STCR APPROACH FOR OPTIMIZING INTEGRATED PLANT NUTRIENTS SUPPLY TO OBTAIN BETTER GROWTH AND YIELD OF HYBRID MAIZE *(Zea mays* L.)

Thesis

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By

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Pantnagar
June, 2019

(Nidhi Luthra)
Authoress

CERTIFICATE

This is to certify that the thesis entitled **"STCR APPROACH FOR OPTIMIZING INTEGRATED PLANT NUTRIENTS SUPPLY TO OBTAIN BETTER GROWTH AND YIELD OF HYBRID MAIZE (*Zea mays* L.)"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** with major in **Soil science**, of the College of Post-Graduate Studies, G. B. Pant University of Agriculture and Technology, Pantnagar, is a record of *bona fide* research carried out by **Ms. Nidhi Luthra, Id. No. 44383** under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been acknowledged.

Ajaya

(Ajaya Srivastava)
Chairman
Advisory Committee

Pantnagar
June, 2019

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Ms. Nidhi Luthra, Id. No. 44383,** a candidate for the degree of **Master of Science in Agriculture** with major in **Soil science**, agree that the thesis entitled **"STCR APPROACH FOR OPTIMIZING INTEGRATED PLANT NUTRIENTS SUPPLY TO OBTAIN BETTER GROWTH AND YIELD OF HYBRID MAIZE (*Zea mays* L.)"** may be submitted in partial fulfillment of the requirements for the degree.

(Ajaya Srivastava)
Chairman
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(S.P. Pachauri)
Member

(Veer Singh)
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Introduction

India being the third largest producer and second largest consumer of fertilizers in the World, has witnessed a tremendous rise in combined production of Nitrogen (N) and Phosphate (P) fertilizers from 0.02 million tonnes in 1951-52 to around 38 million tonnes in the recent years. On the consumption side, it has increased from 0.49 kg ha^{-1} in 1951-52 to around 140 kg ha^{-1} (**Indian Fertilizer Scenario-2014**). Indeed fertilizer plays a crucial role in enhancing agricultural production by increasing the crop yields considerably by supplying required doses of nutrients. Intensification of agriculture is no doubt necessary to feed the expected population of 1.39 billion by 2025. However, the question stands still that whether yield targets can be achieved with economically viable, environmentally sustainable system without degrading and polluting the soil, air, water and environment.

Applying fertilizers of any nutrient by the farmer without considering soil fertility status and nutrient requirement of the crop, affect soil and crop adversely (**Ray *et al.,* 2000**). Intensive cropping along with imbalanced fertilizer use are major causes of depletion of macronutrients like N, P, K and S. **Shukla and Tiwari, 2016** reported micronutrient deficiency in the order: Zn 40%, Fe 12.6%, Cu 4.5%, Mn 6.0 % and B 22.8% in the soils of India.

Considering the above mentioned problems, soil testing is gaining importance with the increasing awareness of precision agriculture. In the current and future scenario, soil testing is and will be proving to have a holistic role not just limited to fertilizer recommendation for a crop based on soil test but a measure to sustain soil quality. The purpose of Soil testing has to be changed from just fertilizer recommendation to Soil test for soil quality assessment and resource management for production systems and variable soil uses. In changing situation of Agriculture where intensification of cropping system, climate, management practices, development of new varieties are prime, there is need to develop & evaluate suitable soil test method particularly those which are more accurate, less time consuming having multi nutrient extraction capabilities.

The primary aim of the soil-testing program is to serve farmers leading to better and more judicial and economic use of fertilizers and better soil management practices for improving agricultural production. It is a basic tool for optimizing the inputs to reach the crop production goals. Soil test values along with soil test crop response data, cropping system information, soil survey data and management conditions, can be used as a valuable guide for recommending fertilizer needs of a crop under a given situation. Therefore, it is necessary to have a locally caliberated soil test crop response research for the efficient working of soil testing advisory service. For this purpose, an All India Coordinated Research Project (AICRP) on Soil Test Crop Response Correlations was started by the Indian Council of Agricultural Research (ICAR) in 1967. The basic assumption of Soil test based fertilizer recommendation is that the crop yield will directly be influenced with an increase or decrease in available nutrient in the soil. There are three phases of soil testing. In the first phase, there is only diagnose or indication of nutrient deficiency or sufficiency on an area basis. In the second stage, critical level of specific nutrient is addressed and this is an improvement in the degree of the first phase. The third phase is targeted yield concept in the development of soil testing methodology. This concept is based on quantitative idea of the fertilizer requirement according to yield and nutritional requirement of the crop, percent contribution from the soil available nutrient and that of the applied fertilizer (**Ramamoorthy *et al.,* 1967**). This approach has resulted from validation through hundreds of demonstration trials in farmers fields **Ramamoorthy and Velayutham (2011**).

Presently when precision agriculture is main concern, the concept of "Soil test based fertilizer recommendation" harmonizes the much concerned approaches namely, "Fertilizing the soil" or "Fertilizing the crop" ensuring the real balance of the applied fertilizer nutrients among themselves along with the soil available nutrients. Soil test based fertilizer recommendations not only results in efficient fertilizer use but also maintains soil fertility. This helps to attain higher response ratio and benefit : cost ratio as the nutrients are applied in proportion to the deficiency of the specific nutrient and the correction of the nutrients imbalance in soil helps to achieve the synergistic effects of balanced fertilization **(Rao and Srivastava, 2000)**.

Soil fertility levels are maintained considering the need of the crop. For sustaining the production system, it is pre-requisite that the nutrient demand of a crop to produce a target yield and the amount extracted from the soil should be perfectly matched. For this, Soil testing is a pre-requisite to recognize the nutrient imbalance in the soils so as to apply the required amounts of nutrients in order to bridge the gap, optimize the crop nutrition for higher yields and maintain the soil health. Therefore, fertilizer recommendations for different crops should be made on the basis of initial soil fertility status by categorizing it into low, medium and high fertility levels. Such considerations hold true for large variation in soil fertility from field to field. There are different methods of fertilizer recommendations and among them the one based on targeting yield is unique because this method considers both the soil test based fertilizer dose and the level of yield a farmer can get if good agronomic practices are being followed to raise the crop. This soil test calibration aims to establish a relationship between the levels of soil nutrients as determined in the laboratory testing and the response of crop to fertilizers observed in the field permitting balanced fertilization of crops. Therefore, a well established soil test calibration helps in applying fertilizers in judicious amounts and obtaining high nutrient use efficiency for maximum possible yield in an eco-system. Also, Nutrient uptake from applied fertilizers is important to consider as it varies with crop species, management practices, soil properties, environmental conditions and most importantly with nutrient sources.

The importance of balanced fertilization for increasing crop productivity is well understood by policy makers and the agricultural scientists. Balanced fertilization refers to the integrated use of all nutrients from different organic or inorganic sources. Once the nutrient requirements of crops is assessed, it gives surety of optimum crop production, improved quality of the produce, maintenance of soil health by efficient and effective use of nutrient sources available with the farmers.

Zea mays (maize), one of the most important cereal crops of the world. In India, it is emerging as a third most important crop after rice and wheat covering an area of 9.4 Mha with the annual production of 23 MT. Its importance lies in the fact that it is not only used for human food & animal feed but also widely used for corn starch industry, corn oil production , baby corn etc. It has become an important raw material in food processing, poultry, dairy, meat and ethanol industry. The introduction of new hybrid seeds that can survive low winter condition, off season diseases & pests with high productivity has made maize a profitable alternative even for small farmers. Maize is grown throughout the year in India. It is predominantly a kharif season crop with 85% of the area under cultivation in the season. Maize has 60-65% starch content, hence can not be easily substituted by the other commodities. Depending upon the variety , maize may contain different quantity of vitamin B, folic acid, vitamin C and provitamin A (precursor to vitamin A). Maize is also rich in phosphorus, magnesium, zinc, copper, iron and selenium, and has small amount of potassium and calcium. It is estimated by the Indian Institute of maize research that hybrids would constitute 90% of the total area by 2050. It was reported that increased application rates of inorganic fertilizers improve maize yield and productivity but it is not a practical option for many small and marginal maize farmers, as they cannot afford inorganic fertilizer.In India, maize is grown traditionally during Kharif i.e. June – October with high temperature i.e. >35˚C. Maize is one of the important cultivated grain crops having tremendous yield potential under irrigated conditions. It is a quick growing and high yielding crop. It is also one of the most efficient field crops as far as producing higher dry matter per unit quantity of water is concerned. The production potential of maize is largely dependent on its nutrient management. Maize is an exhaustive crop i.e. heavy feeder of nutrients and being a C_4 plant, it is capable of efficiently converting solar energy into production of dry matter. Maize has high genetic yield potential So, it is called "Miracle crop" and "Queen of Cereals".

