“SOIL TEST BASED FERTILIZER RECOMMENDATION WITH INM APPROACH FOR MAIZE-POTATO CROPPING SYSTEM IN *INCEPTISOLS* OF BASTAR PLATEAU OF CHHATTISGARH”

M. Sc. (Ag.) THESIS

by

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DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

COLLEGE OF AGRICULTURE
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"SOIL TEST BASED FERTILIZER RECOMMENDATION WITH INM APPROACH FOR MAIZE-POTATO CROPPING SYSTEM IN *INCEPTISOLS* OF BASTAR PLATEAU OF CHHATTISGARH"

THESIS

Submitted to the

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RAKESH MANDAL

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CERTIFICATE - I

This is to certify that the thesis entitled **"Soil test based fertilizer recommendation with INM approach for maize-potato cropping system in *Inceptisols* of Bastar plateau of Chhattisgarh"** submitted in partial fulfillment of the requirements for the degree of **"MASTER OF SCIENCE IN AGRICULTURE"** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) is a record of the bonafide research work carried out by **Shri RAKESH MANDAL** under my guidance and supervision. The subject of the thesis has been approved by Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published/ published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

Date: (Chairman of the Advisory Committee)

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Chairman	: Dr. G. K. Sharma	____________________
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Member	: Dr. D. Sharma	____________________

CERTIFICATE - II

This is to certify that the thesis entitled **"Soil test based fertilizer recommendation with INM approach for maize-potato cropping system in *Inceptisols* of Bastar plateau of Chhattisgarh"** submitted by **Shri RAKESH MANDAL** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfillment of the requirements for the degree of **M. Sc. (Ag.)** in the Department of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** has been approved by the external examiner and Student's Advisory Committee after oral examination.

20.8.14

Date: **EXTERNAL EXAMINER**

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Head of the Department ________________

Dean/ Dean Faculty ________________

Director of Instructions ________________

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Abbreviations	Full form
@	At the rate of
CG	Chhattisgarh
cm	Centimeter
^0C	Degree Celsius
et al.	and co-worker/and others
EC	Electrical Conductivity
Fig.	Figure
FYM	Farm yard manure
g	Gram
ha^{-1}	Per hectare
i.e.	That is
kg	Kilogram
K	Potassium
m	Meter
mm	milimeter
Mt	Million tonne
Wt.	Weight
N	Nitrogen
OC	Organic carbon
pH	Logarithm of the reciprocal of the H^+ ion activity
ppm	Parts per million
P	Phosphorus
%	Per cent
q	Quintal
RDN	Recommended dose of nitrogen
RDF	Recommended dose of fertilizer
RH	Relative humidity
S. No.	Serial number
t	Tonne
viz	That is to say / in other words
Zn	Zinc

Introduction

CHAPTER-I

INTRODUCTION

Fertilizer is one of the most expensive inputs used in the modern agriculture and has contributed handsomely to the total agriculture turnout of the country since last few decades. Use of right amount of fertilizer is fundamental for farm profitability and environmental protection. Fertilization based on blanket recommendation results in either over use or under use of fertilizers, so balanced fertilization is a must for realizing higher efficiency and economy of fertilizer use. Information on optimum doses of fertilizer for a crop under different soil-climate conditions is necessary to have for efficient fertilizer use. Soil test based fertilizer use plays a vital role in ensuring balanced nutrition to crops and fertilizer schedules should therefore be based on the magnitude of crop response to applied nutrients at different soil fertility levels.

Over past few decades fertilizer consumption in India has increased appreciably. But, it is important to note that Indian agriculture is running at 'net negative nutrient balance' of staggering 8-10 Million tonnes per year (Tandon, 2004) which is set to reach around 15 million tonnes by 2025. Application of fertilizer nutrients by the farmer without information on soil fertility status and nutrient requirement by crop affect soil and crop adversely (Ray *et al.* 2000). Intensive cropping and imbalanced fertilizer application are major causes of depletion of macronutrients like N, P, and K. Considering high costs of fertilizers and adverse effect of its overuse on environment and soil health, proper organic manure-fertilizer recommendations on the basis of soil test values, residual effect and yield targets becomes vital. At such point of time, unique 'targeted yield model' of Ramamoorthy *et al.* (1967) to develop proper manure-fertilizer prescription becomes very useful.

'Targeted yield model' is one of the practical approach for efficient use of fertilizers. Theory of formulating optimum fertilizer recommendations for targeted yields was first given by Troug (1960) which was further modified by Ramamoorthy *et al.* (1967) as 'targeted yield model'. Addition of Integrated Plant Nutrition System (IPNS) to this concept ensures balanced fertilization by application of inorganic and organic sources of nutrients. Use of organics to improve nutrient status, soil properties, enhance nutrient recovery, productivity of crops and optimum biological activities has been successfully demonstrated in recent literature (Gangola *et al.* 2012, Bhatt *et al.* 2012 and Bhaduri and Gautam, 2012). Such recommendations are helpful in maintenance and enhancing soil fertility simultaneously with improving crop production and nutrient use efficiencies.

Fertilizer requirements of different crops vary due to their differential production potential and ability to mine nutrients from native and fertilizer sources. Therefore, the quantity of fertilizer to be applied to crops depends upon the initial nutrient status of the soil and thereby, soil test value need considerable attention. The fertilizer requirement of crop also depends upon the yield targets to be achieved. For achieving a definite yield target of a crop, a definite quantity of nutrients must be applied to the crop and this requirement of nutrients can be calculated by taking into consideration the contribution of native soil available nutrients and applied fertilizer nutrients. This forms the basis for the fertilizer recommendation for targeted yield of crops (Subba Rao and Srivastava, 2001)

Soil testing has been recognized as reliable tools for balanced fertilization and efficient fertilizer management. In many cases, farmers apply very high doses of fertilizers than required particularly N without adequate P and K. Such conditions not only results in crop failures through pest and diseases but also causes soil deterioration and pollution hazards besides increasing input cost. Thus, balanced nutrition after soil testing will enhance the fertilizer use efficiency and help in achieving sustainable economic farming. 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.

Soil test based fertilizer application takes into consideration the fertility status of the soil and ensures balanced fertilizer use. Adopting fertilizer prescription based on the soil test, minimizes the risk of uneconomic use of fertilizer. Soil testing is a prerequisite to know the nutrient imbalances in the soil and apply required amount of nutrients to correct such imbalances and optimize crop nutrition. As a diagnostic tool, the value of soil testing is both general and specific fertilizer recommendation based on soil analysis of a farm holding.

Considering the soil fertility status, crop requirement of nutrients, efficiency of soil and fertilizers and the economic condition of the cultivator, it has now been possible to formulate a yield target oriented fertilizer schedule based on the principle of balanced nutrition of crops. In India, Ramamoorthy *et al*. (1967) established the theoretical basis and experimental proof for the fact that Liebig's law of minimum operates equally well for N, P and K. This forms the basis for fertilizer application for targeted yields.

Among the various methods, fertilizer recommendation based on yield targeted is unique in the sense that this method not only indicate soil test based fertilizer dose but also the level of yield that farmer can hope to achieve if good agronomic practices are followed in raising the crop. This approach can be used not only for individual field situations but a better approximation for planning the requirement of fertilizers on an area basis for a given level of crop production. As such data have been found to be fairly constant for a set of soil plant climate conditions and there exist a significant correlation between nutrient uptake and yield of crops in the normal range of soil fertility and fertilizer application (Velayutham *et al.* 1985). One of the important advantages of this approach is that farmers have the options to relate their resources with a desired level of yield target. Choosing the appropriate target and application of required amount of plant nutrient ensure the most judicious and balance fertilization and also helps to sustain soil productivity and crop production. Target yield concept thus, strikes a balance between fertilizing the crop and fertilizing the soil.

Fertilizer application and yield target chosen can be so manipulated that both high profit from fertilizer investment and maintenance of soil fertility can be achieved (Velayutham, 1979). Target yield approach has been used to formulate fertilizer recommendations across the country (Santhi *et al.* 2004).

Chhattisgarh state is broadly divided in to three agro-climatic zones on the basis of rainfall, temperature, soil type and topography of the land as Northern Hills, Chhattisgarh plains and Bastar plateau. The climate of Chhattisgarh state, in general, and Bastar plateau in particular is sub-humid with an average rainfall of about 1400 mm. There is a considerable soil variability spread over the three agro-climatic zones of Chhattisgarh. Bastar soils are composed of sloppy *Marhan (Entisols)* to heavy soils under *Gabhar* (*Alfisols*) conditions. The soils, as most commonly described are identified locally on account of their occurrence, management and use. The topographical variations have marked influence on regulating hydrological conditions and thereby on pedogenic processes responsible for morphological features as well as physical and chemical properties of the soils. The soils so developed have been classified in to four soil taxonomic orders that widely differ in their production potential and management requirements and broadly classified under the taxonomic orders of *Entisols, Inceptisols, Alfisols* and *Vertisols* and locally known as *Marhan, Tikra* (Upper upland), *Mal* (Lower upland), *Gabhar* respectively. The production of the Bastar plateau zone is still far behind due to less coverage of high yielding variety and fertilizers. The nutrient consumption of the area is very low and may be imbalanced. Hence there is a need to develop soil test based fertilizer application to ensure the balanced fertilization in a sustainable way by using IPNS approach.

Soil test based balanced fertilizer application have been developed for the major crops under various soil types covering Chhattisgarh plains area. However, this information is not available for Bastar plateau zone which covers a large area of the state. The nutrient consumption of this zone is very low (16 kg ha^{-1} N P K) and hence crop productivity is also low. To increase the productivity of this zone, there is an urgent need to generate the information on soil test based balanced fertilizer application with INM approach so that efficient and judicious use of plant nutrients can be used to enhance the crop production.

Maize (*Zea mays* L.) is one of the important crops among cereals and it occupies third position in production next to rice and wheat in the world. Maize is known as ‘King of cereals’ because of its high production potential and wider adaptability in India. It is multipurpose crop, provides food for human, feed for animals and poultry and fodder for livestock. It is a rich source of raw material for the industry where it is being extensively used for the preparation of corn starch, dextrose, corn syrup, corn flakes etc. In India, maize is grown on an area of 8.30 million ha with the grain production of 19.29 million tonnes, with an average productivity of 2324 kg ha^{-1} (Anonymous, 2009). In Chhattisgarh state, maize is grown on an area 186.69 thousand ha with a production of 270.37 thousand tonnes with an average productivity of 1448 kg ha^{-1} (Anonymous, 2010). However, there is a lot of scope to increase the productivity in the state by adopting scientific methods of agronomic package of practices, balanced fertilization through integrated approach.

India is the third largest producer of potato (*Solanum tuberosum* L.) in the world after China and Russia. The area under potato cultivation in India is about 1.86 million hectare with production of 42.33 million tonnes and average productivity of 22.70 t ha^{-1} (Anonymous, 2011). Potato is cultivated in almost all the districts of Chhattisgarh state as a *Rabi* crop and it is also grown at Bastar district in *Kharif* and *Rabi* season. Due to its suitability and high returns, the area of potato is being increased every year and presently this crop is being grown in an area of 0.67 million ha with annual production of 11.35 million tonnes and productivity of 16.8 tonnes per ha in Chhattisgarh state (Anonymous, 2011).

In view of this it may be quite worthy to study on "Soil test based fertilizer recommendation with INM approach for maize-potato cropping system in *Inceptisols* of Bastar plateau of Chhattisgarh" with the following objectives:

1. To study the effect of fertilizer doses and soil test levels on crop response.
2. To estimate the nutrients requirement (N P K) for maize and potato crops.
3. To estimate the uptake recovery percentage of NPK in maize and potato crop.
4. To estimate the soil test, fertilizer and FYM efficiencies for crops under study.
5. To evolve fertilizer prescription equations for crops under study.

Review of Literature

CHAPTER-II

REVIEW OF LITERATURE

Soil testing is widely accepted all over the world as quick and effective means to judge the status of the soil available nutrient. A suitable soil test is the only way for formulating a sound fertilizer program to facilitate balanced nutrition of the crop, efficient nutrient use and better utilization of available natural resources to meet the ever increasing demand of food grains. When the supply of a nutrient become limiting for normal plant growth, its addition in the form of fertilizers is required. The selection of proper rate of plant nutrient addition is influenced by knowledge of nutrient supplying power of the soil and efficiency of fertilizers. A soil tests only a relative and not an absolute measure of a plant nutrient amount that is available to plant root system. It has a meaning only when it is correlated with plant performance.

Fitts and Nelson (1956) defined some of the more important objectives of soil test as grouping of soils into classes for purpose of fertilizer and lime requirement, prediction of the probability of getting a profitable of response to the application of fertilizer nutrients and the determination of specific conditions that may be improved by cultural practices. In view of all this, Kanwar (1971) has referred "Soil testing as the key weapon in the armory of a soil scientist".

The importance of soil testing is aptly stated by Tisdale (1967) as "soil testing is to the art of crop production what the thermometer is to the medical profession". A soil test chemically extracts and measures the elements essential to plant nutrition. It also measure soil acidity or alkalinity through pH. These factors are indicator of requirement, nutrient availability and potential of the soil to produce crops (Tucker and Carter, 1998). It is a proven technology for optimum resources utilization and profitable yield.

A soil test value itself has no real meaning until it is correlated with crop response and interpreted in a proper manner to give fertilizer recommendation. Kanwar (1971) has termed soil test as a gimmick unless it gives a correct appraisal of fertility status and predicts fertilizer required for maximum return or a definite yield goals. Melsted and Peek (1977) stated that soil testing results indicate nothing about the potential of soil to produce or amount of nutrients to be added to achieve a desired yield. The interpretation of test results is carried out by correlating data obtained by analysis of soil samples with known field crop response. The accuracy of interpretation depends on the quality of field research work and response of crop to different soil nutrient levels. Calibration and correlation was used by Welch and Wiese (1973) to express the relationship between the soil test results and nutrient uptake of plant. The term calibration was used to express basic principles of relationship between soil test results and yield responses observed from increasing amounts of nutrient applied. Calibration was defined by Cope and Rouse (1973) as a process by which relation between soil test value and crop yield is obtained.

The next important step after soil sampling is extracting the amount of nutrient available and to select a proper extractant or modify it to suit the specific soil conditions. The amount of nutrient in the extract should be measured with reasonable accuracy and speed, and the amounts extracted should be correlated with growth and response of each crop to that nutrient under various conditions. Chand (1993) also suggested that success of soil testing depends on proper stage of sampling, preparation of samples extraction, calibration and interpretation of the test result in the term of fertilizer recommendation.

Berger (1954) proposed a new approach to fertilizer prescription based on available nutrient status of the soil for specific crop yield goals taking into account the nutritional requirement of crops and the nutrient supply from soil and fertilizer sources. He also reported the values of nutritional requirement of corn, soil and fertilizer efficiencies presented a simple way of calculating fertilizer requirements. Soil testing gives precise and quantitative information about fertilizer use to get maximum return. For the accuracy of soil testing a simple laboratory exercise may become a complicated prescription and effectiveness of test result must be judge from actual field performance (Mahajan *et al*. 1995).

2.1 Regression models

Any method of fitting equations to data may be called regression. Such equations are valuable for at least two purposes: making predictions and judging the strength of relationships. Because they provide a way of empirically identifying how a variable is affected by other variables, regression methods have become essential in a wide range of fields, including the social sciences, agriculture, engineering, medical research and business.

Various mathematical models have been used by several workers to express the manner in which crop responds to added nutrients. The exponential, quadratic and straight line are general mathematical expression used to relate soil nutrient levels to crop growth. Immobile nutrients such as P, K, Ca and Mg that are absorbed by soil and therefore, defuse, migrate and move at such slower rate than the root tips penetrate the soil. Such nutrient can usually be related to growth through either the exponential or quadratic expression. Mobile nutrients such as nitrates and borates that are not adsorbed by the soil and can defuse, migrate and move in and out the soil water at rates much faster than the root tips advance, are more often related to plant growth through straight line function (Melsted and Peek, 1977). However, some workers reported that quadratic model is the most appropriate for describing the yield response of potato to N fertilizer and predicting optimum N dose (Belanger *et al.*, 2000). Cerrato and Blackmer (1990) observed that the quadratic-plus-plateau model best describe the yield responses of corn to N application. The quadratic-plus-plateau is preferable to the quadratic model for predicting N fertilizer requirements of corn (Bullock and Bullock, 1994). Harrell *et al.* (2011) compared three models (linear-plateau, quadratic-plateau, and quadratic) that can potentially be used to describe rice yield response to N fertilization and found similar R^2 values indicated that each model fit the data equally well. The linear-plateau model had a tendency to produce lower estimates of the economical optimum N rate (EONR) while providing high estimates of yield at the EONR which, in turn, produced higher economic returns compared with other models. All models were equally stable with respect to input and output cost changes. The model used to predict EONR and economic estimates should be considered when evaluating published planning budgets supplied by economists to producers.

Polynomial models of various degrees are very useful to relate crop yield with fertilizer nutrient as they allow direct calculation of optimal application rates under a variety of circumstances and the interaction of soil and fertilizer nutrients can also be included. According to Colwell (1978), polynomial model are popular because they are easily fit into the data by standard multiple regression procedure. Further they can be made rigid, enough to smooth out any aberrations or "errors" in data by appropriate choice of scale and degree.

Colwell (1967) has on that a better fitness of data of fertilizer experiments to the quadratic or similar type response function. A general procedure has been described by Colwell and Tisdale (1968) for the estimation of fertilizer using polynomial response function and stressed on the need that all factors that affect yield response to the fertilizer should be too included in the calibration equation. They out lined a statistical procedure for converting soil test measurement of any site into a fertilizer recommendation.

In the curve fitting for the regression function, knowledge of the various conditions in which different type of response curves are obtained is always useful. Dean (1954) showed that curves connecting uptake of nutrient with dose of fertilizer are more likely to show linear relationship than those of yield. More or linear response curves or regression are obtained when the response to the various level of nutrients are plotted in a relative deficiency of a related nutrient as for example the response of Mg levels in the absence of added K.

Ramamoorthy *et al*. (1974); Velayutham and Perumal (1976); Velayutham (1979) and Velayutham *et al*.(1985) have proposed a procedure to establish the relation between soil test values, the added fertilizer dose and crop yields by multiple regression equation using the quadratic model as given below.

$$Y = A \pm b_1SN \pm b_2SN^2 + b_3SP \pm b_4SP^2 \pm b_5SK \pm b_6SK^2 \pm b_7FN \pm b_8FN^2 \pm b_9FP \pm b_{10}FP^2 \pm b_{11}FK \pm b_{12}FK^2 \pm b_{13}\,SNFN \pm b_{14}\,SPFP \pm b_{15}\,SKFK$$

Where, Y is crop yield, A is intercept, b_1 to b_{15} are regression coefficients, S and F are available soil and fertilizer nutrients.

Perrin (1976), Lanzer *et al*. (1981), Lanzer and Paris (1985), and Acekllo-Ogutu *et al*. (1985) have criticized polynomial response model, with a view that such model generally over estimates the optimal fertilizer quantity, particularly in Linear and Plateau type response function and also allow for the nutrient substitution. These authors proposed an alternative crop response function based on the principle of Von Liebig response function. Multiple regression models have been calibrated for predicting pod yield of ground nut through soil and fertilizer nutrients and their interaction (Reddy and Krishnaiah, 1999) and the models were found to have a high and significant predictability value. Similarly, Reddy and Ahmed (2000) conducted maize experiment on soil test crop response (STCR) correlation studies in *Inceptisols* of Andhra Pradesh. Multiple regressions have been calibrated for predicting maize yield through soil and fertilizer nutrients and their interactions. The models were found to have a high and significant predictability value.

2.2 Crop response to added fertilizer and FYM

In general, crop response to added fertilizer N, P, K and FYM depends upon inherent soil nutrient status, crop varieties and soil types. Most of the Indian soils are low in available N, P and organic carbon status and medium to high in available K. Hence, good crop response to added N and P can be observed but due to medium to high K status, response may or may not be observed. The FYM or other organic materials have also response to the crop due to major nutrient content.

