPSP +0.00002816*FKSK}\end{aligned}$$

Substituting **SN=**278.90**; SP=**86.1**; and SK=**219.76, gives the reduced complete Second order Response Surface as:

$$\begin{aligned}\mathbf{Y=} \; & \mathbf{14.63111+ 0.322747*FN -0.00531*FP -0.27184*FK -0.00196*FN^2 +0.00193*FP^2} \\ & \mathbf{+0.00504*FK^2 + 0.00115*FNFP + 0.000807*FNFK -0.00505*FPFK}\end{aligned}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**92.04** kg/ha, Fertilizer Phosphorus =**6.15** kg/ha and Fertilizer Potash= **24.10** kg/ha and with predicted yield at stationary point as **2614.74** kg/ha.

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (kg/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
26.41	86.24	4.93	22.23
(at stationary point)	86.28	6.89	18.06
	86.38	10.99	9.36
30.00	86.36	10.30	10.83
	86.35	10.01	11.43
	86.43	13.41	4.21
35.00	86.38	11.18	8.95
	86.19	2.56	27.28
	86.20	3.22	25.86

Optimal doses obtained through Targeted yield equations

T(q/ha)	SN (kg/ha)	SP (kg/ha)	SK (kg/ha)	FYM (t/ha)
26.14	**278.90**	**86.10**	**219.76**	**5**

Targeted Yield Equations

FN =8.03* T -0.45* STVN -0.75* M
FP =1.49* T -0.27* STVP -0.23* M
FK =2.77* T -0.19* STVK -0.14* M
*T= Targeted Yield

Targeted Yield (q/ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
26.14	**80.71**	**14.56**	**29.97**
30.00	**111.57**	**20.01**	**41.27**
35.00	**151.80**	**27.75**	**54.50**

(5) CENTRE : BARRACKPORE CROP: JUTE YEAR: 2008-09

For the STCR experiment on Jute 2008-09 at Barrackpore centre it was observed that the fertility gradient has been created only with respect to SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 5 t/ha and 10 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM). It was observed that the effects Treatment and FYM were significant. So it is possible to identify the best level of FYM here. When ANOVA for Treatment, FYM was carried out with and without interactions and covariates (taking the strips within FYM levels) it was observed that the effect of Treatment, FYM and Strips (within FYM level) were highly significant which indicates creation of fertility gradient in the strips within the FYM levels. The covariates SN,SP and SK were not significant.

The response to N at the middle doses of P and K showed that there is an increasing trend for response over N_0 from N_{40} to N_{80} and then decreasing from N_{80} to N_{120}. In case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y=7.94032+0.04117*FN-0.05611*FP-0.05411*FK-0.0005425*FN^2+0.0001086*FP^2 \\ +0.00211*FK^2+0.000507*FNFP - 0.0005083*FNFK+ 0.000104*FPFK-0.0002*SN \\ + 0.04563*SP+ 0.01675*SK +0.0004486*FNSN+0.000349*FPSP -0.00020117*FKSK$$

Substituting SN=302.05; SP=107.05; and SK=221.92, gives the reduced complete Second order Response Surface as:

$$Y= 16.46916+ 0.176635*FN -0.01877*FP -0.09877*FK -0.00054*FN^2 +0.000109*FP^2 \\ +0.00211*FK^2 + 0.000507*FNFP + 0.00051*FNFK -0.000104*FPFK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**124.2** kg/ha, Fertilizer Phosphorus =**19.97**kg/ha and Fertilizer Potash= **47.41** kg/ha and with predicted yield at stationary point as **2692 kg/ha.** The nature of he stationary point was a Saddle point (neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (q/ha)	**FN (kg/ha)**	**FP (kg/ha)**	**FK (kg/ha)**
25.00	**125.62**	**14.77**	**55.34**
	128.04	**14.22**	**35.25**
	127.36	**14.37**	**40.88**
26.92	**122.27**	**15.53**	**83.17**
	126.03	**14.68**	**51.95**
	130.58	**13.64**	**14.17**
30.00	**129.26**	**13.94**	**25.15**
	130.08	**13.76**	**18.31**
	131.49	**13.44**	**6.61**

Optimal doses obtained through Targeted yield equations

Targeted Yield Equations			T (q/ha)	SN (kg/ha)	SP (kg/ha)	SK (kg/ha)	FYM (t/ha)
			25.00	302.05	107.05	221.92	5
FN =	6.92	* T -		0.35	* STVN -	0.32	* M
FP =	1.70	* T -		0.29	* STVP -	0.14	* M
FK =	2.60	* T -		0.18	* STVK -	0.07	* M

***Targeted Yield**

Targeted Yield (q /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
25.00	65.87	10.65	23.73
26.92	78.97	14.02	29.70
30.00	100.28	19.26	37.70

(6) CENTRE : BARRACKPORE CROP: RICE YEAR: 2005-06

For the STCR experiment on Rice 2005-06 at Barrackpore centre it was observed that the fertility gradient has been created only with respect to SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 5 t/ha and 10 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM). It was observed that only the effect of Treatment and FYM are highly significant. So it is possible to identify the best level of FYM here. When ANOVA for Treatment, FYM and their interaction were carried out in presence of the covariates SN,SP and SK, it was observed that besides Treatment and FYM, the effect of the interaction is also highly significant. When ANOVA for Treatment, FYM and Strips was carried out with and without covariates (taking the strips within FYM levels) it was observed that effect of Treatment and FYM are highly significant whereas the Strips (within FYM level) is not significant.

The response to N at the middle doses of P and K showed that there is an increasing trend for response over N_0 from N_{40} to N_{80} and then decreasing from N_{80} to N_{120}. In case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose.

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For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y = 691.3328+17.8646*FN+ 8.70986*FP-8.27302*FK-0.05836*FN^2 -0.09825*FP^2 -0.0871*FK^2+0.11481*FNFP -0.0024*FNFK+-0.03208*FPFK+ 2.82814*SN +3.0694*SP - 0.7474*SK-0.0174*FNSN-0.04803*FPSP + 0.06564*FKSK$$

Substituting SN=346; SP=120; and SK=209(say, mean values), gives the reduced complete Second order Response Surface as:

$$Y = 1881.993+ 11.8442\ FN +2.9463\ FP +5.4457\ FK – 0.0584\ FN^2 - 0.0982\ FP^2 - 0.0871\ FK^2 +0.1148\ FNFP - 0.0024\ FNFK - 0.0321\ FPFK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**178.72**kg/ha, Fertilizer Phosphorus =**107.70** kg/ha and Fertilizer Potash= **19.95** kg/ha and with predicted yield at stationary point as **3306** kg/ha. The nature of the stationary point: a maximum

Optimal values of FN,FP,FK as obtained from Targeted Yield Equations

Targeted Yield Equations	Soil Test Values (kg/ha)	Targeted Yield (kg/ha)	Optimum Fertilizer Doses		
			FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
FN = 6.84 * T - 0.32 SN	346	3500	129	66	69
FP = 4.21 * T - 0.68 SP	120	3306(RSM)	113	56	61
FK = 3.83 * T - 0.31 SK	209	2500	60	24	31

*** T= Targeted Yield**

(7) **CENTRE : BARRACKPORE CROP: RICE YEAR: 2006-07**

For the STCR experiment on Rice 2006-07 at Barrackpore centre it was observed that the fertility gradient has been created with respect to SN, SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 2.5 t/ha and 5 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM). it is observed that the effects of **Treatment and FYM** are highly significant and that of **Interaction (TREAT*FYM)** is not significant. So it is possible to identify the best level of FYM here. When the ANOVA was carried out for the same but with covariates SN, SP and SK it was found that the interaction term also becomes highly significant.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the Strips within FYM levels) it is observed that the effects of **TREATMENT** and **FYM** are highly significant

The response to N at the middle doses of P and K showed that there is an increasing trend for response over N_0 from N_{40} to N_{80} and then decreasing from N_{80} to N_{120}. In case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose..

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y= 18.74252 - 0.15507*FN - 0.00659*FP + 0.24751*FK - 0.00023*FN^2 --0.00091*FP^2 - 0.0028*FK^2+8.61E-05*FNFP + 0.00018428*FNFK + 0.00191*FPFK- 0.0167*SN + 0.08153*SP + 0.01705*SK+ 0.0009258*FNSN - 0.00192*FPSP -0.00053*FKSK$$

Substituting SN=**291.98**; SP=**13.42**; and SK=**214.81**, gives the reduced complete Second order Response Surface as:

$$Y=18.6139785+ 0.11525472*FN -0.03235*FP +0.133659*FK -0.00023*FN^2 - 0.00091*FP^2 -0.00284*FK^2 +0.00008609*FNFP + 0.000184*FNFK + 0.00191*FPFK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**308.08** kg/ha, Fertilizer Phosphorus =**46.64** kg/ha and Fertilizer Potash= **41.58** kg/ha and with predicted yield at stationary point as **37.99** q/ha. Nature of Stationary Point: **maximum**

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
26.19	291.98	13.42	214.81	5

Targeted Yield Equations

FN =8.35* T -0.52* STVN -0.5* M
FP =2* T -3.01* STVP -0.39* M
FK =3.1* T -0.26* STVK -0.13* M
***T= Targeted Yield**

Targeted Yield (t /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
26.19 (Mean)	64.37	10.03	24.69
30.00	96.17	17.66	36.50
37.99 (RSM)	162.89	33.64	61.27

(8) CENTRE : BARRACKPORE CROP: RICE YEAR: 2007-08

For the STCR experiment on Rice 2007-08 at Barrackpore centre it was observed that the fertility gradient has been created only with respect to SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 5 t/ha and 10 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM). it is observed that the effects of **Treatment and FYM** are highly significant and that of **Interaction (TREAT*FYM)** is not significant. So it is possible to identify the best level of FYM here. When the ANOVA was carried out for the same but with covariates SN, SP and SK the same results were obtained

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the Strips within FYM levels) it is observed that the effects of **Treatment, FYM and (Strips within FYM levels)** were highly significant

The response to N at the middle doses of P and K showed that there is an increasing trend for response over N_0 from N_{40} to N_{80} and then decreasing from N_{80} to N_{120}. In case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\mathbf{Y = 24.67831 + 0.1228*FN - 0.15296*FP - 0.10585*FK - 0.00162*FN^2 + 0.0026*FP^2 + 0.00138*FK^2 + 0.000496*FNFP + 0.00075876*FNFK - 0.00145*FPFK - 0.0461*SN + 0.0399*SP + 0.02648*SK + 0.0007974*FNSN + 0.00042*FPSP - 0.0001912*FKSK}$$

Substituting SN=**309.97**; SP=80.69; and SK=207, gives the reduced complete Second order Response Surface as:

$$\mathbf{Y = 19.1019828 + 0.36997318*FN - 0.11905*FP - 0.14542*FK - 0.00162*FN^2 + 0.0026*FP^2 + 0.00138*FK^2 + 0.000496*FNFP + 0.000759*FNFK - 0.00145*FPFK}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**122.22** kg/ha, Fertilizer Phosphorus =**31.29** kg/ha and Fertilizer Potash= **23.72** kg/ha and with predicted yield at stationary point as **39.43 q/ha**. Nature of Stationary Point: **Saddle Point** (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (q/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
40.00	117.80	2.93	15.58
	117.89	2.67	15.82
	117.39	8.28	10.70
45.00	119.23	16.27	33.06
	119.66	20.97	37.34
	120.28	29.13	44.77

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
33.07	309.97	80.69	207.00	5

Targeted Yield Equations

FN =5.11* T - 0.33* STVN -0.16* M
FP =1.07* T - 0.28* STVP - 0.08* M
FK =2.17* T - 0.22* STVK -0.04* M
*T= Targeted Yield

Targeted Yield (t /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
33.07 (Mean)	66.06	12.76	24.96
39.43 (RSM)	98.40	19.20	39.82
40.00	101.31	19.81	41.06
45.00	126.86	25.16	51.91

(9) **CENTRE : BARRACKPORE CROP: RICE YEAR: 2008-09**

For the STCR experiment on Rice 2008-09 at Barrackpore centre it was observed that the fertility gradient has been created only with respect to SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 5 t/ha and 10 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM). it is observed that the effects of **Treatment and FYM** are highly significant and that of **Interaction (TREAT*FYM)** is significant. So it is possible to identify the best level of FYM here.

When ANOVA for Treatment, FYM and Strips (within FYM levels) was carried out with and without interactions and covariates it is observed that the effects of **Treatment, FYM** were highly significant.

The response to N at the middle doses of P and K showed that there is an increasing trend for response over N_0 from N_{40} to N_{80} and then decreasing from N_{80} to N_{120}. In case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$Y = 7.7382 + 0.53903*FN - 0.45703*FP - 0.23715*FK - 0.00316*FN^2 + 0.00465*FP^2$
$+ 0.00454*FK^2 + 0.001*FNFP + 0.00077477*FNFK --0.000813*FPFK + 0.01434*SN$
$- 0.04055*SP + 0.05411*SK + 0.0002754*FNSN + 0.000904*FPSP - 0.0006395*FKSK$

Substituting SN=**301.48**; SP=**107.05**; and SK=**221.78**, gives the reduced complete Second order Response Surface as:

$Y = 19.72079 - 66.89527*FN - -10.8989*FP -13.3673*FK - 36.5438*FN^2 + 4.256564*FP^2$
$+5.648188* FK^2 * +3.253618\ FNFP + 2.938751*FNFK -0.8678* FPFK$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**109.86**kg/ha, Fertilizer Phosphorus =**31.07**kg/ha and Fertilizer Potash= **36.80**kg/ha and with predicted yield at stationary point as **41.12 q/ha**. Nature of Stationary Point: **Saddle Point** (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (q/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
40	**106.62**	**43.01**	**30.72**
	106.57	**41.49**	**31.38**
	106.27	**31.50**	**35.71**
45	**107.20**	**62.48**	**22.27**
	107.04	**57.34**	**24.51**
	107.18	**61.89**	**22.53**

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
45	301.48	107.05	221.78	5

Targeted Yield Equations

FN =5.30* T - 0.39* STVN -0.12* M
FP =1.03* T - 0.24* STVP - 0.09* M
FK =1.98* T - 0.20* STVK -0.05* M
*T= Targeted Yield

Targeted Yield (t /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
35.63 (Mean)	70.66	10.56	25.94
40.00	94.25	15.61	34.12
41.12 (RSM)	99.76	16.21	36.81
45.00	120.76	20.77	44.04

(10) **CENTRE : BARRACKPORE CROP: LENTIL YEAR: 2005-06**

For the STCR experiment on Lentil 2005-06 at Barrackpore centre it was observed that the fertility gradient has been created only with respect to SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 5 t/ha and 10 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM). it is observed that the effects of **Treatment , FYM** and their **Interaction (TREAT*FYM)** are highly significant. So it is possible to identify the best level of FYM here.

When ANOVA for Treatment, FYM and Strips (within FYM levels) was carried out with and without interactions and covariates, it is observed that the effects of **Treatment, FYM** and **Strips** (within FYM levels) were highly significant.

The response to N at the middle doses of P and K showed that there is a decreasing trend for response over N_0 from N_{40} to N_{80} and then from N_{80} to N_{120}. In case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\begin{aligned}\mathbf{Y} = {} & \mathbf{141.8902 + 0.84991{*}FN - 2.42596{*}FP + 0.91617{*}FK - 0.01534{*}FN^2 +} \\ & \mathbf{+ 0.08689{*}FP^2 + 0.06332{*}FK^2 - 0.01126{*}FNFP - 0.02502{*}FNFK +} \\ & \mathbf{0.0081{*}FPFK - 0.6257{*}SN + 0.87205{*}SP + 0.49785{*}SK +} \\ & \mathbf{+ 0.01069{*}FNSN - 0.01816{*}FPSP - 0.01736{*}FKSK}\end{aligned}$$

Substituting SN=298.99; SP=109.15; and SK=204.87, gives the reduced complete Second order Response Surface as:

$$\begin{aligned}\mathbf{Y} = {} & \mathbf{151.9126 + 4.04622\,FN - 4.4054\,FP - 2.64263FK - 0.01534FN^2 + 0.08689\,FP^2} \\ & \mathbf{+ 0.06332\,FK^2 - 0.01126\,FNFP - 0.02502\,FNFK + 0.0081\,FPFK}\end{aligned}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**90.26**kg/ha, Fertilizer Phosphorus =**28.72** kg/ha and Fertilizer Potash= **38.35** kg/ha and with predicted yield at stationary point as **223.66 kg/ha**. Nature of Stationary Point: **Saddle Point** (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (kg/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
230	**88.5389**	**40.3591**	**37.8629**
	88.5446	**40.1595**	**37.8312**
	88.4192	**44.5550**	**38.5299**
225	**88.9089**	**27.3912**	**35.8017**
	88.8899	**28.0575**	**35.9076**
	88.9254	**26.8152**	**35.7102**
220	**88.5510**	**39.9380**	**37.7960**
	88.8766	**28.5236**	**35.9817**
	88.7268	**33.7745**	**36.8164**

Optimal doses obtained through Targeted yield equations

Targeted Yield Equations	Soil Test Values (kg/ha)	Targeted Yield (kg/ha)	Optimum Fertilizer Doses		
			FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
FN = 93.63 * T - 0.59 SN	323	230	38.94	18.93	21.66
FP = 37.67 * T - 0.61 SP	107	225	34.26	17.04	19.67
FK = 39.72 * T - 0.34 SK	210	220	29.58	15.17	17.68

* T=Targeted Yield

(11) CENTRE : BIKANER CROP: CUMIN YEAR: 2005-06

For the STCR experiment on Cumin 2005-06 at Bikaner centre it was observed that the fertility gradient has been created with respect to SN, SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 5 t/ha and 10 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM). it is observed that the effects of **Treatment, FYM and Interaction (TREAT*FYM)** are highly significant. So it is possible to identify the best level of FYM here.

When ANOVA for Treatment, FYM and Strips (within FYM levels) was carried out with and without interactions and covariates it is observed that the effects of **Treatment, FYM and Strips (within FYM levels)** were highly significant.

The response to N at the middle doses of P and K showed that there is an decreasing trend for response over N_0 from N_{40} to N_{80} and then decreasing from N_{80} to N_{120}. In case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose.

Responses could not be calculated for the treatments 022(N_0 P_2 K_2), 202(N_2 P_0 K_2) and 220(N_2 P_2 K_0) as these combinations were not taken in the experiment. This was compulsory as per the design adopted in the annual workshop at Bhopal. More over the treatment 311 and 331 were also required to be taken in the experiment**.**

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\mathbf{Y = -3.90463 + 0.10669*FN - 0.0068*FP - 0.11702*FK - 0.00117*FN^2 + - 0.00034*FP^2 + 0.00064*FK^2 - 0.00022*FNFP + 0.00056864*FNFK + 0.000838*FPFK + 0.02111*SN - 0.02176*SP + 0.02967*SK + + 0.0002145*FNSN + 0.000514*FPSP + 0.00016391*FKSK}$$

Substituting SN=117 kg/ha; SP=41 kg/ha; and SK=180 kg/ha, gives the reduced complete Second order Response Surface as:

$$\mathbf{Y = 3.01368 + 0.131784\ FN + 0.014259\ FP - 0.08752\ FK - 0.00117\ FN^2 - - 0.00034\ FP^2 + 0.00064\ FK^2 - 0.00022\ FNFP + 0.000569\ FNFK + + 0.000838\ FPFK}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**58.11**kg/ha, Fertilizer Phosphorus =**31.81** kg/ha and Fertilizer Potash= **20.42** kg/ha and with predicted yield at stationary point as **6.13 q/ha**. Nature of Stationary Point: **Saddle Point** (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (q/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
6.10	**66.65**	**36.67**	**34.77**
	66.60	**38.02**	**39.49**
	66.60	**37.93**	**39.18**
6.20	**66.56**	**38.99**	**42.89**
	66.52	**40.17**	**47.04**
	66.57	**38.70**	**41.88**
6.30	**66.67**	**36.19**	**33.08**
	66.62	**37.39**	**37.27**
	66.58	**38.58**	**41.46**

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
6.13	**117**	**41**	**180**	**5**

Targeted Yield Equations

FN =14.35* T - 0.35* STVN - 1.25* M

FP =9.7* T - 0.67* STVP - 0.15* M

FK =8.79* T - 0.13* STVK - 0.12* M

*T= Targeted Yield

Targeted Yield (t /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
5.10(Mean)	**25.99**	**21.25**	**20.83**
6.10	**40.34**	**30.95**	**29.62**
6.13 (RSM)	**40.77**	**31.24**	**29.88**
6.20	**41.77**	**31.92**	**30.50**

(12) **CENTRE : BIKANER CROP: ISABGOL YEAR: 2005-06**

For the STCR experiment on Isabgol 2005-06 at Bikaner centre it was observed that the fertility gradient has been created with respect to SN, SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 5 t/ha and 10 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment*OM) without the covariates. It is observed that the effects of Treatment , FYM and Interaction (TREAT*FYM) were highly significant. When the analysis was performed by taking SN, SP and SK as the covariates it was observed that only Treatment and FYM effects were found to be highly significant. So it is possible to identify the best level of FYM here.

When ANOVA for Treatment, FYM and Strips (within FYM levels) was carried out with and without interactions and covariates it is observed that the effects of **Treatment, FYM and Strips (within FYM levels)** were highly significant. In the covariate analysis , the effect of Strips(within FYM levels) was not found to be significant

The response to N at the middle doses of P and K showed that there is an decreasing trend for response over N_0 from N_{40} to N_{80} and then decreasing from N_{80} to N_{120}. Same is the case of P at middle doses of N and K but for K at middle doses of N and P, there is a gradual decreasing trend as we move from lower to higher dose.