Green revolution in India has witnessed manifold increase in fertilizer consumption. Along with this, the present hike in the chemical fertilizers has compelled the Indian farmers and lead to imbalance in the nutrition of crops and hence reduction in crop yields. So, it is the need of an hour to optimize nutrient use in order to sustain crop production without compromising soil health and environment. The soils of India are now depleted of organic matter and there is an urgent need for balanced fertilizer use **(Anon., 2012).**

Organics alone can't meet the crop demand due to their low nutrient status. Therefore, to maintain soil productivity on a sustainable basis, conjoint use of organic and inorganic sources of nutrient need to be adopted. The use of crop residues and organics in a long run help to build up soil humus and beneficial microbes besides improvement in soil physical properties. Whereas, chemical fertilizers provide essential plant nutrient instantly in adequate quantities. Thus, balanced combination of organics and chemical fertilizers help to maintain soil fertility and crop productivity. Applying Farmyard manure to the crop is an age old practice. Well decomposed FYM supplies plant nutrients and acts as a binding material improving the soil physical properties. Beneficial effects of earthworms are well known from Darwin's era but the potential of vermicompost to supply nutrients for the plant growth and to support beneficial microorganisms has recently been recognized. Moreover, Conjoint application of inorganic fertilizers and organic manures conserves nutrients which could otherwise be lost. The conserved nutrients may be supplied to the crop in succession **(Hedge 1998**).

India has made indiscriminate fertilizers application during last decades. At the same time there are many parts of the country where the yield of many crops are stagnating or even declining. The output per unit of the fertilizer application is not worth mentioning these days. Consequently, the agriculture growth rate does not seem to keep pace with the growth in population. In addition to this, the imbalanced and inadequate application of inorganic fertilizers and that too in intensive cropping systems is the main reason behind stagnation in productivity, food insecurity and environmental threats. These problems are the challenges in front of the scientists which demand for a new research agenda. The use of the fertilizers by the farmers mostly depends on the availability, price, subsidy and is hardly decided by local recommendations. Presently the consumption ratio of major nutrients NPK is 10:2.9:1 as against optimal ratio of 4:2:1 for cereals. This imbalance is prime cause of emerging multi-nutrient deficiencies and their farm level management has become a real challenge at present. These emerging nutrient deficiencies if neglected would make the situation even worse by declining the productivity as well as sustainability.

This is the fact that the 40 years old fertilizer recommendations may not hold true in the present context as there is appreciable decline in the nutrient status of the soil due to intensive cultivation across the country. The nutrients which were sufficient earlier, are now deficient.

There is vehement need of revalidating year old package of practices and fertilizer recommendations. And we are fortunate enough that several approaches for fertilizer recommendations have been developed based on soil test to resolve above mentioned problems related to fertilizer application and to get maximum yield per unit of fertilizer use. However, these fertilizer recommendations does not give much appreciable results when the cropping systems being followed in different parts of the country under different soils are considered.

In order to overcome these, soil test crop response (STCR) is one of the approaches where the amount of fertilizers are added based on the reports of soil testing and response of the crop to achieve targeted yield.

Objectives

Owing to all above points the present investigation "STCR approach for optimizing integrated plant nutrient supply to obtain better growth and yield of hybrid maize (*Zea mays L.)* is carried out with following specific objectives:

1. To study the response of N, P, K and FYM on growth and yield of Hybrid maize.
2. To determine the fertilizer doses for targeted yields of Hybrid maize.
3. To evaluate combined use of fertilizers and FYM for enhanced nutrient use efficiency.
4. To evaluate different methods of estimation of available P and K in soil.
5. To predict the soil test values for succeeding crops for fertilizer recommendation on the basis of post harvest analysis of soil samples.

Review of Literature

Soil test crop response studies facilitate to generate fertilizer adjustment equations and calibrate tables for fertilizers recommendations on the basis of soil test values for attaining the targeted yield of crops. In order to apply fertilizers in balanced proportions according to crop requirements, taking under consideration the soil available nutrients for targeted yields of crop, a complex set of scientific procedures involving accurate analytical methods are required to assess the available nutrient status of soil as uptake of plant nutrients varies with the change in soil fertility levels. Plant nutrients viz. nitrogen, phosphorus and potassium applied alone or in combination affect the crop yield vis-a-vis nutrient uptake by the crop.

In this chapter, an attempt has been made to collect the reviews of the available literature on different methods of determining extractable nitrogen, phosphorus and potassium in soil, crop growth, crop productivity, nutrient uptake and calibration of soil test data with crop response to applied fertilizer and FYM.

2.1 STCR Approach of calibrating soil test values with crop response to fertilizer and farm yard manure application

A calibrated soil test value clearly indicates the degree of deficiency of the particular nutrient and amount of nutrient that must be applied as fertilizer to correct the deficiency. A Sound soil test crop response correlation study is one that helps in making fertilizer recommendations for better crop yield. Such studies have to be crop, soil and climate specific **(Ramamoorthy and Velayutham, 1971).** Also a balanced fertilization considers type of soil, crop or cropping pattern, inputs, residue effects, available soil nutrient status, yield targets, economics of fertilizer use and time of application. Various approaches for calibration of soil test values for fertilizer recommendation are mentioned below:

2.1.1 Targeted yield approach

Concept of fertilizer prescriptions for desired targeted yields based on the available nutrient status was first put for- ward by **Truog (1960)**. **Ramamoorthy *et al.* (1967)** established theoretical basis and experimental verification for the principle of fertilizer application for the targeted yield of field crops. Among the various methods of fertilizer recommendation , the one based on yield targeting is unique in the sense that this method not only indicates soil test based fertilizer dose but also the level of yield that the farmer can hope to achieve if good agronomic practices are followed in raising the crop. The essential basic data required for formulating fertilizer recommendation for targeted yield are:

i. Nutrient requirement (NR) per quintal of grain (economic yield) production
ii. Percent contribution of nutrient from soil (Cs)
iii. Percent contribution of nutrient from targeted fertilizer or fertilizer use efficiency proportion (C_F)

Targeted fertilizer or yield equation functions properly when

i. Used for similar soils of particular agro-eco region.
ii. Maximum target should not exceed 75-80 per cent of the highest yield achieved of the crop in the area.
iii. Fertilizer nitrogen recommendation for legumes should be same as general dose of the crop of area.
iv. Adjustment equation must be made within experimental range of soil test values.
v. Good and recommended agronomic practices to be followed.
vi. Secondary and micronutrients are not limiting in soil
vii. For obtaining the real benefit of fertilizer application based on targeted yield approach, soil testing need to be done as frequently as possible.

2.1.2 Integrated Nutrient Management (INM) concept

Indiscriminate use of chemical fertilizers adversely affects soil health, sustainability of agricultural production and causing environmental hazards. It is a sustainable agricultural system which includes the conjunctive use of chemical fertilizer along with soil organic matter, biofertilizers, vermicomposts, animal manures, crop residues, green manures, sewage sludge and food industry wastes etc without deterioration of soil health. Five basic principles of sustainable integrated nutrient management system may be described as **(Meelu, 1996)**

(i) Nutrient removed must be returned to the soil.

(ii) Organic carbon levels should be maintained and enhanced.

(iii) Soil physical conditions should be maintained and upgraded.

(iv) Build up of abiotic stress should be minimal.

(v) Degradation of land due to soil erosion must be controlled.

2.2 Response of N, P, K and FYM on growth and yield

2.2.1 Grain yield

A significant increase in the grain yield of maize with successive increment in the levels of N,P and K fertilizers from 50% recommended dose (50% RDF) of 100:25.8:33.2 kg NPK/ha to 150 per cent was reported by **Singh *et al.* in 1991**.

In an experiment conducted by **Sharma *et al.* in 2000**, the grain yield of maize has responded to higher level of N up to 120 kg ha^{-1}.