Singh *et al.* (1997) studied in field experiment having three fertilization levels of N: P: K i.e. RDF (100:60:80 kg ha^{-1}), 125 and 150 per cent of the RDF with potato as a test crop. The study showed that plant height, stems m^2 and number of tubers m^2, LAI and dry weight of foliage increased with increase in fertilization levels up to 150% of the recommended dose. Similarly, higher dose of P application @ 100 and 150 kg P_2O_5 ha^{-1} favored the growth parameters, such as number of leaves per plant, plant height, ground coverage (%), number of stem per plant and total tuber yield (Debasish *et al.* 2001). Chettri *et al.* (2005) also studied in similar type of work and reported that the application of 125% RDF of NPK gave the highest potato tuber yield (28.18 t ha^{-1}) followed by 75% RDF of NPK fertilizers. Sharma and Sood (2002) studied the effects of N (60, 120 and 180 kg ha^{-1}) and K (0, 75 and 150 kg ha^{-1}) on the yield and quality of potato as well as on the organic carbon status of the soil and reported that the average tuber yield of potato increased with increasing rates of potash.

Jadhav *et al.* (1998) reported from the field experiment with sugarcane (Co-7219) conducted at MAU, Parbhani that cane yield response to the application of fertilizer N was linear up to 400 kg ha^{-1}. Ramesh and Sumansusan (2003) studied the effects of N (0, 165, and 330 kg ha^{-1}), P (82.5 and 165 kg ha^{-1}) and K (0, 82.5, and 165 kg ha^{-1}) on the yield and juice quality of sugarcane (COT1.88322) at CRIDA, Hyderabad. They observed that crop yield increased with increasing rates of N. Both P and K had no significant effects on the yield of crop. Reddy *et al*. (1999) found the increased plant height, number of leaves, grain and fodder yield of maize with increasing levels of nitrogen up to 120 kg N ha^{-1}. Similarly, Yadav *et al.* (2000) reported consistently higher yield of rice and wheat in all the years when complete dose of NPK was applied through fertilizers along with organic manures as compared to control plots.

Kumar and Sharma (2002) reported that the application of 150% of recommended dose of NPK increased the tuber yield which might be attributed to better crop growth i.e. plant height, number and size of tubers. Similarly, Kumar *et al*. (2005) also found enhanced growth parameters, yield attributes and yield of maize and wheat crops when 100% NPK was applied with farmyard manure @ 10 t ha^{-1}.

Sharma and Sood (2002) studied the effects of N (60, 120 and 180 kg/ha) and K (0, 75 and 150 kg/ha) on the yield and quality of potato *cv. Kufri Jyoti*, in a field experiment conducted at Shimla, Himachal Pradesh. The average tuber yield of potato increased with increasing rates of single or combined application of N and potash.

Crop yield was higher with the application of potash, although differences in the values of the parameters measured due to application or non-application of K were not significant.

Nizamuddin *et al.* (2003) reported that the application of NPK fertilizers increase the potato yield significantly (29-110%). The highest % of marketable tubers (87.33) and yield (44.1t ha^{-1}) was obtained when 200:150:75 kg NPK ha^{-1} was applied. Chettri *et al.* (2004) reported that the application of 125% RDF of NPK gave the highest potato tuber yield (28.18 t ha^{-1}) followed by 75% RDF of NPK fertilizers. Laxminarayana and Patiram (2006) reported that the maize yield increased significantly with the graded doses of 14, 29 and 35% with the application of 50, 100 and 150% NPK, respectively. Thus, the results showed that super-optimal doses of fertilizers caused relatively low crop response as compared to optimum doses of NPK.

Varalakshmi *et al.* (2005) concluded that the beneficial effect of combined use of organic manure and fertilizers due to increased nutrient availability through enhanced microbial activity can increase the overall yield of groundnut as compared to other nutrient management practices. These results are in conformity with the findings of Babhulkar *et al.* (2000). They also found highest grain yield (4.28 t ha^{-1}) and straw yield (9.58 t ha^{-1}) of finger millet in the treatment where NPK fertilizers were applied as per the soil test value based recommendations (25:37.5:25 N:P:K kg ha^{-1}+Dolomitic lime stone @ 500 kg ha^{-1}) followed by fertilizers applied as per package of practices (12.5:25:12.5 N:P:K kg ha^{-1}+7.5t FYM ha^{-1}). It might be attributed to the response of finger millet to the residual effect of liming done in the previous year. These results are in agreement with the findings of Anilkumar *et al.* (2003). The higher yields in the treatment of package of practices can be due to the balanced supply of nutrients from inorganic fertilizers and farmyard manure.

Verma *et al*. (2005) reported that fertilizer recommendation based on targeted yield concept were found more precise and dependable up to the yield targets of 5 t ha^{-1} for rice and maize and 4 t ha^{-1} for wheat, respectively .

Singh *et al.* (2007) reported that significant increase in tuber yield was recorded with increase in fertilizer application from lower (50:50:25 NPK kg ha^{-1}) to medium level (100:100:50 NPK kg ha^{-1}). Further increase in fertility levels i.e. 150:150:100 NPK kg ha^{-1} gave only 5.3 % more tuber yield, which was not significantly different from that obtained with the medium fertility level. NPK dose of 100:100:50 kg ha^{-1} were found suitable for getting high yield of potato.

Bose *et al*. (2008) studied the effect of different level of nitrogen (60, 120 and 180 kg ha^{-1}) and potassium (0, 60 and 120 kg ha^{-1}) of potato *cv. Kufri Sinduri*. They observed that increase in nitrogen and potassium levels show significant increase in growth and yield. Najm *et al.* (2010) also reported that maximum tuber yield (36.8 tones ha^{-1}) by the utilization of 150 kg Nitrogen per hectare + 20 tones manure.

Paramasivan *et al*. (2012) reported that the grain and stover yield of maize influenced significantly by various levels of fertilizers. The highest grain and stover yield (7.71 and 14.05 t ha^{-1}) was recorded in treatment that received 250-76-88-7.4 kg N-P-K-Zn ha^{-1}, respectively.

Saranya *et al*. (2012) was conducted an experiment on Vertic Ustropept following Ramamoorthy's Inductive cum targeted yield model to elucidate the relationship between soil test values and response of ashwagandha (*Withania somnifera* (L.) Dunal) to added fertilizers under Integrated Plant Nutrition System (IPNS). Fertilizer prescription equations for ashwagandha and nomograms were formulated based on the equations for a range of soil test values and desired target yield under IPNS. Following IPNS practice (NPK+ FYM @12.5 t ha^{-1}), 40, 24 and 30 kg ha^{-1} of fertilizer N, P_2O_5 and K_2O respectively, could be saved.

More *et al*. (2013) reported significantly highest cane (103.73 t ha^{-1}) and commercial cane sugar yield (15.06 t ha^{-1}) obtained by the application of 75 per cent NPK RD through chemical and 25 per cent NPK RD through organic fertilizer followed by the application of chemical fertilizer applied as per soil test (100.78 and 14.89 t ha^{-1} cane and commercial cane sugar yields respectively). An application of 25 per cent RD through organic + 75 per cent RD through chemical source and fertilizer dose as per soil test + FYM and biofertilizer were found equally effective for getting highest number of millable canes per hectare (91.13\' 000\' ha-1 and 90.88\' 000\' ha^{-1} respectively). However, fertilizer applied either through combination of organic or chemical sources or alone the per cent commercial cane sugar and average cane weight was statistically equal.

The responses to fertilizers were in the order of NPK>NP>N but the degree of response to individual nutrients varied with the locations. The rate of response declined in some places sharply even after few years whereas at some other places the decline was gradual. The decline was more when high yields were obtained continuously for a number of years with high dose of NPK fertilizers, causing a severe drain from the soil of other essential plant nutrients which became limiting factors for crop production (Swarup, 2010).

2.3 N, P and K uptake and nutrient requirement by crop

Sonar *et al.* (1982) revealed that sorghum hybrid CSH-5 grown on *Vertisols* required 3.4, 0.73 and 3.99 kg N, P_2O_5 and K_2O respectively for production of 100 kg grain. Prasad and Prasad (1994b) revealed that 2.0 kg N, 0.48 kg P_2O_5 and 3.81 kg K_2O were required to produce 0.1 t wheat grain based on soil test calibrations.

Rouf and Islam (1983) reported that the N content of maize grain ranged between 1.36 to 1.75 and P content 0.15 to 0.22 per cent, with nitrogen rates from 50 to 200 kg ha^{-1}. Stapleton *et al.* (1983) reported that the under irrigated conditions the relative N uptake was related to fertilizer application and soil nitrate contents. N contents in maize stover were increased by N fertilizer application up to 300 kg ha^{-1}.

Novero *et al.* (1992) found that the high amounts of nitrogen applied were associated with high N concentration in irrigated maize. Potassium concentration in stover increased with increase in N level applied while that of grain was not affected. Thiraporan *et al.* (1992) reported that the concentration of nitrogen in the grains generally increased with increasing nitrogen fertilization. The total uptake of N and P increased up to 160 kg N ha^{-1}. Misra *et al.* (1994) reported that N uptake was higher under 200 kg N ha^{-1} as compared to those with lower doses of nitrogen. Thakur *et al.* (1998) found that the nitrogen uptake by plants increased significantly up to 150 kg N ha^{-1}, whereas N uptake by baby corn recorded significant increase up to 200 kg N ha^{-1}.

Nanjundappa *et al.* (1994) observed that the uptake of potassium by fodder maize (cv. South African tall) increased by applied nitrogen but slightly decreased by potassium fertilizer application. Nitrogen uptake was also increased by ‘N’ fertilizer application upto 225 kg ha^{-1}.

Prasad *et al.* (1998) found that average nutrient requirement for the production of one quintal of wheat grains were 2.01 kg N, 0.54 kg P_2O_5 and 2.63 kg K_2O in *Alfisols*. Reddy *et al.* (1999) estimated the requirement of NPK as 4.5, 0.77 and 3.58 kg ha^{-1}, respectively to produce one quintal of dry chili. The yield targets of 25 to 30 q ha^{-1} were achievable at these rates of NPK application.

Suri and Verma (2000) found that amounts of nutrients needed to produce one quintal of maize and wheat were 2.30 and 2.35 kg N. 0.81 and 0.63 kg P_2O_5 and 1.64 and 1.66 kg K_2O respectively. Sharma and Singh (2000) obtained the basic data as nutrient requirement of N, P_2O_5 and K_2O was 2.57, 0.82 and 2.98 kg for one quintal of wheat grain production, respectively.

Reddy and Ahmed (2000) developed fertilizer adjustment equations for prescribing optimum fertilizer doses for attaining different yield targets. They reported that nutrient requirements (kg t^{-1}) of N, P_2O_5 and K_2O were 0.166, 0.112 and 0.155, respectively for producing one tonne of maize in *Inceptisols* of Andhra Pradesh

Meena *et al.* (2001) reported the nutrient requirement for producing one quintal of onion bulb in *Alfisols* as 0.26 kg N, 0.22 kg P_2O_5 and 0.20 kg K_2O. Similarly Santhi *et al.* (2004) also reported this basic information for sunflower yield in *Inceptisols* of Tamil Nadu. They observed that 0.375 kg N, 0.329 kg P_2O_5 and 0.466 kg K_2O were required to produce one quintal onion yield.

Sharma and Sood (2002) reported that nitrogen content in potato tubers (*cv. Kufri Jyoti*), increased with increasing K (0, 75 and 150 kg/ha) and N (60, 120 and 180 kg/ha) rates up to 120 kg/ha. On the other hand, K content in potato tubers increased with increasing rate of N up to 120 kg/ha and was highest without or with application of 150 kg K/ha. Dry matter and reducing sugar content in potato tubers increased with increasing rates of N up to 120 kg/ha and of potash up to 75 kg/ha. N and K uptake of the crop increased with increasing rates on N and K. tuber N, K and dry matter content were higher with the application of potash, although differences in the values of the parameters measured due to application or non-application of K were not significant.

Anilkumar and Thakur (2004) found that application of 150 per cent recommended fertilizer resulted in higher uptake of nutrients followed by recommended fertilizer + 10 tonnes FYM ha^{-1}. Similar results were also reported by Singh and Sarkar (2001). Verma *et al.* (2004) reported that application of 100% NPK + FYM 10 tones ha^{-1} showed highest values of growth parameters and grain yield of wheat. The balanced and integrated nutrient supply to maize and wheat showed significantly higher uptake of primary nutrients.

Harikrishna *et al.* (2005) observed significantly higher uptake of N, P and K and readily available N when 200% RDN was applied to maize crop and it was on par with 150% RDN. It is interesting to note that nitrogen use efficiency of maize was significantly higher with 150% RDN applied in four split. Sood (2007) results revealed that combined use of organic and inorganic in the ratio of 1:3 significantly increased plant growth parameters, which was reflected in tuber and nutrients uptake.

Singh *et al.* (2005) conducted a field experiment in maize-chickpea cropping system with integrated use of biogas slurry and fertilizers to estimate the fertilizer requirement for specific yield targets in both crops. The N, P and K requirement for 1 tonne of grain yield was 26.6, 4.5 and 25.3 kg for maize and 46.1, 3.9 and 41.1 kg for chickpea, respectively.

Gayathri *et al.* (2008) reported that the highest tuber yield of 56.43 t ha^{-1} was recorded by the application of 225 kg N, 300 kg P_2O_5 and 300 kg K_2O ha^{-1} along with the application of FYM @ 15 t ha^{-1} and Azospirillum @ 2 kg ha^{-1}. Application of 300 kg N, 200 kg P_2O_5 and 300 kg K_2O ha^{-1} has recorded 336.99, 147.95 and 300.24 kg ha^{-1} of total N, P and K uptake, respectively.

Ahmed *et al.* (2009) developed soil test based fertilizer recommendations with or without use of organic manure (FYM). They reported that 1.82 kg N, 0.22 kg P_2O_5

and 2.05 kg K_2O is required to produce one quintal of tomato fruit yield in *Alfisoils* of Andhra Pradesh under irrigated conditions.

Pandey *et al.* (2009) reported that N uptake from 42.1 to 80.0 kg ha^{-1}, P uptake from 9.7 to 16.7 kg ha^{-1} and K uptake from 49.7 82.6 kg ha^{-1} by rice increased with increasing levels of NPK from 0 to 150%. Datta and Singh (2010) reported that with the application of 10 t cattle manure ha^{-1}, nutrient uptake exhibited 1.38-2.36 and 1.76-2.60 times increase in rice-green gram and rice-field pea cropping systems, respectively.

Prasad *et al.* (2010) reported that the maximum uptake of NPK was recorded when 50% N was substituted by FYM in maize (114.6, 23.9 and 125.5 kg ha^{-1}), wheat (99.7, 18.1 and 89.8 kg ha^{-1}) and maize-wheat system (214.3, 42.0 and 215.3 kg ha^{-1}), respectively which was at par with 25% N through FYM+50% through RDF and 100% NPK in both crops. The NPK uptake by maize, wheat and in whole cropping system increased with increase dose of fertilizer. Substitution of 50% N by FYM, exhibited better response in nutrient uptake over chemical fertilizer due to steady supply of nutrients throughout the growing period of crops (Laxminarayana, 2006).

Bajendra *et al.* (2012) reported that the nutrient requirement (kg q^{-1}) of N, P_2O_5 and K_2O were found to be 6.97, 1.42 and 1.04, respectively for producing one quintal of maize yield in Meghalaya. Similarly, 4.06, 1.60 and 2.15 kg q^{-1} N, P_2O_5 and K_2O were required for producing one quintal of rice yield in Meghalaya.

Jadhav et *al.* (2013) reported that the nutrient requirement for producing one quintal of garlic bulb was 1.81, 0.34 and 1.51 kg of N, P_2O_5 and K_2O, respectively under integrated plant nutrition system in *Inceptisols* of Maharashtra. As per the IPNS based fertilizer prescription equation, for obtaining 100 q ha^{-1} bulb yield of garlic on an *Inceptisol* considering the average soil test values of 220, 16 and 350 kg ha^{-1} of available N, P and K, respectively the requirement of fertilizer nutrient was 110, 71 and 69 kg ha^{-1} of N, P_2O_5 and K_2O, respectively along with 10 t FYM ha^{-1}.

2.4 Nutrients Use Efficiency

Nutrients use efficiency refers to the proportion of applied nutrients recovered by the crop. It is commonly expressed as a percentage of fertilizer used by the crop or alternatively in terms of crop yield per unit of fertilizer (e.g. kg grain kg^{-1} of applied nutrient). Fertilizer use efficiency varies widely and usually decreases with increase in fertilizer rates. Nitrogen efficiency based on grain yield rarely exceeds 50 to 60% and can be as low as 20%. First year fertilizer efficiency is normally 10 to 30% for P and 20 to 60% for K, although efficiencies can be greater over the long-term because of the residual properties of these immobile nutrients (Swarup, 2002). However, experimental plots do not accurately reflect the efficiencies obtainable on-farm. Differences in the scale of farming operations and management practices (tillage, seeding, weed and pest control, irrigation, harvesting) usually result in lower nutrient use efficiency. Nitrogan recovery in crops grown by farmers rarely exceed 50% and is often much lower. A review of best available information suggests that the average N recovery efficiency for fields managed by farmers ranges form about 20 to 30% under rainfed conditions and 30 to 40% under irrigated conditions.

Sonar *et al.* (1982) revealed that the contribution for soil available N, P and K was 10.26, 97.26 and 14.85 per cent respectively for sorghum hybrid CSH-5 grown on *Vertisols*. Prasad *et al.* (1998) found that the fertilizer use efficiency were 40.8 per cent for N, 12.3 per cent for P_2O_5 and 64.3 per cent for K_2O and those of soil were 9.5 per cent for N, 32.9 per cent for P_2O_5 and 24.3 per cent for K_2O in *Alfisols.*

Doberman *et al.* (2000) reported that Site Specific Nutrient Management (SSNM) improved the plant uptake of N, P and K by 10-20 per cent and N use efficiency by 40 per cent. Sharma and Singh (2000) obtained the basic data as utilization efficiency of soil available nitrogen, phosphorus and potassium was 25.1, 53.6 and 29.0 per cent while from fertilizer nutrients it was 52.9, 28.1 and 135.6 per cent, respectively.

Reddy and Ahmed (2000) reported that the % nutrient contributions to maize from soil and fertilizers were 10, 50 and 17; and 40, 70 and 105 of N, P and K nutrients, respectively in the *Inceptisols* of Andhra Pradesh.

Meena *et al.* (2001) reported the contributions (%) from soil and fertilizer nutrients were 21.31 and 44.37 for N, 25.38 and 27.71 for P and 5.76 and 48.57 for K, respectively. Similarly Santhi *et al.* (2004) also reported this basic information for sunflower yield in *Inceptisols* of Tamil Nadu. They observed that the contribution of soil and fertilizer nutrients were found to be 14.13 and 38.28 per cent for N, 35.33 and 56.61 per cent for P_2O_5 and 14.33 and 70.03 per cent for K_2O, respectively.

Sharma and Singh (2003) developed fertilizer recommendations for pearl millet (PBH-47) based on target yield approach with and without FYM and observed that in the presence of FYM the efficiency of N, P and K fertilizers enhanced by 11.3, 4 and 33.6 per cent, respectively over its absence. Enhancement in the yield under FYM condition is due to direct contribution of plant nutrients from FYM to the crop growth as well as indirect effect of FYM in improving the physical and chemical properties of soil which enhances the efificiency of utilization of nutrients.

Ahmed and Reddy (2004) studied the effects of FYM (10 t ha^{-1}), N (100, 200 or 300 kg ha^{-1}), P_2O_5 (0, 75 or 150 kg ha^{-1}) and K_2O (0, 75 or 150 kg ha^{-1}) on sugarcane (cv. 87A-298) based on fertility gradient approach in alluvial soil. The contribution N, P_2O_5 and K_2O from soil and fertilizers reached 91.4, 164.7 and 131.9, and 43.2, 70.7 and 209.1%, respectively.FYM contributed 17.8% N, 11.7% P_2O_5 and 23.9% K_2O. Singh *et al.* (2005) reported that grain yields of maize and chickpea increased by application of biogas slurry up to10 t ha^{-1}. In maize the average N, P and K supply from soil was 19, 36 and 18% of $KMnO_4$-N, Olsen P and NH_4OAc-K, respectively, while the values in chickpea were 25, 27 and 17%, respectively.

Ahmed *et al.* (2009) reported the contributions (%) from soil and fertilizer nutrients in an *Alfisoil* to be 26.79 and 11.79 for N, 14.08 and 12.39 for P_2O_5 and 30.30 and 30.08 for K_2O respectively. The per cent contribution from organic manure (FYM @ 10 t/ha) was 8.01, 4.75 and 2.47 for N, P_2O_5 and K_2O nutrients. The response yard stick (kg output/kg input) was found to be 4.15 based on the targeted yield coefficients. The requirements of chemical fertilizers were reduced to 10 to 15% when organic manure (FYM @ 10 t/ha) was used along with chemical fertilizers for achieving targeted yield of (30 and 35 t/ha) of tomato fruit respectively.