Responses could not be calculated for the treatments 022(N_0 P_2 K_2), 202(N_2 P_0 K_2) and 220(N_2 P_2 K_0) as these combinations were not taken in the experiment. This was compulsory as per the design adopted in the annual workshop at Bhopal. More over the treatment 311 and 331 were also required to be taken in the experiment.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

Y= -6.71415+ 0.16937*FN+ 0.00223*FP+ 0.08223*FK -7E-05*FN^2 +
- 0.00142*FP^2 + 0.00233*FK^2 - 0.00064*FNFP - 0.00135*FNFK +
0.000425*FPFK + 0.01771*SN - 0.00901*SP + 0.0462*SK+
- 0.000418*FNSN+ 0.00256*FPSP - 0.0007522*FKSK

Substituting SN=125; SP=44; and SK=205, gives the reduced complete Second order Response Surface as:

$$\mathbf{Y = 4.57416 + 0.117138\ FN + 0.11487\ FP - 0.07197\ FK - 0.00007008\ FN^2 - 0.00142\ FP^2}$$
$$\mathbf{+ 0.00233\ FK^2 - 0.00064\ FNFP - 0.00135\ FNFK + 0.000425\ FPFK}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**56.83** kg/ha, Fertilizer Phosphorus =**31.72** kg/ha and Fertilizer Potash= **50.75** kg/ha and with predicted yield at stationary point as **10.99** q/ha . Nature of Stationary Point: **Saddle Point** (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (q/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
11.00	**81.69**	**34.82**	**54.42**
	84.04	**34.13**	**39.65**
	85.02	**33.84**	**33.48**
12.00	**86.66**	**33.35**	**23.16**
	86.90	**33.28**	**21.63**
	87.00	**33.25**	**21.04**
13.00	**86.67**	**33.35**	**24.10**
	87.06	**33.25**	**22.92**
	88.36	**32.85**	**22.44**

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
12	125	44	205	5

Targeted Yield Equations

FN =7.8429* T -0.27* STVN -0.07 * M

FP =5.75388* T -0.58* STVP -0.04* M

FK =6.3768* T – 0.14 * STVK -0.02* M

*T= Targeted Yield

Targeted Yield (t /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
10.00 (Mean)	44.33	31.82	34.97
10.99 (RSM)	52.09	37.51	41.28
12.00	60.01	43.33	47.72

(13) CENTRE : BIKANER CROP: GUAR YEAR: 2005-06

For the STCR experiment on Guar 2005-06 at Bikaner centre it was observed that the fertility gradient has been created with respect to SN, SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 5 t/ha and 10 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment*OM) without the covariates. It is observed that the effects of Treatment and FYM were highly significant. When the analysis was performed by taking SN, SP and SK as the covariates it was observed that the effects of Treatment **,** FYM and interaction (Treatment*OM) were found to be highly significant. So it is possible to identify the best level of FYM here.

When ANOVA for Treatment, FYM and Strips (within FYM levels) was carried out with and without interactions and covariates it is observed that the effects of **Treatment, FYM and Strips (within FYM levels)** were highly significant. In the covariate analysis , the effect of Strips(within FYM levels) was not found to be significant

The response to N at the middle doses of P and K showed that there is an increasing trend for response over N_0 from N_{20} to N_{40} and then decreasing from N_{40} to N_{60}. Same is the case of P at middle doses of N and K but for K at middle doses of N and P, there is a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\begin{aligned}\mathbf{Y} = & -1211.112 + 19.1723*FN + 3.07776*FP - 0.27983*FK - 0.43982*FN^2 + \\ & - 0.07601*FP^2 + 0.41562*FK^2 + 0.5273*FNFP + 0.03732*FNFK + \\ & - 0.20015*FPFK + 9.61692*SN - 0.05744*SP + 4.66974*SK + \\ & + 0.0791*FNSN + 0.00395*FPSP - 0.07617*FKSK\end{aligned}$$

Substituting SN=124.43 kg/ha; SP=34.47; and SK=202.66 kg/ha, gives the reduced complete Second order Response Surface as:

$$\begin{aligned}\mathbf{Y} = \; & 927.3899 + 28.98073*FN + 3.21206*FP - 15.7423*FK - 0.43982*FN^2 - \\ & 0.07601*FP^2 + 0.41562*FK^2 + 0.5273*FNFP + 0.03732*FNFK - 0.20015*FPFK\end{aligned}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**89.78** kg/ha, Fertilizer Phosphorus =**57.96** kg/ha and Fertilizer Potash= **36.90** kg/ha and with predicted yield at stationary point as **23.40** q/ha . Nature of Stationary Point: **Saddle Point** (Neither maxima nor Minima)

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
15.67	124.43	34.47	202.66	5

Targeted Yield Equations

FN =4.56*	**T -0.33***	**STVN -0.07 * M**
FP =1.41*	**T -0.43***	**STVP -0.04* M**
FK =2.64*	**T – 0.12 ***	**STVK -0.02* M**

*T= Targeted Yield

Targeted Yield (t /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
15.67 (Mean)	29.47	7.14	16.99
23.40 (RSM)	65.29	17.97	37.36

(14) **CENTRE : HISAR CROP: BARLEY YEAR: 2005-06**

For the STCR experiment on Barley 2005-06 at Hisar centre it was observed that the fertility gradient has been created with respect to SN, SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 7.5 t/ha and 15 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment*OM) without the covariates. It is observed that the effects of Treatment , FYM and Interaction (TREAT*FYM) were highly significant. When the analysis was performed by taking SN, SP and SK as the covariates it was observed that the Treatment**,** FYM and their interaction effects were found to be highly significant. So it is possible to identify the best level of FYM here.

When ANOVA for Treatment, FYM and Strips (within FYM levels) was carried out with and without interactions and covariates it is observed that only the effects of **FYM and Strips (within FYM levels)** were highly significant. The effect of Treatment was not found to be significant. In the covariate analysis , all the effects were found to be non significant.

The response to N at the middle doses of P and K showed that there is a gradual decreasing trend for response over N_0 from N_{40} to N_{80} and then to N_{120}. In the case of P at middle doses of N and K there is an increasing trend over P_0 from to P_{40} to P_{80} and then decreasing from P_{80} to P_{120} . Same is the case with K at middle doses of N and P.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\begin{aligned}\mathbf{Y}= & -5107.201+ 5.67783*FN+ 31.8359*FP+22.58956*FK - 0.08037*FN^2 + \\ & - 0.55091*FP^2 - 0.2817*FK^2 + 0.288*FNFP - 0.17718*FNFK + \\ & +0.36799*FPFK + 11.5157*SN+81.3884*SP - 16.689*SK+ \\ & +0.01969*FNSN- 1.8824*FPSP - 0.02342*FKSK\end{aligned}$$

Substituting SN=133.19; SP=17.67; and SK=278.11, gives the reduced complete Second order Response Surface as:

$$\begin{aligned}\mathbf{Y} = & 3464.244 + 8.2966 * FN - 2.04735 * FP + 16.0788 * FK - 0.08037 * FN^2 - 0.55091 * FP^2 \\ & - 0.28166 * FK^2 + 0.0288 * FNFP - 0.17718 * FNFK + 0.36799 * FPFK\end{aligned}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**68.56** kg/ha, Fertilizer Phosphorus =**24.83** kg/ha and Fertilizer Potash= **24.83** kg/ha and with predicted yield at stationary point as **3903.64** q/ha . Nature of Stationary Point: **Maximum**

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
39.00	133.19	17.67	278.11	5

Targeted Yield Equations

FN =10.00* T -2.40* STVN -0.49 * M

FP =1.89* T -3.38* STVP -0.06* M

FK =2.56* T – 0.24 * STVK -0.06* M

*T= Targeted Yield

Targeted Yield (t /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
35.65 (Mean)	33.17	7.20	24.07
39.0364 (RSM)	67.03	13.60	32.74
39.00	66.67	13.53	32.64

(15) **CENTRE : HISAR CROP: BARLEY YEAR: 2006-07**

For the STCR experiment on Barley 2006-07 at Hisar centre it was observed that the fertility gradient has been created with respect to SN , SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 5 t/ha and 10 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM). it is observed that only the effects of **Treatment and Interaction (TREAT*FYM)** are highly significant and that of FYM is not significant. So it is not possible to identify the best level of FYM here.

When ANOVA for Treatment, FYM and Strips (within FYM levels) was carried out with and without interactions and covariates it is observed that only the effect of **Treatment, is** significant.

The response to N at the middle doses of P and K showed that there is an increasing trend for response over N_0 from N_{60} to N_{120} and then decreasing from N_{120} to N_{180}. In case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y = 2110.376 + 67.8064*FN + 28.7515*FP + 12.46093*FK - 0.31041*FN^2 + - 0.43526*FP^2 - 1.1248*FK^2 + 0.18654*FNFP + 0.28939*FNFK + - 0.28924*FPFK + 18.5982*SN - 24.2612*SP - 0.73637*SK + - 0.32307*FNSN - 0.20608*FPSP + 0.08513*FKSK$$

Substituting SN=**129.5**; SP=**17.57**; and SK=**270.16**, gives the reduced complete Second order Response Surface as:

$$Y = 3942.518 + 24.83806*FN + 25.04205*FP + 36.12707*FK - 0.31041*FN^2 - 0.43526*FP^2 - 1.12479*FK^2 - 0.18654FNFP - 0.28939*FNFK + 0.28924*FPFK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**61.15** kg/ha, Fertilizer Phosphorus =**32.91** kg/ha and Fertilizer Potash= **20.14** kg/ha and with predicted yield at stationary point as **54.70 q/ha**. Nature of Stationary Point: **Maximum**

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
55.00	**129.50**	**17.57**	**270.17**	**5**

Targeted Yield Equations

FN =4.49*	T -1.30*	STVN -0.05* M
FP =0.94*	T -2.48*	STVP -0.11* M
FK =1.66*	T -0.25*	STVK -0.03* M

*T= Targeted Yield

Targeted Yield (t /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
48.65 (Mean)	49.71	1.33	12.99
54.70(RSM)	76.88	7.02	23.03
55.00	78.73	7.66	23.61

(16) **CENTRE : HISAR CROP: PEARL MILLET YEAR: 2006-07**

For the STCR experiment on Pearl Millet 2006-07 at Hisar centre it was observed that the fertility gradient has been created with respect to SN , SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 7.5 t/ha and 15 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM). it is observed that none of the effects of **Treatment,FYM and Interaction (TREAT*FYM)** are significant . So it is not possible to identify the best level of FYM here.

When ANOVA for Treatment, FYM and Strips (within FYM levels) was carried out with and without interactions and covariates it is observed that only the effects of **Treatment,** and Strips (within FYM levels) are significant.

The response to N at the middle doses of P and K showed that there is an gradual decreasing trend for response over N_0 from N_{60} to N_{120} and then decreasing from N_{120} to N_{180}. Same is the case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y = -992.9338 + 21.7163*FN - 1.61505*FP + 18.83317*FK - 0.03764*FN^2 - 0.06527*FP^2 - 0.0629*FK^2 - 0.04879*FNFP - 0.05496*FNFK + 0.23119*FPFK + 3.13808*SN - 3.77079*SP + 6.57197*SK - 0.03373*FNSN + 0.12305*FPSP - 0.06857*FKSK$$

Substituting SN=**126.68**; SP=**16.97**; and SK=**288.39**, gives the reduced complete Second order Response Surface as:

$$\mathbf{Y = 1234.226 + 17.43255*FN + 0.4768*FP - 0.91499*FK - 0.03764*FN^2 - 0.06527*FP^2 - 0.06289*FK^2 - 0.048794FNFP - 0.05496*FNFK + 0.2311*FPFK}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**138** kg/ha, Fertilizer Phosphorus =**71** kg/ha and Fertilizer Potash= **66** kg/ha and with predicted yield at stationary point as **23.78 q/ha**. Nature of Stationary Point: **Saddle Point(Neither maxima nor Minima)**

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (q/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
24.00	**135.79**	**71.02**	**65.48**
	136.06	**70.48**	**64.93**
	140.43	**61.71**	**55.95**
25.00	**142.94**	**56.69**	**50.80**
	148.15	**46.22**	**40.10**
	149.20	**44.11**	**37.94**

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
2110	**126.68**	**16.97**	**288.39**	**5**

Targeted Yield Equations

FN =0.12*	T -1.28*	STVN -0.10* M
FP =0.02*	T -1.77*	STVP -0.09* M
FK =0.05*	T -0.25*	STVK -0.17* M

*T= Targeted Yield

Targeted Yield (kg /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
2110 (Mean)	**90.30**	**11.49**	**32.13**
2378(RSM)	**122.46**	**16.85**	**45.53**
2400	**125.10**	**17.29**	**46.63**
2500	**137.10**	**19.29**	**51.63**

(17) **CENTRE : HISAR CROP: WHEAT YEAR: 2005-06**

For the STCR experiment on Wheat 2005-06 at Hisar centre it was observed that the fertility gradient has been created with respect to SN , SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 7.5 t/ha and 15 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM). it is observed that the effects of **Treatment and FYM** are highly significant . So it is possible to identify the best level of FYM here.

When ANOVA for Treatment, FYM and Strips (within FYM levels) was carried out with and without interactions and covariates it is observed that the effects of **Treatment, FYM** and **Strips (within FYM levels)** are significant.

The response to N at the middle doses of P and K showed that there is a gradual decreasing trend for response over N_0 from N_{60} to N_{120} and then decreasing from N_{120} to N_{180}. Same is the case of P at middle doses of N and K and K at middle doses of N and P respectively, where we find a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

Y= 2397.755+ 30.5581*FN +21.3816*FP - 26.0769*FK - 0.08506*FN^{2} - 0.24757*FP^{2} - 0.0937*FK^{2} + 0.12727*FNFP - 0.05264*FNFK +0.09585*FPFK + 6.22767*SN +67.5768*SP - 6.04803*SK -0.04488*FNSN - 0.83192*FPSP + 0.12645*FKSK

Substituting SN=**134.8**; SP=**18.42**; and SK=**285.9**, gives the reduced complete Second order Response Surface as:

$$Y = 2752.879 + 24.50827 * FN + 6.057644 * FP + 10.07512 * FK - 0.08506 * FN^{2} - 0.24757 * FP^{2}$$
$$- 0.09365 * FK^{2} + 0.12727 * FNFP - 0.05264 * FNFK + 0.09585 * FPFK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**190.66** kg/ha, Fertilizer Phosphorus =**65.69** kg/ha and Fertilizer Potash= **39.42** kg/ha and with predicted yield at stationary point as **54.46 q/ha**. Nature of Stationary Point: **Maximum**

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (kg/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
5500	137.82	53.17	44.47
	134.12	52.18	41.94
	136.90	52.93	44.50
6000	152.51	57.11	42.60
	140.80	53.97	44.09
	154.62	57.68	42.33

Optimal doses obtained through Targeted yield equations

Targeted Yield Equations	Soil Test Values (kg/ha)	Targeted Yield (kg/ha)	Optimum Fertilizer Doses		
			FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
FN = 5.87 * T - 1.17 SN	135	4500	106	51	41
FP = 3.27 * T - 5.30 SP	18	5500	165	84	64
FK = 2.26 * T - 0.21 SK	286	6000	194	101	75

Targeted Yield (kg /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
4519 (Mean)	106.56	51.70	40.79
5446(RSM)	160.98	82.01	61.74

(18) **CENTRE : HISAR CROP: WHEAT YEAR: 2006-07**

For the STCR experiment on Wheat 2006-07 at Hisar centre it was observed that the fertility gradient has been created with respect to SN , SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 7.5 t/ha and 15 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM). it is observed that only the effects of **Treatment** are highly significant . So it is not possible to identify the best level of FYM here.

When ANOVA for Treatment, FYM and Strips (within FYM levels) was carried out with and without interactions and covariates it is observed that the effects of **Treatment, FYM** and **Strips (within FYM levels)** are **highly significant**.

The response to N at the middle doses of P and K showed that there is a gradual decreasing trend for response over N_0 from N_{60} to N_{120} and then decreasing from N_{120} to N_{180}. Same is the case of P at middle doses of N and K and K at middle doses of N and P respectively, where we find a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\begin{aligned}\mathbf{Y} = & -118.6324 + 28.9337*FN - 9.46221*FP + 20.8367*FK - 0.01278*FN^2 + \\ & - 0.13477*FP^2 + 0.07934*FK^2 + 0.00993*FNFP - 0.09871*FNFK + \\ & + 0.18225*FPFK + 5.37055*SN + 13.6808*SP + 6.68525*SK + \\ & - 0.07965*FNSN + 0.59024*FPSP - 0.08683*FKSK\end{aligned}$$

Substituting SN=129.01; SP=16.93; and SK=288.33, gives the reduced complete Second order Response Surface as:

$$\begin{aligned}\mathbf{Y} = & \ 2733.447 + 18.65775 * FN + 0.530881 * FP - 4.19928 * FK - 0.01278 * FN^2 - \\ & - 0.13477 * FP^2 + 0.07934 * FK^2 + 0.00993 * FNFP - 0.09871 * FNFK + \\ & + 0.18225 * FPFK\end{aligned}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**298** kg/ha, Fertilizer Phosphorus =**98** kg/ha and Fertilizer Potash= **113** kg/ha and with predicted yield at stationary point as **5345 kg/ha**. Nature of Stationary Point: **Saddle Point**

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (kg/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
5500	302.96	78.03	92.68
	298.17	82.02	106.30
	304.88	76.44	87.25
6000	297.95	82.20	106.90
	317.76	65.71	50.68
	297.18	82.85	109.10

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
4154	129.01	16.93	288.33	5

Targeted Yield Equations

FN =0.07* T -1.40* STVN -0.36* M

FP =0.01* T -2.16* STVP -0.15* M

FK =0.02* T -0.21* STVK -0.05* M

*T= Targeted Yield

Targeted Yield (kg /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
4154 (Mean)	107.49	3.85	22.16
5345(RSM)	190.84	15.76	45.98
5500	201.69	17.31	49.08
6000	236.69	22.31	59.08

(19) CENTRE : JABALPUR CROP: ONION YEAR: 2006-07

For the STCR experiment on Onion 2006-07 at Jabalpur centre it was observed that the fertility gradient has been created only with respect to SN, SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 10 t/ha and 20 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM). It was observed that only the effect of FYM is significant. So it is possible to identify the best level of FYM here.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels) it was observed that all the effects were highly significant which indicates creation of fertility gradient in the strips within the FYM levels.

The response to N at the middle doses of P and K showed that there is a gradual decreasing trend for response over N_0 from N_{40} to N_{80} and then decreasing from N_{80} to N_{120}. Same is the case of P at middle doses of N and K. For K at middle doses of N and P respectively, we find a gradual increasing trend response over K_0 from K_{40} to K_{80} and then decreasing from K_{80} to K_{120}.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\begin{aligned}\mathbf{Y} &= \mathbf{6.99673 - 0.10583*FN - 0.19045*FP + 0.40833*FK + 0.000981*FN^2 +} \\ &\mathbf{+0.00136*FP^2 - 0.0016*FK^2 - 0.00018*FNFP - 0.0002193*FNFK +} \\ &\mathbf{- 0.000322*FPFK - 0.0079*SN + 0.24752*SP + 0.03635*SK +} \\ &\mathbf{-7.99E\text{-}05*FNSN + 0.00174*FPSP - 0.0002597*FKSK}\end{aligned}$$

Substituting **SN=210.13 kg/ha; SP=17.51 kg/ha; and SK=238.13 kg/ha**, gives the reduced complete Second order Response Surface as:

$$\begin{aligned}\mathbf{Y} &= \mathbf{18.31592 - 0.12261*FN - 0.16*FP + 0.346488*FK + 0.000981*FN^2 + 0.00136*FP^2} \\ &\mathbf{- \quad 0.00161 * FK^2 * - 0.00018*FNFP - 0.00022*FNFK - 0.00032* FPFK}\end{aligned}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**80.17** kg/ha, Fertilizer Phosphorus =**75.48** kg/ha and Fertilizer Potash= **94.59** kg/ha and with predicted yield at stationary point as **23.75** q/ha. Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (q/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
20	**84.99**	**94.01**	**92.53**
	86.33	**85.23**	**92.84**
	87.85	**75.93**	**93.20**
25	**91.53**	**50.97**	**94.05**
	89.56	**63.93**	**95.59**
	92.94	**41.66**	**94.38**
30	**94.88**	**46.99**	**94.23**
	92.29	**45.95**	**94.23**
	97.77	**50.22**	**95.51**

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
25	210.13	17.51	238.13	5

Targeted Yield Equations

FN =8.31* T -0.76* STVN -0.39* M
FP =2.51* T -3.06* STVP -0.19* M
FK =7.19* T -0.55* STVK -0.25* M

*T= Targeted Yield

Targeted Yield (t /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
25.00	46.10	8.22	47.53
30.00	87.65	20.77	83.48

(20) CENTRE : KALYANI CROP: CABBAGE YEAR: 2005-06

For the STCR experiment on Cabbage 2005-06 at BCKVV, Kalyani centre it was observed that the fertility gradient has been created only with respect to SP and SK for overall the strips. , but for organic manure level wise it was created y with respect to SN, SP and SK at 0 t/ha only. At 2.5t/ha., it was created in respect of SP and SK only and at 5 t/h for SK only

The effect of the strips is found to be **significantly different in all the cases .**. This indicates that the fertility gradient was created in respect of N, P and K respectively at FYM at 0 t/ha.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that only the effect of Treatment is highly significant. When the ANOVA for Treatment, Organic manure and their interaction (Treatment * OM) with covariates was carried out, it was observed that the effect of Treatment, FYM and interaction (Treatment * OM) are highly significant. Moreover, the covariate SN is also highly significant .So here it is possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels) it was observed that only the effect of Treatments is highly significant.