88% higher grain yield of maize on application of 120 kg N and 60 kg P_2O_5/ha over no application was reported by **Nair in 2000** in two years of study on maize. Though the soil was low in available K, yet no potassium response was observed.

Brar *et al.* in 2001 reported maize response in terms of grain yield upto 100 kg N and 41.3 kg/ha K only. No further significant increase in the grain yield was observed with 150kg nitrogen and 82.6 kg potassium.

A significant higher grain yield of maize with higher level of 210 kg N, 50 kg P_2O_5 and 150 kg K_2O /ha was observed by **Singh and Sarkar in 2001.**

Supporting the above results **Kumar and Singh in 2003** also recorded a significant yield response of maize grain to increased level of nitrogen and phosphorus upto 100 and 80 kg ha^{-1}.

Verma and Prasad in 2003 conducted an experiment which reveal that maize required 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha to enhance the yield considerably.

Sutaliya and Singh in 2005 in his experiment on maize observed that the maize was highly responsive to high dose of l80:90:60 kg/ha N P and K.

A significant increase in the yield of green cobs of sweet corn with the application of 120:26.2:50 kg NPK/ha was observed by **Sahoo and Mahapatra in 2005.**

In a field experiment conducted on maize - gobhi sarson cropping system**,** **Kumar *et al.* in 2005** reported a significant response of maize to increased level of recommended dose of 120: 60: 40 kg/ ha N P K to 150 percent.

The recommended dose of fertilizer for the maize i.e. 120:26.2:41.5 kg/ha was reported most productive by **Karki *et al.* in 2005.**

Ahlawat *et al.* in 2005 reported a significant increase in the grain yield of maize with 120:60:40 N, P_2O_5, K_2O along with 5 kg Zn /ha over the control and biofertilizers treatments.

Singh *et al.* in 2005 conducted an experiment in the alluvial soils of the the Indo-Gangetic plains to estimate the fertilizer requirement for specific yield targets of maize and he concluded that for one tonne of grain yield, the requirement of N,P and K was 26.6, 4.5 and 25.3 kg, respectively. They also reported a significant higher yield *i.e.* 3.3 t ha^{-1} of grain with the application of 200:65:65 kg NPK ha^{-1}.

Verma *et al.* in 2005 conducted an experiment to validate the soil test based fertilizer prescription equations for targeted yield of maize crop in wet temperate zone of Himachal Pradesh. The results revealed that the fertilizer recommendations based on targeted yield concept were more precise and effective. The higher grain yield of maize (5.2 t ha^{-1}) was recorded with the application of higher doses of NPK *i.e.*162:102:85 kg NPK ha^{-1} in comparison with 3.2 t ha^{-1} state level recommendation of NPK (120:60:40 kg NPK ha^{-1}).

A significantly higher yield of maize was reported by **Dhillon *et al.* in 2006** in their experiment on target yield of maize. The grain yield when compared with general recommendation, farmer's practice was significantly higher *i.e* (27.6 to 46.0 q ha^{-1}) for the targeted yield of 45 q ha^{-1}.

A significant reduction in the yield of maize with lower levels of fertilizers i.e. 40: 60: 20 kg/ha N P K was reported by **Jamwal in 2006.**

Verma *et al.* in 2006 in the field experiment on maize-wheat cropping system suggested that there is a need to revise the recommended dose (RDF) of 90: 30: 15 kg / ha N P K and the recommended dose should be 150 per cent of RDF.

In the experiment on fertilizer requirement of maize, **Singh and Choudhary in 2008** reported significantly higher response of maize grain yield with the application of 120 kg N and 60 kg P / ha over the low levels fertilizers.

Another field experiment was conducted at ZARS, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka to study the effect of optimal rates of nutrient fertilizers through different approach in eggplant production to increase the nutrient use efficiency. The results revealed that the significantly higher fruit yield (37.81 t ha-1) was noticed in soil test crop response (35 t ha-1) with IPNS approach compared to inorganic treatment (35.98 t ha-1) with same target.(**Basavaraja *et al.* 2019)**

Also, an experiment was conducted at soil science research farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, to study the effect of STCR-based manure and fertilizers application on growth and yield of rice, and changes in chemical properties of soil. Experiment was carried out during kharif season of 2016.The result revealed that rice growth parameters and grain yield was significantly affected due to fertilizers and manure application and recorded the highest yield in treatment T6 (5725 kg ha-1) which was significantly superior to the control . **(Chaudhary *et al.* 2019)**

2.2.2 Stover Yield

Dey and Sharma in 1996 in his experiment reported the significant increased stover yield of maize on application of 40 kg N/ha.

Also, **Jha *et al*, 1997** reported that the target yield of 50 q ha^{-1} with the application of fertilizer and FYM (5 t ha^{-1}) recorded significantly higher seed yield of maize (4.8 t ha^{-1}).

Brar *et al.* in 2001 recorded significantly higher yield of stover on application 150 kg N/ha over100 kg N/ha.

However, **Nanjappa *et al.* in 2001** observed no significant improvement in stover yield by increasing the nitrogen levels upto 150 kg/ha.

Singh and Sarkar in 2001 in his experiment on maize**,** reported that on application of 210 kg N, 90 kg P_2O_5 and 150 kg K_2O/ ha stover yield obtained was maximum.

A consistent increase in the yield of maize stover on successive increment in the nitrogen levels upto 150 kg/ha was observed by **Kumar and Singh in 2003.**

Also, **Jayaprakash *et al.* 2005** reported the highest grain yield of maize (67.47 qha^{-1}) with the application of vermicompost @ 2 t ha^{-1} compared to control (52.35 q ha^{-1}).

On application of 120 kg N /ha, 85.5% increase in stover yield over control was reported by **Karki *et al.* in 2005**.

The yield of maize stover was significantly higher with 125% recommended dose of 90 kg Nitrogen and 40 kg phosphorus over 100% recommended dose **Singh and Singh in 2006**.

Arvind *et al.* in 2006 conducted an experiment on maize in order to know the effect of integrated nutrient supply (IPNS) on the yield of maize in sandy clay loam soils of Udaipur. The maximum plant height, leaf area index (LAI) and dry matter (g $plant^{-1}$) at harvest was estimated in the treatment with 150 per cent recommended NPK. The results showed a significantly higher yield of grain (34.15 q ha^{-1}) and stover (47.65 q ha^{-1}), though the results were at par with 100 per cent NPK along with FYM at the rate of 10 t ha^{-1}.

Jayaprakash *et al.* in 2006 reported that on applying higher levels of NPK fertilizers (200, 175, 150 and 125 % NPK of recommended doses) has increased the grain yield of maize to the tune of 30, 26, 22 and 11 per cent, respectively over 100 per cent recommended NPK. Also application of 200 per cent NPK of the recommended dose resulted in significantly higher stover yield *i.e.* 10.31 t ha^{-1} over 100 per cent recommended NPK (9.10 t ha^{-1}).

Arun *et al*. **in 2007** observed different factors in his experiment on maize. He observed that the highest leaf area index(LAI), dry matter yield, number of grains per cob, cob length (cm), cob girth (cm), fresh cob yield (t ha^{-1}) was reported in treatment which received 100% RDN + 100% RDP + 125% RDK over the treatment that received 50% RDN + 75% RDP + 75% RDK.

But on doubling the rate of 180 kg N ha $^{-1}$, 40 kg P ha $^{-1}$, and 75 kg K ha $^{-1}$ fertilizer, only minimal enhancement in grain filling rate (0.8%), grain filling duration (1.6%), grain volume (1.3%) and grain yield (0.4%) over control was observed by **Liu, K. *et al.* in 2011** in summer corn.

Above results are also supported by **Mukhtar *et al*. in 2011.** He conducted an experiment on maize and recorded that all fertilizer rates have significantly showed an increase in the plant height, test weight, grain number per ear, grain weight per ear and grain yield of both the hybrids under study over control. The data revealed that Maximum 1000-grain weight (430.0 g), grain number (658 ear-1), grain weight per ear (281.3 g) and grain yield (8.237 t ha $^{-1}$) were obtained in NP rate of 250-125 kg followed by 300-150 kg NP.