Prasad *et al.* (2010) reported that the highest agronomic efficiency (36.7%) was recorded under the treatment consisting of 25% N through FYM + 75% RDF to maize and 100% RDF to wheat respectively followed by the treatment consisting of 50% N through FYM + 50% chemical fertilizers to maize and 75% RDF to wheat. This finding indicates that the combined application of well decomposed organic nutrient source and chemical fertilizers is superior to sole inorganic fertilizer application.

Saranya *et al*. (2012) elucidated the relationship between soil test values and response of ashwagandha (*Withania somnifera* L.) Dunal) to added fertilizers under Integrated Plant Nutrition System (IPNS). Nutrient requirement and contribution from soil, fertilizers and FYM were calculated. The percent contribution from soil, fertilizer and FYM were 19.03, 31.30 and 23.14 for N; 20.26, 17.30 and 6.38 for P_2O_5; 11.08, 62.53 and 30.39 for K_2O.

Jadhav *et al.* (2013) conducted soil test crop response correlation studies to formulate the fertilizer adjustment equations for garlic (Var. G-41) under integrated plant nutrition system on an *Inceptisols* following Ramamoorthy's inductive-cum-targeted yield approach. The per cent contribution from soil and fertilizer nutrients were found to be 36.0 and 76.1 for nitrogen, 70.2 and 21.2 for phosphorus and 11.1 and 152.0 for potassium, respectively. Similarly, the per cent contribution of fertilizers in presence of FYM was 105.1 for nitrogen, 38.0 for phosphorus and 182.0 for potassium. The per cent nutrient contribution of FYM was 26.1 for nitrogen, 15.0 for phosphorus and 22.1 for potassium.

2.5 Soil fertility status

Soil Fertility status is known in terms of soil test values. Soil fertility status, resulting crop response to applied fertilizer nutrients and net return that can be obtained, are the important constituents to be taken into consideration before arriving at any decision on judicious use of fertilizers.

Verma *et al.* (2002) found that prescription based fertilizer recommendation for the yield targets could be integrated with additional 5 t FYM ha^{-1} , would not only increase rice, maize and wheat yields by 4.2 to 5.7 q ha^{-1} but also build up soil fertility in terms of available N, P_2O_5 and K_2O and DTPA extractable micronutrients.

Subehia *et al.* (2005) reported that the addition of FYM or lime along with organic fertilizers, not only sustained higher crop yields, but also improved the soil quality as well. Imbalanced use of inorganic fertilizers on the other hand reduced the crop productivity and deteriorated the soil health in terms of increased soil acidity and high P adsorption. The continuous application of chemical fertilizers decreased the soil pH significantly in all the treatments except in the lime-treated plots. Nitrogen alone (urea) had the most deleterious effect on soil pH. The organic carbon content of the experimental plots increased, in general, due to continuous cropping. Among the available N, P and K, only P showed a significant build up over initial level, except in treatments where in it was not added.

Varalakshmi *et al.* (2005) reported that the available nitrogen, phosphorus and potassium content of soil after the harvest of groundnut and finger millet crops increased significantly over the initial contents. The increase was maximum in the treatment where NPK fertilizers were applied based on soil test values in both the crops. It may be due to sufficient supply of nutrients by applied NPK fertilizers (Rao *et al.* 1987). The highest available nitrogen (356 kg ha^{-1}) content in *Alfisols* after the harvest of finger millet crop was registered with the treatment of package of practices (12.5:25:12.5 N:P:K kg ha^{-1}+7.5t FYM ha^{-1}). In the treatment of package of practices where 100% recommended dose of NPK fertilizer along with 7.5 t FYM ha^{-1} was applied recorded significantly higher available phosphorus content after groundnut (145 kg ha^{-1}), followed by farmer's practice treatment (136 kg ha^{-1}). Similar results were observed with finger millet cropping with the highest available phosphorus recorded (148 kg ha^{-1}) in the treatment of package of practices followed by farmer's practice (139 kg ha^{-1}). These results are in conformity with the findings of Acharya *et al.* (1988). In the treatment where fertilizers were applied as per STCR approach, recorded the highest available potassium content after groundnut (394 kg ha^{-1}) and after finger millet (399 kg ha^{-1}) and it was followed by treatment of package of practices which recorded 378 kg ha^{-1} after groundnut and 382 kg ha^{-1} after finger millet. The increase in available potassium content in treatment STCR approach might be due to the higher amount of potassium applied. Similar results were reported by Jagadeeshwari and Kumaraswamy (2000).

Singh *et al.* (2007) reported that significant increase in tuber yield was recorded with increase in fertilizer application from lower (50:50:25 NPK kg ha^{-1}) to medium level (100:100:50 NPK kg ha^{-1}). Further increase in fertility levels i.e. 150:150:100 NPK kg ha^{-1} gave only 5.3% more tuber yield, which was not significantly different from that obtained with the medium fertility level. NPK dose of 100:100:50 kg ha^{-1} were found suitable for getting high yield of potato.

Sathish *et al.* (2010) reported that INM practices and inclusion of light irrigated crop like maize in summer season to avoid loss due to shortage of water and other constraints, yield, fertility levels and fertilizer use efficiency can be enhanced. Paramasivan *et al.* (2012) reported that the available N, P, K and Zn were significantly enhanced levels of nutrients at post harvest soil with various levels of fertilizers in this soil series.

2.6 Targeted yield approach

Targeted yield approach is the most appropriate method for balance fertilization. Soil test based fertilizer recommendation calibrate on the logic that nutrient requirement of the crop minus nutrient supplied by soil should be the fertilizer needed. It requires estimating the amount of nutrient removed by a crop for a certain yield level and the contribution of nutrient from the soil source, then finally the amount of fertilizer to be added to meet the requirement of crop is calculated considering the efficiency of fertilizer. This approach provides the basis of optimum resources utilization and balance crop nutrient management. Such type of calculation was first reported by Barger (1973). He suggested that three basic parameters i.e.

nutrient requirement, soil efficiency and fertilizer efficiency must be considered for fertilizer prescription. Ramamoorthy *et al.* (1967) in India established the theoretical basis and experimental proof to fertilizer prescription for desired crop yield based on available nutrient status of soil. They showed that the relationship between grain yield and nutrient uptake follow a linear relationship. This implies that for obtaining a given yield, a definite quantity of nutrient must be taken up by the crop. Once this requirement is known for a given yield, the requirement of fertilizer can be estimated taking into account the efficiency of contribution from the soil available nutrients and that from fertilizer nutrients as given below:

$$FN = \frac{NR.Y}{Ef} - \frac{Sn.\ Es}{Ef}$$

Where,

FN	=	Fertilizer required
NR	=	Nutritional requirement
Ef	=	Efficiency of fertilizer
Y	=	Yield target
Sn	=	Soil nutrients and
Es	=	Efficiency of soil nutrients

In this equation it is clear that NR.Y represents a total nutrient uptake needed to produce the yield "Y".

Standford *et al.* (1965) found that sugarcane crop required approximately 0.91 kg N uptake per tonne of net cane produced and that N supply from soil was approximately twice the mineralizable N index (Nm). They proposed that N fertilizer need (Nf) of sugarcane for potential yield (Y) (t ha^{-1}) can be given by a simple relation that can be written as:

$$NF = \frac{0.91Y - 2Nm}{Ef}$$

Where, Ef is efficiency of fertilizer N and Nf and Nm in terms of kg ha^{-1}. A generalized form of above equation was given by Standford (1973) as

$$Nf = \frac{NY - Ns}{Ef}$$

Where, NY is the N uptake by a crop associated with an attainable yield and Ns are the amount of N obtained by crop from soil.

The validity of fertilizer adjustment equation developed by Ramamoorthy *et al.* (1967) has been tested and results suggest that the yield targets can be achieved with $\pm$10 % deviation in most of all situations. Meelu (1979) observed that yield targets of wheat up to 40 quintals per hectare could be obtained with a reasonable certainty and yield deviated more for higher targets limiting the applicability of the concept. Similar observations were also made by (Sonar *et al.* (1984); Dev *et al.* (1985); Verma *et al.* (1987); Singh and Sharma, (1990); Verma and Singh, (1990); Chand (1993); Dhillon (1997); Velayutham (1979) revealed that this approach provided scientific basis for balanced fertilization. The results of various centers have been summarized by Velayutham *et al.* (1985) describing the origin, philosophy and objectives of soil test crop response correlation studies.

Rao and Singh (1991) reported that after maize, available P in 4 and 5 t ha^{-1} targeted yield showed significantly higher build up (+ 12.7 + 20.3 kg ha^{-1}) compared with 2 t ha^{-1}, general recommended dose and the control treatments. Similarly 6 t ha^{-1} general recommended dose and by 5.8 kg ha^{-1} compared with 5 t ha^{-1} target, where as the depletion was observed under 4 t ha^{-1} target yields.

Tamboli *et al.* (1996) reported that pearl millet and wheat given with standard recommended fertilizer rates based on soil analysis or fertilizers calculated from previously determined equations to given targets of 2, 3 or 4 t ha^{-1} of pearl millet and

3.5 t ha^{-1} of wheat. Pearl millet yield targets were achieved within ± 5 percent variation.

Dhillon *et al.* (1997) developed fertilizer prescription models for wheat *(Triticum aestivum),* rice *(Oryza sativa),* pearl millet *(Pennisetum glaucum),* Indian mustard *(Brassica juncea)* and green gram *(Vigna radiata)* on the basis of basic data generated from field experiments conducted in Samana sandy loam and Gulpur loam soils at the Punjab Agricultural University farms in Ludhiana and Gurdaspur. The validity of these fertilizer adjustment equations was tested by conducting yield target trials with these crops for eight years on farmer's fields. The results showed that wheat, rice, pearl millet, Indian mustard, and green gram yield targets were achieved within reasonable limits when the fertilizer was applied on soil test basis (±10% deviation from the target) in the majority of cases, thus establishing the utility of the adjustment equations for recommending soil test based fertilizers to the farmers. Higher output/input ratios obtained for various crops point out higher fertilizer use efficiency when fertilizers were applied on the basis of targeted yield concept.

Tambe and Bhoi (1999) reported that grain and fodder yield of sorghum were greatest with the application of 285:152:176 NPK kg ha^{-1} which was the NPK rate calculated to given targeted yield of 8 t ha^{-1}. An experiment was conducted based on soil test crop response (STCR) approach for recommendation of fertilizer by Reddy *et al.* (1999b) in a sandy clay loam soil (*Entisols*) of Nellore with groundnut (CV Tirupati-1). The results clearly showed that, the fertilizer dose required for specific yield targets are decreasing with increasing soil test values. The requirement of N, P and K fertilizers were 'zero' when the available soil N, P and K test values were 400, 52 and 300 kg ha^{-1} respectively. Suri and Verma (2000) found that the per cent deviation in actual yields obtained from pre-fixed yield targets was within ± 10 per cent up to the yield target of 50 q ha^{-1}in maize and 40 q ha^{-1} in wheat.

Sharma and Singh (2000) reported the fertilizer adjustment equations were obtained from basic data for achieving targeted yield of wheat; FN = 4.86 T - 0.47 SN, FP_2O_5 = 2.92 T - 4.37 SP and FK_2O = 2.20 T - 0.26 SK where, T denote yield target in q ha^{-1}. They conducted a replicated follow-up field,trial at IARI farm and applied the fertilizer dose from targeted yield equations for the soil for achieving the yield target of 42.53 q ha^{-1} of wheat grain was 103, 53 and 43 kg ha^{-1}. The yield obtained by targeted yield treatment was 44.17 q ha^{-1} as against the targeted yield of 42.53 q ha^{-1} with increase of + 3.9 per cent. This revealed that the yield can be achieved within the deviation of $\pm$10 per cent. They concluded that reommendations based on targeted yield approach were more balanced, and helpful in checking soil nutrient mining which is essential for sustainable crop production.

Reddy and Ahmed (2000) Developed the fertilizer adjustment equations and a ready reckoner of optimum fertilizer doses at varying soil test values for attaining a yield target of 4 and 5 t ha^{-1} of maize yield and calibrated based on the targeted yield concept. Field verification trials were conducted in the farmers' fields of Karimnagar district and the targeted yields could be successfully achieved. The targeted yield equations and the fertilizer ready reckoner developed for maize grown in *Inceptisols* are useful for large-scale recommendation by the soil testing laboratory in that district.

Kadlag and Ghodke (2013) tested the validity of fertilizer adjustment equations by conducting nine follow up trials of maize grain at Rahuri, Maharashtra on three soil series of *Entisol* (Viz.Karwali, Rahuri and Akole), three soil series of *Inceptiso*l (Viz. Pather, Beed and Kolyachiwadi) and three soil series of *Vertisol*

(Viz.Targaon, Ambulga and Babulgaon) during *Kharif* of 2010-11. The results revealed that the fertilizer application as per yield target 60, 80 and 100 q ha^{-1} + 10 t ha^{-1} FYM were achieved the targeted yield with (+ 10 %).

Katharine *et al.* (2013) reported, while working on transgenic cotton under drip fertigation on Vertic Ustropept of Tamil Nadu, that the deviation in the achievement of targets aimed was within the range of ± 10 per cent (90 – 110%) proving the validity of the fertilizer prescription equations. Thus the Targeted yield model used to develop fertilizer prescription equations provides a strong basis for soil fertility maintenance consistent with high productivity and efficient nutrient management in "Precision Farming" for sustainable and enduring Agriculture.

Bhaduri and Gautam (2013) studied optimization and validation of targeted yield equation-based Fertilizer doses under INM for wheat in *Tarai* region of Uttarakhand, India. They revealed the highest response and benefit:cost ratio with yield target 4.51/ha +FYM @ 10 1/ha, with a targeted yield variation of -2.78 to +0.9 percent.

Bera *et al.* (2006) tested the validity of the yield target for 7 and 8 t/ha at farmers' fields in Vindhyan alluvial plain to quantify rice (IR-36) production in the context of the variability of soil properties and use of balanced fertilizers based on targeted yield concept. The yields targets varied at less than 10%. The percent achievement of targets aimed at different level was more than 90%, indicating soil test based fertilizer recommendation approach was economically viable within the agro-ecological zone with relatively uniform cropping practices and socio-economic conditions.

Chatterjee *et al.* (2010) conducted verification trial for fertilizer adjustment equations developed for potato in *tarai* belt of Uttarakhand. The variation in yield obtained from the targeted yield ranged from +9.77 to –9.76%. The farmers' practice of fertilizer application and control were least efficient in producing tuber yield of potato. Both the highest cost: benefit and response ratio was found with farmyard manure 10 tonnes/ha + yield target 2000 kg/ha.

Puri and Bhargava (2001) studied the targeted yield equations for schedule of fertilizer rates for specific yield of rice. Using the STCR generated fertilizer equations, follow-up trials were conducted during 1972-96. These oquations can be used precisely within per cent deviation of ±10% from the yield target of 30, 40, and 50 q ha^{-1}. The yard stick value of the pre-set targets for soil test-based applied nutrients were higher compared to the general recommended of nutrients. A significant correlation (r = 0.5261*) was noted between the observed and targeted yield.

Santhi *et al.* (2004) gave the fertilizer adjustment equation for maximum and economical yield of sunflower and showed that the per cent achievement of the targets aimed was more than 90 indicating the validity of the equations for prescribing fertilizer doses for sunflower. Singh *et al.* (2005) reported that the quantitative relationships of fertilizer N, P and K requirement, soil nutrient status and recovery efficiency of added nutrient to achieve a target yield of maize and chickpea were derived from the experiment. The adjustment equations for estimating NPK requirement for maize and chickpea with and without manure application have been developed for fertilizer recommendation in the alluvial soils of Indo-Gangetic plains.

Verma *et al.* (2005) conducted forty one field verification trials maize *(Zea mays* L.), rice *(Oryza sativa* L.*)* and wheat *(Triticum aestivum* L.*)* during 1995-2001 at farmer's fields to ascertain the validity of soil-test based fertilizer prescriptions for achieving specific yield targets in wet temperate zone of Himachal Pradesh, India.

Different fertilizer recommendation methods along with fertilizer doses calculated through fertilizer adjustment equations for varying levels of targeted yields of maize, rice and wheat were evaluated. The fertilizer recommendations based on targeted yield concept were found more precise and dependable up to the yield targets of 5 tonnes ha^{-1} for rice and maize and 4 tonnes ha^{-1} for wheat, respectively.

Kadam and Sonar (2006) reported that, the results of two follow-up trials on onion in Otur (Typic Chromusterts) and Sawargaol series (Vertic Ustropepts) showed that yield targets of 30, 40 and 50 t ha^{-1} were achieved under SSNM practice. The highest yield (53.5 t ha^{-1}) and profit (Rs.90, 300 ha^{-1}) were noticed under 50 t ha^{-1} yield target of onion followed by 40 t ha^{-1} targeted yield treatment. Fertilizer application based on targeted yield approach was found to be superior to as per soil test value.

Deshmukh (2008) reported that, application of higher dose of fertilizer based on SSNM significantly influenced the growth and yield components of chilli. The targeted yield level treatments of 30 q ha^{-1} recorded significantly higher growth and yield characters.

Bajendra *et al*. (2012) reported that the fertilizer adjustment equations and a ready reckoner of optimum fertilizer doses at varying soil test values for attaining yield target of 40 and 50 q ha^{-1} of maize yield have been calibrated based on the targeted yield concept. Using these fertilizer equations, four field experiments with maize were conducted during *Kharif,* 2006 at different locations in farmer's fields. The experiments indicated that it is possible to target the maize yield up to 45 q ha^{-1}. The targeted yield equations and the fertilizer ready reckoner developed for maize grown in Meghalaya are useful for large scale recommendation by the soil testing laboratories of Meghalaya along with fertilizer adjustment equations.

Biradar *et al.* (2013) reported that among the treatments specific nutrients management through fertilizers for targeted yield of 10 t ha^{-1} recorded significantly higher plant height (204.7 cm), number of green leaves $plant^{-1}$ (6.4), leaf area $plant^{-1}$ (4003.3 cm), total dry matter production plant (501.4 g), cob length (20.3 cm) number of grain rows cob^{-1} (20.5), number of grains row^{-1} (41.3), number of grains plant-1 (891.2) test weight (32.9 g), grain yield (9.77t ha^{-1}) and Stover yield (11.25 t ha^{-1}) as compared to other treatments

Fertilizer adjustment equations based on soil test have been formulated for different crops under varying soil and climatic condition and widely reported in literature. (Patil *et al.* 1997 ; Sonar *et al.* 1987; Tamboli *et al.* 1996; Selva Kumari *et al.* 1997; Sharma *et al.* 2000; Arya , 2003 ; Ahmed *et al.* 2003).

Materials and Methods

CHAPTER – III

MATERIALS AND METHODS

This chapter deals with the description of the materials used and the methods or techniques adopted during the course of investigation.

3.1 Experimental site

Field experiments were conducted at the Research Farm of Shaheed Gundadhoor College of Agriculture and Research Station Kumhrawand, Jagdalpur, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during *Kharif and Rabi* season (2013-14) for investigation on soil test crop response correlation for N, P, K and FYM in order to evolve, "Soil test based fertilizer recommendation with INM approach for maize-potato cropping system in *Inceptisols* of Bastar plateau of Chhattisgarh."

3.2 Geographical situation

Bastar is situated in between $17^0 46'$ to $20^0 34'$ North latitude and $80^0 15'$ to $82^0 15'$ East longitude with altitude ranging from 550-760 m above mean sea level. The area is under forest and natural vegetative cover and occurs on gently sloping subdued plateaus, as well as on upper and lower piedmonts with different physiographic settings.

3.3 Climatic and weather condition

Bastar plateau is one of the three agro-climatic zones of the Chhattisgarh which comes under sub-humid climatic condition. The normal average annual rainfall of the area is 1440 mm but its distribution is very erratic. Major amount of precipitation occurs between June and September (about 3-4 Months).The hottest and coolest months are May and December, respectively. The detail weekly meteorological data recorded from meteorological observatory during the crops period presented in Fig. 3.1.

3.4 Soil characteristics

The soil of the experimental field comes under the soil order of *Inceptisols*. This soil is locally known as *Tikra*. It is considered to be immature soil with poor soil profile features having light texture sandy clay loam, red to yellow in color, acidic in reaction due to heavy rainfall and undulated land situation. Some physico-chemical properties of experimental soil are presented in Table 3.1.