The response to N at the middle doses of P and K showed that there is a decreasing trend for response over N_0 from N_{120} to N_{150} and then increasing from N_{150} to N_{170}. In the case of P at middle doses of N and K we find there is a slight increase from P_{50} to P_{60} then decreasing from P_{60} to P_{80} . For K at middle doses of N and P respectively, we find a gradual decreasing trend response over K_0 from K_{60} to K_{80} and then decreasing from K_{80} to K_{100}.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\begin{aligned}Y= & -33.36641-2.12234*FN + 14.3501*FP +2.70493*FK +0.03962*FN^2 +0.13568*FP^2 \\ & + 0.05952*FK^2 - 0.16219*FNFP +0.00819*FNFK - 0.12487*FPFK -1.4261*SN \\ & +0.46723*SP + 7.75364*SK+0.00598*FNSN +0.00331*FPSP --0.07373*FKSK\end{aligned}$$

Substituting **SN=192.4 kg/ha; SP=26.8 kg/ha;** and **SK=98.17 kg/ha**, gives the reduced complete Second order Response Surface as:

$$\begin{aligned}Y= & 465.9582 - 0.97179FN + 14.438848FP – 4.5331441FK –0.03962FN^2 – 0.13568FP^2 \\ & + 0.05952FK^2 – 0.16219FNFP + 0.00819FNFK - 0.12487FPFK\end{aligned}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**105.97** kg/ha, Fertilizer Phosphorus =**46.01** kg/ha and Fertilizer Potash= **70.88** kg/ha and with predicted yield at stationary point as **611.13** q/ha. Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (q / ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
610	110.50	57.47	80.42
	111.98	54.55	81.75
	111.83	54.83	81.62
615	113.64	51.23	83.25
	113.70	51.12	83.30
	113.15	52.21	82.80
620	117.12	44.32	86.37
	117.61	43.35	86.81
	117.37	43.82	86.60

Optimal doses obtained through Targeted yield equations

T	**SN**	**SP**	**SK**	**FYM**
610	**192.4**	**27**	**98.17**	**5**

Targeted yield equations

FN =0.4* T -0.58* STVN - 0.39 * M
FP =0.15* T -1.42* STVP - 0.19 * M
FK =0.28* T -1.06* STVK - 0.25 * M

*T= Targeted Yield

Targeted Yield (q /ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
610	130.46	52.21	65.49
615	132.46	52.96	66.89
620	134.46	53.71	68.29

(21) Cemtre : Kerala (Vellanikkara) Crop: Bhindi; Year: 2005-06

For the STCR experiment on Bhindi 2005-06 at Vellanikkara centre, it was observed that the fertility gradient has been created with respect to SN, SP and SK for both overall the strips and Organic manure level wise at 0 t/ha., 6 t/ha and 12 t/h of FYM

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that all the effect were highly significant. When the ANOVA for Treatment, Organic manure and their interaction (Treatment * OM) with covariates was carried out, it was observed that all the effects were highly significant .So it is possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out without interactions and covariates (taking the strips within FYM levels) it is observed that the effects of TREATMENT, FYM and (STRIPS within FYM levels) are highly significant. So here it is possible to identify the best level of FYM and this also indicates creation of fertility gradient in the strips within the FYM levels.

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The response to N at the middle doses of P and K showed that there is an decreasing trend for response over N_0 from N_{25} to N_{50} and then decreasing from N_{50} to N_{100}. In case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y= -8.18892+1.2131*FN+3.81173*FP+0.52349*FK- 0.00315*FN^2+0.11766*FP^2 - 0.0152*FK^2 - 0.00976*FNFP +0.00201*FNFK - 0.05629*FPFK + 0.07359*SN +1.65146*SP - 8.1889*SK -0.00173*FNSN - 0.17599*FPSP + 0.00141*FKSK$$

Substituting **SN=**367.35 kg/ha**; SP=**20.90 kg/ha**; and SK=**536.86 kg/ha, gives the reduced complete Second order Response Surface as:

$$Y= 39.05256 + 577585 *FN + 133539*FP +1.280463*FK-0.00315*FN^2 +0.11766*FP^2 - 0.0152 * FK^2 * - 0.00976FNFP - 0.00201*FNFK - 0.05629* FPFK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**86.67** kg/ha, Fertilizer Phosphorus =**10.53** kg/ha and Fertilizer Potash= **31.93** kg/ha and with predicted yield at stationary point as **82.90** q /ha.

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (kg/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
85	85.80	12.90	28.85
	86.05	6.55	30.10
90	85.76	13.96	28.62
	85.70	15.44	28.33
95	80.54	19.47	27.52
	80.67	16.36	28.15

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
85	367.35	20.9	536.86	6

Targeted Yield Equations

FN =3.62* T -0.2* STVN -0.19* M
FP =0.18* T -0.12* STVP -0.02* M
FK =0.53* T -0.03* STVK -0.03* M

* T=Targeted Yield

Targeted Yield (kg/ha)	**Optimum fertilizer doses**		
	FN (kg/ha)	**FP (kg/ha)**	**FK (kg/ha)**
82.9(S.point)	**225.68**	**12.31**	**27.68**
85	**233.09**	**12.67**	**28.76**
90	**251.19**	**13.57**	**31.41**
95	**269.29**	**14.47**	**34.06**

(22) CENTRE : KERALA (Vellanikkara) CROP: BHINDI YEAR: 2006-07

For the STCR experiment on Bhindi 2006-07 at Vellanikkara centre, it was observed that the fertility gradient has not been created with respect to SN, SP and SK when analysis was carried out taking soil nutrients as dependent variables separately. When ANOVA was carried out taking SN,SP and SK as dependent variables separately at different FYM levels at 0 t/ha., 6 t/ha and 12 t/ha , it was observed that only in the case of SN at 12t/ha the fertility gradient was found to be significant.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that all the effect were significant. When the ANOVA for Treatment, Organic manure and their interaction (Treatment * OM) with covariates was carried out, same results was observed .So it is possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out without interactions and covariates (taking the strips within FYM levels) it is observed that the effects of TREATMENT, FYM and (STRIPS within FYM levels) were not significant. When the ANOVA was carried out using the covariates, it was observed that all the effects were significant. So here it is possible to identify the best level of FYM and this also indicates creation of fertility gradient in the strips within the FYM levels.

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The response to N at the middle doses of P and K showed that there is an decreasing trend for response over N_0 from N_{25} to N_{50} and then decreasing from N_{50} to N_{100}. In case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\mathbf{Y= -23.38959+0.80558*FN + 4.44571*FP +1.37569*FK - 0.00662*FN^2 +0.06438*FP^2 +0.03669*FK^2 - 01861*FNFP +0.00279*FNFK - 0.18874*FPFK+ 0.14838*SN -1.01615*SP + 0.07889*SK - 0.000286*FNSN+0.06333*FPSP - 0.00358*FKSK}$$

Substituting **SN=**404.89 kg/ha**; SP=**20.20 kg/ha**;** and SK=434.49 kg/ha, gives the reduced complete Second order Response Surface as:

$$Y=50.43867+ 0.689688*FN + 5.724976*FP - 0.179778*FK – 0.00662*FN^2+ 0.6438*FP^2+ 0.03669*FK^2 - 0.01861*FNFP + 0.00279*FNFK – 0.18874*FPFK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=45.26 kg/ha, Fertilizer Phosphorus =11.59 kg/ha and Fertilizer Potash= 28.60 kg/ha and with predicted yield at stationary point as 99.09 q /ha.

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (kg/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
115	44.26	11.97	34.61
	44.19	13.04	33.67
	44.06	15.13	31.85
120	44.18	13.25	33.48
	44.43	9.25	36.97
	44.47	8.60	37.54

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
99.09	404.89	20.2	434.49	5

Targeted Yield Equations

FN =0.72 * T -0.06* STVN -0.08* M
FP =0.04* T -0.07* STVP -0.01* M
FK =0.34* T -0.04* STVK -0.03* M

*T= Targeted Yield

Targeted Yield (q /ha)	**Optimum fertilizer doses**		
	FN (kg/ha)	**FP (kg/ha)**	**FK (kg/ha)**
86.0	**38.02**	**2.42**	**14.08**
99.09	**46.6514**	**2.4996**	**16.161**
115	**58.1066**	**3.136**	**21.5704**
120	**61.7066**	**3.336**	**23.2704**

(23) CENTRE : KERALA (Vellanikkara) CROP: SNAKE GUARD YEAR: 2005-06

For the STCR experiment on Snake Guard 2005-06 at Vellanikkara centre, it was observed that the fertility gradient has been created with respect to SN, SP and SK for overall the strips. For FYM level wise at 0 t/ha., 15 t/ha and 30 t/h of FYM it is observed that fertility gradient has been created only in case of SN and SK whereas for SP it is created only FYM level at 30 t/ha

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that only the effect of Treatment is highly significant. When the ANOVA for Treatment, Organic manure and their interaction (Treatment * OM) with covariates was carried out, it was observed that all the effects were not significant .So it is not possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out without interactions and covariates (taking the strips within FYM levels) it is observed that only the effect of (STRIPS within FYM levels) is highly significant. So here it is not possible to identify the best level of FYM and this also indicates creation of fertility gradient in the strips within the FYM levels.

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The response to N at the middle doses of P and K showed that there is an increasing trend for response over N_0 from N_{35} to N_{70} and then decreasing from N_{70} to N_{140}. In case of P at middle doses of N and K and K at middle doses of N and P respectively, there is a gradual decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\mathbf{Y = 233.0858 - 2.38416*FN + 3.45163*FP + 2.60457*FK + 0.01182*FN^2 - 0.03022*FP^2 - 0.0092*FK^2 - 0.01503*FNFP + 0.00414*FNFK + 0.02042*FPFK - 0.6803*SN + 4.22049*SP + 0.51361*SK + 0.00449*FNSN - 0.02652*FPSP - 0.02942*FKSK}$$

Substituting SN**=**228.14 kg/ha**;** SP**=**14.17 kg/ha**;** and SK=64.78 kg/ha, gives the reduced complete Second order Response Surface as:

$$\mathbf{Y = 170.949 - 1.35981*FN + 3.075842*FP + 0.698742*FK + 0.01182*FN^2 - 0.03022*FP^2 - 0.092*FK^2 * - 0.01503*FNFP + 0.00414*FNFK + 0.02042*FPFK}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**79.67** kg/ha, Fertilizer Phosphorus =**71.01** kg/ha and Fertilizer Potash= **102.96** kg/ha and with predicted yield at stationary point as **208.94 q /ha.**

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (kg/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
209.27	69.21	58.60	81.40
(Mean Yield)	70.72	58.33	81.66
	72.15	58.08	81.90
210.00	66.47	59.08	80.94
	69.93	58.47	81.53
	72.26	58.06	81.92
215.00	86.81	55.50	84.39
	95.60	53.90	85.88
	87.10	55.45	84.44

Optimal doses obtained through Targeted yield equations

			T	SN	SP	SK	FYM
			209.27	**228.14**	**14.17**	**64.78**	**5**

Targeted Yield Equations

FN =0.93* T -0.57* STVN -0.11* M
FP =0.13* T -1.71* STVP -0.04* M
FK =0.16* T -0.37* STVK -0.01* M
*T=Targeted Yield

Targeted Yield (kg/ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
209.27(Mean)	63.92	2.73	9.45
210.00	64.60	2.83	9.57
215.00	69.25	3.48	10.37
220	73.90	4.13	11.17

(24) Centre : Kerala (Vellanikkara); Crop: Snake Guard; Year: 2006-07

For the STCR experiment on Snake Guard 2006-07 at Vellanikkara centre, it was observed that the fertility gradient has been created only with respect to SN and SK for overall the strips. For FYM level wise at 0 t/ha it was created only in respect of SN, at 15 t/ha and at 30 t/h of FYM, it was created in respect of only SK

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that only the effect of Treatment is highly significant. When the ANOVA for Treatment, Organic manure and their interaction (Treatment * OM) with covariates was carried out, it was observed that all the effects were not significant .So it is not possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out without interactions and covariates (taking the strips within FYM levels) it is observed that only the effect of Treatment and (STRIPS within FYM levels) is highly significant. So here it is not possible to identify the best level of FYM and this also indicates creation of fertility gradient in the strips within the FYM levels.
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The response to N at the middle doses of P and K showed that there is an increasing trend for response over N_0 from N_{35} to N_{70} and then decreasing from N_{70} to N_{140}. Same is the case with P at middle doses of N and K. For K at middle doses of N and P, it was observed that the response decreased from $K_{12.5}$ to K_{25} and then increased from K_{25} to K_{50}

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\begin{aligned} Y = {} & 292.3548 - 2.28553*FN + 1.98883*FP - 0.10562*FK + 0.01316*FN^2 - 0.0193*FP^2 \\ & + 0.04548*FK^2 - 0.019*FNFP - 0.00822*FNFK + \\ & - 0.02347*FPFK - 0.5873*SN + 0.33277*SP - 0.1792*SK + \\ & + 0.00485*FNSN + 0.03713*FPSP + 0.00471*FKSK \end{aligned}$$

Substituting SN**=185.11** kg/ha**;** SP**=37.76** kg/ha**;** and SK=**153.57** kg/ha, gives the reduced complete Second order Response Surface as:

$$\begin{aligned} Y = {} & 17.17136 + 0.590012*FN - 0.42289*FP -- 0.33536*FK -- 0.00316*FN^2 + 0.00465*FP^2 \\ & + 0.00454*FK^2 * + 0.001FNFP + 0.000775*FNFK - 0.00081*FPFK \end{aligned}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**83.40** kg/ha, Fertilizer Phosphorus =**38.12**kg/ha and Fertilizer Potash= **13.21** kg/ha and with predicted yield at stationary point as **184.26 q /ha.**

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
209.22	185.11	37.76	153.57	5

Targeted Yield Equations

FN =0.65* T - 0.43* STVN -0.08* M
FP =0.10* T - 0.36* STVP -0.03* M
FK =0.14* T - 0.12* STVK -0.02* M
* T=Targeted Yield

Targeted Yield (kg/ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
184.26(Stn. Pt.)	39.77	4.68	7.27
209.22(Mean)	57.48	7.44	10.99
215.00	59.75	7.76	11.57
220	63.00	8.26	12.27

(25) Centre : Ludhiana;   Crop: Rice; Year: 2006-07

For the STCR experiment on Rice 2006-07 at Ludhiana centre, it was observed that the fertility gradient has been created only with respect to SP and SK for overall the strips. For FYM level wise at 0 t/ha it was not created, at 15 t/ha and at 30 t/h of FYM, it was created in respect of only for SP and SK

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that only the effect of Treatment and interaction (Treatment * OM) are highly significant. When the ANOVA for Treatment, Organic manure and their interaction (Treatment * OM) with covariates was carried out, it was observed that none of the effects were not significant .So it is not possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels) it is observed that none of the effects are significant. So here it is not possible to identify the best level of FYM.

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The response to N at the middle doses of P and K showed that there is an decreasing trend for response over N_0 from N_{90} to N_{120} and then increasing from N_{120} to N_{150}. Same is the case with P at middle doses of N and K. For K at middle doses of N and P, it was observed that the response decreased from K_{15} to K_{30} and then again decreases from K_{30} to K_{45}

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\mathbf{Y = 4311.252 + 9.4658*FN + 118.018*FP - 127.868*FK + 0.03634*FN^2 + + 0.63869*FP^2 + 0.33734*FK^2 - 0.64449*FNFP + 0.28961*FNFK + - 0.2425*FPFK + 11.2874*SN + 36.9115*SP - 19.4807*SK + - 0.01122*FNSN - 1.18817*FPSP + 0.63987*FKSK}$$

Substituting SN=116.10 kg/ha**;** SP=49.73 kg/ha**;** and SK=110.91 kg/ha, gives the reduced complete Second order Response Surface as:

$$\mathbf{Y = 5296.723 + 8.163158*FN + 58.93018*FP - 56.9004*FK + 0.03634*FN^2 + 0.63869*FP^2 + 0.33734*FK^2 - 0.64449*FNFP + 0.28961*FNFK - 0.2425*FPFK}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**160.60** kg/ha, Fertilizer Phosphorus =**42.79** kg/ha and Fertilizer Potash= **30.81** kg/ha and with predicted yield at stationary point as **63.61 q /ha.** Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (q/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
65.00	119.05	46.85	38.89
	120.95	42.23	41.36
	121.02	42.07	44.44
70.00	122.78	37.81	43.71
	125.51	31.19	47.25
	126.32	29.21	48.29

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
62.52	116.10	49.73	110.91	5

Targeted Yield Equations

FN =6.18* T -2.48* STVN -0.61* M
FP =0.47 *T -0.52* STVP -0.07* M
FK =1.26* T -0.66* STVK -0.27* M

*T=Targeted Yield

Targeted Yield (kg/ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
62.52 (Mean Yield)	95.16	3.16	4.50
63.61 (Stationary point)	102.13	3.69	5.60
65.00	110.72	4.34	7.35
70.00	141.62	6.69	13.65

(26) Centre : Ludhiana; Crop: Wheat; Year: 2006-07

For the STCR experiment on Wheat 2006-07 at Ludhiana centre, it was observed that the fertility gradient has been created only with respect to SP for overall the strips. For FYM level wise at 0 t/ha and 10 t/ha, it was created in respect of only SP, and at 30 t/h of FYM, it was not created in respect of any of the soil nutrients.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that only the effect of Treatment is highly significant. When the ANOVA for

Treatment, Organic manure and their interaction (Treatment * OM) with covariates was carried out, same results were observed .So it is not possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels) it is observed that only the Treatment and (strips within FYM levels) effects are significant. So here it is not possible to identify the best level of FYM.

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The response to N at the middle doses of P and K showed that there is an decreasing trend for response over N_0 from N_{90} to N_{120} and then from N_{120} to N_{150}. Same is the case with P at middle doses of N and K and K at middle doses of N and P.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y= 1963.793+ 16.5432*FN - 10.2463*FP + 67.57291*FK - 0.02765*FN^2 + 0.12835*FP^2 - 0.3177*FK^2+0.07041*FNFP\ 0.05353*FNFK- 0.67362*FPFK+4.39654*SN-2.18561*SP - 0.90197*SK - 0.02365*FNSN + 0.09148*FPSP - 0.18304*FKSK$$

Substituting SN=146.72 kg/ha**;** SP=48.14 kg/ha**;** and SK=107.80 kg/ha, gives the reduced complete Second order Response Surface as:

$$Y= 2406.418+ 13.07321*FN – 5.84256*FP+ 47.8412*FK -0.02765*FN^2 +12835*FP^2 -0.31767* FK^2 +0.07041* FNFP +0.05353*FNFK -67362* FPFK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**326.96** kg/ha, Fertilizer Phosphorus =**51.79** kg/ha and Fertilizer Potash= **51.83** kg/ha and with predicted yield at stationary point as **56.23 q /ha.** Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (q/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
60.00	389.95	65.06	51.78
	389.96	64.74	52.01
	389.98	63.29	53.01
65.00	390.17	51.18	61.41
	389.99	62.67	53.44
	389.90	68.42	49.46
70.00	390.11	54.88	58.98
	389.95	65.39	51.56
	389.97	64.13	52.43

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
40.34	146.72	48.14	107.80	5

Targeted Yield Equations

FN =5.35* T - 0.79* STVN -0.51* M
FP =1.23* T - 0.62* STVP -0.19* M
FK =0.70* T - 0.11* STVK -0.04* M

T = Targeted Yield

Targeted Yield (kg/ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
40.34 (Mean Yield)	98.21	19.01	15.78
56.23 (Stationary point)	182.37	38.37	27.30
60.00	202.54	43.00	29.94
65.00	229.29	49.15	33.44
70.00	256.04	55.30	36.94

(27) Centre : New Delhi; Crop: Pearl Millet; Year: 2005-06

For the STCR experiment on Pearl Millet 2005-06 at New Delhi centre, it was observed that the fertility gradient has been created only with respect to SN and SP for overall the strips. For FYM level wise at 0 t/ha, it was created in respect of only SP, and at 5 t/h of FYM, it was created in respect of all the soil nutrients and at 10 t/ha of FYM it was only created for SN and SP.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that all the effects are highly significant. When the ANOVA for Treatment, Organic manure and their interaction (Treatment * OM) with covariates was carried out, same results were observed .So it is possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels, it is observed that only the effect of Treatment and FYM are highly significant. So here it is possible to identify the best level of FYM.
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The response to N at the middle doses of P and K showed that there is an decreasing trend for response over N_0 from N_{50} to N_{100} and then from N_{100} to N_{150}. Same is the case with P at middle doses of N and K and K at middle doses of N and P.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y = 2146.592 + 6.44485*FN + 1.6285*FP - 19.073*FK - 0.03777*FN^2 - 0.02543*FP^2 - 0.0212*FK^2 + 0.03559*FNFP - 0.04131*FNFK - 0.07569*FPFK + 7.07713*SN + 7.07713*SP - 10.6797*SK + 0.05841*FNSN - 0.34771*FPSP + 0.08886*FKSK$$

Substituting SN=211.00 kg/ha; SP=17.00 kg/ha; and SK=239.75 kg/ha, gives the reduced complete Second order Response Surface as

$$Y = 13.04565 + 0.186752*FN - 0.02492*FP + 0.02637*FK - 0.0004*FN^2 - 0.00049*FP^2 - 0.00032*FK^2 + 0.000453*FNFP - 0.00045*FNFK + 0.00081*FPFK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=357.9 kg/ha, Fertilizer Phosphorus =220.5 kg/ha and Fertilizer Potash= 23.5 kg/ha and with predicted yield at stationary point as 42.60 q /ha**.** Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
25.26 (Mean Yield)	**211**	**17**	**239.75**	**5**

Targeted Yield Equations

FN =7.88* T - 0.50* STVN -0.61* M
FP =5.55* T - 4.16* STVP -0.07* M
FK =5.03* T - 0.26* STVK -0.27* M

T=Targeted Yield

Targeted Yield (kg/ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
25.26 (Mean Yield)	90.50	69.12	63.37
42.60 (Stationary point)	227.14	165.36	150.59

(28) Centre : New Delhi; Crop: Wheat; Year: 2007-08

For the STCR experiment on Wheat 2007-08 at New Delhi centre, it was observed that the fertility gradient has been created only with respect to SP for overall the strips. For FYM level wise at 0 t/ha, 5t/ha and 10 t/ha it was created only in respect of SP,

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that all the effects are highly significant. When the ANOVA for Treatment, Organic manure and their interaction (Treatment * OM) with covariates was carried out, it was observed that only the effects of Treatment and FYM are highly significant. So it is possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels), it is observed that only the effect of Treatment and FYM are highly significant. So here it is possible to identify the best level of FYM.