Sankar *et al.* 2011 on the basis of a very long-term comprehensive study (1984–2008),) found that application of FYM and maize residues increased millet yield as well as sustainability in rainfed semiarid tropical Alfisols.

Spandana Bhatt in 2012 conducted a field experiment on sweet corn and recorded a significant increase in plant height from 198.2 to 210.2 cm on increasing nitrogen levels from 120 to 210 kg ha$^{-1.}$

The highest stover and grain yield was obtained by **Hemalatha and Prathyush in 2013** on their experiment on maize. They reported stover yield of 8082 kg ha^{-1} and grain yield of 5366 kg ha $^{-1}$ with the higher level of nitrogen (N-120 kg ha $^{-1}$).

2.3 Fertilizer doses for targeted yields

As per the Liebig's law of minimum, a particular amount of soil nutrient is sufficient for one particular yield. However, according to Mitscherlich-Baule sufficiency concept, a given amount of soil nutrient is not only sufficient for one particular yield but also for wide range of yields. Bray and Kurtz in 1954 gave a statement according to which relatively mobile nutrients *i.e.* N follow Liebig's law of minimum and law of limiting nutrients and the immobile nutrients *i.e.*P and K follow the percentage sufficiency concept of Mitcherlich and Baule.

Ramamoorthy *et al.* in 1967 established a theoretical basis with the experimental proof for contradicting the above mentioned statement and said that

Leibig's law of the minimum operates equally well for N, P and K. This forms a base for fertilizer recommendation for specific targeted yields.

Fertilizer recommendations for targeted yield can be worked out by the given formula as described by **Ramamoorthy *et al.* in 1975.**

$$T = NS / (M-R) \text{ and}$$

$$F.D = R\ M\ S / (M-R)$$

Where,

T = Target yields in q ha^{-1}

N = Ratio of the percentage contribution from soil and fertilizer nutrient

R = Nutrient requirement in kg ha^{-1}

M = Ratio of nutrient requirement and contribution from fertilizer

S= Soil test value in kg ha^{-1}

F.D= Fertilizer dose in kg ha^{-1}

In another study, **Hegde and Gowda, 1986** reported that finger millet grain yield was 23.1 kg per kg N at 20 kg N ha^{-1}, while the yield benefit declined to 19.9 kg per kg N at 60 kg N ha^{-1}.

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 were prepared by **Reddy and Ahmed, 2000** based on the targeted yield concept for use by the farmers.

In an another study**, Singh *et al*., 2006** estimated the fertilizer requirement for attaining the specific yield targets of maize in the alluvial soils of Indo-gangetic plains. He reported that the requirement of N, P, and K for one tonne of grain yield was 26.6, 4.5 and 25.3 kg, respectively.

Also, **Sanjay *et al.*, 2006** reported that application of double the fertilizer dose and application of fertilizer for targeted paddy yield of 10 t ha^{-1} through 100 per cent inorganic sources recorded significantly higher grain yield (10330 and 10262 kg ha^{-1} , respectively).

Suri *et al.,* 2010 also reported that the inoculation of three VAM cultures alone or with increasing applied phosphorus levels from 25 to 75% of recommended P_2O_5 based on soil test crop response (STCR) precision model improved the plant height, shoot and root dry matter accumulation, root length and root weight density as well as yield attributes of rainfed maize in an acid Alfisol of N-W Himalayas. They also reported the saving of applied P to the tune of about 25% without impairing the soil fertility in the present study.

Based on a 25 year long term experiment conducted under rainfed conditions on Alfisols in Bangalore (Southern India), **Sankar *et al.,* 2011** observed that application of $N:P_2O_5:K_2O$ at 50:50:25 kg ha^{-1} increased finger millet yield and soil fertility status compared to non-fertilized plants.

Singh *et al.,* 2015 conducted an experiment for target yield equation (TYE) based on integrated nutrient management in maize (*Zea mays L*) and wheat (*Triticum aestivum L*) and results showed an achievement of 98.5% of the target yield in maize and 96.6% in wheat.

2.4 Nutrient Use Efficiency as influenced by application of fertilizers and /or manures

To show how nutrient use efficiency is influenced by application of fertilizers and/or manures, in a study higher nutrient content in Ragi crop with compost + 100 per cent NPK in a green house experiment carried out on red and black soils was observed by **Lakshman and Manickam, 1993.**

Also**, Prasad and Prasad, 1994** observed that the correlation coefficients between grain yield of rice and N, P and K uptake were 0.95, 0.91 and 0.85, respectively. The highly significant linear relationship between yield and uptake revealed that to produce a specific yield a definite quantity of nutrients must be absorbed by plants.

In an another study, **Dhillon and Brar, 1998** studied a complex soil test crop response correlation experiment revealed that nutrient uptake (NPK) values were of higher order in FYM treated plots as compared to unmanured plots and improved with graded levels of nutrients application in FYM treated plots .

Also, **Duryodhana *et al.*, 2004** gives combined application of agrimagic + 100 per cent NPK and FYM with general recommended fertilizers increased the nutrient uptake over absolute control in ragi.

Milapchand *et al.*, 2004 stated that the per cent P contribution from soil increased with increasing N rates and at the same rate of fertilizer N, it decreased as the STV of P increased. The effect of N fertilizer in influencing P supply to plants was due to better root proliferation. In control plot the mean P uptake found to be 14.4 kg ha^{-1} whereas in treated plots P uptake found to be 16.2 kg ha^{-1}, which was fertilized by 150 kg ha^{-1} of N.

Also, **Anand *et al.*, 2005** found that STCR approach recorded higher agronomic and nutrient use efficiency, whereas recommended dose of fertilizer recorded higher grain yield and nutrient uptake in groundnut – maize cropping system.

A higher nutrient use efficiency for nitrogen, phosphorus and potassium was observed by **Ashwini in 2007**, when nutrients were applied according to POP (package of practice) which was followed by targeted yield of 50 q ha^{-1} for fingermillet.

Basavaraja *et al.* in 2011 in his experiment on paddy reported that nutrient uptake and nutrient use efficiency was significantly higher in treatment that followed integrated approach while lowest nutrient uptake and nutrient use efficiency was observed in the treatment that followed inorganic fertilizer solely.

Anupama *et al.*, 2012 conducted an experiment on Maize under IPNS System and he reported that fertilizer efficiencies for P were less than soil test efficiencies but contrary to this, fertilizer efficiencies for nitrogen and potash were observed higher than soil test efficiencies. The efficiency of FYM for N was found to be higher and minimum value was observed with phosphorous.

In another study, **Chatterjee *et al.*, 2013** reported that maize may be grown with 75 Kg N ha^{-1} and wheat residue mulch @ 10 t ha^{-1} to achieve higher yield, water use efficiency and N use efficiency.

Similar observation was reported by **Santhosha in 2013** in maize that higher nutrient use efficiency was recorded under soluble fertilizer while lowest NUE was observed in conventional fertilizers.

A significant high agronomic nutrient use efficiency in maize was reported by **Basavaraja *et al*. in 2014** which revealed that in STCR approach for target yield of 90 q ha $^{-1}$ with IPNS system, the nutrient use efficiency was 10.86 kg kg^{-1} in comparison with 3.09 kg kg^{-1} with purely inorganic fertilizers.

Also **Singh *et al.*, 2015** in another study on integrated nutrient management in maize (*Zea mays L*) and wheat (*Triticum aestivum L*) reported that N, P, and K uptake were higher in maize with 100% NPK with 2 t ha^{-1} farm yard manure, estimated at 91.08, 37.00 and 80.00 kg ha^{-1}, compared with 55.66, 27.00 and 59.20 kg ha^{-1} of N, P, and K uptake, respectively, in maize with 100% fertilizer NPK application.

In support of the above reviews, an another study was conducted by **Thangasamy *et al.*, 2017.** He reported that the application of NPK +FYM increased nutrient uptake significantly compared to remaining fertilizer treatments and control to the tune of 131.3 to 227.3 percent higher N, P,K compared to control and 11.2 to 29.2 percent compared to NPK treatment.

2.5 Different methods of estimation of N,P,K in soil

For quick characterization of soil fertility status and prediction of crop nutrient requirement, soil testing is scientifically well recognized approach. The success of soil testing approach largely depends on the method and procedure chosen for testing. The effective method is one that can extract the nutrients in proportion to the amount of that nutrient actually taken up the by the crop.