Table 3.1: Physico-chemical properties of soil of experimental

Properties	**Rating/value**
pH (1:2.5)	6.0- 6.5
EC (dSm^{-1})	0.09
CEC (C mol (p^{+}) kg^{-1})	18.4
Organic C (g kg^{-1})	6.8
Alkaline $KMnO_4$-N (kg ha^{-1})	214
Bray's P (kg ha^{-1})	20.75
Neutral Normal NH_4-Ac. Extractable -K (kg ha^{-1})	245
Available Zn (ppm)	1.00
Available Cu (ppm)	1.79
Available Mn (ppm)	33.42

Available Fe (ppm)	32.51
Mechanical analysis	
Sand (%)	65.18
Silt (%)	10.81
Clay (%)	23.90
Textural class	Sandy clay loam

3.5 Experimental technique

A special field technique developed by Ramamoorthy *et al.*,(1967) was used for this study. Prior to conduct the experiment, a fertility gradient was already created during prevous seasson (2012-13) by growing sorghum crop applying the graded dose of NPK fertilizer for obtaining the appropriate variation in soil fertility in different strips. The field was divided in to three equal long strips (48.5 m × 14.5 m) and was denoted as L_0, L_1 and L_2. Variation in soil fertility with respect to N, P and K were created by applying 150-100-100, and 300-200-200 kg ha^{-1} of N, P_2O_5 and K_2O respectively in L_1 and L_2 strip respectively, keeping L_0 strip as unfertilized (control).The main complex experiment with maize during kharif and potato during rabi seasson was taken during 2013-14. Each fertiility strip was devided into 3 equal size for 3 level of FYM (0, 5, and 10 t h^{-1} denoted as F_0, F_5, and F_{10}) treated as blocks. The 24 selected fertilizer treatments constituted 4 levels of N(0, 60, 120,180, kg h^{-1}), P_2O_5 (0, 30, 60,90 kg h^{-1}), and K_2O (0, 30, 60,90 kg h^{-1}) in maiz during *Kharif* and the same dose applied in potato during *Rabi* seasson, 2013-14. This treatments were established in each block of the strips having treatments in each block. Plot- wise soil samples (0-15 cm depth) were collected befor application of fertilizers and FYM treatments for each seasson.

3.5.1 Technical Programme of Work

Field experiments in *Inceptisols* was conducted during *Kharif* season, 2013 with maize and *Rabi* season, 2013-14 with potato crop with the following treatments and other information.

3.5.1.1General information:

Location : S.G. College of Agriculture and Research Station, Jagdalpur (C.G.)

Land situation : Midland

Soil type : *Inceptisols*

Season : Kharif -2013 and Rabi -2013-14

Crop : Maize and Potato

Varieties : Maize (Hybrid) –*Dhanya (5052)* and Potato-*Kufri pukhraj*

Experimental area: Net plot size 8.0 m X 4.0 m = 32 sq. m, Channel= 1.5 & 1.0

Spacing : Maize- row to row=60 cm, plant to plant=40 cm

: Potato- row to row=50 cm, plant to plant=20 cm

Date of sowing : Maize-26 Jun 2013; Potato: 9th December 2013

Date of harvesting: Maize- 4th November 2013 and Potato - 23th Mar 2014

Total No. of plots : 72

3.5.1.2 Statistical design

1. Experimental Design: Re-inforced Resolvable Block Design.

2. Replication: 3 ($L_{2;}$ $L_1$and L_0 fertility strips)

3. Number of Blocks within replication: 3 (F_{10}; F_5; and F_0) (Total no. of block: 9)

4. Total number of treatment combinations per block: 8 (7+1 Control)

5. Replication of treatment combinations: 3

6. Replication of control treatment: 9

7. Total number of treatments: 21+ 3 Control

3.5.1.3 Fertilizers and FYM Details for Maize (*Zea mays* L) and Potato (*Solenum tuberosum* L)

N levels: 4 (0, 60, 120 and 180 kg ha $^{-1}$)

P levels: 4 (0, 30, 60 and 90 kg ha^{-1})

K levels: 4 (0, 30, 60 and 90 kg ha^{-1})

FYM Levels: 3 (0, 5 10and t ha^{-1})

3.5.1.4 Lay- out plan for maize –potato crops in *Inceptisols* during *Kharif and Rabi* 2013-14 at SGCARS Jagdalpur, Bastar (C.G.)

Treatments details : 21+ 3 controls

A	B	C
T1 120:90:90	T3 00:00:00	T5 120:60:90
T2 180:90:90	T4 120:90:60	T6 120:00:60
T7 00:00:00	T9 180:30:30	T11180:60:30
T8 00:60:60	T10 180:60:60	T12 00:00:00
T13 180:90:30	T15120: 30:60	T17 60:60:30
T14 180:90:60	T16 60:60:60	T18 60:30:30
T19 60:30:60	T21 120:60:00	T23 120:30:30
T20 180:60:90	T22 120:60:60	T24 120:60:30

Selected treatment combinations of N, P and K would be taken as per the norms of AICRIP on STCR, the level of FYM 0, 5 and 10 ton ha^{-1} accommodated in such a way that all treatments are super imposed over levels of three fertility strips and treatments of organic manure-FYM (as per approved layout).

3.6 Analysis work to be done:

1) Soil analysis:

(i) Available N, P and K and micro nutrient analysis (Zn, Cu, Fe and \Mn)

2) Plant analysis:

(i) N, P, K. uptake by maize and potato crop.

3) N, P, K. content of FYM applied in experiment

3.7 Observations recorded for each crop

Grain and straw yields of maize and tuber and straw yield of potato plot wise taken after harvest.

3.8 Soil parameter

Soil samples at 0–0.15 m depth were collected from each plot before sowing of test crop (Maize and Potato) in *Khari* and *Rabi* season, dried and passed through 2 mm sieve and analyzed for physicochemical characteristics as described by *Jackson* (1973).

3.8.1 pH

Soil pH was determined in 1:2.5 soil- water suspensions after stirring for 30 minutes, by glass electrode pH meter as suggested by Piper (1966).

3.8.2 Electrical Conductivity

The sample soil used for pH determination was allowed to settle down for four hours then conductivity of supernatant liquid was determined by Solu-bridge as described by Black (1965).

3.8.3 Cation Exchange Capacity

The cation exchange capacity was determined by leaching the soil with neutral normal ammonium acetate as described by Black (1965).

3.8.4 Organic carbon

Organic carbon was determined by Walkley and Black's rapid titration method (1934) as described by Piper (1966).

3.8.5 Available nitrogen

Available N was determined by alkaline permanganate method as suggested by Subbiah and Asija (1956).

3.8.6 Available phosphorus

Available soil P was extracted by 0.03 *N* NH_4F and 0.025 *N* HCl phosphorus in the extract was determined by ascorbic acid method for - acidic soils (Bray, 1948).

3.8.7 Available potassium

Soil potassium was extracted by neutral normal ammonium acetate (Hanway and Heidal, 1952) and determined with the help of flame photometer as described by Muhr *et al*. (1965).

3.9 Mechanical analysis

The mechanical analysis of soil was carried out by International Pipette Method as described by Piper (1966).

3.10 Analysis of micronutrients: Zn, Cu, Mn, Fe

Soil metallic cations Zn, Cu, Mn, Fe was extracted by DTPA (Diethylene triamine pentaacitic acid) given by Lindsay and Norvell (1978). The extract is determined by on an Atomic Absorption Spectrophotometer (AAS).

3.11 Plant Analysis

Air dried Plant samples were grinded and used for analysis.

3.11.1 Nitrogen

Nitrogen content of plant samples was determined using method as described by Chapman and Pratt (1961). 0.25 g uniform prepared plant sample was taken in digestion tube. Salt mixture (K_2SO_4 and $CuSO_4.5H_2O$ in the ratio of 10:1) was added in the tube. 5 ml. of concentrated H_2SO_4 acid was added and material was digested at 350 ^{0}C in digestion block till the material becomes colorless. Then the nitrogen in digested material was distilled by automatic KEL plus system.

3.11.2 Phosphorus and Potassium

One gram of dried plant samples was taken in digestion tube and add 10 ml of tri acid mixture (Concentrated HNO_3, H_2SO_4 and $HClO_4$ in the ratio of 9:4:1) The material was digested at 150 ^{0}C in KEL plus digestion block till the material become colorless. The digested material was transferred in to 100 ml volumetric flasks by repeated washing with distilled water and made up the volume up to the mark. This digested material was used for the estimation of P and K content analysis as given below:

3.11.2.1 Phosphorus

Phosphorus content was determined by vanadomolybdo-phosphoric acid yellow color complex method as described by Jackson (1973) - An aliquot of 10 ml. was taken, 10 ml. of vanado-molebdate yellow reagent was added and volume was made up to 50 ml. After half an hour color intensity was measured by Spectrophotometer.

3.11.2.2 Potassium

Potassium content was determined by flame photometer as described by Chapman and Pratt (1961) - An aliquot of 5 ml. was taken and made up to volume of 25 ml. in volumetric flask and potassium content was determined by flame photometer.

3.12. Calculation of basic parameters

3.12.1. Nutrient requirement (NR)

a) Kg N required per quintal grain production

$$= \frac{\text{Uptake of N in kg ha}^{-1}\text{ from grain + straw}}{\text{Grain yield in q ha}^{-1}}$$

b) Kg P_2O_5 required per quintal grain production

$$= \frac{\text{Uptake of } P_2O_5 \text{ in kg ha}^{-1}\text{ from grain + straw}}{\text{Grain yield in q ha}^{-1}}$$

c) Kg K_2O required per quintal grain production

$$= \frac{\text{Uptake of } K_2O \text{ in kg ha}^{-1}\text{ from grain + straw}}{\text{Grain yield in q ha}^{-1}}$$

3.12.2 Per cent nutrient contribution from soil to total nutrient uptake (Es)

a) Per cent contribution of N from soil

$$\text{Per cent contribution of N from soil} = \frac{\text{Uptake of N (kg ha}^{-1}\text{) from grain + straw from control plot}}{\text{Soil test value for available N(kg ha}^{-1}\text{) from control plot}} \times 100$$

b) Per cent contribution of P_2O_5 from soil

$$\text{Per cent contribution of } P_2O_5 \text{ from soil} = \frac{\text{Uptake of } P_2O_5 \text{ (kg ha}^{-1}\text{) from grain + straw from Control plot}}{\text{Soil test value for available } P_2O_5 \text{ (kg ha}^{-1}\text{) from control plot}} \times 100$$

c) Per cent contribution of K_2O from soil

$$\text{Per cent contribution of } K_2O \text{ from soil} = \frac{\text{Uptake of } K_2O \text{ (kg ha}^{-1}\text{) from grain + straw from Control plot}}{\text{Soil test value for available } K_2O \text{ (kg ha}^{-1}\text{) from control plot}} \times 100$$

3.12.3 Per cent nutrient contribution from fertilizer to total uptake (Ef)

(a) Per cent contribution of N fertilizer from fertilizer

$$= \frac{\left(\begin{array}{l}\text{Uptake of} \\ \text{N in kg ha}^{-1} \\ \text{from grain} \\ \text{+ straw}\end{array}\right) - \left(\begin{array}{l}\text{Soil test} \\ \text{value for} \\ \text{available} \\ \text{N (kg ha}^{-1}\text{)}\end{array} \times \begin{array}{l}\text{Per cent} \\ \text{contribution} \\ \text{of N from} \\ \text{soil /100}\end{array}\right)}{\text{Fertilizer N applied in kg ha}^{-1}} \times 100$$

(b) Per cent contribution of P_2O_5 from fertilizer

$$= \frac{\left(\begin{array}{l}\text{Uptake of } P_2O_5 \\ \text{in kg ha}^{-1} \text{ from} \\ \text{grain + straw}\end{array}\right) - \left(\begin{array}{l}\text{Soil test value} \\ \text{for available} \\ P_2O_5 \text{ (kg ha}^{-1}\text{)}\end{array} \times \begin{array}{l}\text{Per cent} \\ \text{contribution} \\ \text{of } P_2O_5 \text{ from} \\ \text{soil /100}\end{array}\right)}{\text{Fertilizer } P_2O_5 \text{ applied in kg ha}^{-1}} \times 100$$

(c) Per cent contribution of K_2O from fertilizer

$$\text{Per cent contribution of } K_2O \text{ from fertilizer} = \frac{\left(\text{Uptake of } K_2O \text{ in kg ha}^{-1} \text{ from grain + straw}\right) - \left(\text{Soil test value for available } K_2O \text{ (kg ha}^{-1}) \times \text{Per cent contribution of } K_2O \text{ from soil /100}\right)}{\text{Fertilizer } K_2O \text{ applied in kg ha}^{-1}} \times 100$$

3.12.4 Per cent nutrient contribution from FYM to total uptake (E_{FYM})

$$\text{Per cent contribution of Nutrients from FYM } (E_{FYM}) = \frac{\left(\text{Nutrient uptake in Kg ha}^{-1} \text{ from grain + straw from only FYM treated plot} - \text{Nutrient uptake in kg ha}^{-1} \text{ from grain + straw from control plot}\right)}{\text{FYM applied in kg ha}^{-1}} \times 100$$

If uptake or soil test values for phosphorus and potassium are in terms of P and K, then multiply P with 2.29 and K with 1.21 to get P_2O_5 and K_2O, respectively.

3.12.5 Yield targeting equations or fertilizer adjustment equations

The yield targeting equations were calculated from the above parameters as given below:

$$FN = \left(\frac{NR}{Ef} \times Y\right) - \left(\frac{Es}{Ef} \times SN\right) - \left(\frac{E_{FYM}}{Ef} \times FYM \text{ (t ha}^{-1})\right)$$

$$F\,P_2O_5 = \left(\frac{NR}{Ef} \times Y\right) - \left(\frac{Es}{Ef} \times 2.29 \times SP\right) - \left(\frac{E_{FYM}}{Ef} \times FYM \text{ (t ha}^{-1})\right)$$

$$F\,K_2O = \left(\frac{NR}{Ef} \times Y\right) - \left(\frac{Es}{Ef} \times 1.21 \times SK\right) - \left(\frac{E_{FYM}}{Ef} \times FYM \text{ (t ha}^{-1})\right)$$

Where,

FN	=	Fertilizer N (kg ha^{-1})
F P_2O_5	=	Fertilizer P_2O_5 (kg ha^{-1})
F K_2O	=	Fertilizer K_2O (kg ha^{-1})
NR	=	Nutrient requirement of N or P_2O_5 or K_2O kg q^{-1} produce.
Es	=	Per cent contribution from soil
Ef	=	Per cent contribution from fertilizer
E_{FYM}	=	Per cent contribution from FYM
SN	=	Soil test value for available N (kg ha^{-1})
SP	=	Soil test value for available P (kg ha^{-1})
SK	=	Soil test value for available K (kg ha^{-1})
Y	=	Yield target (q ha^{-1})
FYM	=	Farmyard manure (t ha^{-1})

The concept of fertilizer prescription for desired crop yields, based on the available nutrient status, was first enunciated by Troug (1960). In India, Ramamoorthy *et al.* (1967), established the theoretical basis and experimental proof for the Liebig's law of minimum, which operates equally well for N, P or K for wheat, contrary to the belief that it is valid for N alone and not for P and K, which are not expected to follow the percentage sufficiency concept of Mitscherlich and Baule (1961). They showed that the relationship between grain yield and uptake of nutrients was linear. This implies that for obtaining a given yield, a definite quantity of nutrients must be taken up by the plant. Once this is known, the fertilizers that need to be applied can be estimated by taking into account the efficiency of contribution from soil available nutrients and the efficiency of uptake from applied fertilizer nutrients towards total uptake of the nutrient. This forms the basis for fertilizer recommendation for targeted yield of a crop.

3.13 Interpretation of soil test in terms of quantity of fertilizer

Yield targeting equation or fertilizer adjustment equation as prescribed previously derived from the linear response and plateau consideration in the form of equation as given by (Goswami *et al*. 1986, Randhawa and Velayutham, 1982, Velayutham, 1979 and Velayutham *et al*. 1985) as,

$$F = \frac{NR}{Ef} Y - \frac{Es}{Ef} S - \frac{E_{FYM}}{Ef} FYM$$

Considering the basic equations calculation, fertilizer adjustment equations were derived by the STCR software supplied from the All India Coordinated Research Project on Soil Test - Crop Response Correlation, Indian Institute of Soil Science, Bhopal.

3.14 Statistical Analysis

Standard regression procedure was used to relate the soil test and fertilizer with crop yield response. The nutrient requirement, soil and fertilizer efficiencies were estimated with the help of STCR software.

S
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Fig.3.2: Lay out plan for STCR Maize-Potato Expt. in *Inceptisols* during Kharif and Rabi-2013-14 at Jagdalpur

	L2 (4.0 m)			L2 (1.0 m)	L1 (1.5 m)	L1	L1	L1	L0 (1.5 m)	L0	L0	L0
8.0 m	N 120 P 90 K 90 **72**	N 180 P 90 K 90 **66**	N 180 P 60 K 90 **60**	N 0 P 60 K 60 **54**	N 120 P 60 K 0 **48**	N 60 P 60 K 60 **42**	N 0 P 0 K 0 **36**	N 120 P 30 K 60 **30**	N 120 P 60 K 30 **24**	N 60 P 30 K 30 **18**	N 0 P 0 K 0 **12**	N 120 P 0 K 60 **6**
No FYM	N 0 P 0 K 0 **71**	N 180 P 90 K 30 **65**	N 180 P 90 K 60 **59**	N 60 P 30 K 60 **53**	N 120 P 90 K 60 **47**	N 120 P 60 K 60 **41**	N 180 P 60 K 60 **35**	N 180 P 30 K 30 **29**	N 120 P 30 K 30 **23**	N 60 P 60 K 30 **17**	N 180 P 60 K 30 **11**	N 120 P 60 K 90 **5**
FYM 5 t	N 120 P 60 K 90 **70**	N 120 P 0 K 60 **64**	N 60 P 30 K 30 **58**	N 60 P 60 K 30 **52**	N 120 P 90 K 90 **46**	N 180 P 90 K 90 **40**	N 180 P 60 K 90 **34**	N 0 P 0 K 0 **28**	N 120 P 60 K 60 **22**	N 60 P 60 K 60 **16**	N 180 P 60 K 60 **10**	N 120 P 90 K 60 **4**
	N 180 P 60 K 30 **69**	N 120 P 60 K 30 **63**	N 120 P 30 K 30 **57**	N 0 P 0 K 0 **51**	N 0 P 60 K 60 **45**	N 180 P 90 K 60 **39**	N 180 P 90 K 30 **33**	N 60 P 30 K 60 **27**	N 120 P 60 K 0 **21**	N 120 P 30 K 60 **15**	N 180 P 30 K 30 **9**	N 0 P 0 K 0 **3**
FYM 10 t	N 120 P 90 K 60 **68**	N 60 P 60 K 60 **62**	N 120 P 30 K 60 **56**	N 180 P 60 K 60 **50**	N 180 P 60 K 30 **44**	N 120 P 60 K 90 **38**	N 120 P 60 K 30 **32**	N 60 P 60 K 30 **26**	N 180 P 60 K 90 **20**	N 180 P 90 K 60 **14**	N 0 P 60 K 60 **8**	N 180 P 90 K 90 **2**
	N 0 P 0 K 0 **67**	N 180 P 30 K 30 **61**	N 120 P 60 K 60 **55**	N 120 P 60 K 0 **49**	N 120 P 0 K 60 **43**	N 120 P 30 K 30 **37**	N 60 P 30 K 30 **31**	N 0 P 0 K 0 **25**	N 60 P 30 K 60 **19**	N 180 P 90 K 30 **13**	N 0 P 0 K 0 **7**	N 120 P 90 K 90 **1**

Net plot size 8.0 m X 4.0 m = 32 sq.m Channel= 1.5 & 1.0 m **row to row=60cm plant to plant=40 cm** **pond**

Results and Discussion

CHAPTER- IV

RESULT AND DISCUSSION

This chapter presents the results of experiment conducted on "Soil test based fertilizer recommendation with INM approach for maize-potato cropping system in *Inceptisols* of Bastar plateau of Chhattisgarh" at the Research Farm of Shaheed Gundadhoor College of Agriculture and Research Station, Jagdalpur (Chhattisgarh), Indira Gandhi Krishi Vishwavidhyalaya, Raipur (Chhattisgarh) during, *Kharif* and *Rabi* season 2013-14. The results obtained over the season on various parameters are presented and discussed under following heads:

4.1 Soil available nutrients

Soil samples from each plot were taken before conducting the main experiments during *Kharif* season 2013 and *Rabi* season 2013-14 and analyzed for available N, P and K. Tables 4.1 and 4.2 show the range and mean values of available nutrients (N, P and K) during *Kharif* and *Rabi* season 2013-14.