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The response to N at the middle doses of P and K showed that there is an increasing trend for response over N_0 from N_{50} to N_{100} and then decreasing from N_{100} to N_{150}. In the case with P at middle doses of N and K and K at middle doses of N and P it is observed that there is a decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y= 26.32715+ 0.31323*FN - 0.0792*FP - 0.06702*FK - 0.00185*FN^2 +0.000604*FP^2 + 0.00075*FK^2 - 0.00035*FNFP - 0.0001508*FNFK + 0.000785*FPFK - 0.0456*SN + 0.00806*SP + 0.02389*SK+ 0.0009311*FNSN + 0.000292*FPSP - 0.0003056*FKSK$$

Substituting SN=**237.79** kg/ha; SP=**13.10** kg/ha; and SK=**204.90** kg/ha, gives the reduced complete Second order Response Surface as

$$Y=21.61.308+0.534631*FN-0.07043*FK-0.00185*FN^2+0.000604*FP^2+0.000751*FK^2 -0.00035*FNFP-0.00015*FNFK+0.000785*FPFK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**137.02** kg/ha, Fertilizer Phosphorus =**41.52** kg/ha and Fertilizer Potash= **86.94** kg/ha and with predicted yield at stationary point as **50.59** q /ha**.** Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (kg/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
5000	137.07	38.24	88.26
	137.09	37.86	87.78
	136.87	40.95	91.67
5500	137.03	38.82	88.99
	136.03	52.54	106.29
	134.30	76.27	136.19
6000	134.31	76.18	136.08
	132.04	52.44	106.16
	137.76	28.71	76.24

Optimal doses obtained through Targeted yield equations

Targeted Yield Equations			Target	SN	SP	SK	FYM
			44.04	237.79	13.10	204.90	5
FN =	3.95	* T -	(mean)	0.37	* STVN -	0.11	* M
FP =	1.21	* T -		2.09	* STVP -	0.09	* M
FK =	2.27	* T -		0.29	* STVK -	0.13	* M

***T=Targeted Yield**

Targeted Yield (q/ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
44.04 (Mean Yield)	85.47	25.47	39.92
50.59 (Stationary point)	111.30	33.38	54.77
50.00	109.25	32.94	54.13
55.00	128.98	39.01	65.48
60.00	148.71	45.08	76.83

(29) Centre : New Delhi; Crop: Mustard; Year: 2007-08

For the STCR experiment on Mustard 2007-08 at New Delhi centre, it was observed that the fertility gradient has been created only with respect to SN for overall the strips. For FYM level wise at 0 t/ha it was created only in the case of SP and SK, at 5t/ha, none of the effects were significant and therefore it is inferred that the fertility gradient was not created ,at 10 t/ha it was created only in respect of SN and SK,

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that all the effects are highly significant incase of Treatment and FYM. When the ANOVA for Treatment, Organic manure and their interaction (Treatment * OM) with covariates was carried out, it was observed that all the effects of Treatment , FYM and interaction (Treatment * OM)are highly significant. So it is possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels), it is observed that only the effect of Treatment and FYM are highly significant. So here it is possible to identify the best level of FYM.

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The response to N at the middle doses of P and K showed that there is an decreasing trend for response over N_0 from N_{100} to N_{150} and then increasing from N_{150} to N_{200}. In the case with P at middle doses of N and K and K at middle doses of N and P it is observed that there is a decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\mathbf{Y= 759.9208+ 1.26751*FN +6.01189*FP + 6.30484*FK - 0.01506*FN^2 - 0.01691*FP^2 - 0.0113*FK^2 - 0.01738*FNFP + 0.03693*FNFK - 0.04188*FPFK + 1.18467*SN - 1.64877*SP + 3.04215*SK+ 0.0119*FNSN + 0.08708*FPSP - 0.02344*FKSK}$$

Substituting SN=**206.38** kg/ha; SP=**21.27** kg/ha; and SK=**262.54** kg/ha, gives the reduced complete Second order Response Surface as

$$\mathbf{Y=1704.129+ 3.782337*FN + 7.44035*FP + 0.750263*FK - 0.01506*FN^2- 0.01691*FP^2- 0.01125*FK^2 - 0.01738*FNFP + 0.03693*FNFK - 0.04188*FPFK}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**135.82** kg/ha, Fertilizer Phosphorus =**107.77** kg/ha and Fertilizer Potash= **55.39** kg/ha and with predicted yield at stationary point as **24.02** q /ha**.** Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (kg/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
2600	138.45	87.09	61.67
	139.08	86.49	62.48
	141.08	84.61	65.06
3000	160.57	66.27	90.16
	165.27	61.85	96.20
	166.73	60.47	98.09

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
22.19	206.38	21.28	262.54	5

Targeted Yield Equations

FN =9.26* T -0.27* STVN -1.25* M
FP =5.78* T -1.27* STVP -0.15* M
FK =12.52* T -0.7* STVK -0.12* M

* T=Targeted Yield

Targeted Yield (q/ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
22.19 (Mean Yield)	143.51	100.48	93.44
24.02 (Stationary point)	160.45	111.06	116.35

(30) Centre : New Delhi; Crop: Arhar; Year: 2007-08

For the STCR experiment on Arhar 2007-08 at New Delhi centre, it was observed that the fertility gradient has not been created only with respect to SN,SP and SK for overall the strips. For FYM level wise at 0 t/ha and 10 t/ha, it was not created At 5t/ha, only the effect of SK is significant and therefore it is inferred that the fertility gradient was created only for SK.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that only the effects of Treatment and FYM are highly significant. So it is possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels), it is observed that only the effect of Treatment and FYM are highly significant. So here it is possible to identify the best level of FYM.
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The response to N at the middle doses of P and K showed that there is a decreasing trend for response over N_0 from N_{20} to N_{40} and then from N_{40} to N_{60}. In the case with P at middle doses of N and K and K at middle doses of N and P it is observed that there is a decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\mathbf{Y= 1046.057+ 20.6614*FN +4.19309*FP + 6.4985*FK - 0.23802*FN^2 - 0.01507*FP^2 - 0.0158*FK^2 + 0.0491*FNFP - 0.00605*FNFK + 0.02159*FPFK - 0.3567*SN + 6.47479*SP + 1.5913*SK+ 0.00223*FNSN - 0.07688*FPSP - 0.01196*FKSK}$$

Substituting SN=222.15kg/ha; SP=38.71kg/ha; and SK=285.14 kg/ha, gives the reduced complete Second order Response Surface as

$$\mathbf{Y=1671.223+ 20.16597*FN + 1.216873*FP + 3.088239*FK - 0.23802*FN^2 - - 0.01507*FP^2-0.01583*FK^2 + 0.0491*FNFP - 0.00605*FNFK + 0.02159*FPFK}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**63.33** kg/ha, Fertilizer Phosphorus =**36.66** kg/ha and Fertilizer Potash= **71.45**kg/ha and with predicted yield at stationary point as **24.85**q /ha**.** Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
22.48	222.15	38.71	285.14	5

Targeted Yield Equations

FN =0.05* T -0.38* STVN -0.13* M
FP =0.03* T -1.30* STVP -0.33* M
FK =0.06* T -0.36* STVK -0.03* M

* T=Targeted Yield

Targeted Yield (q/ha)	**Optimum fertilizer doses**		
	FN (kg/ha)	**FP (kg/ha)**	**FK (kg/ha)**
22.48 (Mean Yield)	**32.43**	**14.36**	**34.18**
24.85 (Stationary point)	**39.21**	**22.59**	**46.34**

(31) Centre : Pantnagar; Crop: Garlic; Year: 2005-06

For the STCR experiment on Garlic 2005-06 at Pantnagar centre, it was observed that the fertility gradient has been created with respect to SN, SP and SK for overall the strips. For FYM level wise at 0 t/ha and 20 t/ha, it was created for all the soil nutrients. At 10t/ha, only the effect of SN and SK is significant.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that none of the effects significant. So it is not possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels), it is observed that only the effect of strips is highly significant. So here it is not possible to identify the best level of FYM.

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The response to N at the middle doses of P and K showed that there is a decreasing trend for response over N_0 from N_{75} to N_{100} and then from N_{100} to N_{125}. In the case with P at middle doses of N and K there was negative response observed. For K at middle doses of N and P it is observed that there is a decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$\mathbf{Y} = -29.22577 + 0.51356*FN + 0.56871*FP - 1.02686*FK - 0.00043*FN^2 + 0.00024*FP^2 - 0.0087*FK^2 - 0.00693*FNFP + 0.00572*FNFK - 0.0016*FPFK + 0.13217*SN - 0.27309*SP + 0.64535*SK - 0.00174*FNSN + 0.00239*FPSP + 0.0067*FKSK$$

Substituting SN=186.6 kg/ha; SP=68.7 kg/ha; and SK=176.2 kg/ha, gives the reduced complete Second order Response Surface as

$$Y= 90.41991+ 0.188883*FN + 0.732896*FP+ 0.154024*FK -0.00043*FN^2 -0.00024*FP^2 -0.00869* FK^2 -0.00693* FNFP +0.00572*FNFK -0.0016* FPFK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**94.76** kg/ha, Fertilizer Phosphorus =**43.87** kg/ha and Fertilizer Potash= **35.86** kg/ha and with predicted yield at stationary point as **118.52** q /ha**.** Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (q/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
100	93.93	39.78	35.17
	96.91	37.05	36.07
	97.86	36.18	36.35
110	99.63	34.56	36.88
	108.71	26.26	39.59
	109.74	25.31	39.90
118	101.58	32.78	37.46
	110.11	34.12	37.02
	112.13	23.12	40.62
120	117.80	17.94	42.31
	122.69	13.47	43.77
	126.67	9.82	44.96

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
110.00(mean)	186.60	68.70	176.24	5

Targeted Yield Equations

FN =0.94 * T -0.35* STVN -0.27* M
FP =0.28 * T -1.34* STVP -0.23* M
FK =0.43 * T -0.12* STVK -0.05* M

Targeted Yield (q/ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
110.0 q/ha (Mean Yield)	77.18	12.98	25.72
118.0 q/ha (Stationary point)	99.67	18.94	34.53
120	105.71	20.38	36.91

(32) Centre : Pantnagar; Crop: Mustard; Year: 2006-07

For the STCR experiment on Mustard 2006-07 at Pantnagar centre, it was observed that the fertility gradient has been created only with respect to SP and SK for overall the strips. For FYM level wise at 0 t/ha , 10t/ha and 20 t/ha, it was not created for all the soil nutrients.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that only the effect of FYM is significant. So it is possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels), it is observed that only the effect of FYM is highly significant. So here it is possible to identify the best level of FYM.

The response to N at the middle doses of P and K showed that it is observed that there is no change in response over N_0 from N_{75} to N_{100} and then from N_{100} to N_{125}. In the case with P at middle doses of N and K and for K at middle doses of N and P it is observed that there is a decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y= 15.01326 - 0.03157*FN+ 0.09764*FP - 0.09552*FK + 0.000167*FN^2 + 0.000235*FP2 + 0.00031*FK^2 - 0.00103*FNFP + 0.00051643*FNFK -0.00129*FPFK- 0.0224*SN + 0.10236*SP -0.00052*SK+ 0.0003038*FNSN - 0.00183*FPSP - 8.458E-05*FKSK$$

Substituting SN=**168.84**kg/ha; SP=**36.08**kg/ha; and SK=**233.7**kg/ha, gives the reduced complete Second order Response Surface as

$$\mathbf{Y= 14.80044+0.019718*FN + 0.031613*FP -0.11529*FK+ 0.000167*FN^2 +0.000235*FP^2 + 0.000308* FK^2 -0.00103* FNFP +0.000516*FNFK + 0.00129* FPFK}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**74.79** kg/ha, Fertilizer Phosphorus =**51.62** kg/ha and Fertilizer Potash= **16.36** kg/ha and with predicted yield at stationary point as **24.00** q/ha**.** Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (q/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
15	58.51	53.69	28.28
	62.11	43.26	20.17
	58.74	53.02	27.76
20	63.31	39.77	17.46
	65.30	34.00	12.98
	64.42	36.55	14.96
25	61.80	44.15	20.87
	61.10	46.19	22.45
	50.80	76.00	45.62

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
20.00	168.84	36.08	233.70	5

Targeted Yield Equations

FN =16.78* T -1.16* STVN -0.96* M
FP =4.20* T -1.82* STVP -0.53* M
FK =8.51* T -0.52* STVK -0.28* M
T=Targeted Yield

Targeted Yield (q/ha)	**Optimum fertilizer doses**		
	FN (kg/ha)	**FP (kg/ha)**	**FK (kg/ha)**
20.00 q/ha	**135.26**	**15.85**	**47.05**
25.00 q/ha (Stationary point)	**202.07**	**32.48**	**81.32**

(33) Centre : Pantnagar; Crop: Onion; Year: 2005-06

For the STCR experiment on Onion 2005-06 at Pantnagar centre, it was observed that the fertility gradient has been created with respect to SN, SP and SK for overall the strips. For FYM level wise at 0 t/ha , 10t/ha and 20 t/ha, it was also created for all the soil nutrients.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that non of the effect is significant. So it is not possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels), it is observed that only the effect of Treatment and Strips(within FYM levels) were highly significant. So here it is not possible to identify the best level of FYM.

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The response to N at the middle doses of P and K showed that it is observed that there is not appreciable change in response over N_0 from N_{75} to N_{100} and then from N_{100} to N_{125}. In the case with P at middle doses of N and K and for K at middle doses of N and P it is observed that there is a increasing trend as we move from lower to middle dose and decreases from middle to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y= 202.914 + 2.96564*FN - 3.68328*FP - 0.34687*FK - 0.00793*FN^2 -0.01922*FP2 - 0.0028*FK^2 + 0.02183*FNFP - 0.02046*FNFK + 0.01908*FPFK + 0.67826*SN - 1.40332*SP + 0.22692*SK- 0.00732*FNSN +0.03741*FPSP + 0.01089*FKSK$$

Substituting SN=187 kg/ha; SP=69 kg/ha; and SK=176 kg/ha, gives the reduced complete Second order Response Surface as

$$Y=272.1792+1.60412FN-1.10199FP+1.5677FK-3.33793\,FN^2-0.01922FP^2-0.00277FK^2 +0.2183FNFP - 0.02046FNFK+ 0.01908FPEK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**128.85** kg/ha, Fertilizer Phosphorus =**71.95**kg/ha and Fertilizer Potash= **55.29**kg/ha and with predicted yield at stationary point as **379.27** q /ha**.** Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (Q/ha)	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
360	97.171	19.039	36.163
	105.192	23.281	41.638
	80.818	17.0758	24.538
351.73 (Observed Mean)	92.883	9.585	33.732
	95.429	10.868	35.473
	90.764	8.603	32.276

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
351.73 (mean)	187	69	176	5

Targeted Yield Equations

FN =1.01* T -1.46* STVN - 0.96* M
FP =0.48* T -1.81* STVP - 0.53* M
FK =0.41* T -0.58* STVK - 0.28* M

T=Targeted Yield

Targeted Yield (q/ha)	**Optimum fertilizer doses**		
	FN (kg/ha)	**FP (kg/ha)**	**FK (kg/ha)**
360 q/ha	**85.78**	**45.26**	**44.12**
351.73 q/ha (mean)	**77.43**	**41.29**	**40.73**
379.2757 (Stationary point)	**105.25**	**54.51**	**52.02**

(34) Centre : Pantnagar; Crop: Potato; Year: 2006-07

For the STCR experiment on Potato 2006-07 at Pantnagar centre, it was observed that the fertility gradient has been created with respect to SN, SP and SK for overall the strips. and for FYM level wise at 0 t/ha , 10t/ha and 20 t/ha.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that none of the effect is significant. So it is not possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels), it is observed that only the effect of Treatment is highly significant. So here it is not possible to identify the best level of FYM.

The response to N at the middle doses of P and K showed that it is observed that there is not appreciable change in response over N_0 from N_{100} to N_{150} and then from N_{150} to N_{200}. In the case with P at middle doses of N and K and for K at middle doses of N and P it is observed that there is a decreasing trend as we move from lower to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y= 31.00178 - 0.44937*FN + 0.51702*FP + 0.69321*FK + 0.000331*FN^2 - 0.00059*FP^2 - 0.0028*FK^2 + 0.00187*FNFP + 0.00039003*FNFK -0.00174*FPFK - 0.4566*SN + 0.52791*SP + 0.41595*SK + 0.00377*FNSN - 0.007*FPSP - 0.0003803*FKSK$$

Substituting SN=115.7 kg/ha; SP=66 kg/ha; and SK=172.5 kg/ha, gives the reduced complete Second order Response Surface as

$$\mathbf{Y= 84.77001- 0.01318*FN +0.05502*FP + 0.62761*FK + 0.000331*FN^2 - 0.00059*FP^2 - 0.00279*FK^2 + 0.00187*FNFP+ 0.00039\ FNFK - 0.00174*FPFK}$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**143.29** kg/ha, Fertilizer Phosphorus =**71.83** kg/ha and Fertilizer Potash= **104.20** kg/ha and with predicted yield at stationary point as**137.71** q /ha**.** Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
127.65	115.68	65.98	172.50	5

Targeted Yield Equations

FN =2.11* T -1.30* STVN -0.48* M
FP =0.99* T -1.48* STVP -0.15* M
FK =1.51* T -0.76* STVK -0.12* M

T=Targeted Yield

Targeted Yield (q/ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
127.65 q/ha (observed Mean)	116.66	28.09	61.27
137.71 q/ha (Stationary point)	137.78	37.93	76.24

(35) Centre : Pantnagar; Crop: Wheat; Year: 2005-06

For the STCR experiment on Wheat 2005-06 at Pantnagar centre, it was observed that the fertility gradient has been created with respect to SN, SP and SK for overall the strips. and for FYM level wise at 0 t/ha , 5 t/ha and10t/ha.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that none of the effect is significant. So it is not possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels), it is observed that only the effect of Treatment and Strips (within FYM levels) are highly significant. So here it is not possible to identify the best level of FYM.

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The response to N at the middle doses of P and K showed that it is observed that there is not appreciable change in response over N_0 from N_{100} to N_{150} and then from N_{150} to N_{200}. Same is the case with P at middle doses of N and K and for K at middle doses of N and P.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y= 0.26728 + 0.11273*FN + 0.2222*FP + 0.03941*FK -7.5E\text{-}06*FN^2 +0.00039*FP2 - 0.0006*FK^2 - 0.00108*FNFP + 0.00014329*FNFK - 0.000183*FPFK - 0.0034*SN + 0.10912*SP + 0.08128*SK+ 3.713E\text{-}05*FNSN - 0.000357*FPSP + 0.00005064*FKSK$$

Substituting SN=189.4kg/ha; SP=65.2 kg/ha; and SK=176.2kg/ha, gives the reduced complete Second order Response Surface as

$$Y= 21.06327+ 0.119762*FN + 0.198937*FP+ 0.048333*FK-0.00000747*FN^2 +0.00039*FP^2 -0.00058* FK^2 -0.00108* FNFP +0.000143*FNFK -0.00018* FPFK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**244.72** kg/ha, Fertilizer Phosphorus =**113.28** kg/ha and Fertilizer Potash= **49.26** kg/ha and with predicted yield at stationary point as **48.66** q /ha**.** Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Optimal doses obtained through Targeted yield equations

Target	SN	SP	SK	FYM
41.34	189.40	65.24	176.23	5

Targeted Yield Equations

FN =6.79* T -0.78* STVN -0.52 * M
FP =1.03* T -0.34* STVP -0.14 * M
FK =1.48* T -0.19* STVK -0.06 * M
* T=Targeted Yield

Targeted Yield (q/ha)	**Optimum fertilizer doses**		
	FN (kg/ha)	**FP (kg/ha)**	**FK (kg/ha)**
41.34 q/ha (observed Mean)	**129.42**	**19.53**	**28.32**
48.66 q/ha (Stationary point)	**180.07**	**27.24**	**38.23**

(36) Centre : Pusa; Crop: Rice; Year: 2005-06

For the STCR experiment on Rice 2005-06 at Pusa centre, it was observed that the fertility gradient has been created with respect to SN, SP and SK for overall the strips. and for FYM level wise at 0 t/ha , 5 t/ha and10t/ha.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that only the effects of Treatment and FYM are highly significant. So it is possible to identify the best level of FYM.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels), it is observed that the effect of Treatment, FYM and Strips (within FYM levels) are highly significant. So here it is possible to identify the best level of FYM.

.

The response to N at the middle doses of P and K showed that it is observed that there is there is gradual increase in response over N_0 from N_{50} to N_{100} and then from N_{100} to N_{150}. Same is the case with P at middle doses of N and K. For K at middle doses of N and P it is observed that there is a decrease in response over K_0 from K_{20} to K_{40} and then increase from K_{40} to K_{60} .

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be homogeneous and therefore, combined regression over all the levels of FYM was obtained to arrive at appropriate response function.

$$Y= 1395.644+ 7.76755*FN + 7.36824*FP + 15.21554*FK - 0.00202*FN^2 - 0.07267*FP2 - 0.1874*FK^2 + 0.00201*FNFP - 0.00862*FNFK + 0.14471*FPFK - 1.3173*SN + 12.0748*SP + 6.02142*SK+ 0.01292*FNSN - 0.08863*FPSP - 0.0566*FKSK$$

Substituting SN=**178.43** kg/ha; SP=**15.92**kg/ha; and SK=**147.90** kg/ha, gives the reduced complete Second order Response Surface as

$$Y=3015.237 + 3.934033*FN -24.5262*FP +29.14809*FK+0.05108*FN^2 +0.16008*FP^2 -0.28002* FK^2 * +0.03283FNFP -0.12606*FNFK +-0.22556* FPFK$$

Canonical analysis of Response Surface gave the stationary point as Saddle Point with optimum doses of Fertilizer Nitrogen=**129.12** kg/ha, Fertilizer Phosphorus =**95.54** kg/ha and Fertilizer Potash= **61.46** kg/ha and with predicted yield at stationary point as **42.01** q /ha**.** Nature of Stationary Point: Saddle Point (Neither maxima nor Minima)

Exploration of Response Surface in the vicinity of Stationary point

Desired Yield (kg/ha)	**FN (kg/ha)**	**FP (kg/ha)**	**FK (kg/ha)**
3700	**82.43**	**45.59**	**30.00**
4000	**119.73**	**47.96**	**30.18**
4500	**149.65**	**49.33**	**30.38**

Optimal doses obtained through Targeted yield equations

T	SN	SP	SK	FYM
36.77	178.43	15.92	147.90	5

Targeted Yield Equations

FN =4.54* T -0.46* STVN -0.28* M
FP =0.78* T -0.69* STVP -0.04* M
FK =1.66* T -0.26* STVK -0.11* M
* T=Targeted Yield

Targeted Yield (q/ha)	Optimum fertilizer doses		
	FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
36.77 q/ha (observed Mean)	83.37	17.64	21.71
42.01 q/ha (Stationary point)	107.25	21.58	30.73

(37) Centre : Rahuri; Crop: Garlic; Year: 2005-06

For the STCR experiment on Garlic 2005-06 at Rahuri centre, it was observed that the fertility gradient has been created with respect to SN, SP and SK for overall the strips. and for FYM level wise at 0 t/ha , 10 t/ha and 20t/ha.