Different scientists have worked for determining the effective and efficient method of soil testing which is been reviewed below.

2.5.1 Soil testing methods for nitrogen

It is established that Indian soils are deficient in nitrogen, so for getting the highest yield advantage, it is required in comparatively large amount for the crops. Before going for fertilizer nitrogen recommendation, it is necessary to determine the soil supplying capacity of nitrogen. Different chemical and biological methods for nitrogen extraction in soil are given below:

1. Organic carbon by **Walkley and Black in 1934**
2. Alkaline $KMnO_4$ oxidizable N (0.32% $KMnO_4$ + 2.5% NaOH) by **Subbiah and Asija in 1956**

3. Boiling water extractable N by **Livens in 1959**

4. 0.25 N H_2SO_4 by **Richard *et al.* in 1960**

5. 1N NaOH by **Cornfield in 1960**

6. Ca $(OH)_2$-Nitrogen by **Prasad in 1961**

7. Nitrate-nitrogen by **Bremner in 1965**

8. Electro-Ultrafication method by **Nemeth in 1979**

Corelation studies under soil test crop response have been done by many workers. The correlation coefficient between alkaline $KMnO_4$ method of estimating nitrogen and yield response of wheat was 0.61 according to the reports of ICAR coordinated project on STCR at pantnagar. Also the correlation between alkaline $KMnO_4$ method of estimating nitrogen and organic carbon was equally high **(ICAR 1972).**

Among different chemical methods of available nitrogen estimation, **Lakminarayan and Rajagopal, 2000** have reported that available nitrogen estimated by hot $K_2Cr_2O_7$, cold $K_2Cr_2O_7$ and alkaline $KMnO_4$ were found suitable for nitrogen availability prediction for rice.

Soil organic carbon and soil nitrogen was signicantly coordinated by **Bhaskar Rao *et al.*** in **2002.**

Also **Sati, 2008** in his study on yellow sarson have observed that organic carbon and alkaline-$KMnO_4$ methods were equally suitable for evaluation of available nitrogen.

Bordoloi *et al,* 2013 have also evaluated different methods of available nitrogen estimation. In his study on twenty acidic soils varying widely in properties, among six chemical indices of soil nitrogen availability Phosphate-Borate buffer extractable N (PBB-N) was reported as an appropriate index of N- availability and was equally correlated with the plant (maize) parameters.

2.5.2 Soil testing methods for phosphorus

Different methods for estimating extractable phosphorus in soil have been proposed by different scientists which are given below:

1. 0.002 N H_2SO_4 (pH 3.0) by **Truog in 1930**

2. 0.125 N NaOH + 0.175 N NaOAc by **Morgan in 1941**

3. 0.025 N HCl + 0.03 N NH_4F (Bray I) by **Bray and Kurtz in 1945**

4. 0.1 N HCl + 0.03 N NH_4F (Bray II) by **Bray in 1945**

5. 0.05 N HCl + 0.025 N H_2SO_4 by **Nelson et al. in 1953**

6. 0.05 N HCl + 0.025 M H_2SO_4 by **Mehlich No. 1 in 1953**

7. 0.5 M $NaHCO_3$ (pH 8.5) by **Olsen et al. in 1954**

8. Phosphorus fractionation by **Chang and Jackson in 1957**

9. Phosphate potential by **Beckett and White in 1964**

10. Neutral 0.0025 N Na_2-EDTA by **Ahmed and Islam in 1975**

11. AB-DTPA 1M NH_4HCO_3 + 0.005 M DTPA (pH 7.6) by **Soltanpour and Schwab in 1977**

12. 0.73 M NaOAc + 7.4 M HOAc (pH 4.8) by **Morgan and Wolf in 1982**

A relationship between the olsen's method of extractable phosphorus and relative yield along with relative phosphorus uptake was observed significantly higher *i.e.* r= 0.66 in rice by **Laxminarayana in 2001.**

Fransson in 2001 reported a signicant correlation between oxalate extraction method and Na_2SO_4+NaF extraction.

In case of phosphorus, **Dolui and Majumdar, 2003** have reported suitability of different extractants in the order : Bray-2 > Olsen > North Carolina > Bray-1 > Soltanpour and Schwab, for estimating the available phosphorus status of West Bengal and Uttar Pradesh.

2.5.3 Soil test methods for Potassium

No doubt that Indian soils are rich in potassium but because of not adding potassic fertilizers and luxury consumption of potassium by the crop, potassium status of soil is depleting. The various methods available for estimating extractable potassium in soil are given below:

1. 1 N HNO_3 soluble potassium by **Wood and De Turk in 1940**

2. 0.125 N NaOH + 0.175 N NaOAc by **Morgan in 1941**

3. 1 N neutral NH_4OAc by **Hanway and Hiedal in 1952**

4. Acetic acid soluble by **Willium and Stewart in 1955**

5. 1.38 N H_2SO_4 soluble by **Hunter and Pratt in 1957**

6. Q/I parameters by **Beckett in 1964**

7. Water soluble potassium by **American Society of Agronomy in 1965**

8. AB-DTPA (1 M NH_4HCO_3 + 0.005 M DTPA at pH 7.6) by **Soltanpour and Schwab in 1977.**

For suitability of potassium availability indices, **Tiwari *et al.,* 2001** conducted an experiment and found that boiling 1N HNO_3 and 1N NH_4OAc (pH 7.0) methods were superior over other methods.

An another study was conducted by **Shanwal and Singh, 2004** for evaluating available potassium extracting methods and he reported that 0.5 N HNO_3 at 25º C was found best method for barley and maize and 3N HNO_3 at 40º C for wheat and bajra.

Materials and Methods

Chapter 3 MATERIALS AND METHODS

In order to evaluate the response of maize in relation to integrated plant nutrient supply (IPNS) on maize yield and uptake in Mollisol of Uttarakhand, following work has been done.

The details of the materials being used and methodology being adopted during the research work entitled “STCR approach for optimizing integrated plant nutrients supply to obtain better growth and yield of hybrid maize *(Zea mays L.)”* are described in this chapter.

3.1 Description of the Experimental Site

3.1.1 Site

The present investigation was conducted in D7 block of Norman E. Borlaug Crop Research Centre (NEB-CRC), G.B. Pant University of Agriculture and Technology, Pantnagar, Distt. U.S. Nagar, Uttarakhand during 2017-18. The field is situated at the foot hills of Shivalik range of Himalayas at the latitude of 29^0 N, longitude of $79^0$29’ E and an altitude of 243.84 m above the mean sea level.

3.1.2 Weather and climate

Climate of this area is humid, sub-tropical with hot and dry summers and cool winters. The monsoon season usually starts from third week of June and extends up to last week of September. Few spell of downpours are generally received during winter season (November to March). Approximately 70 percent of it is received during rainy season. Different weather parameters during the period of experimentation (2017 to 2018) as recorded at the meteorological observatory located at NEB-CRC are depicted in figure 3.1 and also presented in Appendix VI.

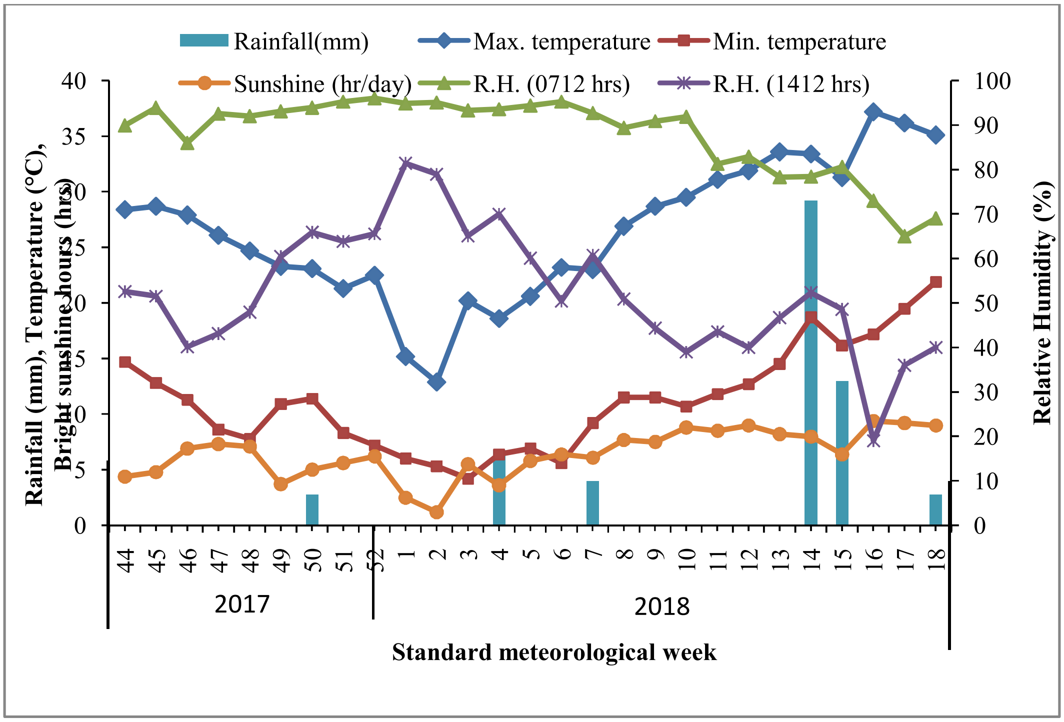


Fig.3.1: Meteorological data

3.1.3 Soil

The soil of the experimental site was classified by **Despande *et al*.** in **1971** as