Mean values on soil N ranged from 191-240 and 192-250 kg N during *Kharif* and *Rabi* season, respectively. The level of soil P increased with respect to fertility strips from L_0 to L_2. Average soil P ranged from 6.70 - 40.47 during *Kharif* and 6.20-40.50 kg ha^{-1} during *Rabi s*eason before taking the test crops. Similarly, the mean values of available K status were recorded in the range from 164-317 and 169-320 kg K ha^{-1} before *Kharif* and *Rabi* season, respectively.

The soil test data indicate that available N, P and K varied with different fertility strips although available N and K variations with respect to fertility strip were marginal however, available P variation in different strips were quite marked and it increased across the fertility strips. Gradient with respect to available P was observed clearly due to immobile nature of P and fixed with soil constituents to form insoluble compounds depending on the nature of soil and thus remains in soil. However, there was no gradient created with respect to N and K as the nature of N in soil is very dynamic and its different forms are subjected to losses through leaching, volatilization and de-nitrification. Average K status of the experimental field soil was in medium level and maintainance of its dynamic equilibrium might be the possible reason for almost the same mean soil test K levels in all strips.

Table 4.1: Range and mean values of available N, P and K (kg/ha) before *Kharif* season, 2013 with hybrid maize

Fertility Strips	Minimum	Maximum	Mean	SD	CV (%)
	Alkaline $KMnO_4$–N (kg ha^{-1})				
L_0	191	240	214	11.87	5.55
L_1	191	238	212	13.81	6.51
L_2	193	236	217	10.62	4.89
All strips	191	240	214	12.18	5.69
	Bray's-P (kg ha^{-1})				
L_0	6.70	22.73	14.53	4.75	32.69
L_1	10.11	29.62	19.57	5.33	27.24
L_2	16.03	40.47	28.15	6.26	22.23
All strips	6.70	40.47	20.75	7.83	37.72
	NH_4OAc-K (kg ha^{-1})				
L_0	164	279	205	25.03	12.31
L_1	202	308	253	37.21	14.70
L_2	227	317	276	24.76	8.97
All strips	164	317	245	41.81	17.07

Table 4. 2: Range and mean values of available N, P and K (kg/ha) before *Rabi* season, 2013-14 with potato

Fertility Strips	Minimum	Maximum	Average	SD	CV (%)
	Alkaline $KMnO_4$–N (kg ha^{-1})				
L_0	192	243	214	13.11	6.13
L_1	192	250	220	15.72	7.15
L_2	194	238	221	12.53	5.67
All strips	192	250	218	14.04	6.44
	Bray's-P (kg ha^{-1})				
L_0	6.2	29.4	15.8	6.30	39.87
L_1	8.9	35.7	20.8	7.01	33.70
L_2	15.2	40.5	28.5	6.82	23.93
All strips	6.2	40.5	21.7	8.45	38.94
	NH_4OAc-K (kg ha^{-1})				
L_0	169	285	207	26.95	13.00
L_1	201	315	256	40.56	15.84
L_2	227	320	274	25.65	9.36
All strips	169	320	246	42.20	17.15

4.2 Response of maize and potato crops to added nutrients

The results in Table 4.3 show the range and average values of maize and potato yields in relation to three fertility strips during *Kharif* and *Rabi* seasons 2013-14. The over all maize yields were recorded in the range of 20.81-89.03 q ha^{-1} with an average value of 58.51 q ha^{-1}. There was an increasing trend in the grain yields from

L_0 to L_2 strip. Similarly, the potato yields were recorded in the range from 56.82-205.92 q ha^{-1} with an average yield of 144.59 q ha^{-1}. It was observed that standard deviation (SD) and coefficient of variation (CV%) were higher in L_0 strip and declined under L_1 and L_2 strip in both the crop season with maize and potato indicating thereby that yield variations were higher in L_0 strip due to soil nutrients variation. The increase in maize grain and potato tuber yields with respect to fertility strips may be due to fertility gradient in soil P status from L_0 to L_2.

Table 4.3: Range and mean of grain and tuber yields of maize and potato during *Kharif* and *Rabi* season, 2013-14 in relation to fertility strips.

Fertility Strips	Grain yield (q ha^{-1})			SD	CV %
	Minimum	Maximum	Average		
***Kharif* season, 2013 with hybrid maize (*Dhanya 5052*)**					
L_0	20.81	86.79	54.75	18.61	34.00
L_1	24.70	87.24	58.34	19.08	32.71
L_2	26.70	89.03	62.43	19.39	31.05
All strips	20.81	89.03	58.51	19.03	32.52
***Rabi* season, 2013-14 with potato (*Kufri Pukhraj*)**					
L_0	56.82	205.92	134.18	44.33	33.04
L_1	64.36	201.07	146.29	42.77	29.24
L_2	68.38	204.82	153.31	44.38	28.95
All strips	56.82	205.92	144.59	43.94	30.39

The crop responses to fertilizer N, P, K and FYM have been depicted in Figs. 4.1 to 4.8 which showed that good crop responses to the fertilizer N and P application were observed with maize and potato whereas crop response to K application was less consistent. Crop response to FYM application was not quite marked as shown in Fig 4.4 and 4.8.

The relation of maize and potato yields with different plant nutrients as independent variables were derived by regression analysis to evaluate the yield variations due to various nutrients and presented in the table 4.4. Results indicate that the larger proportion of variation in grain and tuber yields of both the crops was accounted for by N alone. Higher crop responses were attributed to the high N requirement and being a mobile nature of this element, it is accessible to the plant in the root system sorption zone (Ramamoorthy *et al*., 1967). Fertilizer P_2O_5 and K_2O were the next to explained the rest of variations. The P ions react very quickly with soil constituents to form insoluble compounds and are thus rendered immobile in the soil. Further more, the requirement of P nutrient in maize and potato was lower than N. The curvilinear nature of maize and potato yield responses to P application also did not reflect on yield variation due to poor R^2 value as compared to linear relationship. The yield variation due to FYM application was also acounted very poor correlation. However, 89.0 % of the yield variations were estimated due to fertilizer N and P only as reflected in the equation. Curvilinear relation of fertilizer N and P did not reflect on yield variations. Similar trends were also recorded in case of potato yield and plant nutrients relationship.

Table 4.4: Selected regression model to account for yield variation of maize and potato.

S.No.	General regression models for maize	R^2
1	Y = 28.56+ 0.27FN	0.84
2	Y = 35.79+ 0.45FP	0.50
3	Y = 44.04+ 0.31FK	0.22
4	Y = 54.65+ 0.77FYM	0.03
5	Y = 30.50 + 0.20 FN -0.000 FN^2	0.85
6	Y = 34.59 + 0.55 FP -0.001 FP^2	0.51
	Nutrient substitution models for maize	
7	Y = 25.11+ 0.23FN +0.17FP	0.89
8	Y = 25.31 +0.23 FN + 0.17FP – 0.013FK	0.89
9	Y = 21.46 + 0.23FN + 0.17FP – 0.013FK + 0.77FYM	0.92
10	Y = 24.71+ 0.27FN + 0.77FYM	0.87
11	Y = 7.50 + 0.10SN + 0.26FN	0.85
12	Y = 32.37+ 0.23SP + 0.42FP	0.51
	General regression models for potato	
13	Y = 80.31 + 0.597 FN	0.731
14	Y = 85.83 + 1.175 FP	0.634
15	Y = 107.5 + 0.800 FK	0.277
16	Y = 139.3 + 1.042 FYM	0.009
17	Y = 79.03 + 0.650 FN -0.000 FN^2	0.731
18	Y = 78.43 + 1.766 FP - 0.006 FP^2	0.652
	Nutrient substitution models for potato	
19	Y=66.767+0.414FN +0.667 FP	0.866
20	Y=66.252 +0.411 FN +0.653 FP + 0.033 FK	0.867
21	Y=61.039+ 0.411 FN + 0.653 FP + 0.033 FK + 1.043 FYM	0.876
22	Y = 75.10+ 0.59FN + 1.04FYM	0.74
23	Y =47.53 + 0.16 SN +0.57FN	0.73
24	Y = 84.52+ 0.10SP + 1.15FP	0.63

Where, FN, FP and FK are fertilizer N, P_2O_5, and K_2O (Kg ha^{-1}) respectively. FYM is Farm Yard Manure (t ha^{-1}). SN, SP and SK are soil test values (kg h^{-1}) for $KMnO_4$- N, Bray 's P and ammonium acetate extractable K and Y is crop yield.

4.3 Relationship between yield and nutrient uptake

The yield of maize and potato crops were showed the close association with total N, P and K uptake (Table 4.5). This relation was used to estimate the nutrient requirement for maize and potato (Table 4.6). The nutrient requirement (NR) is defined as the amount of nutrient required to produce per unit amount of yield. The nutrient requirement can be given by the regression coefficient (b_1) of yield (Y) and total nutrient uptake (U).

$$\mathbf{Y = b_1 U \quad or\ U = 1/b_1 * Y}$$

Where, $1/ b_1$ gives the NR.

Table 4.5: Relation of maize and potato yield (Y) with total nutrient uptake (U)

Nutrient	Maize		Potato	
	Y = b1 U	**R^2**	**Y = b1 U**	**R^2**
N	Y=0.618 U	0.895	Y = 2.065 UN	0.881
P	Y=3.184 U	0.767	Y = 8.818 UP	0.693
K	Y=0.561 U	0.848	Y = 1.922 UK	0.922

Table 4.6: Nutrient requirement for maize and potato

Nutrient	Nutrient requirement (kg/q)	
	Maize	**Potato**
N	1.65	0.48
P	0.31	0.11
K	1.83	0.52

The amount of nutrients absorbed by the crop decides a definite amount of biomass production. Nutrient requirments for maize and potato crops have been estimated based on conventional and regression methods which are almost similar values and are shown in the Table 4.6. and depicted graphically in Figs. 4.9-4.14 showing a close association between crop yields and nutrient uptake with almost a linear relationship. The amount of nutrient required to produce one quintal of maize grain was found to be 1.65 kg N, 0.31 kg P and 1.83 kg K. Similarly, 0.48 kg N, 0.11 kg P and 0.52 kg K were required to produce one quintal of potato tuber production. The nutrient requirement is also estimated by the conventional method as given below:

$$\text{NR (kg/q)} = \frac{\text{Total Nutrient Uptake (kg/ha)}}{\text{Grain Yield}}$$

This parameter gives better results with the regression methods which is being followed in present study. Several workers have reported the nutrient requirement of different crops at various places. Ramamoorthy *et al.* (1967) reported for wheat crop which required 2.5 kg N, 0.8 kg P_2O_5 and 1.0 kg K_2O for one quintal of grain production. Prasad *et al.* (1981) estimated the nutrient requirement of sugarcane for the production of 1 tonne of cane as 1.71 kg N, 0.18 kg P_2O_5 and 1.80 kg K_2O. Bajendra *et al*. (2012) reported that the nutrient requirement (kg q^{-1}) of N, P_2O_5 and K_2O were found to be 6.97, 1.42 and 1.04, respectively for producing one quintal of maize yield in Meghalaya. Suri and Verma (2000) found that amounts of nutrients needed to produce one quintal of maize and wheat were 2.30 and 2.35 kg N 0.81 and 0.63 kg P_2O_5 and 1.64 and 1.66 kg K_2O, respectively.

4.4 Efficiencies of fertilizer, soil test and FYM

The efficiencies of fertilizer, soil test and FYM were estimated by using the conventional methods with the help of software developed by AICRP on STCR, Indian Institute of Soil Science, Bhopal (MP). The fertilizer efficiencies of N P and K for maize crop were estimated as 39.16, 31.12 and 123.65 per cent, respectively

(Table 4.7). Similarly, the fertilizer efficiencies of N P and K for potato crop were estimated as 32.94, 28.30 and 97.40 per cent, respectively. The efficiencies of soil test for maize were recorded as 24.28 % N, 71.91% P and 27.34% K and that for potato were as 16.42% N, 64.47 %P and 18.33% K. The efficiencies of organic source (FYM) were observed as 14.37, 7.49, 11.95 and 11.09, 5.88, 5.55 per cent N, P and K for maize and potato crops, respectively. The chemical analysis of organics were recorded for NPK @ 0.4: 0.3:0.8 percent, respectively.

Table 4.7: Efficiencies of ferlilizer, soil and FYM for maize and potato.

Parameters	Maize			Potato		
	N	P	K	N	P	K
Fertilizer Efficiency (%) E_f	39.16	31.12	123.65*	32.94	28.30	97.40
Soil Test Efficiency(%) E_s	24.28	71.91	27.34	16.42	64.47	18.33
FYM Efficiency (%) Eorg	14.37	7.49	11.95	11.09	5.88	5.55

It is well known that approximate 2/3rd of the applied fertilizer N lost through leaching, volatilization, de-nitrification and by run-off. Similarly, a large fraction of applied fertilizer P is fixed in soil by reacting with dominant cations present in the soil like Fe, Mn, Ca, Mg etc. High efficiency of applied fertilizer K observed seems to be due to higher uptake of this nutrient as luxury consumption. Soil test efficiencies for N and K were recorded less than fertilizer sources and reverse trend was seen in case of soil test P. Ramamoorthy *et al.* (1967) reported the efficiency of soil N, P and K were 37, 14 and 44.0 per cent, respectively and the efficiency of fertilizer N, P and K were 34, 41 and 36 per cent, respectively. Similarly Santhi *et al.* (2004) reported the contribution of soil and fertilizer nutrients as 14.13 and 38.28 per cent for N, 35.33 and 56.61 per cent for P_2O_5 and 14.33 and 70.03 per cent for K_2O, respectively for onion bulb yield in *Inceptisols* of Tamil Nadu.

4.5 Estimation of fertilizer adjustment equations

Based on the basic parameters *viz.* nutrient requirement, efficiencies of fertilizer, soil test and organic source (FYM), fertilizer adjustment equations were evolved for maize and potato crops to achieve a definite yield goal. The following equations (Table 4.8) were evolved for maize and potato for fertilizer N, P_2O_5 and K_2O.

Table 4.8: Fertilizer adjustment equations

S. No.	Fertilizer adjustment equations	
	Maize	Potato
1	FN = 4.21 Y - 0.62 SN - 0.37 FYM	FN = 1.44 Y - 0.50 SN - 0.34 FYM
2	FP = 1.00 Y - 2.31 SP- 0.24 FYM	FP = 0.39Y - 2.28 SP - 0.21 FYM
3	FK = 1.48 Y - 0.22 SK- 0.10 FYM	FK = 0.53Y - 0.19 SK - 0.06 FYM

Where, FN, FP and FK are fertilizer N, P_2O_5 and K_2O (Kg ha $^{-1}$) respectively. FYM is Farm Yard Manure (t ha^{-1}). SN, SP and SK are soil test values (kg ha^{-1}) for $KMnO_4$ N, Bray 's P and ammonium acetate extractable K and Y is crop yield in q ha^{-1} .

4.6 Ready reckoners chart for fertilizer recommendation for maize and potato

The ready reckoners for maize and potato with the use of 5 tonnes of FYM are shown in Tables 4.9 and 4.10 with ¼ of general state fertilizer recommendation in similar way by replacing of negligible fertilizer requirement which created through fertilizer adjust equation. The application of chemical fertilizer with FYM in integrated manner has beneficial effect by several ways in terms of soil fertility and physical properties improvement and higher fertilizer use efficiencies. It is further evident that the fertilizer requirements decreased with increase in soil test values. Therefore, a slightly lower yield target may be considered for a poor resource farmers to obtain maximum profit per unit cost spent on fertilizer, whereas, a higher yield target for a resourceful farmers who are interested for maximum potential production per unit area. Hence, for maintaining soil fertility, it is necessary to choose appropriate yield targets and fertilizer use practices that achieve the twin objectives of high yield and maintenance of soil fertility.

Thus the targeted yield approach of fertilizer recommendation ensures nutrient balancing to suit the situations involving different yield goals, soil fertility and resources of the farmer (Dev *et al.,* 1985). Several workers have used this approach of fertilizer prescription Patil, (1985); Acharya *et al.* (2001) and Arya, (2003).

Table 4.9: Ready Reckoners for soil test based fertilizer N P_2O_5 and K_2O recommendation of hybrid maize (*Dhanya 5052*) in *Inceptisols* with 5 tonnes of FYM.

Soil Test values (kg/ha)			Yield Target of maize (q/ha)								
			60			70			80		
N	P	K	FN	FP	FK	FN	FP	FK	FN	FP	FK
150	4	200	116	40	30	158	50	44	200	60	59
175	6	225	100	35	24	142	45	39	185	55	54
200	8	250	85	30	19	127	40	33	169	50	48
225	10	275	69	26	13	111	36	28	154	46	43
250	12	300	54	21	10	96	31	22	138	41	37
275	14	325	38	17	10	80	27	17	123	37	32
300	16	350	26	15	10	65	22	10	107	32	26
325	18	375	26	15	10	49	17	10	92	27	21
350	20	400	26	15	10	26	15	10	76	23	15
375	22	425	26	15	10	26	15	10	60	18	10
400	24	450	26	15	10	26	15	10	45	15	10

Table 4.10: Ready Reckoners for soil test based fertilizer N P_2O_5 and K_2O recommendation of potato (*Kufri Pukhraj*) in *Inceptisols* with 5 tonnes of FYM

Soil Test values (kg/ha)			Yield Target of potato (q/ha)								
			100			150			200		
N	P	K	FN	FP	FK	FN	FP	FK	FN	FP	FK
150	4	200	67	29	25	139	48	41	211	68	68
175	6	225	55	25	25	127	44	37	199	63	63
200	8	250	42	25	25	114	39	32	186	59	58
225	10	275	38	25	25	102	35	27	174	54	54
250	12	300	38	25	25	89	30	25	161	50	49
275	14	325	38	25	25	77	26	25	149	45	44
300	16	350	38	25	25	64	25	25	136	41	39
325	18	375	38	25	25	52	25	25	124	36	35
350	20	400	38	25	25	39	25	25	111	31	30
375	22	425	38	25	25	38	25	25	99	27	25
400	24	450	38	25	25	38	25	25	86	25	25

Summary, Conclusions and Suggestions for Future Work

CHAPTER -V

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH WORK

Experiments were conducted to study, "Soil test based fertilizer recommendation with INM approach for maize-potato cropping system in *Inceptisols* of Bastar plateau of Chhattisgarh" at the Research Farm of Shaheed Gundadhoor College of Agriculture and Research Station, Jagdalpur (Chhattisgarh), under Indira Gandhi Krishi Viswavidyalaya, Raipur, during *Kharif* and *Rabi* season, 2013-14 for maize and potato crops with the following objectives:

1. To study the effect of fertilizer doses and soil test levels on crop response.
2. To estimate the nutrients requirement (N P K) for maize and potato crops.
3. To estimate the uptake recovery percentage of NPK in maize and potato crop.
4. To estimate the soil test, fertilizer and FYM efficiencies for crops under study.
5. To evolve fertilizer prescription equations for crops under study.

A special field technique developed by Ramamoorthy *et al.* (1967) was used for this experiment. The experiment was designed and approved by the Indian Agricultural Statistical Research Institute, New Delhi for calibration of fertilizer, soil test and crop yield to prescribe the fertilizer doses adopted in All India Coordinated Research project on Soil Test Crop Response Correlation. The experiment field was divided into three equal long fertility strip having gradient already created previously and named as L_0 L_1 and L_2. Each strip was divided into 3 block having 0, 5 and 10 t ha^{-1} FYM and hence there were nine blocks in all. Experiment in these three blocks were conducted in a re-inforced resolvable block design; such that the 21 selected treatment combinations of the 4 x 4 x 4 (NPK) was divided in to three groups and each group thus had eight treatment combinations (seven treatment + one control).

Soil samples from each plot were taken before conducting the main experiments during *Kharif* season 2013 and *Rabi* season 2013-14 and analyzed for available N, P and K. Mean values on soil N ranged from 191-240 and 192-250 kg during *Kharif* and *Rabi* season, respectively. The level of soil P increased with respect to fertility strips from L_0 to L_2. Average soil P ranged from 6.70 - 40.47 and 6.20-40.50 kg ha^{-1} during *Kharif* and *Rabi* season before taking the test crops. Similarly, the mean values of available K status were recorded in the range from 164-317 and 169-320 kg K ha^{-1} before *Kharif* and *Rabi* season, respectively. The available N, P and K varied with different fertility strips although available N and K variations with respect to fertility strip were marginal however, available P variation in different strips were quite marked and it increased across the fertility strips. Gradient with respect to available P was observed clearly and there was no gradient created with respect to N and K.