To identify the best level of Organic manure, analysis of variance was carried out for the Treatment, Organic manure and their interaction (Treatment * OM) without covariates. It was observed that only the effects of Treatment and FYM are highly significant. So it is possible to identify the best level of FYM. When ANOVA was carried out including the covariates SN,SP and SK in the analysis, it was observed that besides Treatment and FYM, the effect of Interaction of Treatment* FYM is also highly significant.

When ANOVA for Treatment, FYM and Strips was carried out with and without interactions and covariates (taking the strips within FYM levels), it is observed that the effect of Treatment, FYM and Strips (within FYM levels) are highly significant. So here it is possible to identify the best level of FYM.

.

The response to N at the middle doses of P and K showed that it is observed that there is there is gradual decrease in response over N_0 from N_{50} to N_{100} and then from N_{100} to N_{200}. In the case with P at middle doses of N and K and for K at middle doses of N and P it is observed that there is an increase in response from lower to middle dose and then decrease from middle to higher dose.

For obtaining the optimum dose of FN, FP and FK, separate multiple regressions were fitted at the three levels of FYM and found to be heterogeneous and therefore, combined regression over all the levels of FYM could not be given.

Homogeneity of Regression Equations

FYM LEVELS	ERROR SUM OF SQUARE	DF
FYM0	159	8
FYM 5	256	8
FYM 10	1317	8
FULL	1732	24
COMBINED (REDUCED)	15244	56

$$F = \frac{(SSE_{REDUCED} - SSE_{FUll})/24}{SSE_{REDUCED}/56} = \frac{(15244-1732)/24}{15244/56} = \frac{569}{272.2142} = 2.0682$$

Prob> F=0.01315**(Highly Significant). This shows heterogeneity among the regression equations and therefore the above three regression equations could not be combined.

Optimal doses obtained through Targeted yield equations

Targeted yield equations	Soil Test Values (kg/ha)	Targeted Yield (Q/ha)	Optimum Fertilizer Doses		
			FN (kg/ha)	FP (kg/ha)	FK (kg/ha)
FN = 2.01 * T - 0.47 SN	175	120	158	81	70
FP = 1.09 * T - 2.49 SP	20	100	118	59	53
FK = 0.85 * T - 0.07 SK	450	90	99	48	45

CHAPTER-V

5.0 Analysis of data of experiments conducted in the past

The past data of experiments conducted under STCR (prior to 2005-06), were analyzed with the methodology of multiple regression. An attempt was made to see whether it is possible to pool the fertilizer adjustment equations over the years being derived by the cooperating centres. This requires data of the same crop over a number of years. Unfortunately, data available at the centres are of maximum 2 to 3 years. So it was not possible to pool such data. Only we could find a data set from Hisar which was from 1983 to 1989 which was subjected to pooled analysis.

Individual and over the years multiple regression

Variable	**Parameter Estimate**	**Parameter Estimate**	**Parameter Estimate**	**Parameter Estimate**	**Parameter Estimate**	**Parameter Estimate**	**Parameter Estimate**
	1983	**1984**	**1985**	**1986**	**1988**	**1989**	**Over all years**
Intercept	**979.81207**	**676.14674**	**979.65767**	**612.17214**	**714.76465**	**592.63609**	**534.02552**
FN	**11.21763**	**8.24112**	**11.54191**	**9.42606**	**11.07700**	**11.00623**	**9.75426**
FP	**6.86035**	**9.37363**	**6.73240**	**6.42193**	**8.43196**	**9.46005**	**8.37852**
FK	**0.43394**	**3.84085**	**2.54225**	**-1.40316**	**-0.33228**	**-2.19769**	**-0.89129**
FN^2	**-0.04680**	**-0.04640**	**-0.04674**	**-0.04361**	**-0.04842**	**-0.03932**	**-0.04232**
FP^2	**-0.14121**	**-0.16039**	**-0.17328**	**-0.14092**	**-0.19762**	**-0.13797**	**-0.15223**
FK^2	**0.05407**	**-0.06218**	**-0.01808**	**0.03185**	**-0.01860**	**-0.02969**	**0.01520**
SN	**0.26957**	**0.69329**	**0.35387**	**1.49526**	**0.07180**	**0.92702**	**3.60964**
SP	**3.06302**	**6.10934**	**10.51495**	**4.66739**	**4.28073**	**1.91475**	**-0.71556**
SK	**0.70899**	**0.81178**	**0.27636**	**0.63808**	**1.02178**	**0.99227**	**0.65775**
FN*FP	**0.06708**	**0.06041**	**0.07611**	**0.07011**	**0.07983**	**0.05096**	**0.06028**
FN*FK	**-0.01124**	**0.01568**	**-0.01980**	**-0.00434**	**-0.00385**	**0.01360**	**-0.00615**
FP*FK	**-0.01045**	**0.00943**	**0.05029**	**-0.00430**	**0.03827**	**0.01248**	**0.01873**
FN*SN	**0.01071**	**0.02667**	**0.00789**	**0.01586**	**0.01004**	**-0.01351**	**0.01295**
FP*SP	**-0.02446**	**-0.10003**	**-0.02049**	**-0.03494**	**-0.01552**	**-0.01284**	**-0.03872**
FK*SK	**-0.00142**	**-0.00733**	**-0.00518**	**0.00230**	**-0.00054**	**0.00469**	**0.00115**
No. Of Obvs.	**120**	**120**	**120**	**120**	**120**	**120**	**720**
R^2	**0.9850**	**0.9863**	**0.9885**	**0.9918**	**0.9885**	**0.9882**	**0.9302**
Root MSE	**69.88139**	**62.30820**	**59.59621**	**45.56138**	**58.19671**	**48.23350**	**136.15641**
Coeff Var	**3.36806**	**3.45849**	**3.07506**	**2.70300**	**3.08816**	**2.86248**	**7.38002**
Error D.F.	**104**	**104**	**104**	**104**	**104**	**104**	**704**

Homogeneity of the regression equations were tested and found to be heterogeneous. The analysis is given below.

Homogeneity of Regression Equations:

YEARS	ERROR SUM OF SQUARES	DF
1983	507874	104
1984	403760	104
1985	369378	104
1986	215887	104
1988	352233	104
1989	241953	104
FULL	2091085	624
COMBINED (REDUCED)	13051152	704

$$F = \frac{(SSE_{REDUCED} - SSE_{FULL})/80}{SSE_{REDUCED}/704} = \frac{(13051152 - 2091085)/80}{13051152/704} = \frac{137000.84}{18538.57} = 7.39004$$

PROB> F = 3.26588E-53 (Highly significant)

The results therefore do not show the possibility of a combined analysis.

APPENDIX-I

Table 1 Experimental Sites, Agro -Eco region and Soil types of different cooperating centres of the STCR project

S.No.	Cooperating Centre	Date of Start	Experimental Site	Agro- Eco Region	Agro- Eco Subregion	Soil Type
1.	UAS, Bangalore	1.10.1970	Bangalore	Hot semi- arid, 8	Hot Moist semi-Arid, 8.2	Medium to deep red loam
2.	CRIJAF, Barrackpore	27.02.1971	Barrackpore	Hot sub-humid to humid(inclusion of per humid) ,15	Hot Moist sub Humid, 15.1	Deep loamy to clayey alluvial derived
3.	OUAT, Bhubaneswar	1.9.1996	Bhubaneswar	Hot sub Humid,12	Hot Moist sub Humid, 12.2	Medium to deep loamy red & red lateritic soil
4.	RAU, Bikaner	1.9.1996	Bikaner	Hot arid, 2	Hot hyperarid, 2.1	Shallow & deep sandy desert soils
5.	TNAU, Coimbatore	1.4.1967	Coimbatore	Hot semi-Arid, 8	Hot dry semi-Arid, 8.1	Medium deep to deep, loamy to clayey mixed red & black
6.	HAU, Hisar	1.4.1967	Hisar	Hot arid, 2	Hot typic arid, 2.3	Deep loamy desert soils
7.	APAU, Hyderabad	1.4.1967	Hyderabad	Hot semi-Arid, 7	Hot Moist semi-Arid, 7.2	Deep loamy and clayey mixed red &black
8.	JNKVV, Jabalpur	1.4.1967	Jabalpur	Hot sub Humid , 10	Hot dry sub Humid, 10.1	Medium black
9.	BCKV, Kalyani	21.11.1997	Kalyani	Hot semi-Arid , 15	Hot Moist sub Humid, 15.1	Deep loamy to clayey alluvial derived
10.	PAU, Ludhiana	1.4.1967	Ludhiana	Hot semi-Arid , 4	Hot Moist semi-Arid, 4.1	Deep loamy alluvial

Table 1 (contd.) Experimental Sites, Agro -Eco region and Soil types of different Cooperating centres of the project

S.No.	Cooperating Centre	Date of Start	Experimental Site	Agro- Eco Region	Agro- Eco Subregion	Soil Type
11.	IARI, New Delhi	1.5.1967	New Delhi	Hot semi-Arid, 4	Hot semi-Arid, 4.1	Deep loamy alluvial derived
12.	HPKV, Palampur	1.7.1970	Palampur	Warm sub-humid to humid with inclusion of perhumid , 14	Warm humid to perhumid Transitional,14.3	Podzolic
13.	GBPUA&T, Pantnagar	1.4.1970	Pantnagar	Warm sub-humid to humid with inclusion of perhumid , 14	Warm humid/per humid, 14.5	Medium to deep loamy tarai
14.	RAU, Pusa	1.12.1967	Pusa	Hot sub Humid , 13	Hot dry to moist Sub humid, 13.1	Deep loamy alluvial derived
15.	MPKVV, Rahuri	28.10.1970	Rahuri	Hot semi-Arid , 6	Hot dry semi-arid, 6.1	Shallow & medium loamy black
16	IGKVV, Raipur	1.4.1981	Raipur	Hot/Moist/dry sub humid transitional , 11	------	Deep loamy to clayey red & yellow
17.	KAU, Vellanikkara	1.11.1996	Vellanikkara	Moist humid-per humid , 19	Hot moist sub humid to humid transitional, 19.2	Deep loamy to clayey red & lateritic soils

APPENDIX -II

Details of data received from different Cooperating centres

S.N.	Centre	Year	Crop	Season	No. of treats/ strip	Remarks
1	Hyderabad	2005-06	Mustard	Rabi	24	four strips &
			Cabbage	Rabi	24	Without
			Sesamum	Rabi	16	Organic
			Chickpea	Rabi	21	Manure
			Ragi	Rabi	21	
				Kharif	21	
	Jagtial		Turmeric-	Kharif	21	
	Utukur		Turmeric-	Kharif	21	
			Groundnut	Rabi	21	
2	Pantnagar	2005-06	Onion	Rabi	24	
		2005-06	Garlic			
		2005-06	wheat			
		2006-07	Potato			
		2006-07	Mustard			
3	Hisar	2005-06	Wheat	Rabi	24	
		2006-07		Rabi	24	
		2005-06	Barley	Rabi	24	
		2006-07				
		2006-07	Pearl Millet	Kharif	24	
4	Bikaner	2005-06	Guar	Kharif	24	
			Isabgol	-------	24	
			Cumin	-------	24	
5	Raipur	2005-06	Brinjal	Rabi	36	
		2007-08	Sugarcane		24	
6	New Delhi	2005-06	Pearl millet	Kharif	24	
		2007-08				
		2005-06	Wheat	Rabi		
		2007-08				
		2006-07	Mustard	Rabi		
		2007	Pigeon Pea	Kharif		
7	Barrackpore	2005,	Jute	Kharif	21	
		2006,	Rice	Kharif	21	
		2007,	Lentil	Rabi	21	
		2008,				

8	Rahuri	2005-06	Garlic	Rabi	24	
9	Bangalore	2005-06	Onion	Rabi	24	
10	Bhubaneswar	2005-06 2006-07 2006-07 2006-07 2006-07	Seasamum Ladyfinger Pumpkin Brinjal Potato	Rabi Rabi Rabi	24	four strips & Without Organic Manure
11	Palampur	2005-06	Turmeric	Rabi	24	
12	Kalyani	2005-06	Cabbage	Rabi	21	
13	Pusa	2005-06 2005-06 2005-06	Rice Maize Potato	Kharif Rabi Rabi	24 24 24	
14	Jabalpur	2006-07	Onion	Rabi	24	
15	Kerala	2005 2006 2005-06 2006	Bhindi Bhindi Snake Gourd Snake Gourd	Kharif Rabi Rabi Kharif	24 24 24 24	
16	Ludhiana	2006-07 2006-07	Rice Wheat	Kharif Rabi	24 24	
17	Coimbatore	Nil	Nil	Nil	Nil	

APPENDIX- III

SAS CODE FOR GENERATING OPTIMAL VALUES IN THE VICINITY OF THE STATIONARY PONT-I

```
/* SAS Code for sn sp sk fn fp fk fn*fn fp*fp fk*fk fn*fp fn*fk fp*fk fn*sn fp*sp fk*sk */
data lahiri1;
input  sno rep trt fn fp fk fym sn sp sk yld;
/*Generation of the square and cross product terms */
fn2=fn*fn;
fp2=fp*fp;
fk2=fk*fk;
fnp =fn*fp;
fnk=fn*fk;
fpk=fp*fk;
fnsn=fn*sn;
fpsp=fp*sp;
fksk=fk*sk;
/* enter the data to be analyzed */
cards;
----
---
---
;
proc print;
run;
/* Invoke PROC IML and create the X and Y matrices */
/* Use variables sn sp sk fn fp fk fn*fn fp*fp fk*fk fn*fp fn*fk fp*fk fn*sn fp*sp fk*sk */;
proc iml;
use lahiri1 ;
read all var{'sno', 'sn', 'sp','sk', 'fn', 'fp', 'fk', 'fn2', 'fp2', 'fk2', 'fnp', 'fnk', 'fpk', 'fnsn', 'fpsp',
'fksk'} into X;
read all var{'yld'} into Y;
/* Define the number of observations (N) as number of rows of X */;
N=nrow(X);
/* Define the Number of variables (p) as the number of columns of X */
p=ncol(X);
/* Compute C, the inverse of X'X */
C=inv(X`*X);
/* Obtain the vector of estimated coefficients as BHAT */
BHAT = C*X`*Y;
/* Comput Estimated response, YEST */
YEST = X*BHAT;
/* Obtain the residuals, e , error sum of squares, SSE and error mean square, MSE */
e=Y-Yest;
SSE=e`*e;
DFE=N-p;
MSE=SSE/DFE;
/*  Compute the dispersion matrix of the estimates, DISPMAT */
DISPMAT=MSE@C;
```

```
/* Compute Regression Sum of Squares, SSR, Mean Squares due to regression, MSR */
U=j(n,1,1);
SSR=bhat`*X`*Y-Y`*U*U`*Y/N;
DFR=p-1;
MSR=SSR/DFR;
/*  Compute total sum of squares, SST*/

SST=Y`*Y-Y`*U*U`*Y/N;
TDF=N-1;
/*  Compute corresponding F-ratio,   and standard error of the estimated response, SE*/
F=MSR/MSE;
RSQ=ssr/sst;
RSQA=1-(TDF*SSE)/(DFE*SST);
SE=SQRT(MSE);
Print bhat , dispmat, rsq, rsqa, se, dfr, ssr, msr, f, dfe, sse, mse, tdf,sst;
/*give the given values of sn sp sk*/;
gsn=335;
gsp=23.4;
gsk=336;
/*obtain new BHATR*/;
bhatr1=bhat[1,1]+bhat[2,1]*gsn+bhat[3,1]*gsp+bhat[4,1]*gsk;
bhatr2=bhat[5,1]+bhat[14,1]*gsn;
bhatr3=bhat[6,1]+bhat[15,1]*gsp;
bhatr4=bhat[7,1]+bhat[16,1]*gsk;
bhatr5=bhat[8,1];
bhatr6=bhat[9,1];
bhatr7=bhat[10,1];
bhatr8=bhat[11,1];
bhatr9=bhat[12,1];
bhatr10=bhat[13,1];
bhatr=bhatr1//bhatr2//bhatr3//bhatr4//bhatr5//bhatr6//bhatr7//bhatr8//bhatr9//bhatr10;
/* Obtain the vector of estimated coefficients of linear terms, b1r */
b1=bhatr[2,1]//bhatr[3,1]//bhatr[4,1];
b2=bhatr[5,1]//0.5*bhatr[8,1]//0.5*bhatr[9,1];
b3=0.5*bhatr[8,1]//bhatr[6,1]//0.5*bhatr[10,1];
b4=0.5*bhatr[9,1]//0.5*bhatr[10,1]//bhatr[7,1];
/* Obtain the matrix coefficients corresponding to squares and cross product terms, b */
B=b2||b3||b4;
/*  Compute B-1, binv */
Binv=inv(B);
/* Obtain eigenvalues and eigenvectors of B beig, eigvec */
beig=eigval(B);
beigvec=eigvec(B);
/* Compute the stationary point, B-1b/2*/
xest=(-0.5)@(Binv*b1);
/* Compute the estimated response at the stationary point */
Yxest=bhatr[1,1]+(xest`*b1)+ xest`*B*xest;
/* Print the Various Statistic obtained */
print B, beig, beigvec, xest, yxest;
run;
```

APPENDIX- IV

SAS CODE FOR GENERATING OPTIMAL VALUES IN THE VICINITY OF THE STATIONARY PONT-II

```
PROC IML;
W=J(3,1,0);
Ydes=6000;
W2=0;
W3=0;
Dif=Ydes-5664.5034 ;
Ax1=Sqrt(dif/0.0819615);
u= uniform(0);
W1= ax1*(2*u-1); print w1;
w[1,] = w1;
w[2,] = 0;
w[3,] = 0;

m = {-0.07672     0.0300211     0.9966006,
     0.9970513    0.0006604     0.0767347,
     0.0016455    0.999549     -0.029983};

xest = {145.26043, 30.493334, 77.376379};
x = m*w+xest;
print x;
run;
```

Table 1.1 : Table showing the creation of fertility gradient with respect to SN, SP and SK and also at different levels of organic manure for all the centres and crops in different years

S. No.	Centre	Crop/ Year	Prob.>F Dependent Variable Over all			Prob.>F Levels of Organic Manure								
						0			1			2		
			SN	SP	SK	SN	SP	SK	SN	SP	SK	SN	SP	SK
1.	Barrackpore	Rice 2005	0.5880^{NS}	<0.0001**	<0.0001**	0.3914 ^{NS}	<.0001**	0.0254**	0.4369 ^{NS}	<.0001**	<.0001**	0.3604 ^{NS}	<.0001**	0.0187**
		Rice 2006	<.0001**	<.0001**	<.0001**	<.0004**	<.0001**	<.0001**	0.0272**	<.0001**	0.0016**	0.003*	<.0001*	<.0001*
		Rice 2007	0.1985^{NS}	<.0001**	<.0001**	0.3922 ^{NS}	<.0001**	0.0103**	0.4653 ^{NS}	0.0004**	<.0001**	0.8618 ^{NS}	<.0001**	0.0058**
		Rice 2008	0.8016^{NS}	<.0001**	<.0001**	0.9343^{NS}	<.0001*	<.0001*	0.4137^{NS}	<.0001**	0.0002**	0.0996^{NS}	<.0001**	0.0001**
		Jute 2005	0.0002*	<.0001*	<.0001*	0.0111*	<.0001*	0.0003*	0.3567 ^{NS}	<.0001*	0.0002*	0.0404*	<.0001*	<.0001*
		Jute 2006	<.0001**	<.0001**	<.0001**	0.0004**	<.0001**	<.0001**	0.0272 *	<.0001**	0.0016**	0.0031**	<.0001**	<.0001**
		Jute 2007	0.003**	0.0001**	<.0001**	0.0071**	0.1323^{NS}	0.0002**	0.1252^{NS}	0.0700**	<.0001**	0.0525*	0.0161**	<.0001**
		Jute 2008	0.6202^{NS}	<.0001**	<.0001**	0.5987^{NS}	<.0001**	<.0001**	0.4137 ^{NS}	<.0001**	0.0002**	0.0996^{NS}	<.0001**	0.0002**
		Lentil 2005	<.0001**	<.0001**	<.0001**	0.2085 ^{NS}	0.0218*	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	0.0014**	<.0001**
2.	Bikaner	Guar 2005	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**
		Isabgol 2005	<.0001*	<.0001*	<.0001*	0.0111**	<.0001**	0.0003**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**
		Cumin 2005	<.0001**	<0.0001**	<0.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**

S. No.	Centre	Crop/ Year	Prob.>F			Prob.>F								
			Dependent Variable Over all			Levels of Organic Manure								
						0			1			2		
			SN	**SP**	**SK**	**SN**	**SP**	**SK**	**SN**	**SP**	**SK**	**SN**	**SP**	**SK**
3.	**Bangalore**	**Onion 2005-06**	0.0450*	<.0001**	<.0001**	0.0393*	< .0001**	< .0001**	0.0094**	<.0001**	<.0001**	0.0733^{NS}	<.0001**	<.0001**
4.	**Hisar**	**Wheat 2005-06**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**
		Wheat 2006-07	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0002**	<.0001**	<.0001**	<.0004**	<.0001**
		Barley 2005-06	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*
		Barley 2006-07	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**
		P.millet 2006-07	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
5.	**Jabalpur**	**Onion 2006-07**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001*	0.0014*	0.0033**	<.0001**	0.0229**	0.5022^{NS}	<.0001**	0.0020**
6.	**Kalyani**	**Cabbage 2005-06**	0.1728^{NS}	0.0040**	<.0001**	0.0638*	0.0176**	<.0001**	0.6136^{NS}	0.0014**	<.0001**	0.3098^{NS}	0.9785^{NS}	0.0004**
7.	**Kerala**	**Bhindi 2005**	0.8230^{NS}	0.0874^{NS}	0.2743^{NS}	0.1607^{NS}	0.3123^{NS}	0.9617^{NS}	0.9412^{NS}	0.5591^{NS}	0.8719^{NS}	0.3646^{NS}	0.3051^{NS}	0.1008^{NS}
		Bhindi 2006	0.0925^{NS}	0.2242^{NS}	0.1559^{NS}	0.3364^{NS}	0.3353^{NS}	0.8720^{NS}	0.6801^{NS}	0.1215^{NS}	0.7299^{NS}	0.0018**	0.5399^{NS}	0.1970^{NS}
		S.Guard 2005-06	<.0001**	0.0290**	<.0001**	<.0001**	0.2773^{NS}	<.0001**	<.0001**	0.1706^{NS}	<.0001**	0.0019**	0.0364**	<.0001**
		S.Guard 2006-07	0.0254**	0.1818^{NS}	0.0004**	0.0005**	0.6414^{NS}	0.1874^{NS}	0.6068^{NS}	0.1821^{NS}	0.0071**	0.5889^{NS}	0.6137^{NS}	0.0228**