Order	:	Mollisol
Suborder	:	Udoll
Great group	:	Hapludoll
Subgroup	:	Aquic hapludoll
Family	:	Fine, mixed loamy, hyperthermic
Soil series	:	Pattharchatta Sandy loam

Soils of this region are developed from medium to moderately coarse textured calcareous alluvium brought down from mountains by numerous streams flowing through the Bhabar and Tarai. These are mainly silty and loamy in texture with weak fine to medium fine granular structure, having good moisture storage capacity and are highly productive.

Other soil characteristics of the experimental site were as follows:

- Slope : 1-3%
- Drainage : Moderately well to well drained
- Present land use : Cultivated land.
- Colour : Yellowish brown
- Soil texture : Sandy loam
- Consistency : Moist friable to loose
- Soil Structure : Granular

Table 3.1: Physico-chemical properties of the soil of the experimental site (0-15 cm soil depth)

S. No.	Property	Value obtained	Method employed
1.	Textural analysis		Bouyoucos Hydrometer method (**Black, 1965)**
	Sand (%)	53.62	
	Silt (%)	26.14	
	Clay (%)	20.24	
	Textural class	Sandy loam	USDA textural triangle
2.	pH (1:2.5 soil water suspension	6.76	Glass electrode pH meter **(Jackson, 1958)**
3.	Electrical conductivity (dS m^{-1})	0.19	**Bower and Wilcox (1965)**
4.	Organic carbon (%)	0.62	Walkley and Black method **(1934)**
5.	Available nitrogen (kg N ha^{-1})	135.5	Alkaline $KMnO_4$ method **(Subbiah and Asija, 1956)**
6.	Available phosphorus (kg P ha^{-1})	12.8	Olsen's extraction method **(Olsen *et al.*, 1954)**
7.	Available potassium (kg K ha^{-1})	170.3	Neutral 1 *N* NH_4OA_C extraction method **(Hanway and Hiedal, 1952)**

3.2 Methodology of Experiments

Soil Test Crop Response studies for balanced fertilization in maize based on Integrated Plant Nutrition System (STCR - IPNS) were conducted adopting the Inductive cum Targeted yield model, on a Mollisol in tarai region, India. This study comprised of two phases viz., fertility gradient experiment with wheat var. (UP2526) (Phase I *i.e.* preparatory trial) in year 2017-18, test crop experiment with hybrid maize var. (P3377) (Phase II *i.e.* main trial) in year 2018.

Before starting the first phase of the experiment composite soil sample from the experimental field was collected and analyzed for various physico-chemical properties, presented in table 3.1. The above experiments were conducted as per the technical programme and methodology of STCR to study the effect of balanced fertilization on growth, quality and yield of hybrid maize. The details of the field experiments carried out and methods of analysis of soil and plant samples and the methodology followed in the development of prescription equations are presented as follow:

3.2.1 Soil Fertility gradient Experiment (First Phase)

In the soil fertility gradient experiment, operational range of variation in soil fertility was created deliberately. For this purpose, the experimental field was divided into three equal strips, the first strip received no fertilizer (N0P0K0), the second strips received 100:100:100 N, P_2O_5 and K_2O kg ha^{-1} (N1P1K1) and third strip received 200:200:200 N, P_2O_5 and K_2O kg ha^{-1} (N2P2K2). An exhaust crop of wheat var. (UP2526) was grown during Rabi 2017 for successful conduct of soil test crop response study and for minimizing the interference of other soil and management factors affecting crop yield. Pre-sowing and post-harvest soil samples of soil were collected from each fertility strip and analyzed for alkaline $KMnO_4$-N (**Subbiah and Asija, 1956**), Olsen –P (**Olsen *et al*., 1954**) and NH_4OAc-K (**Hanway and Hiedal, 1952**). At harvest, biomass yield and grain yield was recorded (q ha^{-1}) in different strips. The layout is shown in figure 1:

Plate 1: Photographic view of exhaust crop experiment

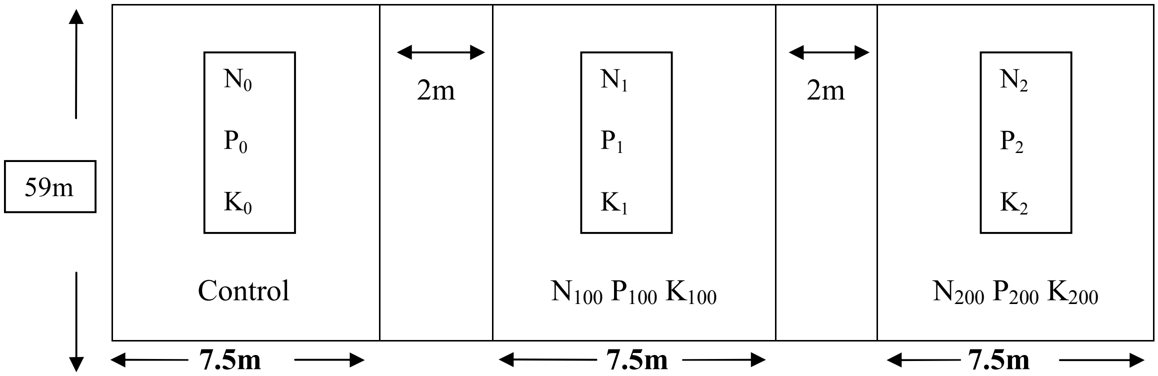


Fig. 3.2: Layout of the fertility gradient experiment (Exhaust crop)

In the first phase, 2017, land was prepared in the month of November. For preparation of field one disc ploughing followed by two cross harrowing was done on November 21, 2017. Layout of the field was prepared on November 22, 2017. The furrows were opened by using furrow opener. Seeds were placed and patela was used to cover the seed. The roller was then used to compact the field and maintain the moisture in the field. Also, the pre-emergence weedicide was applied on November 23, 2017. Experimental site was divided into three equal strips (60.0m × 7.5 m) to apply three levels of nutrients, viz. 0, 1, 2 (i.e. N0P0K0, N1P1K1 and N2P2K2) as given in table 3.2. Nitrogen, phosphorus and potassium were applied as urea, single super phosphate and murate of potash, respectively. Half dose of nitrogen and full dose of phosphorus and potassium were broadcasted on November 23, 2017 as basal. While remaining half dose of nitrogen was applied in two split doses as top dressing.

Sowing was done at 23 cm row to row distance on November 23, 2017. Seeds of variety UP2526 were sown at the rate of 100 kg ha $^{-1}$ or 4.5 kg per strip. Plant population was maintained by gap filling at improper germination sites after fifteen days after sowing. An attempt was made to keep crop free of weeds, insects, pests and diseases through recommended agronomic practices. Harvesting was done on April 23, 2018. Photographic view of this experiment is presented in Plates 1 & 2.