The over all maize yields were recorded in the range of 20.81-89.03 q ha^{-1} with an average value of 58.51 q ha^{-1}. There was an increasing trend in the grain yields from L_0 to L_2 strip. Similarly, the potato yields were recorded in the range from 56.82-205.92 q ha^{-1} with an average yield of 144.59 q ha^{-1}. It was observed that standard deviation (SD) and coefficient of variation (CV%) were higher in L_0 strip and declined under L_1 and L_2 strip in both the crop season with maize and potato indicating thereby that yield variations were higher in L_0 strip due to soil nutrients variation. The increase in maize grain and potato tuber yields with respect to fertility strips may be due to fertility gradient in soil P status from L_0 to L_2.

The good crop responses to the fertilizer N and P application were observed with maize and potato whereas crop response to K application was less consistent. Crop response to FYM application was not quite marked. The relation of maize and potato yields with different plant nutrients as independent variables were indicate that the larger proportion of variation in grain and tuber yields of both the crops was accounted for by N alone. Fertilizer P_2O_5 and K_2O were the next to explained the rest of variations. The curvilinear nature of maize and potato yield responses to P application also did not reflect on yield variation due to poor R^2 value as compared to linear relationship. The yield variation due to FYM application was also acounted very poor correlation. However, 89.0 % of the yield variations were estimated due to fertilizer N and P. Curvilinear relation of fertilizer N and P did not reflect on yield variations. Similar trends were also recorded in case of potato yield and plant nutrients relationship.

The yield of maize and potato crops were showed the close association with total N, P and K uptake. The amount of nutrient required to produce one quintal of maize grain was found to be 1.65 kg N, 0.31 kg P and 1.83 kg K. Similarly, 0.48 kg N, 0.11 kg P and 0.52 kg K were requireed to produce one quintal of tuber production. The nutrinent requirement is also estimated by the conventional method but this parameter gives better results with the regression methods.

The efficiencies of fertilizer, soil test and FYM were estimated by using the conventional methods with the help of software developed by AICRP on STCR, Indian Institute of Soil Science, Bhopal (MP). The fertilizer efficiencies of N P and K for maize crop were estimated as 39.16, 31.12 and 123.65 per cent, respectively. Similarly, the fertilizer efficiencies of N P and K for potato crop were estimated as 32.94, 28.30 and 97.40 per cent, respectively. The efficiencies of soil test for maize were recorded as 24.28 % N, 71.91% P and 27.34% K and that for potato were as 16.42% N, 64.47 %P and 18.33% K. The efficiencies of organic source (FYM) were observed as 14.37, 7.49, 11.95 and 11.09, 5.88, 5.55 per cent N, P and K for maize and potato crops, respectively. The chemical analysis of organics were recorded for NPK @ 0.004: 0.003:0.008 percent, respectively.

Based on the basic parameters *viz.* nutrient requirement, efficiencies of fertilizer, soil test and organic source (FYM), fertilizer adjustment equations were evolved for maize and potato crop to achieve a definite yield goal. The following equations were evolved for maize and potato for fertilizer N, P_2O_5 and K_2O.

Fertilizer adjustment equations

S. No.	Fertilizer adjustment equations	
	Maize	**Potato**
1	FN = 4.21 Y - 0.62 SN - 0.37 FYM	FN = 1.44 Y - 0.50 SN - 0.34 FYM
2	FP = 1.00 Y - 2.31 SP- 0.24 FYM	FP = 0.39Y - 2.28 SP - 0.21 FYM
3	FK = 1.48 Y - 0.22 SK- 0.10 FYM	FK = 0.53Y - 0.19 SK - 0.06 FYM

Where, FN, FP and FK are fertilizer N, P_2O_5 and K_2O (Kg ha $^{-1}$) respectively. FYM is Farm Yard Manure (t ha^{-1}). SN, SP and SK are soil test values (kg ha^{-1}) for $KMnO_4$ N, Bray 's P and ammonium acetate extractable K and Y is crop yield in q ha^{-1} .

The ready reckoners for maize and potato with the use of 5 tonnes of FYM. The application of chemical fertilizer with FYM in integrated manner has beneficial effect by several ways in terms of soil fertility and physical properties improvement and higher fertilizer use efficiencies. It is further evident that the fertilizer requirements decreased with increase in soil test values. Therefore, a slightly lower yield target may be considered for a poor resource farmers to obtain maximum profit per unit cost spent on fertilizer, whereas, a higher yield target for a resourceful farmers who are interested for maximum potential production per unit area. Hence, for maintaining soil fertility, it is necessary to choose appropriate yield targets and fertilizer use practices that achieve the twin objectives of high yield and maintenance of soil fertility.

CONCLUSION:

It can be concluded from the results that maize and potato responded to the application of fertilizer N and P markedly but less response to K application was observed. Crops response to FYM application was not quite marked. The relation of maize and potato yields were accounted by fertilizer N alone followed by P_2O_5 and K_2O. Curvilinear relation of fertilizer N and P did not reflect on yield variations for both crops. Soil test based fertilizer calibration was excercised taking in to the account in relation of yield, uptake, soil test and fertilizer efficiency.

The fertilizer adjustment equations were evolved for maize and potato to achieve a definite yield goal of the crop considering the nutrient present in soil and FYM or other organic sources. Yield targeting equations can be used for similar soils situation with chosen appropriate yield target within yield range of the main complex experiment. Ready reckoners were prepared based on which a balanced nutrition for maize and potato crop can be suggested to the farmers through state soil testing laboratory.

SUGGESTIONS FOR FUTURE RESEARCH WORK:

1. The current study focused to generate the soil test based fertilizer prescription for individual crops. However, fertilizer recommendation based on soil test must be evolved for maize- potato cropping system as a whole using post harvest soil test value which can be overcome the soil analysis.
2. Fertilizer prescription equations should be derived for other dominant crops or cropping system prevailing in the region.
3. The information generated as soil test based fertilizer application with organic source need to be tested on farmer's field in the similar soil situation for its suitability.
4. Fertilizer recommendation based on soil test for maize and potato crop should be derived in other agro-climatic zones having different soil situation.
5. In our country, state soil testing facilities are limited in number, therefore, linking fertilizer equations with soil fertility map is an attractive possibility for transferring soil test technology to the farmers.

Abstract

"Soil test based fertilizer recommendation with INM approach for maize-potato cropping system in *Inceptisols* of Bastar plateau of Chhattisgarh"

by

Rakesh Mandal

ABSTRACT

Field experiments were carried out to study **"Soil test based fertilizer recommendation with INM approach for maize-potato cropping system in *Inceptisols* of Bastar plateau of Chhattisgarh"** during *Kharif* and *Rabi* seasons 2013-14. The objectives of the study were (1) To study the effect of fertilizer doses and soil test levels on crop response (2) To estimate the nutrients requirement (N P K) for maize and potato crops (3) To estimate the uptake recovery percentage of NPK in maize and potato crop (4) To estimate the soil test, fertilizer and FYM efficiencies for crops under study (5) To evolve fertilizer prescription equations for crops under study.

As per the approved lay out, the field was divided into three equal long fertility strips as replications having fertility gradient deliberately created previously and named as L_0, L_1 and L_2. Three equal blocks were created by dividing each strip for applying 0, 5 and 10 t ha^{-1} FYM and hence there were nine blocks in all. These three blocks were further devided into eight equal plots and introduced in a reinforced resolvable block design; such that the 21 selected treatment combinations of the 4 x 4 x 4 (NPK) and 3 control was divided in to three groups and in each group thus had eight treatment combinations (seven treatments + one control).

Before taking the main experiments during *Kharif* and *Rabi* season 2013-14, soil samples from each plot were taken and analyzed for available N, P and K. Mean values on soil N ranged from 191-240 and 192-250 kg N during *Kharif* and *Rabi* season, respectively. The level of soil P increased with respect to fertility strips from L_1 to L_2. Average soil P ranged from 6.70 - 40.47 and 6.20-40.50 kg ha^{-1} in two seasons. Similarly, the mean values of available K status were recorded in the range from 164-317 and 169-320 kg K during *Kharif* and *Rabi* seasons. The available K status did not reflect with respect to fertility strips. The soil test data indicate that soil test N P and K varied with different fertility strips although soil test N variation with respect to fertility strip were marginal however, soil P variation in different strips were quite marked and it increased across the fertilily strips.

The fertilizer N and P application were observed good crop responses with maize and potato whereas crop response to K application was less consistent. Crop response to FYM application was not quite marked. The relation of maize and potato yields with different plant nutrients as independent variables were derived by regression analysis to evaluate the yield variations due to various nutrients. Results indicate that the larger proportion of variation in grain and tuber yields of both the crops was accounted for by N alone. Fertilizer P_2O_5 and K_2O were the next to explained the rest of variations. The curvilinear nature of maize and potato yield responses to P application also did not reflect on yield variation due to poor R^2 value

as compaired to linear relationship. The yield variation due to FYM application was also acounted very poor correlation.

Close relationship were observed between yield of maize and potato with their N, P and K uptake. This relation was used to estimate the nutrient requirement for maize and potato. The amount of nutrient required to produce one quintal of maize grain was found to be 1.65 kg N, 0.31 kg P and 1.83 kg K. Similarly, 0.48 kg N, 0.11 kg P and 0.52 kg K were required for one quintal of potato tuber production. The efficiencies of fertilizer, soil test and FYM were estimated by using the conventional methods with the help of STCR software. The fertilizer efficiencies of N P K were estimated as 39.16, 31.12 and 123.65 and 32.94, 28.30 and 97.40 per cent for maize and potato crops, respectively. The efficiencies of soil test were recorded as 24.28 % N, 71.91% P and 27.34% K for maize and 16.42% N, 64.47 %P and 18.33% K for potato crop. The efficiencies of organic source (FYM) as NPK were observed as 14.37, 7.49, 11.95 and 11.09, 5.88, 5.55 per cent N, P and K for maize and potato crops, respectively.

Based on the above basic parameters, the following fertilizer N, P_2O_5 and K_2O adjustment equations were evolved for maize and potato crops to achieve a definite yield target. Ready reckoners, useful for the soil testing laboratories, were also prepared for soil test based application of fertilizer N, P_2O_5 and K_2O for specific yield targets of maize and potato.

Maize	Potato
FN = 4.21 Y - 0.62 SN - 0.37 FYM	FN = 1.44 Y - 0.50 SN - 0.34 FYM
FP = 1.00 Y - 2.31 SP- 0.24 FYM	FP = 0.39Y - 2.28 SP - 0.21 FYM
FK = 1.48 Y - 0.22 SK- 0.10 FYM	FK = 0.53Y - 0.19 SK - 0.06 FYM

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References

REFERENCES

Acekllo - Ogutu, L., Pairs, Q. and Williams, W. A. 1985. Testing a Von - Liebig crops response function against polynomal specification. *Amer. J. Agri. Econ.,* **67**: 873-880.

Acharya, C. L., Bishnoi, S. K. and Yadhuvanshi, H. S. 1988. Effect of long-term application of fertilizers and organic and inorganic amendments under continuous cropping on soil physical and chemical properties. *Indian Journal of Agricultural Sciences,* **58**: 507-516.

Ahmed, S. R. and Ramprakash, T. 2009. Studies on influence of organic manure in conjunction with inorganic fertilizers in tomato (*Lycopersicon Esculentum* Mill.). *Veg. Sci.* **36**(1): 64-68

Ahmed, S. R. and Reddy, P. V. K. 2004. Influence of organic manure (Farm Yard Manure) in presentation of inorganic fertilizers for different yield target of sugarcane (*Saccharum officinarum* L.) based on soil test crop response correlation. *Cooperative Sugar* **36**(1): 29-36

Ahmed, S. R., Reddy, P. V. K. and Rao, V. M. 2003. Evaluation of soil test crop response correlation studies for sugarcane grown on alluvial soils in Nellor district of Andhra Pradesh. *Co-operative Sugar*, **34**(7):553-557.

Anilkumar and Thakur, K. S. 2004. Effect of integrated nutrient managemet on promising composite maize (*Zea mays* L.) varieties under rainfed mid-hill conditions of Himachal Pradesh. *Indian Journal of Agricultural Sciences*, **74**(1):40-42.

Anilkumar, B. H., Sharanappa, K. T., Krishne, G. and Sudhir, K. 2003. Growth, yield and nutrient uptake as influenced by integrated nutrient management in dryland finger millet. *Mysore J. of Agri. Sci.,* **37**:24-28.

Anonymous, 2008-09. All India Coordinated Research Project on Soil Test Crop Response Correlation. *Annual Progress Report*, IGKV, Raipur Centre.

Anonymous, 2010. Indian Horticulture Database. Ministry of Agriculture, New Delhi.

Anonymous, 2011. Area and production of vegetable crops, Directorate of Horticulture, Raipur. Website- http:// agridept.cg.gov.in/agriculture/ horticulture.htm.

Anonymous, 2011. Indian Horticulture Database 2010. National Horticulture Board, Ministry of Agriculture, Government of India, Gurgaon, India. Website: www.nhb.gov.in.

Arya, V. M. 2003. Fertilizer recommendation based on soil test for rice in *Inceptisol*s and *Vertisols* of C.G. M.Sc. (Ag), Thesis, IGKVV, Raipur (CG), India.

Babhulkar, R. M., Wandile, W. P., Badole and Balpande, S. S. 2000. Residual effect of long term application of FYM and fertilizer on soil properties (*Vertisols*) and yield of soybean. *Journal of the Indian Society of Soil Science,* **48**: 89-92.

Bajendra, Patiram and Singh, L. S. 2012. Soil test based fertilizer recommendation and verification for maize grown in mid hills of Meghalaya. *An Asian Journal of Soil Science,* **7**(1):124-126.

Barger, S. A. 1973. The changing philosophy of soil test interpretation "soil testing and plant analysis (ED)" L.M. walsh. Madison. Wis. *Soil Sci. Soc Amer.*

Belanger, Gilles, Walsh, John R., Richards, John E., Milburn, Paul H. and Ziadi, Noura. 2000. Comparison of Three Statistical Models Describing Potato Yield Response to Nitrogen Fertilizer. Agron. J., **92**:902–908.

Bera, R., Seal, A., Bhattacharyya, P., Das, T. H., Sarkar, D. and Kangjoo, K. 2006. Targeted yield concept and a framework of fertilizer recommendation in irrigated rice domains of subtropical India. *Journal of Zhejiyang University Science B*, 7(12): 963-968.

Berger, K. C., 1954. Soil tests and fertilizer prescription. *Farm Chem.,* **11**(7):47-50.

Bhaduri, D and Gautam, P. 2012. Balanced use of fertilizers and FYM to enhance nutrient recovery and productivity of wheat (*Triticum aestivum* cv UP-2832) in Mollisol of Uttarakhand. International Journal of Agriculture, Environment and Biotechnology **5**: 435-439.

Bhaduri, D and Gautam, P. 2013.Optimization and Validation of Targeted Yield Equation-based Fertiuzer Doses under INM for Wheat in Tarairegion of Uttarakhand, India. *Indian Journal of Agricultural Research*, **47**(1): 16-25

Bhatt, B., Chandra, R. and ShriRam 2012. Long-term application of fertilizer and manure on rice productivity and soil biological properties. International Journal of Agriculture Environment and Biotechnology **5**: 429-433.

Biradar, Ashok, Jayadeva, H. M., Shankaralingappa, B. C. and Vishwanath, A. P. (2013).Growth and Yield of Maize and Nutrient Balance in Soil as Influenced by Targeted Yield Approach. *J. Agric. Res. Technol.*, **38** (3): 348-352

Black, C. A. 1965. Methods of Soil Analysis. Amer. Soc. of Agro. Inc. Publ. Madison, Wisconsin, USA.

Bose, U. S., Bisen, A. and Nayak, S. 2008. Effect of different levels of nitrogen and potassium on growth and yield of potato (*Solanum tuberosum* L.).*Green Farming,* **2**(1):16-17.

Bray, R. H. 1948. Requirements for successful soil test. *Soil Science,* **66:**83-89.

Bullock, Donald G. and Bullock, David S. 1994.Quadratic and Quadratic-Plus-Plateau Models for Predicting Optimal Nitrogen Rate of Corn: A Comparison. *AGRON. J.*; **86**(1): 191-195

Cerrato, M. E. and Blackmer, A. M. 1990. Comparison of Models for Describing; Corn Yield Response to Nitrogen Fertilizer. *AGRON J.*, **82**(1):138-143

Chand, M. 1993. Soil test crop response correlation studies for efficient management of nutrients under intensive agriculture, In: *Annual Report STCR- 1993-98 IISS Bulletin*, pp. 79-82.

Chapman, H. D. and Pratt, P. F. 1961. Soil water and plant analysis. *In*. Univ. California Agri. Div. Publisher.

Chatterjee, Dibyendu, Srivastava, Ajaya and Singh, R K. 2010. Fertilizer recommendations based on targeted yield concept involving integrated nutrient management for potato (Solanum tuberosum) in tarai belt of Uttarakhand. *Indian Journal of Agricultural Sciences*, **80** (12): 1048–53.

Chettri, M., Basu, A., Konar, A. and Mondal, A. B. 2005. Effect of organic sources of nutrients on potato production in West Bengal. *Potato Journal,* **32**(3-4):163-164.

Colwell, J. D. 1967. Calibration and assessment of soil test for estimating fertilizer requirement. (I) statistical models and tests of significance. *Aust. J. Soil Res*., **5**: 275-298.

Colwell, J. D. 1978. Computation of studies of soil fertility and fertilizer requirements. In: Common Wealth Agricultural Survey Report Bureaux. England , pp. 200-204.

Colwell, J. D. and Tisdale, R. J. 1968. The calibration, interpretation and evaluation of tests for the phosphorus fertilizer requirement of wheat in Northern Need South Wales. *Aust. J. Soil Res*., **6**:105-120.

Cope, J. T. and Rouse, R. D. 1973. Interpretation of soil test results. In: Walsh, L. M. and Beaton, J. D. (ed.). Soil testing and plant analysis. *Soil Sci. Soc. Amer.* Madison. Wis. 34-35.

Datta, M. and Singh, N. P. 2010. Nutrient Management in Rice-based Cropping Systems as Influenced by Applying Cattle Manure alone or in Combination with Fertilizers in Upland Acid Soils of Tripura. *Journal of the Indian Society of Soil Science*, **58** (1):94-98.

Dean, A. L. 1954. Yield of phosphorus curves. *Soil Sci. Soc. Amer. Proc.,***18**:462-466.

Debasish, B., Sharma, B. N. and Saikia, M. 2001. Effect of phosphorous on growth and tuber yield of potato raised from TPS transplants. *J. Agric. Sci. Society of North East India,* **14**(2):236-239.

Deshmukh, A. K. 2008. Response of chilli (*Capsicum annum* L.) to site specific nutrient management through targeted yield approach in Northern Zone of Karnataka. *M. Sc. (Agri.) Thesis,* Uni. Agril. Sci., Dharwad, Karnataka (India).

Dev, G., Dillion, N. S., Brar, J. S. and Vig, A. C. 1985. Soil test based yield targets for wheat arid rice-cropping system. *Fert. News,* **30**(5):42-50.

Dhillon, N. S., Vig, A. C. and Brar, J. S. 1997. Soil test based targeted yield approach to formulating crop fertilization programme in Punjab. *J. Research, Punjab Agri. Uni.,* **34:**384-392.

Doberman, A. and Fairhurst, T. 2000. Rice: Nutrient Disorders and Nutrient Management, Potash and Phosphate Institute of Canada and International Rice Research Institute, Singapore and Los Banos, pp. 191.

Doberman, A., Witt, C., Robert, P. C. and Larson, W. E. 2000. SSNM concept for irrigated via system. *Proc. of 5th International Con. on Presis*, **25:** 1-7.

Fitts, J. W. and Nelson, W. L. 1956. The determination of time and fertilizer requirement of soil through chemical tests. *Advan. Agron*., **8**:241-283.

Gangola, P., Singh, R., Bhardwaj, A.K. and Gautam, P. 2012. Effect of moog straw on soil properties under INM in long-term rice-wheat cropping system in a Mollisol. International Journal of Agriculture Environment and Biotechnology **5**: 281-186.

Gayathri, A., Vadivel, A., Santhi, R. and Boopathi, P. M. 2008.Yield, response and nutrient uptake by potato as soil fertility and integrated plant nutrition system on *Ultisols. Indian J. Agric. Res.,* **42**(4):303-306.