S. No.	Centre	Crop/ Year	Prob.>F Dependent Variable Over all			Prob.>F Levels of Organic Manure								
						0			1			2		
			SN	SP	SK	SN	SP	SK	SN	SP	SK	SN	SP	SK
8.	Ludhiana	Rice 2006-07	0.6507^{NS}	0.0363**	0.0008**	0.7589^{NS}	0.6331^{NS}	0.0796^{NS}	0.3993^{NS}	0.0074**	0.0230**	0.9214^{NS}	0.0146**	0.0115**
9.	New Delhi	P.millet 2005-06	0.0004*	0.0446*	0.1645 ^{NS}	0.4393 ^{NS}	0.0001**	0.9652 ^{NS}	0.0084**	<.0001**	0.0283**	0.0021**	0.0132**	0.1621 ^{NS}
		Wheat 2007-08	0.4800^{NS}	<.0001**	0.7573 ^{NS}	0.8193 ^{NS}	<.0001**	0.1679 ^{NS}	0.9390 ^{NS}	0.0006**	0.0517 ^{NS}	0.3759 ^{NS}	<.0001**	0.3134 ^{NS}
		Mustard 2006-07	0.0049**	0.3767^{NS}	0.5060 ^{NS}	0.1819 ^{NS}	0.0007**	0.0068**	0.4734 ^{NS}	0.7883 ^{NS}	0.0756 ^{NS}	<.0001**	0.8305 ^{NS}	0.0212**
		P.Pea 2005	0.0004*	0.0446*	0.1645 ^{NS}	0.4393 ^{NS}	0.0001**	0.9652 ^{NS}	0.0084**	<.0001**	0.0283**	0.0021**	0.0132**	0.1621 ^{NS}
10.	PantNagar	Onion 2005-06	<.0001 **	<.0001 **	<.0001 **	<.0001*	0.0022*	<.0001*	<.0001*	0.3524 ^{NS}	<.0001*	<.0001*	0.0331*	<.0001*
		Garlic 2005-06	<.0001**	<.0001**	<.0001**	<.0001**	0.0022**	<.0001**	<.0001**	0.3524^{NS}	<.0001**	<.0001**	0.0331*	<.0001**
		Wheat 2005-06	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**
		Potato 2006-07	0.0008**	<.0001**	<.0001**	0.0223**	0.0002**	0.0002**	0.0013**	<.0002**	0.0002**	0.0260**	<.0001**	<.0327*
		Mustard 2006-07	0.0939^{NS}	0.0333*	0.0205*	0.3061^{NS}	0.0855 ^{NS}	0.1131 ^{NS}	0.1860 ^{NS}	0.0856 ^{NS}	0.0375*	0.5171^{NS}	0.7326 ^{NS}	0.9093 ^{NS}
11.	Pusa	Rice 2005-06	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*

S. No.	Centre	Crop/ Year	Prob.>F Dependent Variable Over all			Prob.>F Levels of Organic Manure								
						0			1			2		
			SN	SP	SK	SN	SP	SK	SN	SP	SK	SN	SP	SK
12.	**Rahuri**	**Garlic 2005-06**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	<.0001**	0.0039**	<.0001**	<.0001**
13.	**Raipur**	**Sugar-cane 2000-07**	0.0042*	<.0001*	0.0382*	0.1889	<.0001*	0.7661	0.3562^{NS}	<.0001*	0.6189^{NS}	0.0054*	<.0001*	0.0273*

Table 1.2: Showing the Analysis of Variance for Treatment, Organic Manure and their interaction for different centres with and without SN, SP and SK as covariates

S. No.	Centre	Crop/ Year	Prob.>F Without Covariates			Prob.>F With Covariates					
			Treatment	FYM	Treat x FYM	Treatment	FYM	Treat x FYM	SN	SP	SK
1.	Barrackpore	Rice 2005	<.0001**	0.0075**	0.1412 NS	0.0003**	0.0026**	0.0226**	0.7661 NS	0.0237**	0.0422**
		Rice 2006	0.0002**	0.0012**	0.2038NS	0.0005**	0.0058**	0.0282**	0.7769NS	0.0250**	0.9700NS
		Rice 2007	0.0001**	0.0029**	0.4944NS	0.0010**	0.0197**	0.1967NS	0.9867 NS	0.8679 NS	0.0810 NS
		Rice 2008	<.0001**	<.0001**	0.0541*	0.0005**	0.0051**	0.1409NS	0.8938 NS	0.7974 NS	0.3964 NS
		Jute 2005	0.0009**	0.1467 NS	0.6034 NS	0.0016**	0.0312**	0.1124NS	0.0528**	0.0257**	0.4887NS
		Jute 2006	0.0297*	0.0762NS	0.9037NS	0.2500NS	0.5444 NS	0.9947 NS	0.9117 NS	0.9821 NS	0.8399 NS
		Jute 2007	0.0027**	0.3564NS	0.9942NS	0.0154**	0.9348NS	0.8269NS	0.8869NS	0.5607NS	0.1339NS
		Jute 2008	0.0014**	0.0035**	0.1721NS	0.0070**	0.0912*	0.3014NS	0.5285 NS	0.2360 NS	0.4167 NS
		Lentil 2005	0.0046**	0.0016**	0.0806*	0.0247*	0.0253*	0.1065*	0.4597 NS	0.3779 NS	0.3961 NS
2.	Bikaner	Guar 2005	0.0011**	0.0013**	0.1659NS	<.0001**	<.0001**	0.0006**	0.7360NS	0.0051**	0.2602NS
		Isabgol 2005	<.0001**	<.0001**	0.0253**	<.0001**	<.0001**	0.1453 NS	0.9535 NS	0.8673 NS	0.2396 NS
		Cumin 2005	<.0001**	<.0001**	0.0066**	<.0001**	<.0001**	0.0111**	0.4517NS	0.1246NS	0.0572*

S. No.	Centre	Crop/ Year	Prob.>F Without Covariates			Prob.>F With Covariates					
			Treatment	FYM	Treat x FYM	Treatment	FYM	Treat x FYM	SN	SP	SK
3.	**Bangalore**	**Onion 2005-06**	0.3232 NS	0.8631 NS	0.1324 NS	0.4538 NS	0.4967 NS	0.3921 NS	0.6669 NS	0.4813 NS	0.3028 NS
4.	**Hisar**	**Wheat 2005-06**	0.0013*	0.0628*	0.2249NS	0.0092*	0.1656NS	0.1423NS	0.6594NS	0.8354NS	0.8136NS
		Wheat 2006-07	0.0154**	0.1157NS	0.5497 NS	0.0166**	0.0934NS	0.2807 NS	0.4296 NS	0.9985 NS	0.1195 NS
		Barley 2005-06	0.0007**	0.0004**	0.0005**	0.0468*	0.0183*	0.0501*	0.8797NS	0.9071NS	0.9268NS
		Barley 2006-07	0.0038**	0.6559NS	0.0251*	0.0009**	0.0757NS	0.0028**	0.1670NS	0.9676NS	0.9491NS
		P.millet 2006-07	0.3899NS	0.6549NS	0.9470NS	0.1810 NS	0.3854 NS	0.6123 NS	0.5650 NS	0.7549 NS	0.1549 NS
5.	**Jabalpur**	**Onion 2006-07**	0.2070NS	0.0017**	0.6514NS	0.1048NS	0.0001**	0.4297 NS	0.0402*	0.0891 NS	0.3984 NS
6.	**Kalyani**	**Cabbage 2005-06**	0.0032**	0.8599 NS	0.2313 NS	0.0027**	0.0586*	0.0431*	0.0456*	0.1146 NS	0.1188 NS
7.	**Kerala**	**Bhindi 2005**	0.0003**	<.0001**	0.0028**	0.0063**	0.0012**	0.0152**	0.1029NS	0.1034 NS	0.0896 NS
		Bhindi 2006	<.0001**	<.0001**	<.0001**	0.0010**	0.0353**	0.0020**	0.3995NS	0.7529 NS	0.4476 NS
		S.Guard 2005-06	0.0141**	0.2989NS	0.0992 NS	0.1524NS	0.5636 NS	0.4586 NS	0.8517 NS	0.8881 NS	0.5972 NS
		S.Guard 2006-07	0.0146**	0.2794 NS	0.3240 NS	0.1575 NS	0.5859 NS	0.7310 NS	0.7468 NS	0.6952 NS	0.7247 NS

S. No.	Centre	Crop/ Year	Prob.>F Without Covariates			Prob.>F With Covariates					
			Treatment	FYM	Treat x FYM	Treatment	FYM	Treat x FYM	SN	SP	SK
8.	**Ludhiana**	**Rice 2006-07**	0.0095**	0.2704NS	0.0281**	0.1110NS	0.5253NS	0.2003NS	0.5162NS	0.4401NS	0.6392NS
9.	**New Delhi**	**P.millet 2005-06**	<.0001**	<.0001**	0.0172**	<.0001**	<.0001**	0.0054**	0.0084*	0.3100 NS	0.0951*
		Wheat 2007-08	<.0001**	0.0001**	0.0266*	<.0001**	0.0478*	0.0765NS	0.3285 NS	0.1451 NS	0.1775 NS
		Mustard 2006-07	0.0091**	0.0009**	0.0678 NS	0.0053**	0.0144**	0.0143**	0.0119**	0.3046 NS	0.1268 NS
		P.Pea 2007	<.0001**	0.0001**	0.1053 NS	0.0059**	0.0590NS	0.3540 NS	0.5808 NS	0.3801 NS	0.9249 NS
10.	**Pantnagar**	**Onion 2005-06**	0.2736 NS	0.3575 NS	0.7178 NS	0.5467 NS	0.5198 NS	0.8949 NS	0.8538 NS	0.9417 NS	0.6807 NS
		Garlic 2005-06	0.5424NS	0.6041 NS	0.4050 NS	0.3251 NS	0.3628 NS	0.4834 NS	0.7394 NS	0.6508 NS	0.6856 NS
		Wheat 2005-06	0.0687NS	0.9876NS	0.9994NS	0.0583NS	0.7784NS	0.8976NS	0.0706NS	0.2248NS	0.4101NS
		Potato 2006-07	0.2516NS	0.9072NS	0.9410NS	0.5167NS	0.7511NS	0.9809 NS	0.4341 NS	0.8211 NS	0.4194 NS
		Mustard 2006-07	0.8006NS	0.0353*	0.9821NS	0.9914NS	0.2202 NS	0.9654 NS	0.4424 NS	0.7792 NS	0.6785 NS
11.	**Pusa**	**Rice 2005-06**	0.0292*	0.0397*	0.8766NS	0.0023**	0.0057**	0.1641NS	0.4989 NS	0.8292 NS	0.3559 NS

S. No.	Centre	Crop/ Year	Prob.>F Without Covariates			Prob.>F With Covariates					
			Treatment	FYM	Treat x FYM	Treatment	FYM	Treat x FYM	SN	SP	SK
12.	Rahuri	Garlic 2005-06	<.0001**	<.0001**	0.3118^{NS}	<.0001**	<.0001**	0.0041**	0.0357*	0.1511^{NS}	0.1821 ^{NS}
13.	Raipur	Sugar-cane 2000-07	0.0007**	0.0050**	0.7927^{NS}	0.0019**	0.0045**	0.1851^{NS}	0.9140^{NS}	0.0338*	0.7195^{NS}

Table 1.3 : Showing the Analysis of Variance for Treatment, Strips within FYM (Organic Manure) levels and their interaction with and without SN,SP and SK as covariates

S. No.	Centre	Crop/ Year	Prob.>F Without Interactions and Covariates			Prob.>F With Interactions and Covariates					
			FYM	Strip Within FYM	Treatment	FYM	Strip Within FYM	Treatment	SN	SP	SK
1.	Barrackpore	Rice 2005	0.0005**	0.0750*	<.0001**	0.0115**	0.3662 NS	<.0001**	0.4380 NS	0.4901NS	0.4778NS
		Rice 2006	<.0001**	0.5662NS	<.0001**	0.0016**	0.9850NS	<.0001**	0.2046 NS	0.5826 NS	0.7370 NS
		Rice 2007	<.0001**	0.0051**	<.0001**	<.0001**	0.5891NS	<.0001**	0.6977 NS	0.8603 NS	0.8019 NS
		Rice 2008	<.0001**	0.0657NS	<.0001**	<.0001**	0.3849NS	<.0001**	0.7337 NS	0.9945 NS	0.3369 NS
		Jute 2005	0.0325**	0.0038**	<.0001**	0.0413**	0.0064**	<.0001**	0.8561 NS	0.6197 NS	0.6196 NS
		Jute 2006	0.0001**	0.0189**	<.0001**	0.0103**	0.1201NS	<.0001**	0.2636 NS	0.5829 NS	0.2605 NS
		Jute 2007	0.0356*	0.1257NS	<.0001**	0.0167**	0.2320NS	<.0001**	0.9258NS	0.1249NS	0.6123NS
		Jute 2008	<.0001**	<.0001**	<.0001**	<.0001**	0.0019**	<.0001**	0.8905NS	0.5475 NS	0.3041 NS
		Lentil 2005	<.0001**	0.0034**	<.0001**	<.0001**	0.0192**	<.0001**	0.4695 NS	0.4834 NS	0.6028 NS
2.	Bikaner	Guar 2005	<.0001**	<.0001**	<.0001**	<.0001**	0.8560NS	<.0001**	0.3836 NS	0.7405 NS	0.5575 NS
		Isabgol 2005	<.0001**	<.0001**	<.0001**	<.0001**	0.7041NS	<.0001**	0.6545NS	0.3548NS	0.1245NS
		Cumin 2005	<.0001**	<.0001**	<.0001**	<.0001**	0.0431*	<.0001**	0.5034NS	0.3194NS	0.4662NS

S. No.	Centre	Crop/ Year	Prob.>F Without Covariates			Prob.>F With Covariates					
			Treatment	FYM	Treat x FYM	Treatment	Treat x FYM	FYM	SN	SP	SK
3.	Bangalore	Onion 2005-06	0.7259 NS	<.0001**	0.5959 NS	0.3253 NS	0.0002**	0.5991 NS	0.5771 NS	0.1786 NS	0.3205 NS
4.	Hisar	Wheat 2005-06	0.0577*	0.0449*	<.0001*	0.0848*	0.5182NS	<.0001*	0.6840NS	0.7264NS	0.7901NS
		Wheat 2006-07	0.0151**	0.0129**	<.0001**	0.0143**	0.0014**	<.0001**	0.7565 NS	0.0571 NS	0.8922 NS
		Barley 2005-06	0.0518*	0.0247*	0.3315NS	0.1178NS	0.5807NS	0.4803NS	0.3687NS	0.3628NS	0.7030NS
		Barley 2006-07	0.8730NS	0.7972NS	0.0481*	0.4221NS	0.4424NS	0.0274*	0.4484NS	0.6344NS	0.0274NS
		P.millet 2006-07	0.5386NS	0.0203**	0.0007**	0.5610NS	0.5373 NS	0.0045 **	0.6663 NS	0.7621 NS	0.6496 NS
5.	Jabalpur	Onion 2006-07	<.0001**	<.0001**	0.0003**	<.0001**	<.0001**	0.0003**	0.2432NS	0.3661NS	0.3837NS
6.	Kalyani	Cabbage 2005-06	0.4758 NS	0.0709*	<.0001**	0.4845 NS	0.9529 NS	<.0001**	0.4998 NS	0.7552NS	0.4244 NS
7.	Kerala	Bhindi 2005	<.0001**	<.0001**	0.0012**	<.0001**	<.0001**	0.0035**	0.3237NS	0.5264 NS	0.8308 NS
		Bhindi 2006	0.2884NS	0.1073 NS	0.0336 NS	0.0503*	0.0297*	0.0157*	0.0328*	0.0542*	0.9975 NS
		Snake Guard 2005-06	0.4456 NS	0.0056**	0.3050 NS	0.4471 NS	0.0484	0.3014 NS	0.5166 NS	0.2713 NS	0.4546 NS
		Snake Guard 2006-07	0.1034 NS	<.0001**	0.0001**	0.2919 NS	0.0002**	0.0003**	0.2734 NS	0.8609 NS	0.8050 NS

S. No.	Centre	Crop/ Year	Prob.>F Without Covariates			Prob.>F With Covariates					
			Treatment	FYM	Treat x FYM	Treatment	Treat x FYM	FYM	SN	SP	SK
8.	**Ludhiana**	**Rice 2006-07**	0.6246 NS	0.0061**	<.0001**	0.7947 NS	0.0193**	<.0001**	0.6814 NS	0.7997 NS	0.5290 NS
9.	**New Delhi**	**P.millet 2005-06**	<.0001**	0.6152 NS	<.0001**	<.0001**	0.6654 NS	<.0001**	0.8555 NS	0.4130 NS	0.4596 NS
		Wheat 2007-08	<.0001**	0.0652 NS	<.0001**	<.0001**	0.0570 NS	<.0001**	0.7637 NS	0.3683 NS	0.2260 NS
		Mustard 2006-07	0.0002**	0.2141 NS	0.0042**	0.1021 NS	0.1344 NS	0.0104**	0.2436 NS	0.6083 NS	0.3491 NS
		P.Pea 2007	<.0001**	0.1057 NS	<.0001**	0.0003**	0.2357 NS	<.0001**	0.7058 NS	0.8442 NS	0.5950 NS
10.	**PantNagar**	**Onion 2005-06**	0.1009 NS	0.0016**	0.0009**	0.1069 NS	0.0113**	0.0022**	0.3380 NS	0.6069 NS	0.9487 NS
		Garlic 2005-06	0.4494 NS	<.0001**	0.1032 NS	0.9084 NS	0.0099**	0.1396 NS	0.0535 NS	0.1590 NS	0.6534 NS
		Wheat 2005-06	0.3197 NS	<.0001**	<.0001**	0.2304 NS	0.0063**	<.0001**	0.1132 NS	0.0505 NS	0.5495 NS
		Potato 2006-07	0.6703 NS	0.1786 NS	0.0003**	0.2770 NS	0.0779 NS	<.0001**	0.0743 NS	0.0298*	0.0802 NS
		Mustard 2006-07	0.0001*	0.4012 NS	0.1580 NS	0.0001**	0.3841 NS	0.5320 NS	0.3068 NS	0.9387 NS	0.7013 NS
11.	**Pusa**	**Rice 2005-06**	<.0001**	<.0001**	<.0001**	<.0001**	0.3175 NS	<.0001**	0.9431 NS	0.4739 NS	0.7044 NS

S. No.	Centre	Crop/ Year	Prob.>F Without Covariates			Prob.>F With Covariates					
			Treatment	FYM	Treat x FYM	Treatment	FYM	Treat x FYM	SN	SP	SK
12.	Rahuri	Garlic 2005-06	<.0001**	0.0500*	<.0001**	<.0001**	0.0201*	<.0001**	0.0299*	0.3045 NS	0.4216 NS
13.	Raipur	Sugar-cane 2000-07	<.0001**	0.3282 NS	<.0001**	<.0001**	0.2722 NS	<.0001**	0.1254 NS	0.1474 NS	0.4338 NS

*- Significant at 5% level
** - Significant at 1% level (Highly Significant)
NS – Not Significant

Table 1.4 : Showing Comparison of Optimal doses of N,P and K obtained through Targeted yield Equations and Response surface methodology

S.NO.	Centres	Crop	Targeted Yield (Q/ha)	Optimal Doses through					
				Targeted Yield Equations			Response Surface Methodology		
				FN	FP	FK	FN	FP	FK
1.	Barrackpore	Rice 2005	33.00	115	57	62	179	108	20
		Rice 2006	37.99	163	34	61	308	47	42
		Rice 2007	40.00	122	31	24	101	20	41
		Rice 2008	40.00	94	16	34	107	43	31
		Jute 2005	22.00	113	51	51	111	50	46
		Jute 2006	21.00	93	9	39	120	24	35
		Jute 2007	26.14	81	15	30	92	6	24
		Jute 2008	26.92	79	14	30	124	20	47
		Lentil 2005	230.00	39	19	22	89	40	38
2.	Bikaner	Guar 2005	23.39	60	32	67	90	58	37
		Isabgol 2005	10.00	45	32	35	57	32	51
		Cumin 2005	6.00	45	31	29	67	36	31
3.	Bangalore	Onion 2005-06	350.00	93	37	12	88	32	139

S.NO.	Centres	Crop	Targeted Yield (Q/ha)	Optimal Doses through					
				Fertilizer Adjustment Equations			Response Surface Methodology		
				FN	FP	FK	FN	FP	FK
4.	Hisar	Wheat 2005-06	55.00	165	84	64	138	53	44
		Wheat 2006-07	54.46	275	89	115	199	17	48
		Barley 2005-06	39.00	67	14	32	69	25	25
		Barley 2006-07	55.00	79	8	24	61	33	20
		P.millet 2006-07	23.78	123	17	46	138	71	66
5.	Jabalpur	Onion 2006-07	25.00	46	8	49	92	51	94
6.	Kalyani	Cabbage 2005-06	610.00	132	53	67	112	55	82
7.	Kerala	Bhindi 2005	82.90	226	12	28	87	11	32
		Bhindi 2006	99.09	47	3	16	45	12	29
		S.Guard 2005-06	258.94	110	10	17	80	71	103
		S.Guard 2006-07	184.26	83	38	13	40	5	7