Table 3.2: Nutrients applied in fertility gradient stabilizing experiment

Strip	Symbol	Nutrient level (kg ha^{-1})		
		N	P_2O_5	K_2O
I	$N_0P_0K_0$	0	0	0
II	$N_1P_1K_1$	100	100	100
III	$N_2P_2K_2$	200	200	200

3.2.2 Test crop experiment (second phase)

After establishing the fertility gradient in the experimental field, the second phase *i.e.* test crop experiment was proceeded. In this phase, Land was prepared in the month of june with one disc ploughing followed by four cross harrowing was done within each strip. The field was leveled with the help of leveler to furnish gentle slope for better drainage. Then field was divided into 3 equal strips corresponding to those made in the fertility gradient experiment. Each strip was further divided into 24 plots (21 treatments+ 3 controls) resulting in 72 (24x3) total plots. Prior to any other operation, the initial soil samples were collected from all the 72 plots of the three strips and analysed for extractable N,P and K by using $KMnO_4$-N, Olsen's-P and NH_4OAc-K methods respectively. The experiment was conducted in a fractional factorial design comprising twenty four treatments and the test crop experiment with hybrid maize was conducted with four levels each of N (0, 60, 120 and 180 kg ha $^{-1}$), P_2O_5 (0, 30, 60 and 90 kg ha $^{-1}$) and K_2O (0, 20, 40 and 60 kg ha $^{-1}$) and three levels of FYM (0, 5and 10 t ha-1). 72 different combinations of treatments were made. These treatments comprised of various combinations and levels of nitrogen, phosphorous, potash and farm yard manure (FYM) as given in table 3.3. Hybrid maize (var. P3377) was planted on the site of fertility gradient experiment during kharif, 2018. Hybrid maize variety P3377 is an early maturity hybrid with high shelling percentage and good stress tolerance. Half dose of nitrogen, full dose of P , K and FYM was applied at the time of sowing *i.e.* June 25, 2018. While one fourth nitrogen was applied after 30-45 days after sowing *i.e.* August 9, 2018 and remaining one fourth nitrogen was given just before tasseling. To keep crop free from weeds, insects, pests and diseases, the recommended agronomic practices were followed during the crop season. The proposed layout of the experiment is given in fig.3.3.

Table 3.3: Nutrients applied in test crop experiment

Nutrient level	FYM (t ha^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
0	0	0	0	0
1	5	60	30	20
2	10	120	60	40
3	-	180	90	60

STRIP 1

STRIP 1

STRIP 3

Plate 2: Photographic view of test crop experiment

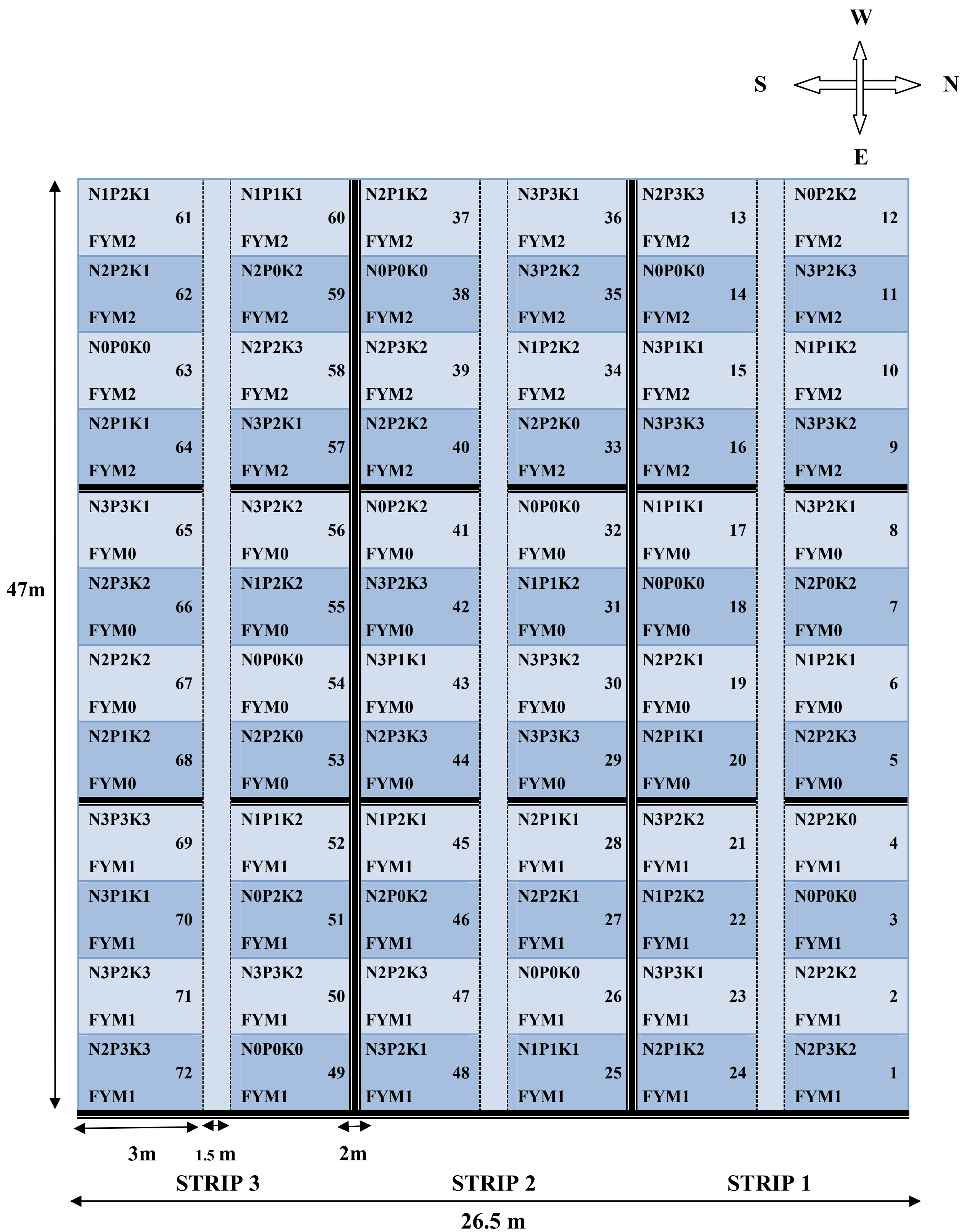


Fig.3.3: layout plan with different treatment combination s for the test crop experiment

a) **Test Crop: Hybrid maize (*Zea mays*)**

b) **Treatments:** Various combinations of N,P,K and FYM treatments are selected as suggested by AICRP on STCR.

Different levels of N,P,K and FYM are as follows-

N_0	=	0 kg N ha^{-1}
N_1	=	60 kg N ha^{-1}
N_2	=	120 kg N ha^{-1}
N_3	=	180 kg N ha^{-1}
P_0	=	0 kg P_2O_5 ha^{-1}
P_1	=	30 kg P_2O_5 ha^{-1}
P_2	=	60 kg P_2O_5 ha^{-1}
P_3	=	90 kg P_2O_5 ha^{-1}
K_0	=	0 kg K_2O ha^{-1}
K_1	=	20 kg K_2O ha^{-1}
K_2	=	40 kg K_2O ha^{-1}
K_3	=	60 kg K_2O ha^{-1}
FYM_0	=	0 tonnes FYM ha^{-1}
FYM_1	=	5 tonnes FYM ha^{-1}
FYM_2	=	10 tonnes FYM ha^{-1}

c) **Strips:** 3

d) **Plots within each strip:** 24

e) **Plots size:** 3m×3m

3.3 Observations

3.3.1 Collection of Soil Samples

Different soil samples were collected at different phases of the experiments. First soil sample was collected from 5-6 places at 0-15 cm depth for initial characterization of soil before the fertility gradient experiment. Another lot of soil samples were collected before the start of test crop experiment (72 samples) from each plot according to layout plan. Soil samples were also collected after harvesting the main crop *i.e.* Hybrid maize. After air drying, soil samples were finely ground and passed through 2mm sieve prior to analysis.

3.3.2 Collection of Plant Samples

Plant samples and grain samples were collected from each plot. Air dried plant samples were kept in paper bags and oven dried at 60°C for 48 hours. Dry matter yield was recorded and samples were then grinded. Similarly, the grain samples were collected, oven dried and grinded for chemical analysis.

3.3.3 Yield

3.3.3.1 Total biomass yield (Grain + stover)

Maize plants were harvested manually and above ground biomass was recorded from each plot as kg per plot and the it was converted in q ha^{-1}. Plant samples were also collected for nutrient uptake analysis from each plot.