Goswami, N. N., Bapat, S. R. and Pathak, V. N. 1986. Studies on the relationship between soil tests and crop response to phosphorus under field condition. Int. Sym. Soil fert. Evalu. Proc., **1**:351-359.

Hanway, J. J., Heidal, H.(1952):Soil analysis methods as used in Iowa State College. *Agriculture Bulletin.***57**, 1–13.

Harikrishna, B. L., Dasog, G. S. and Patil, P. L. 2005. Effect of soil depths, N-doses and its split application on maize plant height, LAI and dry matter yield at different growth stages. *Karnataka J. Agric. Sci.,* **18**(2):364-369.

Harrell, Dustin L., Walker, Timothy W., Salassi, Michael E., Bond, Jason A. and Gerard, Patrick D. 2011. Modelling Rice Grain Yield Response to Nitrogen Fertilization for Delayed-Flood Production. *Journal of Plant Nutrition*, **34**:2158-2171.

Jackson, M. L. 1973. Soil Chemical analysis. Prentice-Hall of India Pvt Ltd., New Delhi.

Jadhav, A. B., Kadlag, A. D., Patil, V.S., Deshpande; A. N. and Durgude, A. G. 2013. Response of Garlic to Integrated Nutrient Management Based on Targeted

Yield Concept in *Inceptisol. Journal of the Indian Society of Soil Science*; **61**(4): 347-350

Jadhav, G. S., Oza, S. R., Sondge, V. D., Chavan, D. A. 1998. Response of pre-season sugarcane to irrigation and nitrogen levels. *Journal of Maharashtra Agricultural Universities,* **22**(3):313-315.

Jagadeeshwari, P. V. and Kumaraswamy, K. 2000. Long term effects of manure, fertilizers schedule on the yield and nutrient uptake by rice crop in a permanent manurial experiment. *Journal of the Indian society of Soil Science,* **48**:833-836.

Kadam, B. S. and Sonar, K. R. 2006. Targeted Yield Approach for Assessing the Fertilizer Requirement of Onion in Vertisols. *J. Indian Soc. Soil Sci.,* **54**(4):513-515.

Kadlag A.D, Ghodke P.D. 2013. Validation of Fertilizer Prescription Equations of Kharif Grain Maize on Different Soil Order. *Online International Interdisciplinary Research Journal*, **3** (4):63-72

Kalaichelvi, K. and Chinnasamy, C. 2004. Evaluation of STCR recommended fertilizer nutrients and potassium humate on yield attributes and yield of inter irrigated cotton. In : *International Symposium on "Strategies for Sustainable Cotton Production –A Global Vision*" 2. Crop Production, UAS, Dharwad, Karnataka, India, pp. 249.

Kanwar, J. S. 1971.Soil fertility evaluation. 1N. Proc. Int. Symp. Soil fertility Evaluation, New Delhi, **1**(1):103-113.

Katharine, S. Praveena, Santhi, R., Maragatham, S., Natesan, R., Ravikumar, V. and Dey, Pradip. 2013. Soil Test Based Fertilizer Prescriptions Through Inductive

Cum Targeted Yield Model for Transgenic Cotton on Inceptisol. IOSR Journal of Agriculture and Veterinary Science, **6** (5): 36-44

Kumar, A., Gautam, R. C., Singh, R., and Rana, K. S. 2005.Growth, yield and economics of maize (*Zea mays* L.) - wheat (*Triticum aestivum* L.) cropping sequence as influenced by integrated nutrient management. *Indian Journal of Agricultural Science*, **75**(11):709-711.

Kumar, B., Kumar, J., Singh, S. S. and Singh, M.V. 1996. Response of potato varieties Kufri Lalima to nitrogen fertilization under eastern Uttar Pradesh conditions. *New Agriculturist*, **7**(1):11-15.

Kumar, V., Singh, N., Malik, Y. S., Bhatia, A. K. and Nehra, B. K. 2002. Effect of nitrogen and crop duration on bulking behaviour of potato cv. Kufri Sutlej. *Haryana J. Hort. Sci*., **31**(3-4):259-261.

Kumar, D. and Sharma, R. C. 2002.Fertilizer management for sustainable production of potato (*Solanum tuberosum* L.) onion (*Allium cepa*).Rice (*Oryza sativa*) sequences in alluvial soil of Bihar. *Indian J. Agric. Sci.,* **72**(9):503-507.

Lanzer, E. A. and Paris, Q. 1985. A new model considering plateau effect and technical analysis of prescription based Fertilizer recommendation. *Agron. J*., **79**:648-652.

Lanzer, E. A. and Paris, Q. and Williams, W. A. 1981. A dynamic model for technical economic analysis for Fertilizer recommendation. *Agron. J*., **73**:733-739.

Laxminarayana, K. and Patiram. 2006. Effect of Integrated Use of Inorganic, Biological and Organic Manures on Rice Productivity and Soil Fertility in *Ultisols* of Mizoram. *Journal of the Indian Society of Soil Science,* **54**(2):213-220.

Lindsay, W. L. and Norvell, W. A. 1978. Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc Amer. J*. **42**: 421- 428.

Mahajan, J. P., Singh, R. P. and Dwivedi, A. K. 1995. Phosphorus utilization by rice varieties in *Vertisols*. *Journal of Nuclear Agriculture and Biology*, **24**(3):154-157.

Meelu, O. P. 1979. Soil tests for nitrogen, phosphorus and potassium and crop response to application of fertilizers in eastwhile Punjab. *Fert. News,* **24**(8):22-26.

Meena, M., Ahmed, S. R., Reddy, K. C. and Rao, B. R. C. P. 2001. Soil test crop response calibration studies on onion (*Allium cepa*) in *Alfisols*. *Journal of Indian Society of Soil Science*, **49**:409-412.

Melsted, S. W. and Peek, T. R. 1977. The Mitscherlich- Bray growth functions Soil testing correlation and interpretation analytical results. *Amer. Soc. of Agron.,* **29**: 1-18.

Misra, B. N., Yadav, R. S., Rajut, A. I. and Pandey, S. M. 1994. Effect of plant geometry and nitrogen application on yield and quality of winter maize. *Indian Journal of Agronomy*, **39**(3):268-269.

Mitscherlich and Baule. 1961. Status and methods of research in economic and agronomic aspects of fertilizer response and use. National Academy of Sciences-National research Concil, 2101. Constitution Avenue, Washington, D.C.

More, N. B., Deshmukh, S. U., Bhoye, U. K. and Pawar, S. M. (2013). Influence of Organic and Chemical Nutrient Sources on Sugarcane Yield and Soil in Inceptisol. *J. Agric. Res. Technol.*, **38** (3): 353-360

Muhr, G. R., Datta, N. P., Subramoney, H., Leley, V. K. and Donahue, R. L. 1965. Soil testing in India. United States Agronomy for International development mission on India, New Delhi.

Mukhtar, T., Arif, M., Hussain, S., Tariq, M., and Mehmood, K. J. 2011. Effect of different rates of nitrogen and phosphorous fertilizers on growth and yield of maize. *Agric. Res.,* **49**(3):333-339.

Nizamuddin, M., Mahmood, M., Khalid, F., and Raiz, S. 2003. Response of potato crop to various levels of NPK. *Asian J. Plant Sci.,* **2**(2):149-151.

Najm, M., R. Fazeli, F. and Shamorady, M. 2010. Effect of utilization of organic and inorganic nitrogen source on the potato shoots matter, leaf area index and plant height, during middle stage of growth. *Int. J. Agric. Biol. Sci.,* **1**:1-1.

Nanjundappa, G., Munare, G. R. and Badiger, M. K. 1994. Yield and nutrient uptake of fodder maize as influenced by nitrogen and potassium. *Indian Journal of Agronomy*, **39**(3):473-475.

Nizamuddin, M., Mahmood, M., Khalid, F., and Raiz, S. 2003. Response of potato crop to various levels of NPK. *Asian J. Plant Sci.,* **2**(2):149-151.

Novero, R. P., Data, S. K. and Aragon, E. L. 1992. Grain yields and nutrient uptake of irrigated maize, sorghum and rice fertilized with different levels of nitrogen. *Philippines Journal of Crop Science*, **17**(1):37-43.

Pandey, A. K., Kumar, V. and Kumar, R. 2009. Effect of long-term organic and inorganic nutrients on transplanted rice under rice-wheat cropping system. *Oryza,* **46**(3): 209-212.

Paramasivan, M., Malarvizavhi, P., Thiyageswari, S. 2012. Balanced use of inorganic fertilizers on maize (*Zea mays* L.) yield, nutrient uptake and soil fertility in *Alfisols*. Announcement, **25**(4):102-107.

Patil, S. K., Mishra, V. N., Das, R. O., Pal, A. R. and Katre, R. K. 1997. Response. plateau models for soil test "Phosphorus" calibration. *J. Indian Soc. Soil Sci.,* **45**(2):284-287.

Perrin, R. F. 1976. The value of information and the theoretical models in crop response research. *Amer J. Agric. Econ.,* **58**:51-54.

Piper, C. S. 1966. Soil and Plant Analysis. Hans Publishcr, Bombay. pp. 85-102.

Prasad, J., Karmakar, S., Kumar, R. and Mishra, B. 2010. Influencc of integrated nutrient management on yield and soil properties in maize-wheat cropping system in a *Alfisols* of Jharkhand. *J. Indian Soc. Soil. Sci.,* **58**(2):200-204.

Prasad, B., Prasad, C. R., Mishra, G. K., Verma, S. N. P. and Rai, Y. 1981. Fertilizer requirement for different yield targets of sugar cane based on soil test values in calcareous soils of Bihar. *Indian Sugar crops Journal,* **8**(3):18-20.

Prasad, B. and Prasad, J. 1994b. Balanced and efficient fertilization of wheat for its specific yield through soil testing and integrated nutrient management in calcareous soil. *Ann. Agric. Res.,* **15(**3**):** 291-296.

Prasad, B., Prasad, J., Prasad, R. and Sharma, V. K., 1998. Fertilizer prescription for *rabi* maize based on targeted concept under varying soil fertility calcareous soils. *Ann. Agric. Res.,* **9(**2**)**:154 - 158.

Puri, G. and Bhargava, O. D. 2001. Nutrient management for rice, based on targeted yield concept in medium black soil of Satpura and Kaymore plateau in Madhya Pradesh., *JNKVV, Research Journal*, **35**:8-11.

Ramamoorthy, B., Narasimhan, R. L. and Dinesh, R. S. 1967. Fertilizer application for specific yield targets of Sonara-64. *Indian Farming,* **17**(5):43-45.

Ramamoorthy, B., Velayuthan, M. and Mahajan. V. K. 1974. Recent, trends in making fertilizer recommendation based on soil test under fertilizer resource constraints in India. In: Proc. FAI/FAO Natl. Seminar, New Delhi, 335-346.

Ramesh, V. and Sumansusan, V. 2003. Effect of fertilizer levels of N, P and K on the yield and juice quality of sugarcane. *Indian Sugar*; **53**(3):175-177.

Randhawa, N. S. and Velayutham, M. 1982. Research and development programme for soil testing in India. *Fertilizer News,* **27**(9):55-64.

Rao, M. R., Rego, T. J. and Wiley, R. W. 1987. Response of cereals to nitrogen in sole cropping and inter cropping with different legumes. *Plant and Soil,* **101**:167-177.

Rao, C. S. and Singh, K. D. 1991. Effect of fertilization for different production levels of maize (*Zea mays* L.) - wheat (*Triticum aestivum* L.) cropping system on change in available phosphorus of a Typic Ustochrept. *Indian J. Agric. Sci.,* **61**(9):637- 642.

Ray, P.K., Jana, A.K., Maitra, D.N., Saha, M.N., Chaudhury, J., Saha, S. and Saha, A.R. 2000. Fertilizer prescriptions on soil test basis for jute, rice and wheat in Typic Ustochrept. Journal of Indian Society of Soil Science **48**: 79-84

Reddy, B. G. and Reddy, M. S. 1999. Available macronutrient status in soil as influenced by integrated nutrient management in maize-soybean cropping system. *J. Res., ANGRAU,* **27**(4):404-407.

Reddy, K. C., Ahmed, S. R. and Reddy, P. V. 1999b. Soil Test Based Fertilizer Prescription for Summer Groundnut Grown in Alluvial Soils of Nellore In Andhra Pradesh. *J. Res. ANGRAU,* **27**(4):82-86.

Reddy, K. C. and Ahmed, S. R. 2000. Soil test based fertilizer recommendation for maize grown in Inceptisols of Jagtiyal in Andhra Pradesh. *Journal of the Indian Society of Soil Science*, **48** (1): 84-89

Reddy, M. N. and Krishnaiah, K. 1999. Current study of crop response to fertilizer in different agro climatic region. In: Experiences of All India Co-ordinated Rice Improvement Project. *Fert. News,* **44**(4):113-126.

Rouf, M. A. and Islam, M. S. 1983. Yield response of maize to different rates of nitrogen and phosphorus fertilizers under rainfed conditions. *Bangladesh Journal of Agricultural Research*, **12**(3):169-179.

Sathish , A., Hugar, A. Y. Kusagur, N. Chandrappa, H., and Sannathimmappa, H. G. 2010. Effect of integrated use of inorganic and organic sources of nutrients on yield, nutrient uptake response and nutrient use efficiency of rice-maize cropping system. *Crop Res.,* **40**(1, 2 & 3):1-6.

Santhi, R., Natesan, R., Andi, K. and Selvakuari, J. 2004. Soil test based fertilizer recommendation for sunflower. *(Heliathus annus* L). in *Inceptisol* of Tamilnadu *J.Oil Seed Res*., **21**(1):78-81.

Saranya, S.; Santhi, R.; Appavu, K.; Rajamani, K. 2012. Soil Test Based Integrated Plant Nutrition System For Ashwagandha on *Inceptisols*. *Indian Journal of Agricultural Research*, **46** (1):88-93

Selva Kumari, G., Santhi, R., Natesan and Perumal, R. 1997. Soil test crop response technology in the sustenance of soil fertility. In: National seminar on development in soil sciencc 1997. 62$^{\text{'ld}}$ Annual convention of IISS held at Kolkatta. 199-203.

Sharma, B. M. and Singh, R. V. 2003. Integrated balanced fertilizer recommendation for pearl millet based on targeted yield approach. *Am. Pl. Soil Res.,* **5**(2):134-137.

Sharma. B. M. and Singh, R. V. 2000. Fertilizer recommendations for wheat based on regression and targeted yield approach - A comparison. *J. Indian Soc.Soil. Sci.,* **48**(2):396-397.

Sharma, B. M. and Singh, R. V., 1999. Fertilizer Recommendations for wheat based on regression and targeted yield approaches - A comparison. *J. Indian Soc. Soil Sci.,* **47**:356- 367.

Sharma, M. P, Bali, S. V. and Gupta, D. K. 2001. Soil fertility and productivity of *(Oryza sativa* L.*)* - wheat *(Triticum aestivum* L.*)* cropping system in an Inceptisol as influenced by integrated nutrient management. *Indian J. Agric. Sci.,* **71**(2):82-86.

Sharma, M.P., Bali, S.V. and Gupta, D.K. 2000. Crop yield and properties of *Inceptisol* as influenced by residue management under rice-wheat cropping sequence. *Journal of the Indian Society of Soil Science*, **48**:506-509.

Sharma, M. P. and Gupta, J. P. 1998. Effect of organic material on grain yield and soil properties of maize (*Zea mays* L.) - wheat cropping system. *Indian Journal of Agriculture Sciences,* **68**(11):715-717.

Sharma, R. C. and Sood, M. C. 2002. Nitrogen and potassium interaction on the tuber yield, quality and organic carbon status of Shimla soils. *Potato, Globa-research and development Proceedings of the Global Conference on Potato, New Delhi, India,* pp. 843-851.

Singh, A., Nehra, B. K.,Khurana, S. C. and Singh N. 1997. Influence of plant density and fertility level on growth and yield in seed crop of potato. *Potato J.,* **24**(1-2).

Singh, J., Bajaj J. C., Pathak, H. 2005. Quantitative estimation of fertilizer requirement for maize and chickpea in the alluvial soil of the Indo-Gangetic plains. *Journal of Indian Society of Soil Science,* **53**(1):101-106.

Singh, K. D. and Sharma, B. M. 1990. Soil test based specification for efficient use for fertilizer and targeted yield of wheat and rice in Typic ustochrept soil of Delhi region. *Indian J. Agric. Sci.,* **60**(1):36-40.

Singh, K. P., Singh, R. K., Singh, S. N., and Singh V. K. 2007.Effect of fertilizer level, seed rate and seed size on yield of potato in acidic soils of Manipur. *Potato J.,* **34**(1-2):93-94.

Singh, S. P., Sreedevi, B. and Kumar, R. M. 2009. Integrated nitrogen management for seed production of hybrid rice. *Oryza,* **46**(3):254-256.

Singh, S. S. and Maurya, A. N. 1983. Response of NPK and their combination on yield contribution character of Brinjal *var.* Pusa Kranti, *Haryana J. Hort. Sci***.,** **12**(3-4): 237-240.

Sonar, K. R., Dhage, A. K., Bagul, K. M., Kadain, J. R., Patil, N. D. Mahajan, S. V. and Bhapkar. K. 1984. Fertilizer requirements for targeting Kharif sorghum yield in *Vertisol* of Maharastra. *ln: 12th* workshop of All lndian Co-ordinated Projeet for investigation on soil test crop response correlation, pp.24-29.

Sonar, K. R., Tamboli, B. P. and Somwanshi, R. H. 1982. Targeted yield concept for balanced fertilizer of pigeon pea in vertisol *In:* Annual Report Dr.P.D.K.V., Akola (MS), pp. 43-45.

Sonar, K. R., Shinde, S. S., Khumbar, D. D., Patil, B. P. and Patil, N. D. 1984. Fertilizer requirements of cotton based on targeted yield approach. *Cotton Dev.,* **14**(1):36-37.

Sonar, K. R., Tamboli, B. P. and Somwanshi, R. B. 1987. Targeted yield concept for balanced fertilizer of pigeonpea in *Vertisol. In*: Annual Report Dr. P. D. K. V., Akola (MS), pp. 43-45.

Sood, M. C. 2007. Integrated nutrient supply and management for potato production in Mid Hills of Shimla. *Potato J.,* **34**(1-2):101-102.

Standford, G. 1973. Rational for optimum nitrogen fertilization in corn production. *J. Environ. Quality*, **2**: 156-166.

Standford, G., Ayres, A. S. and Doi, M. 1965. Minevalizable soil nitrogen in relation to fertilizer needs of sugarcane in Hawai. *Soil Sci.,* **99**:132-137.

Stapleton, A. R. A., Wagenet, R. J. and Turner, D. L. 1983. Corn growth and nitrogen uptake under irrigated, fertilized condition. *Irrig. Sci*., **4**:1-15.

Subba Rao, A. and Srivastava, S. 2001. Soil Testing for Targeted Crop response. *Fifty Years of Natural Resource Management Research,* pp. 230-244.

Subbiah, B. V. and Asija, G. L. 1956. A rapid procedure the estimation of available nitrogen in soils. *Curr. Sci.,* **25**:259-260.

Subehia, S .K., Verma, S. and Shrma, S. P. 2005. Effect of long-term use of chemical fertilizers with and without organics on forms of soil acidity, phosphorus adsorption and crop yields in an Acid Soil. *Journal of the Indian Society of Soil Science,* **53**(3):308-314.

Suri, V. K. and Verma, T. S., 2000. Nutrient efficiency and their evaluation maize (Cv. Parvati) and wheat (cv. Aradhana) on farmers' field for prescription based fertilizer recommendations, *Res. On Crops*, **1**(2):128-132.

Syafruddin, Rauf, M., Arvan, R.Y. and Akil, M. 2009. Requirements for N, P, and K fertilizers on *Inceptisol Haplustepts* soil. *Indonesian Journal of Agricultural*, **2**(1):77-84.

Swarup, A. 2002. Lessons from long-terrn fertilizer experiments improving fertilizer use efficiency and crop yields. *Fert. News,* **47**(12):59-73.

Swarup, A. 2010. Integrated plant nutrient supply and management strategies for Enhancing Soil Quality, Input Use efficiency and Crop Productivity. , *Indian Soc. Soil. Sci.,* **58**(1):25-31.

Tambe, S. P. and Bhoi, P. G., 1999, Yield maximization of *kharif* sorghum through fertilizer levels, plant densities and plant growth regulator. *J. Maharashtra Agric. Univ.,* **24**(2): 212-213.