S.NO.	Centres	Crop	Targeted Yield (Q/ha)	Optimal Doses through					
				Fertilizer Adjustment Equations			Response Surface Methodology		
				FN	FP	FK	FN	FP	FK
8.	Ludhiana	Rice 2006-07	63.61	102	4	6	161	43	31
		Wheat 2006-07	56.23	182	38	27	327	52	52
9.	New Delhi	P.millet 2005-06	42.60	227	165	151	358	220	24
		Wheat 2007-08	50.59	111	33	55	137	41.	87
		Mustard 2007-08	24.02	160	111	116	136	108	55
		Pigeon-Pea 2005	24.86	39	23	46	63	37	71
10.	PantNagar	Onion 2005-06	360	91	48	46	97	19	36
		Wheat 2005-06	48.66	130	20	27	180	27	38
		Potato 2006-07	137.71	138	38	76	143	72	104
		Mustard 2006-07	20	135	18	47	65	34	13
		Garlic 2005-06	120	46.26	59.51	29.24	94.76	43.87	35.86

S.NO.	Centres	Crop	Targeted Yield (Q/ha)	Optimal Doses through					
				Fertilizer Adjustment Equations			Response Surface Methodology		
				FN	FP	FK	FN	FP	FK
11.	Pusa	Rice 2005-06	42.01	107	22	31	129	96	61
12.	Raipur	Sugar-cane 2007-08	875	237	45	65	399	146	347
13.	Rahuri	Garlic 2005-06	90	99	48	45	----	-----	-----

Table 1.5 : Showing the regression coefficients of Multiple regression with all observations of the experiment in all the centres

Centre	Crop	Year	Intercept	FN	FP	FK	FN2	FP2	FK2	FNFP	FNFK	FPFK
Banglore	**Onion**	**2005**	306.6445	0.99432	-2.95947	-0.37056	-0.00859	-0.01284	0.00192	0.01214	-0.00554	0.01026
Barrakpore	**Jute**	**2005**	-173.6665	29.2418	12.6676	-20.2643	-0.10569	-0.06729	0.13118	0.04392	0.00866	0.05301
Barrakpore	**Jute**	**2006**	0.75786	0.05219	-0.17311	0.37354	-0.00084	0.00104	-0.0003	0.000334	0.0000115	0.000993
Barrakpore	**Jute**	**2007**	2.3832	0.37059	0.1557	-0.27803	-0.00196	0.00193	0.00504	0.00115	0.00080676	-0.00505
Barrakpore	**Jute**	**2008**	7.94032	0.04117	-0.05611	-0.05411	-0.00054	0.000109	0.00211	0.000507	-0.0005083	0.000104
Barrakpore	**Rice**	**2005**	691.3328	17.8646	8.70986	-8.27302	-0.05836	-0.09825	-0.0871	0.11481	-0.0024	-0.03208
Barrakpore	**Rice**	**2006**	18.74252	-0.15507	-0.00659	0.24751	-0.00023	-0.00091	-0.0028	8.61E-05	0.00018428	0.00191
Barrakpore	**Rice**	**2007**	24.67831	0.1228	-0.15296	-0.10585	-0.00162	0.0026	0.00138	0.000496	0.00075876	-0.00145
Barrakpore	**Rice**	**2008**	7.7382	0.53903	-0.45703	-0.23715	-0.00316	0.00465	0.00454	0.001	0.00077477	-0.000813
Barrakpore	**Lentil**	**2005**	141.8902	0.84991	-2.42596	0.91617	-0.01534	0.08689	0.06332	-0.01126	-0.02502	0.0081
Hisar	**Barley**	**2005**	5107.201	5.67783	31.8359	22.58956	-0.08037	-0.55091	-0.2817	0.288	-0.17718	0.36799
Hisar	**Barley**	**2006**	2110.376	67.8064	28.7515	12.46093	-0.31041	-0.43526	-1.1248	0.18654	0.28939	-0.28924
Hisar	**P.Millet**	**2006**	-992.9338	21.7163	-1.61505	18.83317	-0.03764	-0.06527	-0.0629	-0.04879	-0.05496	0.23119
Hisar	**Wheat**	**2005**	2397.755	30.5581	21.3816	-26.0769	-0.08506	-0.24757	-0.0937	0.12727	-0.05264	0.09585
Hisar	**Wheat**	**2006**	-118.6324	28.9337	-9.46221	20.8367	-0.01278	-0.13477	0.07934	0.00993	-0.09871	0.18225
Jabalpur	**Onion**	**2006**	6.99673	-0.10583	-0.19045	0.40833	0.000981	0.00136	-0.0016	-0.00018	-0.0002193	-0.000322
Kalyani	**Cabbage**	**2005**	-33.36641	-2.12234	14.3501	2.70493	0.03962	0.13568	0.05952	-0.16219	0.00819	-0.12487
Kerala	**Bhindi**	**2005**	-8.18892	1.2131	3.81173	0.52349	-0.00315	0.11766	-0.0152	-0.00976	0.00201	-0.05629
Kerala	**Bhindi**	**2006**	-23.38959	0.80558	4.44571	1.37569	-0.00662	0.06438	0.03669	-0.01861	0.00279	-0.18874
Kerala	**SGrd**	**2005**	233.0858	-2.38416	3.45163	2.60457	0.01182	-0.03022	-0.0092	-0.01503	0.00414	0.02042
Kerala	**SGrd**	**2006**	292.3548	-2.28553	1.98883	-0.10562	0.01316	-0.0193	0.04548	-0.019	-0.00822	-0.02347
Ludhiana	**Rice**	**2006**	4311.252	9.4658	118.018	-127.868	0.03634	0.63869	0.33734	-0.64449	0.28961	-0.2425
Ludhiana	**Wheat**	**2006**	1963.793	16.5432	-10.2463	67.57291	-0.02765	0.12835	-0.3177	0.07041	0.05353	-0.67362
New Delhi	**P.Millet**	**2005**	2146.592	6.44485	1.6285	-19.073	-0.03777	-0.02543	-0.0212	0.03559	-0.04131	0.07569

Table 1.5 : Showing the regression coefficients of Multiple regression with all observations of the experiment in all the centres Continued

New Delhi	**Wheat**	**2007**	26.32715	0.31323	-0.0792	-0.06702	-0.00185	0.000604	0.00075	-0.00035	-0.0001508	0.000785
New Delhi	**Mustard**	**2007**	759.9208	1.26751	6.01189	6.30484	-0.01506	-0.01691	-0.0113	-0.01738	0.03693	-0.04188
New Delhi	**Arhar**	**2007**	1046.057	20.6614	4.19309	6.4985	-0.23802	-0.01507	-0.0158	0.0491	-0.00605	0.02159
Pantnagar	**Garlic**	**2005**	-29.22577	0.51356	0.56871	-1.02686	-0.00043	-0.00024	-0.0087	-0.00693	0.00572	-0.0016
Pantnagar	**Mustard**	**2006**	15.01326	-0.03157	0.09764	-0.09552	0.000167	0.000235	0.00031	-0.00103	0.00051643	0.00129
Pantnagar	**Onion**	**2005**	202.914	2.96564	-3.68328	-0.34687	-0.00793	-0.01922	-0.0028	0.02183	-0.02046	0.01908
Pantnagar	**Potato**	**2006**	31.00178	-0.44937	0.51702	0.69321	0.000331	-0.00059	-0.0028	0.00187	0.00039003	-0.00174
Pantnagar	**Wheat**	**2005**	0.26728	0.11273	0.2222	0.03941	-7.5E-06	0.00039	-0.0006	-0.00108	0.00014329	-0.000183
Pusa	**Rice**	**2005**	1395.644	7.76755	7.36824	15.21554	-0.00202	-0.07267	-0.1874	0.00201	-0.00862	0.14471
Rahuri	**Garlic**	**2005**	80.52406	1.2215	-1.0958	0.56594	-0.00152	0.000482	-0.0041	-0.00064	0.00087986	0.00381

Table 1.5 : Showing the regression coefficients of Multiple regression with all observations of the experiment in all the centres (continued)

Centre	Crop	Year	SN	SP	SK	FNSN	FPSP	FKSK
Banglore	**Onion**	**2005**	0.30795	-0.2305	-0.0556	0.00372	0.00715	-5.078E-05
Barrakpore	**Jute**	**2005**	2.31619	5.10736	0.05092	-0.02508	-0.12976	0.03499
Barrakpore	**Jute**	**2006**	-0.032	0.06473	0.08627	0.0005344	0.000864	-0.00175
Barrakpore	**Jute**	**2007**	0.01085	0.06563	0.01625	-0.000172	-0.00187	0.00002816
Barrakpore	**Jute**	**2008**	-0.0002	0.04563	0.01675	0.0004486	0.000349	-0.0002012
Barrakpore	**Rice**	**2005**	2.82814	3.0694	-0.7474	-0.0174	-0.04803	0.06564
Barrakpore	**Rice**	**2006**	-0.0167	0.08153	0.01705	0.0009258	-0.00192	-0.00053
Barrakpore	**Rice**	**2007**	-0.0461	0.0399	0.02648	0.0007974	0.00042	-0.0001912
Barrakpore	**Rice**	**2008**	0.01434	-0.0406	0.05411	0.0002754	0.000904	-0.0006395
Barrakpore	**Lentil**	**2005**	-0.6257	0.87205	0.49785	0.01069	-0.01816	-0.01736
Hisar	**Barley**	**2005**	11.5157	81.3884	-16.689	0.01969	-1.8824	-0.02342
Hisar	**Barley**	**2006**	18.5982	-24.261	-0.7364	-0.32307	-0.20608	0.08513
Hisar	**P.Millet**	**2006**	3.13808	-3.7708	6.57197	-0.03373	0.12305	-0.06857
Hisar	**Wheat**	**2005**	6.22767	67.5768	-6.048	-0.04488	-0.83192	0.12645
Hisar	**Wheat**	**2006**	5.37055	13.6808	6.68525	-0.07965	0.59024	-0.08683
Jabalpur	**Onion**	**2006**	-0.0079	0.24752	0.03635	-7.99E-05	0.00174	-0.0002597
Kalyani	**Cabbage**	**2005**	-1.4261	0.46723	7.75364	0.00598	0.00331	-0.07373
Kerala	**Bhindi**	**2005**	0.07359	1.65146	-8.1889	-0.00173	-0.17599	0.00141
Kerala	**Bhindi**	**2006**	0.14838	-1.0162	0.07889	-0.000286	0.06333	-0.00358
Kerala	**SGrd**	**2005**	-0.6803	4.22049	0.51361	0.00449	-0.02652	-0.02942
Kerala	**SGrd**	**2006**	-0.5873	0.33277	-0.1792	0.00485	0.03713	0.00471

Table 1.5 : Showing the regression coefficients of Multiple regression with all observations of the experiment in all the centres(Continued)

Ludhiana	**Rice**	**2006**	11.2874	36.9115	-19.481	-0.01122	-1.18817	0.63987
Ludhiana	**Wheat**	**2006**	4.39654	-2.1856	-0.902	-0.02365	0.09148	-0.18304
New Delhi	**P.Millet**	**2005**	7.07713	11.5369	-10.68	0.05841	-0.34771	0.08886
New Delhi	**Wheat**	**2007**	-0.0456	0.00806	0.02389	0.0009311	0.000292	-0.0003056
New Delhi	**Mustard**	**2007**	1.18467	-1.6488	3.04215	0.0119	0.08708	-0.02344
New Delhi	**Arhar**	**2007**	-0.3567	6.47479	1.5913	-0.00223	-0.07688	-0.01196
Pantnagar	**Garlic**	**2005**	0.13217	-0.2731	0.64535	-0.00174	0.00239	0.0067
Pantnagar	**Mustard**	**2006**	-0.0224	0.10236	-0.0005	0.0003038	-0.00183	-8.458E-05
Pantnagar	**Onion**	**2005**	0.67826	-1.4033	0.22692	-0.00732	0.03741	0.01089
Pantnagar	**Potato**	**2006**	-0.4566	0.52791	0.41595	0.00377	-0.007	-0.0003803
Pantnagar	**Wheat**	**2005**	-0.0034	0.10912	0.08128	3.713E-05	-0.000357	0.00005064
Pusa	**Rice**	**2005**	-1.3173	12.0748	6.02142	0.01292	-0.08863	-0.0566
Rahuri	**Garlic**	**2005**	-0.1453	-3.9293	0.11265	-0.00392	0.06027	-0.000318

Table 1.6: Showing Optimum Response ratio over control to different levels of nutrient application

S.No.	Centre	Crop/ Year	Response ratio to N at middle dose of P and K		Response ratio to P at middle dose of N and K		Response ratio to K at middle dose of N and P	
			Over N_0		**Over P_0**		**Over K_0**	
1.	**Barrackpore**	**Rice 2005**	N_{40}	8.775	P_{20}	44.690	K_{20}	53.691
			N_{80}	12.365	P_{40}	24.730	K_{40}	24.730
			N_{120}	11.583	P_{60}	13.435	K_{60}	14.296
		Rice 2006	N_{40}	12.301	P_{20}	43.365	K_{20}	35.847
			N_{80}	15.776	P_{40}	31.552	K_{40}	31.552
			N_{120}	9.977	P_{120}	16.495	K_{120}	14.649
		Rice 2007	N_{40}	0.200	P_{20}	0.832	K_{20}	0.866
			N_{80}	0.214	P_{40}	0.428	K_{40}	0.428
			N_{120}	0.179	P_{60}	0.328	K_{60}	0.327
		Rice 2008	N_{40}	0.132	P_{20}	0.966	K_{20}	0.954
			N_{80}	0.263	P_{40}	0.527	K_{40}	0.527
			N_{120}	0.196	P_{120}	0.381	K_{120}	0.349
		Jute 2005	N_{40}	11.511	P_{20}	43.239	K_{20}	42.122
			N_{80}	11.364	P_{40}	22.728	K_{40}	22.728
			N_{120}	8.040	P_{60}	13.024	K_{60}	17.102
		Jute 2006	N_{40}	11.370	P_{20}	11.310	K_{20}	4.828
			N_{80}	12.810	P_{40}	9.155	K_{40}	3.914
			N_{120}	9.623	P_{60}	4.103	K_{60}	0.831
		Jute 2007	N_{40}	0.093	P_{20}	0.479	K_{20}	0.726
			N_{80}	0.133	P_{40}	0.265	K_{40}	0.265
			N_{120}	0.101	P_{60}	0.203	K_{60}	0.227
		Jute 2008	N_{40}	9.625	P_{20}	39.867	K_{20}	42.017
			N_{80}	13.963	P_{40}	27.925	K_{40}	27.925
			N_{120}	10.564	P_{60}	17.189	K_{60}	18.956
		Lentil 2005	N_{40}	1.444	P_{20}	5.889	K_{20}	5.389
			N_{80}	1.097	P_{40}	2.194	K_{40}	2.194
			N_{120}	0.384	P_{60}	2.574	K_{60}	1.741
2.	**Bikaner**	**Guar 2005**	N_{20}	18.714	P_{15}	36.063	K_{15}	50.063
			N_{40}	30.432	P_{30}	40.576	K_{30}	40.576
			N_{60}	17.232	P_{45}	24.747	K_{45}	25.991
		Isabgol 2005	N_{20}	16.719	P_{15}	24.804	K_{15}	23.559
			N_{40}	13.451	P_{30}	17.935	K_{30}	17.935
			N_{60}	9.223	P_{45}	9.801	K_{45}	13.809
		Cumin 2005	N_{20}	7.231	P_{15}	18.174	K_{15}	19.796
			N_{40}	6.265	P_{30}	9.398	K_{30}	9.398
			N_{60}	5.855	P_{45}	7.191	K_{45}	5.443

S.No.	Centre	Crop/ Year	Response ratio to N at middle dose of P and K		Response ratio to P at middle dose of N and K		Response ratio to K at middle dose of N and P	
			Over N_0		Over P_0		Over K_0	
3.	Bangalore	Onion 2005-06	N_{75}	1.198	P_{25}	1.274	K_{25}	0.331
			N_{125}	0.283	P_{50}	-0.783	K_{50}	-0.592
			N_{150}	0.341	P_{75}	0.460	K_{75}	0.186
4.	Hisar	Wheat 2005-06	N_{60}	25.094	P_{30}	32.489	K_{30}	25.811
			N_{120}	18.106	P_{60}	12.833	K_{60}	6.011
			N_{180}	13.152	P_{90}	6.204	K_{90}	3.907
		Wheat 2006-07	N_{60}	19.906	P_{30}	70.811	K_{30}	39.489
			N_{120}	10.194	P_{60}	20.389	K_{60}	20.389
			N_{180}	9.680	P_{90}	18.874	K_{90}	13.996
		Barley 2005-06	N_{40}	17.925	P_{20}	-16.700	K_{20}	-0.250
			N_{80}	9.367	P_{40}	16.508	K_{40}	13.008
			N_{120}	2.361	P_{60}	2.000	K_{60}	3.717
		Barley 2006-07	N_{60}	6.731	P_{30}	58.952	K_{30}	41.107
			N_{120}	9.471	P_{60}	18.943	K_{60}	18.943
			N_{180}	8.833	P_{90}	15.988	K_{90}	9.840
		P.millet 2006-07	N_{60}	13.033	P_{30}	25.489	K_{30}	45.644
			N_{120}	8.744	P_{60}	17.489	K_{60}	17.489
			N_{180}	5.528	P_{90}	13.085	K_{90}	12.630
5.	Jabalpur	Onion 2006-07	N_{40}	0.146	P_{30}	0.190	K_{40}	0.63
			N_{80}	0.113	P_{60}	1.50	K_{80}	0.113
			N_{120}	0.054	P_{90}	0.082	K_{120}	0.017
6.	Kalyani	Cabbage 2005-06	N_{120}	1.833	P_{50}	4.320	K_{60}	4.222
			N_{150}	1.742	P_{60}	4.356	K_{80}	3.267
			N_{170}	1.929	P_{80}	3.367	K_{100}	2.307
7.	Kerala	Bhindi 2005	N_{25}	1.597	P_{4}	13.700	$K_{12.5}$	2.651
			N_{50}	0.999	P_{8}	6.242	K_{25}	1.997
			N_{100}	0.782	P_{16}	3.377	K_{50}	0.493
		Bhindi 2006	N_{25}	2.358	P_{4}	8.342	$K_{12.5}$	3.935
			N_{50}	0.633	P_{8}	3.954	K_{25}	1.265
			N_{100}	0.362	P_{16}	2.727	K_{50}	1.507
		S.Guard 2005-06	N_{35}	-0.016	$P_{12.5}$	0.356	$K_{12.5}$	5.556
			N_{70}	0.266	P_{25}	0.744	K_{25}	0.744
			N_{140}	0.062	P_{50}	0.356	K_{50}	0.522
		S.Guard 2006-07	N_{35}	0.022	$P_{12.5}$	0.396	$K_{12.5}$	5.382
			N_{70}	0.213	P_{25}	0.598	K_{25}	0.598
			N_{140}	0.035	P_{50}	0.266	K_{50}	1.749
8.	Ludhiana	Rice 2006-07	N_{90}	9.498	P_{15}	63.919	K_{15}	122.185
			N_{120}	5.965	P_{30}	23.859	K_{30}	23.859
			N_{150}	8.692	P_{45}	34.240	K_{45}	28.721
		Wheat 2006-07	N_{90}	19.440	P_{45}	42.279	K_{15}	114.770
			N_{120}	15.969	P_{60}	31.937	K_{30}	63.874
			N_{150}	13.606	P_{75}	23.141	K_{45}	40.723

S.No.	Centre	Crop/ Year	Response ratio to N at middle dose of P and K		Response ratio to P at middle dose of N and K		Response ratio to K at middle dose of N and P	
			Over N_0		Over P_0		Over K_0	
9.	**New Delhi**	**P.millet 2005-06**	N_{50}	16.000	P_{40}	3.833	K_{40}	1.867
			N_{100}	15.433	P_{80}	3.311	K_{80}	1.156
			N_{150}	13.800	P_{120}	1.833	K_{120}	0.333
		Wheat 2007-08	N_{50}	0.249	P_{30}	0.748	K_{40}	0.787
			N_{100}	0.276	P_{80}	0.345	K_{80}	0.345
			N_{150}	0.193	P_{120}	0.261	K_{120}	0.270
		Mustard 2007-08	N_{90}	7.707	P_{15}	12.967	K_{15}	11.300
			N_{120}	4.52	P_{30}	5.650	K_{30}	5.650
			N_{150}	7.520	P_{45}	4.322	K_{45}	4.506
		P.Pea 2007	N_{20}	25.000	P_{30}	19.222	K_{30}	26.222
			N_{40}	19.667	P_{60}	13.111	K_{60}	11.722
			N_{60}	11.556	P_{90}	9.259	K_{90}	9.704
10.	**Pantnagar**	**Onion 2005-06**	N_{75}	1.0827	P_{25}	0.8520	K_{25}	0.0613
			N_{100}	1.1080	P_{50}	1.4080	K_{50}	0.6540
			N_{125}	0.7784	P_{75}	0.3227	K_{75}	0.3142
		Garlic 2005-06	N_{75}	0.304	P_{25}	-0.673	K_{25}	0.565
			N_{100}	0.189	P_{50}	-0.085	K_{50}	0.518
			N_{125}	0.030	P_{75}	-0.298	K_{75}	0.272
		Wheat 2005-06	N_{100}	0.066	P_{50}	-0.032	K_{50}	-0.017
			N_{150}	0.067	P_{100}	0.021	K_{100}	0.041
			N_{200}	0.058	P_{150}	0.017	K_{150}	0.011
		Potato 2006-07	N_{100}	0.365	P_{50}	1.235	K_{50}	0.804
			N_{150}	0.395	P_{100}	0.593	K_{100}	0.593
			N_{200}	0.387	P_{150}	0.520	K_{150}	0.301
		Mustard 2006-07	N_{60}	0.027	P_{20}	0.075	K_{20}	0.070
			N_{90}	0.027	P_{40}	0.061	K_{40}	0.061
			N_{120}	0.025	P_{60}	0.032	K_{60}	0.043
11.	**Pusa**	**Rice 2005-06**	N_{50}	7.933	P_{30}	0.000	K_{20}	8.833
			N_{100}	8.633	P_{60}	3.167	K_{40}	2.250
			N_{150}	10.622	P_{90}	4.444	K_{60}	6.167
12.	**Rahuri**	**Garlic 2005-06**	N_{50}	64.733	P_{25}	42.533	K_{25}	53.200
			N_{100}	52.667	P_{50}	47.667	K_{50}	70.000
			N_{200}	30.617	P_{100}	46.667	K_{100}	40.467
13.	**Raipur**	**Sugar-cane 2000-07**	N_{150}	2.189	P_{75}	6.765	K_{60}	10.729
			N_{300}	1.802	P_{150}	3.605	K_{120}	4.506
			N_{450}	1.383	P_{225}	2.514	K_{180}	3.573