Tamboli, B. D., Patil, Y. M., Bhakhare, B. D. and Sonar, K. R. 1996. Yield targeting approach for fertilizer recommendation to wheat on vertisol of Maharastra. *J. Indian Soc. Soil Sci.,* **44**(1):81-84.

Thakur, D. R., Prakash, B. M., Kharwar, P. C. and Bhalla, S. K. 1998. Effect of nitrogen and plant spacing on yield, nitrogen uptake and economics in baby corn (*Zea mays* L.). *Indian Journal of Agronomy*, **43**(4):668-671.

Thiraporan, R., Feil, B. and Stamp, P. 1992. Effect of nitrogen fertilization on grain yield and accumulation of nitrogen, phosphorus and potassium in the grain of tropical maize. *Journal of Agronomy and Crop Science*, **169**(1-2):9-16.

Tisdale, S. L. 1967. Soil testing and plant analysis. In part I soil testing No. 2 *Soil Sci. Soc. Amer.* Special Publication Series. 1-11.

Tandon, H.L.S. 2004. Fertilizers in Indian agriculture – from 20th to 21st century. FDCO, New Delhi.

Truog, E. 1960. Transaction, Seventh International Congress Soil Sci., **4**(7):46-52

Tucker, M. R. and Carter, C. C. 1998. Understanding the soil test report. NCDA and CS (Agronomic division) Miscellaneous Publication, 1998. pp. 17-23.

Varalakshmi, L .R., Srinivasamurthy, C. A. and Bhaskar, S. 2005. Effect of lntegrated Use of Organic Manures and Inorganic Fertilizers on Organic Carbon, Available N, P and K in Sustaining Productivity of Groundnut Fiinger Millet Cropping System. *J. Indian Soc. Soil. Sci.,* **53**(3):315-318.

Velayutham, M. 1979. Fertilizer recommendation based on targeted yield concept problem and prospects. *Fert. News*, **24**(9):12-17.

Velayutham, M. and Perumal, R. 1976. An experimental evaluation of soil testing for fertilizer recommendation under multiple cropping. ILRISO. **25**:185-190.

Velayutham, M., Reddy, K. C. K. and Sankar, G. R. M. 1985. Soil test crop response research work in India for fertilizer recommendation. *ln.* Proc. In SYMP. Soil Test Crop Response Correlation Studied, Dhaka, Bangladesh. 662-644.

Vasanthi, D. and kumarswamy, K. 2000. Efficiency of uptake of Nutrient by cereal fodder crop and on soil fertility. *Journal of Indian Society of Soil Science,* **48**(3):510-515.

Verma, A., Nepalia,V., and Kanthaliya, P.C. 2004. Effect of integrated nutrient supply on growth, yield and nutrient uptake by maize *(Zea mays)*-wheat *(Triticum aestivum)* cropping system. *Indian Journal of Agronomy*. **51**(1):3-6.

Verma, D. P. and Singh, K. D. 1990. Targeted yield concept in a maiz-rice cropping systern for efficient and economic fertilizer use and nativc fertility building up in a Typic ustochrept. *Fert. New,* **35**(7):31-41.

Verma, T. S., Singh, V. K. and Paul, J. 2002. Prescription based fertilizer recommendations for rice, maize and wheat in different agro-climatic zones of Himachal Pradesh. *J. Indian Soc. Soil Sci.,* **50**(3):272-277.

Verma, T. S., Minhas, R. S., Jaggi, R. C. and Sharma, P. K. 1987. Efficiencies of nitrogen, phosphorus and potassium for rice and wheat and their verification for prescription based fertilizer recommendation. *J. Indian Soc. Soil Sci.,* **35**:421-425.

Verma, T. S.. Suri, V. K.. Sandal, S. K. and Paul, J. 2005. Validation of soil test based Fertilizer adjustment equations on targeted yield in wet temperatute zone of Himachal Pradesh. *Indian J. Agril. Sci.,***75**:654-657.

Walkley, A. and Black, C. A. 1934. Estimation of soil organic carbon by chromic acid titration method. *Soil Sci.,* **47**:29-38.

Welch, C. O. and Wiese, R. A. 1973. Opportunities to improve soil testing programrne. *In:* Soil testing and plant analysis (ed) L.W. Walsh and J.D. Beaton, *Soil Sci. Soc. Amer Inc*. Madison Wis. USA, 1-11.

Yadav, R. L., Diwedi, B. S. and Pandey, P. S. 2000. Rice-wheat cropping system: assessment of sustainability under green manuring and chemical fertilizer inputs. *Field Crops Research,* **65**(1):15-30.

Appendices

Appendix –I

SOIL TEST CROP RESPONSE DATA OF MAIZE

Location –Research Farm, SGCARS, Jagdalpur — **Crop- Hybrid maize**

Soil Depth- 0-15 cm — **Variety- Dhanya 5052**

Season- Kharif, 2013 — **Soil type-*Inceptisols***

Plot No.	Maize Grain yield (q/ha)	Nutrient uptake(kg/ha)			Soil test value(kg/ha)			Fertilizer doses (kg/ha)			FYM (t/ha)
		N	P	K	N	P	K	N	P	K	
L_0 Strip											
1	65.42	98	20.72	124	216	18.82	232	120	90	90	10
2	72.90	113	25.45	127	233	18.41	245	180	90	90	10
3	26.67	47	9.79	61	208	9.00	164	0	0	0	5
4	56.87	103	14.28	104	208	20.79	204	120	90	60	5
5	54.79	102	16.71	105	226	15.04	230	120	60	90	0
6	35.60	64	11.21	68	223	6.87	200	120	0	60	0
7	28.52	50	9.01	60	206	8.65	183	0	0	0	10
8	43.64	68	12.78	96	201	15.00	201	0	60	60	10
9	69.35	113	22.89	126	221	6.70	191	180	30	30	5
10	75.08	118	26.28	109	216	13.63	211	180	60	60	5
11	69.04	109	21.05	111	211	15.89	200	180	60	30	0
12	20.81	40	7.03	43	202	10.32	184	0	0	0	0
13	83.64	143	27.66	138	223	21.56	204	180	90	30	10
14	86.79	157	23.97	165	240	22.73	236	180	90	60	10
15	56.44	97	12.77	118	191	11.60	215	120	30	60	5
16	43.69	72	14.61	77	196	19.04	279	60	60	60	5
17	39.81	75	11.40	75	208	14.38	182	60	60	30	0

18	33.23	59	9.86	60	211	10.36	192	60	30	30	0
19	42.31	80	12.80	89	201	13.33	190	60	30	60	10
20	78.78	131	27.82	134	226	16.39	203	180	60	90	10
21	64.07	129	16.52	116	221	19.24	190	120	60	0	5
22	61.72	106	21.80	126	216	15.88	209	120	60	60	5
23	49.14	89	11.53	80	218	8.05	179	120	30	30	0
24	55.77	85	14.89	88	206	17.06	196	120	60	30	0
L_1 Strip											
25	32.36	58	11.04	70	198	11.51	207	0	0	0	10
26	43.00	73	14.41	103	228	15.39	202	60	60	30	10
27	35.40	59	11.54	64	191	14.02	292	60	30	60	5
28	28.59	50	9.13	58	206	27.10	221	0	0	0	5
29	67.56	108	16.92	102	238	16.81	244	180	30	30	0
30	56.63	87	19.18	93	213	20.90	281	120	30	60	0
31	44.65	72	15.24	81	201	16.68	229	60	30	30	10
32	66.96	115	23.25	148	226	18.87	204	120	60	30	10
33	87.24	132	26.13	157	228	21.94	209	180	90	30	5
34	80.68	130	29.65	114	203	17.06	225	180	60	90	5
35	71.07	99	22.47	102	201	19.79	213	180	60	60	0
36	24.70	49	9.14	47	203	15.30	203	0	0	0	0
37	61.72	106	17.97	121	218	10.11	246	120	30	30	10
38	68.71	118	20.40	129	201	16.08	266	120	60	90	10
39	84.71	131	25.82	152	228	25.05	293	180	90	60	5
40	86.15	120	21.63	160	236	25.15	244	180	90	90	5
41	57.33	99	15.40	98	221	16.18	255	120	60	60	0
42	39.48	63	12.93	56	191	21.43	294	60	60	60	0
43	53.69	94	22.13	95	201	18.14	308	120	0	60	10
44	80.10	122	25.40	132	213	22.41	268	180	60	30	10
45	36.81	68	9.99	67	216	25.47	274	0	60	60	5
46	70.77	115	23.46	108	213	29.62	302	120	90	90	5

47	62.90	94	23.09	122	201	29.24	301	120	90	60	0
48	58.97	89	14.34	132	203	15.40	296	120	60	0	0
						L_2 Strip					
49	70.33	107	16.17	146	213	29.54	317	120	60	0	10
50	89.03	105	32.84	153	226	33.24	271	180	60	60	10
51	29.92	51	10.02	62	218	16.03	305	0	0	0	5
52	38.99	58	10.70	87	221	29.43	272	60	60	30	5
53	40.78	71	14.11	83	201	27.83	271	60	30	60	0
54	39.55	56	10.47	71	216	28.71	275	0	60	60	0
55	67.90	94	24.40	107	208	31.29	231	120	60	60	10
56	71.72	98	18.44	125	213	25.84	289	120	30	60	10
57	56.58	102	18.90	99	222	24.59	266	120	30	30	5
58	48.33	83	13.66	84	223	21.68	299	60	30	30	5
59	79.90	138	20.71	126	218	33.15	312	180	90	60	0
60	84.97	124	24.02	126	223	20.26	291	180	60	90	0
61	80.64	123	32.65	145	226	25.83	266	180	30	30	10
62	54.36	96	14.37	111	193	28.75	271	60	60	60	10
63	70.82	112	24.38	120	236	33.86	280	120	60	30	5
64	51.10	91	14.39	90	213	23.19	302	120	0	60	5
65	81.45	128	22.27	123	231	39.52	244	180	90	30	0
66	86.84	149	24.03	149	229	24.95	254	180	90	90	0
67	35.69	59	14.21	73	208	25.83	263	0	0	0	10
68	73.18	121	25.91	141	201	40.47	265	120	90	60	10
69	79.96	116	19.35	117	226	25.42	227	180	60	30	5
70	65.52	94	21.68	103	201	28.75	317	120	60	90	5
71	26.70	48	11.14	57	213	18.81	259	0	0	0	0
72	74.17	100	16.68	115	221	38.72	289	120	90	90	0

Appendix –II

SOIL TEST CROP RESPONSE DATA OF POTATO

Location –Research Farm, SGCARS, Jagdalpur **Crop- POTATO**

Soil Depth- 0-15 cm **Variety- Kufri Pukhraj**

Season- Rabi, 2013-14 **Soil type-*Inceptisols***

Plot No.	Potato tuber yield (q/ha)	Nutrient uptake(kg/ha)			Soil test value(kg/ha)			Fertilizer doses (kg/ha)			FYM (t/ha)
		N	P	K	N	P	K	N	P	K	
L_0 Strip											
1	174.78	76	15.11	92	213	23.9	238	120	90	90	10
2	204.63	100	19.75	94	233	22.3	248	180	90	90	10
3	58.04	33	6.52	34	204	8.4	169	0	0	0	5
4	152.38	68	19.09	83	206	24.7	207	120	90	60	5
5	137.82	62	13.39	69	221	19.2	239	120	60	90	0
6	72.59	35	9.49	38	224	10.1	210	120	0	60	0
7	70.96	37	9.09	37	204	7.8	182	0	0	0	10
8	89.04	41	9.52	35	204	18.7	210	0	60	60	10
9	172.94	90	14.96	87	224	6.2	186	180	30	30	5
10	131.97	62	13.81	71	218	13.7	220	180	60	60	5
11	181.38	92	23.99	99	211	14.7	198	180	60	30	0
12	56.82	26	7.83	34	196	9.9	178	0	0	0	0
13	187.78	76	15.83	99	224	23.7	200	180	90	30	10
14	205.92	95	27.20	108	243	29.4	235	180	90	60	10
15	125.56	59	10.48	61	192	11.0	219	120	30	60	5
16	141.39	52	12.54	73	194	18.3	285	60	60	60	5
17	118.17	49	7.84	55	206	13.9	185	60	60	30	0

18	110.94	46	7.90	51	209	9.8	190	60	30	30	0
19	119.32	54	11.56	59	202	13.6	198	60	30	60	10
20	191.84	94	21.37	89	234	17.8	207	180	60	90	10
21	131.10	56	14.83	73	224	17.4	188	120	60	0	5
22	141.88	63	17.82	73	214	17.8	212	120	60	60	5
23	117.88	68	9.85	59	221	7.4	176	120	30	30	0
24	125.22	65	12.28	61	209	20.3	194	120	60	30	0
L_1 Strip											
25	75.16	44	8.35	42	205	10.9	205	0	0	0	10
26	137.97	68	13.48	69	236	15.8	201	60	60	30	10
27	140.99	67	12.57	75	202	15.1	296	60	30	60	5
28	64.36	33	9.00	36	212	25.2	214	0	0	0	5
29	169.56	89	19.59	86	250	14.9	240	180	30	30	0
30	132.53	57	12.86	74	223	20.6	276	120	30	60	0
31	128.71	71	14.49	65	200	16.0	219	60	30	30	10
32	166.22	74	15.98	88	238	20.9	211	120	60	30	10
33	193.62	83	21.96	88	243	25.5	222	180	90	30	5
34	181.54	95	19.83	101	213	17.4	223	180	60	90	5
35	190.11	102	25.22	99	215	20.6	212	180	60	60	0
36	66.58	30	8.59	40	200	14.9	201	0	0	0	0
37	140.46	65	15.67	66	226	8.9	238	120	30	30	10
38	170.26	77	15.66	86	212	16.9	267	120	60	90	10
39	198.88	93	22.62	101	236	28.2	301	180	90	60	5
40	201.07	96	26.61	106	248	29.2	257	180	90	90	5
41	165.99	75	15.20	83	229	17.6	261	120	60	60	0
42	125.06	66	11.60	61	192	25.1	302	60	60	60	0
43	90.45	35	11.43	49	215	17.6	314	120	0	60	10
44	190.27	92	22.86	104	223	22.9	261	180	60	30	10
45	93.69	42	8.54	49	217	28.6	283	0	60	60	5
46	180.34	100	24.04	101	223	34.9	314	120	90	90	5

47	172.52	75	16.88	79	213	35.7	315	120	90	60	0
48	134.54	50	11.45	69	218	16.2	300	120	60	0	0
L_2 Strip											
49	160.25	81	15.94	103	226	30.5	320	120	60	0	10
50	197.77	101	27.57	109	238	31.6	273	180	60	60	10
51	68.38	32	7.51	39	208	15.2	303	0	0	0	5
52	149.79	79	14.14	72	221	32.8	278	60	60	30	5
53	145.52	56	12.43	69	198	27.6	266	60	30	60	0
54	92.39	42	11.02	50	211	31.9	280	0	60	60	0
55	162.74	68	20.62	65	211	31.2	238	120	60	60	10
56	138.58	53	16.37	73	221	25.7	288	120	30	60	10
57	154.55	78	17.27	81	228	23.4	263	120	30	30	5
58	127.02	51	11.03	67	219	21.2	297	60	30	30	5
59	200.83	97	22.13	110	221	35.9	314	180	90	60	0
60	194.04	101	23.09	103	231	22.9	287	180	60	90	0
61	192.85	102	25.89	89	238	22.8	253	180	30	30	10
62	149.31	63	19.00	75	194	30.1	277	60	60	60	10
63	156.03	82	22.48	83	237	35.2	282	120	60	30	5
64	89.93	41	9.70	50	218	20.9	308	120	0	60	5
65	200.78	105	22.94	84	234	40.5	246	180	90	30	0
66	204.82	95	28.40	110	238	26.7	258	180	90	90	0
67	79.65	37	8.77	50	213	24.7	255	0	0	0	10
68	187.26	107	23.90	95	213	40.3	277	120	90	60	10
69	196.72	98	18.99	100	236	26.0	231	180	60	30	5
70	184.35	99	19.29	103	213	30.7	227	120	60	90	5
71	70.14	33	9.28	40	211	17.9	252	0	0	0	0
72	175.69	88	17.43	96	223	38.7	296	120	90	90	0

Appendix-III

Weekly meteorological data during growth period of Maize and Potato

(25th June 2013- 25th March 2014)

Week No.	Standard Meteorological Week	Temperature(^{0}C)		Rainfall (mm)	Relative Humidity		Evaporation (mm)	Bright Sunshine (Hours)
		Maximum	Minimum		(I)	(II)		
26	25 June -1 July	28.0	22.8	48.9	89.9	84.3	1.4	2.1
27	2 July -8 July	30.1	22.8	28.6	92.0	51.1	1.5	3.4
28	9 July -15 July	28.0	22.7	36.5	91.0	65.6	1.3	1.4
29	16 July -22 July	27.0	22.2	8.6	92.4	70.0	1.0	0.0
30	23 July -29 July	25.6	21.6	85.2	92.3	73.6	0.6	0.0
31	30 July -5 Aug	30.0	23.0	23.4	89.3	60.2	1.6	2.9
32	6 Aug -12 Aug	28.3	22.4	52.1	91.1	60.9	1.9	1.6
33	13 Aug -19 Aug	30.1	23.1	36.4	89.0	53.7	2.6	4.5
34	20 Aug -26 Aug	27.6	22.0	33.3	89.6	61.3	2.0	2.9
35	27 Aug-2 Sep	29.2	22.1	20.1	88.4	51.3	3.7	3.8
36	3 Sep -9 Sep	30.3	21.7	26.6	91.7	55.0	4.1	3.4
37	10 Sep -16 Sep	30.7	21.7	57.9	90.6	45.4	4.7	7.3
38	17 Sep -23 Sep	29.1	22.0	11.3	91.0	55.0	5.5	3.1
39	24 Sep -30 Sep	30.5	21.4	38.0	89.7	49.6	4.2	5.5
40	1 Oct -7 Oct	29.9	21.1	53.8	89.9	54.9	2.2	3.8
41	8 Oct -14 Oct	29.6	21.2	20.2	90.4	50.7	2.1	3.6
42	15 Oct -21 Oct	30.1	19.7	30.0	92.8	50.3	3.0	7.2
43	22 Oct -28 Oct	26.2	20.6	76.5	94.1	73.3	1.7	1.5
44	29 Oct-4 Nov	28.8	19.1	53.6	91.0	58.7	2.3	5.1
45	5 Nov -11 Nov	30.6	21.0	13.6	89.6	47.0	2.2	4.3
46	12 Nov -18 Nov	26.2	12.1	0.0	89.9	43.9	2.1	6.7
47	19 Nov -25 Nov	28.0	16.3	3.8	89.9	54.1	2.2	4.1

48	26 Nov-2 Dec	29.0	15.6	0.0	90.4	44.6	2.7	5.9
49	3 Dec -9 Dec	27.0	8.8	0.0	89.0	38.9	3.0	5.7
50	10 Dec -16 Dec	26.9	7.7	0.0	89.3	41.4	2.3	7.8
51	17 Dec -23 Dec	27.1	8.5	0.0	94.3	52.9	2.2	7.4
52	24 Dec -31 Dec	28.2	9.1	0.0	92.6	52.3	2.4	6.9
1	1Jan-7Jan	28.5	10.3	0.0	94.1	45.7	2.8	7.9
2	8Jan-14 Jan	28.4	12.0	0.0	91.1	39.1	2.4	5.7
3	15 Jan-21 Jan	29.2	13.1	0.0	91.6	40.0	2.4	5.2
4	22 Jan-28 Jan	28.1	11.0	0.0	89.9	38.3	2.8	6.3
5	29 Jan-4 Feb	27.5	8.0	0.0	92.0	33.0	4.0	7.0
6	5 Feb - 11 Feb	32.3	12.7	0.0	94.4	41.9	4.2	9.3
7	12 Feb - 18 Feb	30.0	14.6	0.0	92.4	40.0	4.2	6.5
8	19 Feb - 25 Feb	30.6	14.3	0.0	94.7	40.0	4.1	8.8
9	26 Feb - 4 March	32.0	17.0	25.4	90.0	37.0	4.4	9.3
10	5 Mar - 11 Mar	27.4	16.4	50.8	95.1	56.9	2.5	3.7
11	12 Mar - 18 Mar	32.2	18.9	0.0	93.7	36.3	4.0	7.3
12	19 Mar - 25 Mar	34.9	20.9	0.0	88.6	35.0	5.9	6.4