सारांश

मृदा परीक्षण और फसल की जरूरत के आधार पर प्रमुख उर्वरक पोषकों यानि नाइट्रोजन, फासफोरस और पोटेशियम की अनकूल मात्रा अर्थात संतुलित उपयोग कृषि के उच्च उत्पादन को अक्षुण बनाए रखने का सर्वाधिक महत्वपूर्ण पहलू है । इसके लिए जरूरी है कि किसी विशिष्ट मृदा फसल जलवायवीय दशाओं में उचित विधि और उचित समय पर उचित अनुपात में उर्वरकों की अनुकूल संतुलित मात्राा डाली जाए। ऐसा करने से उत्पाद अधिक मात्राा में मिलता है, मिट्टी की उर्वरता बनी रहती है और डाले गए उर्वरकों का कुशल और विवेकपूर्ण इस्तेमाल सुनिश्चित होता है । विश्व के किसी भी देश में आमतौर पर और खासकर कृषि समुदाय के लिए अक्षुण कृषि उत्पादन लेने के लिए मृदा की उर्वरता का विकास और परिष्कृत उर्वरक के निर्धारण की बड़ी भारी महत्व है इसलिए मिट्टी में उपलब्ध पोषक तत्व का स्तर जानने के लिए मिट्टी का परीक्षण सटीकता से करना होगा ताकि उर्वरकों की सिफारिश, फसल अनुक्रिया और आर्थिक परिस्थिति के आधार पर की जा सके ।

मृदा परीक्षण बहुमूल्य सूचनाएं प्रदान करते हैं जिनका उपयोग ऐसी दूसरी सूचनाओं के साथ किया जा सकता है जो उर्वरकों की जरूरत का आकलन करने के लिए उपलब्ध हैं ।

भारत ही नहीं विदेशों में भी एक लम्बे अर्से से मृदा परीक्षण फसल अनुक्रिया पर अध्ययन चल रहे हैं । मृदा परीक्षण फसल अनुक्रिया सहसम्बन्ध पर एक अखिल भारतीय समन्वित अनुसंधान परियोजना सन् 1967–68 के दौरान शुरू की गई थी । इस समय मृदा परीक्षण फसल अनुक्रिया सहसम्बन्ध पर एक अखिल भारतीय समन्वित अनुसंधान परियोजना के 17 सहयोगी केन्द्र हैं ।

मृदा परीक्षण फसल अनुक्रिया सहसम्बन्ध पर एक अखिल भारतीय समन्वित अनुसंधान परियोजना के तहत किसी दी हुई परीक्षणात्मक दशाओं में फसलों की अधिकाधिक उपज प्राप्त करने के लिए जरूरी पोषकों की खुराक की गणना हेतु बहु समाश्रयण विधि का उपयोग किया जा सकता है । इसके अलावा इसका उपयोग, स्थिर कारकों जैसे–मूल समीकरण में प्रति इकाई निवेश (उर्वरक) को शामिल कर उर्वरक पोषकों की किफायती खुराक की गणना करने के लिए भी किया जा सकता है । इस विधि में उपज को मृदा पोषक तत्वों, उर्वरक पोषकों, उनकी द्विघाती पद और मिट्टी एवं उर्वरक पोषकों के अन्योन्यकिया पदों के साथ समाश्रयित किया जाता है । इसके लिए निम्न मानदण्डों को पूरा किया जाना चहिए ।

(क) किसी फसल की लाभप्रद उपज का मृदा परीक्षण फसल अनुक्रिया अंशांकन केवल तभी संभव है जब डाले गए पोषकों की अनुक्रिया (ला आफ डिमिनीशिंग रिटर्न) ह्रासमान लाभ के कानून का अनुसरण करे, यानि रैखिकता के आंशिक समाश्रयण गुणांकों (पार्शियल रिग्रेशन कोएफिशिएन्टस) के चिन्हों, पोषकों के द्विघातीय पदों, और उनकी उपलब्ध, मृदा पोषकों के साथ अनुक्रिया, आमतौर पर कमशः धनात्मक, ऋणात्मक और ऋणात्मक (+, –,–) होनी चाहिए ।

(ख) निर्धारण का गुणांक (R^2) उच्च होना चाहिए ।

(ग) आंशिक समाश्रयण गुणांक सांख्यिकी रूप से महत्वपूर्ण (सिर्गानफिकेन्ट) होना चाहिए।

(घ) परीक्षण में पर्याप्त डिजाइन बिन्दु होने चाहिए यानि उपचारों की संख्या मॉडल में चरों की संख्या से कम से कम 2 या अधिक हों ।

मृदा परीक्षण फसल अनुक्रिया परियोजना के आंकड़ों में उक्त मानदण्ड कम ही पूरे होते हैं । ऐसे मामलों में पोषकों के इष्टतम मान या तो निकाले ही नहीं जा सकते या फिर निकाले जा सकते हैं तो ये या तो बहुत ज्यादा होते हैं या बहुत कम ।

उक्त समस्याओं को ध्यान में रखते हुए और आंकड़ों का बेहतर विश्लेषण करने के लिए, उनकी व्याख्या करने के लिए तथा मृदा परीक्षण अंशांकन में सुधार लाने के लिए परियोजना समन्वयक (Project Coordinator) (मृदा परीक्षण फसल अनुकिया) STCR भारतीय मृदा विज्ञान संस्थान, भोपाल औपचारिक रूप से भारतीय कृषि सांख्यिकी अनुसंधान संस्थान, नई दिल्ली के पास सहयोग की अपेक्षा से आए ।

परिणाम स्वरूप ष्मृदा परीक्षण फसल अनुकिया सह–सम्बन्ध पर अखिल भारतीय समन्वित अनुसंधान परियोजना से सम्बंधित परीक्षणों का नियोजन, डिजाइनिंग और विश्लेषणष नामक एक परियोजना 1 मार्च, 2000 से भारतीय कृषि सांख्यिकी अनुसंधान संस्थान में शुरू की गई तथा समाप्ती पर इसकी रिपोर्ट का प्रकाशन 2003 मे किया गया।

इस रिपोर्ट में विभिन्न डिजाइन बिन्दुओं वाली अनेक नई डिज़ाइनों का प्रस्ताव रखा गया था । कुछ ऐसी डिजाइनें भी तैयार की गईं जिनके उपचार संयोजनों में कार्बनिक और अकार्बनिक उर्वरक शामिल हैं । इन डिज़ाइनों मे से एक डिज़ाइन जो (3x3x3) Factorial एवम 24 अभिकल्पना बिन्दुओं पर आधारित है वो एस.टी.सी.आर. परियोजना के 2005 के वार्षिक सम्मेलन मे परीक्षणों के लिए स्वीकृत किया गया। एस.टी.सी.आर. परियोजना के सभी केन्द मे परीक्षण के लिए तथा भारतीय कृषि सांख्यिकी अनुसंधान संस्थान मे उन परीक्षणों के आंकडो का विश्लेषण करने कि सहमति हो गई।

अतः 01 मार्च, 2007 से "मृदा परीक्षण फसल अनुक्रिया सह–सम्बन्ध पर अखिल भारतीय समन्वित अनुसंधान परियोजना से सम्बंधित परीक्षणों का नियोजन, डिजाइनिंग और विश्लेषण" (Planning, designing and analysis of experiments relating to AICRP on Soil Test Crop Response Correlations) नामक एक परियोजना भारतीय कृषि सांख्यिकी अनुसंधान संस्थान में शुरू की गई ।

नई उपचार संरचना (Treatment structure) जिसमें जैविक खाद (Organic manure) और प्रमुख उर्वरक नाइट्रोजन (N) फासफोरस (P) और पोटाश (K) शामिल है एवं 24 अभिकल्पना बिन्दुओं पर आधारित है , AICRP on STCR के सभी केन्द्रों पर परीक्षण हो रहे हैं जिसका सांख्यिकी विश्लेषण भारतीय कृषि सांख्यिकी अनुसंधान संस्थान द्वारा किया जा रहा है।

इस परियोजना के प्रमुख उद्देश्य निम्नानुसार हैं :

1. चल रहे एस.टी.सी.आर. परीक्षणों के आंकड़ों का विश्लेषण करने के लिए पद्धति में सुधार करना ।
2. मृदा परीक्षण फसल अनुक्रिया सह–सम्बन्ध पर अखिल भारतीय समन्वित अनुसंधान परियोजना से सम्बंधित परीक्षणों का नियोजन, डिजाइनिंग और विश्लेषण करना

इस रिपोर्ट में पहले 2 अध्याय प्रस्तावना और साहित्य समीक्षा से सम्बंधित है । तीसरे अध्याय में परियोजना के कार्यप्रणाली पर विचार किया गया है । विश्लेषण के लिए पहले यह देखना अति अवश्यक है कि क्या उर्वरता–प्रवणता (fertility gradient) बनी है या नहीं । इसके लिए प्रसरण विश्लेषण (Analysis of variance) का प्रयोग किया गया जिसमें मृदा में पाई जाने वाली उर्वरक नाइट्रोजन (SN) फासफोरस (SP) और पोटाश (SK) को आश्रित चर (dependent variable) माना गया है और इनका अलग अलग से विश्लेषण किया गया है। तत्पश्चात नीचे दिये गये विभिन्न प्रकार के विश्लेषण किये गये हैं।

(1) N, P, K की मध्यम खुराक मात्रा की अनुकिया (Response) का मूल्यांकन
(2) सहप्रसरक (covariates) SN, SP एवम् SK के साथ और सहप्रसरक के बिना प्रसरण विश्लेषण

(3) अनुक्रिया अन्तरापृष्ठ की फिटिंग, जैविक खादो की विभिन्न मात्रा एवं उनके समस्त सम्मिलित मात्रा पर करना
(4) समाश्रयण समीकरणों (Regression equations)की संभगता (Homogeneity) की जांच करना
(5) स्तब्ध बिन्दु (saddle point) के परिवेश (vicinity) में अनुक्रिया अन्तरापृष्ठ का अन्वेषण करना
(6) उर्वरक पोषको नाइट्रोजन, फासफोरस और पोटेशियम के ईष्टतम मानों का आंकलन
(7) लक्षित उपज समीकरण (Targeted yield equation) विधि द्वारा उर्वरक (fertilizer nutrients) नाइट्रोजन, फासफोरस और पोटेशियम पोषको के ईष्टतम मानों का निर्धारण।

अध्याय 4 में परिणामों और विचारों की व्याख्या की गई है । हांलाकि हमें 16 केन्द्रो से आंकड़े प्राप्त हुए परन्तु उनमें विरोधाभास सम्बन्धी जानकारी के रहते केवल 13 केन्द्रों (कुल लगभग 37 परीक्षणों) के आंकड़ों पर विस्तार से विचार किया गया है ।

संक्षिप्त परिणामों का विवरण नीचे दिया गया है।
यह देखा गया है कि 13 केन्द्रों में से 9 केन्द्रो पर उर्वरता–प्रवणता (fertility gradient) SN, SP और SK के पक्ष में बना है। बाकी केन्द्रों पर SN या SP या SK उर्वरता–प्रवणता के पक्ष का नहीं बना है। जब जैविक खाद की मात्रा (doses) पर विश्लेषण किया गया तो पाया की 6 केन्द्रों पर उर्वरता–प्रवणता ही बनी है।

प्रसरण विश्लेषण (Analysis of variance) से यह पता चला कि Treatment, FYM एवं अनके अन्योन्यक्रिया (interaction) का प्रभाव 6 केन्द्रो पर सार्थक (significant) है। अनेक केन्द्रों पर यह देखा गया है कि केवल अन्योन्योक्रिया का प्रभाव सार्थक नहीं है। परन्तु जब प्रसरण विश्लेषण (Analysis of variance) SN, SP और SK को सहप्रसरक मान कर किया गया तो अधिकांश केन्द्रो पर अन्योन्योक्रिया का प्रभाव भी सार्थक पाया गया और विचरण गुणांक (coefficient of variation) की मात्रा भी अधिक कम पाई गई। पंतनगर केन्द्र पर देखा गया कि चाहे प्रसरण विश्लेषण हो या सहप्रसरण विश्लेषण हो सभी 5 फसलों के लिए Treatment, FYM एवं उनके अन्योन्यक्रिया (interaction) का प्रभाव सार्थक नहीं है।

देखा गया कि जब Treatment, FYM एवं पट्टीयों (Strips) (FYM की मात्रा अनुसार) का प्रसारण विश्लेषण (Analysis of variance) किया गया तो प्रायः सभी केन्द्रो में इनका प्रभाव (effect) सार्थक रहा।

नाइट्रोजन (N) फासफोरस (P) और पोटाश (K) उर्वरकों का इष्टतम मान (optimal doses) के मुल्यांकन के लिए STCR परियोजना उर्वरक समायोजन समीकरण (Fertilizer adjustment equation) विधि का उपयोग करते हैं जब बहु समाश्रयण (Multiple regression) विधि उपयुक्त नहीं होती है। यह समीकरण यद्यपि अच्छे फल दर्शाते है जब अनुवर्तन (follow up trials) किया जाता है , परन्तु यह सांख्यिकी की द्रिष्टी से सही नहीं है।

इसके फलस्वरूप समीकरण (equation) के गुणांक हर वर्ष बदलते रहते है। अतः इस विधि को सांख्यिकी समर्थन देने के लिए इस परियेाजना में एक विधि की खोज की गई लिसमें उर्वरक समायोजन समीकरण (Fertilizer adjustment equation) और अनुक्रिया अन्रापृष्ठ (Response Surface) विधि का समन्वय है।

लक्षित उपज विधि में यह एक मूलभूत पूर्वनिधारण (Basic Assumption) है कि पौधे अपनी उर्वरक नियंत्रित भूमिखण्ड (जहां उर्वरक न डाले गये हों) (control plot) तथा संसाधित भूमिखण्ड (Treated plots) से समान रूप से लेते है। इस हेतु यह सोचा गया कि उर्वरकों नाइट्रोजन (N) फासफोरस

(P) और पोटाश (K) के इष्टतम मान अनुक्रिया अन्तरापृष्ठ विधि (response surface methodology) के द्वारा मूल्यांकन किया जाय और स्तब्ध बिन्दु (Stationary point) के परिवेश (vicinity) में पता लगया जाये। यह विधि तभी उपयोगी है जब स्तब्ध बिन्दु परीक्षण क्षेत्र के भीतर हों। यदि न हो तो भी विहित विश्लेषण (canonical analysis) एवं रिज विश्लेषण द्वारा इसका पता लगया जा सकता है । यदि किसी एक स्थल का मृदा परीक्षणों का मान उपलब्ध हो तो इस विधि से उर्वरकों का इष्टतम मान निकाला जा सकता है। ।

SUMMARY

The balanced application of fertilizer nutrients particularly the major nutrients, N P and K in optimum quantity, based on soil test and crop requirement is one of the most vital aspects for sustaining higher agricultural production. This requires the application of optimally balanced quantity of fertilizers in right proportion through correct method and time of application for a specific soil-crop-climate situation. It ensures increased quantity of produce, maintenance of soil productivity and the most efficient and judicious use of applied fertilizers. Thus in this situation the soil fertility evolution and refined fertilizer prescription for sustained agricultural production is of great importance to any country of the world in general and farming community in particular. Hence the soils have to be tested precisely for their available nutrient status for making fertilizer recommendation based on crop response and economic circumstances.

Soil tests can provide a valuable piece of information and as such should be used in conjunction with such other information that is available for the estimation of fertilizer requirements.

Soil test crop-response studies has been going on for a quite a long period of time both in India and abroad. The All India Coordinated Research Project on Soil Test Crop Response Correlations (STCR) was initiated during the year 1967-68. Currently, STCR project is having 17 cooperating centres.

Earlier, the STCR project used multiple regression approach to calculate the dose of nutrient (s) required to obtain the maximum yield of crops under given set of experimental conditions. It can further be used to calculate the economic dose of fertilizer nutrients by incorporating a constant factor i.e. per unit cost of input (fertilizer) in the original equation. In this approach yield is regressed with soil nutrients, fertilizer nutrients, their quadratic terms and the interaction term of soil and fertilizer nutrients.

For this the following criteria should be fulfilled (Annual report, AICRP on STCR, 1993-98)

(a) Soil test crop response calibration for economic yield of a crop is possible only when the response to added nutrients follow the law of diminishing returns. i.e. the signs of partial regression coefficients of linear, quadratic terms of nutrients and their interaction with available soil nutrients should in general be positive, negative and negative (+,⁻,⁻) respectively.

(b) The coefficient of determination (R^2) should be high.

(c) The partial regression coefficients should be statistically significant.

(d) The experiment should have sufficient design points i.e. the number of treatments should be at least two or more than the number of variables in the model.

The above criterions are seldom fulfilled using multiple regression. In such cases the optimum values of the nutrients cannot be derived or if they could be derived, they are either too high or too low.

Keeping in view of the above problems and for better analysis of data, their interpretation and improvement in soil test calibration, the projector coordinator (STCR) Indian Institute of Soil Science, Bhopal, formally approached IASRI, New Delhi for collaboration. Consequently a project entitled "Planning, designing and analysis of experiments relating to AICRP on soil test crop response correlations" was under taken at IASRI w.e.f.1st march 2000 and its report was published in 2003.

Thereafter in the annual workshop of STCR on 1st January, 2005 at IISS, Bhopal, a new design structure which was suggested in the earlier report, was accepted for experimentation. Since 2005, experiments with new treatment structure involving organic manures and major nutrients N, P and K along, in 24 design points are being conducted at all the centres of AICRP on STCR using the design suggested by the Institute and the data of conducted experiments are being analyzed at IASRI. New Delhi.

As a consequence of that this present project was launched with effect from. 1st March 2007 at IASRI with collaboration of STCR (IISS), Bhopal with the following objectives:

(1) To develop suitable methodology for the analysis of data of past experiments conducted under STCR

(2) To plan, design and analyze the data of experiments relating to AICRP on Soil test crop response correlations (STCR).

In this report, the first two chapters contain introduction and review of literature. In the third chapter the methodology used has been discussed In order to analyze the data, at first, it is examined whether the fertility gradient has been created. For this analysis of variance was carried out using the soil nutrients, SN, SP and SK separately as dependent variables.. Then the following types of analysis were performed:

(1) Evaluation of responses to middle doses of N, P and K, (2) Analysis of variance with and without covariates SN , SP and SK, (3) Fitting of response surfaces at various levels of organic manure and also combined over all levels, (4) Testing of Homogeneity of the regression equations, (5) Exploration of response surface in the vicinity of the stationary point, (6) Estimating the optimal values of N, P and K to be applied and (7) Targeted yield equations.

In chapter four, results of all the analyzed experiments have been presented with interpretation. Although we have received the data from 16 centres but due to pending query for discrepancies, only data of 13 centres (totaling about 37 experiments) have been discussed in detail.

To summarize the results, it is observed that out of 13 centres, the fertility gradient was created in respect of SN, SP and SK over all the field of experimentation in 9 centres. In the remaining centres it is not created for either in respect of SN or SP or SK. While checking the creation of fertility gradient, Organic manure level wise, it was observed that in 6 centres the fertility gradient was created for SN, SP and SK. In the remaining centres, it was not created for either in respect of SN or SP or SK.

When analysis of variance was carried out for Treatment, FYM and their interaction, it was observed that in 6 centres all the effects were significant. In the remaining centres, it was observed that in most of the cases, the interaction effect is not significant. However when Analysis of Covariance was carried out taking the soil available nutrients SN ,SP and SK, it was observed that in most of the cases, the interaction effect was also significant along with considerable reduction in coefficient of variation. In Pantnagar it was observed that for all the 5 crops, the Treatment, FYM and their interaction effects are non-significant for both Analysis of variance as well as Analysis of Covariance..

When analysis of variance was carried out for Treatment, FYM and Strips (within FYM levels), it was observed that at almost all the centres, all the effects were significant. In some cases we find that the effects of the Strips (within FYM levels) were not significant.

To evaluate the optimal doses of N, P and K, the STCR project uses Fertilizer adjustment equations for a fixed targeted yield when multiple regression equations do not provide any solution. The equations thus generated although provide good results at the follow up trials but are not statistically sound. Therefore, there is variation in the coefficients from year to year and so these cannot be pooled. In order to give a statistical backing to the whole process, a method has been worked out at IASRI to get the desired results by combining the method of fertilizer adjustment equations with that of response surface methodology.

The basic assumption in the targeted yield approach is that the plant nutrient uptake from the control plots and treated plots is same. Therefore it was felt that the doses of FN, FP and FK be worked out through Response Surface Methodology by exploring the response surface in the vicinity of stationery point. The stationery point is a point of a maximum, minimum or a saddle point (which neither maximum nor minimum). This method is applicable when the stationery point lies within the experimental region. If it is not within the experimental region, then also it is possible to find out the different combination of doses of FN, FP and FK with the help of canonical analysis of the response surface and ridge analysis.

In this method, the optimal values of N, P and K fertilizer nutrients can be derived if the soil test values for a particular site are available.

The optimal values of the fertilizer nutrients N, P and K obtained by Response Surface Methodology, has been found to be closely related to that obtained by Targeted yield approach(fertilizer adjustment equations) adopted by the STCR project. Thus one could advocate for the adoption of the Targeted yield approach as has been tested by sound statistical system of Response Surface Methodology.

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