3.3.3.2 Grain yield

Grain yield per plot was obtained by harvesting of cobs from each plot separately and reported as q ha-1. Grain samples were also taken for N,P and K analysis.

3.3.4 Chemical analysis of Soil Samples

All soil samples were analysed for:

i) pH (**Jackson ,1967**)

ii) EC (**Bower & Wilcox ,1965**)

iii) O.C. (**Walkely & Black,1934**)

iv) Available N (**Alkaline $KMnO_4$ method (Subbiah and Asija, 1956**)

v) Available P (**Olsen's extraction method (Olsen *et al.*, 1954)**

vi)Available K (**Neutral 1 *N* NH_4OA_C extraction method (Hanway and Hiedal, 1952**)

3.3.4.1 Availability indices of Phosphorus

Phosphorus content in the samples were analysed by two methods:

(a) Olsen method : Phosphorus was analysed using olsen's reagent 0.5 M $NaHCO_3$ at pH 8.5 **(Olsen et al., 1954**) followed by colour development using ascorbic acid method (**Murphy and Riley, 1962**) and the extractable phosphorus concentration in soil samples was recorded from readings through spectrophotometer at 730 nm wavelength. Final values of P in soil were recorded and converted into kg ha^{-1}.

(b) AB-DTPA method : By using ammonium bicarbonate-diethylene triamine penta acetic acid (AB-DTPA) (1M NH_4HCO_3 +0.005M DTPA at pH 7.6) as extractant suggested by **Soltanpour and Schwab, 1977** followed by colour development using ascorbic acid method (**Murphy and Riley, 1962**) and phosphorus concentration was recorded by using spectrophotometer at 820 nm wavelength. Final values were recorded in kg ha^{-1}.

3.3.4.2 Availability indices of Potassium

(a) Neutral ammonium acetate method: Extractable Potassium in the soil samples was determined by neutral ammonium acetate as extractant as suggested by **Hanway and Hiedal, 1952.** Potassium concentrations in the extracts were recorded by using flame photometer. Final values of potassium in soil were reported in kg ha^{-1}

(b) AB-DTPA method: By using AB - DTPA (1M NH_4HCO_3+ 0.005M DTPA at pH 7.6) as extractant discovered by **Soltanpour and Schwab, 1977**. Final values of potassium in soil were reported in kg ha^{-1}.

3.3.5 Chemical analysis of Plant Sample

Processed plant and grain samples of maize were analyzed for N, P and K content. Digestion of 0.5g plant sample in order to oxidize the organic material and release the minerals, was done with di-acid mixture of concentrated HNO_3 and 70 per


BOROSIL
500ml
4980


CLEAN THE
GLASSWARE
AFTER USE

cent perchloric acid in the ratio of 9:4. **(Jackson, 1967).** The digested residue material was dissolved in 6 N HCl. The 100 times volume makeup was done by distilled water in volumetric flask.

Details of these analysis are given below.

3.3.5.1 Nitrogen

The nitrogen content in the plant and grain samples was determined by modified micro-kjeldahl method (**Jackson, 1967**). The digestion of processed plant sample (0.2 gm) was done by using 10 ml of sulphuric acid (H_2SO_4) along with 1 gm of catalyst mixture in a digestion tube. The tubes were kept overnight for pre-digestion. Now, the digestion was being carried on digestion assembly till it becomes colourless. The digested material was distilled and liberated ammonia was absorbed in 4% Boric acid solution with mixed- indicator. The distillate was titrated by N/20 H_2SO_4 solution to estimate the nitrogen content. Both plant and grain nitrogen was then expressed in percentage on dry weight basis.

3.3.5.2 Phosphorus

Phosphorus in both plant and grain of maize was determined by Vanadomolybdo-Phosphoric acid, yellow colour-method in acid system and the yellow colour intensity was recorded by UV-VIS spectrophotometer at 420 nm wavelength as suggested by **Chapman and Parker,1961**. The contents were expressed as percent dry weight.

3.3.5.3 Potassium

The potassium content in the digested material was estimated by using flame photometer. The contents were expressed as percent potassium in both plant and grain samples.

3.3.6 Total nutrient uptake

(a) Uptake by plant (kg ha^{-1}) = Nutrient content (%) in plant × dry matter yield of plant (kg ha^{-1}) / 100

(b) Uptake by grain (kg ha^{-1}) = Nutrient content (%) in grain × dry matter yield of grain (kg ha^{-1}) / 100

(c)Total nutrient uptake by plant (kg ha^{-1}) = Uptake by plant (kg ha^{-1}) + Uptake by grain (kg ha^{-1})

3.3.7 Basic data for Fertilizer Recommendation

Basic data required for fertilizer recommendation was estimated with the help of soil & applied fertilizer nutrients, plant and grain yield, nutrient uptake of plants and grain.

3.3.7.1 Nutrient requirement for production of one quintal of economic yield (grain)

The nutrient requirement was calculated as follows:

$$\text{Nutrient requirement (NR)} = \frac{\text{Total nutrient uptake (kg)}}{\text{Grain yield (q)}}$$

The values were reported as kg of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) required for producing one quintal of grain. These values were separately calculated for each plot and then average value was taken.

3.3.7.2 Soil Contribution of nitrogen, phosphorus and potassium (Cs)

In order to estimate the contribution of NPK from soil, the efficiency of soil nutrients was calculated from soil test values of unfertilized plots *i.e.* control plots. The soil efficiency was estimated as a ratio of total uptake to the soil test value of a nutrient. This was done for each control plot and their average was made. The soil contribution of each plot was calculated by the product of the soil test value of the plot with the average soil efficiency which was determined from the unfertilized plots.

The soil efficiency was calculated as given below:

Percent contribution of available nutrient from soil (Cs)

$$= \frac{\text{Total uptake of nutrient in control plot}}{\text{Soil test value of that nutrient in control plot}} \times 100$$

For each nutrient, the average of all the control plots for that particular nutrient is calculated.

3.3.7.3 Contribution of concerned nutrient from fertilizer without FYM (Cf)

The efficiency of the applied fertilizer was calculated from treated plots taking into consideration the soil contribution. The fertilizer efficiency was computed as a ratio of the difference of the total uptake and soil contribution to the applied fertilizer dose in each treated plot.

$$Cf = \frac{T-\left(S\ X\frac{CS}{100}\right)-\left(N\ X\frac{CFYM}{100}\right)}{FD}\ X\ 100$$

Where,

T = total uptake of nutrients (kg/ha) in fertilizer and FYM treated plots

S= soil test values of nutrients in fertilizer and FYM treated plots

N= nutrient added (kg/ha) through FYM

FD= fertilizer dose (N/P/K) applied (kg/ha)

3.3.7.4 Contribution of nitrogen, phosphorus and potassium from FYM (Cfym)

The efficiency of FYM for any nutrient was computed from those plots that had only FYM treatment (6 plots). This efficiency is calculated by the ratio of difference between total nutrient uptake from only FYM treated plot and soil test value of nutrients in only FYM treated plot to the dose of FYM applied.

Percent contribution of nutrient from FYM

$$= \frac{T-\left(S\ X\frac{CS}{100}\right)}{FYMA}\ X\ 100$$

Where,

T= total uptake of nutrients (kg/ha) in only FYM treated plots

S= soil test values of nutrients in only FYM treated plots

FYMA= FYM nutrient dose (N/P/K) applied (kg/ha)

3.3.7.5 Contribution of particular nutrient from fertilizer with FYM (Cf*)

The nutrient efficiency of fertilizer with FYM was computed from treated plots taking into consideration the soil and FYM contribution. The efficiency was calculated as a ratio of the difference between the total uptake of nutrient and soil & FYM contribution to the applied fertilizer dose in each treated plot.

Per cent contribution of nutrients from fertilizer with FYM (CF %)

$$= \frac{T-\left(S\ X\frac{CS}{100}\right)}{FD}\ X\ 100$$

Where,

T= total uptake of nutrients (kg/ha) in fertilizer + FYM treated plots

S= Soil test values of nutrients in fertilizer + FYM treated plots

FD= Fertilizer dose (N/P/K) applied (kg/ha)

3.3.8 Fertilizer requirement for targeted yield

Fertilizer requirement equation for nitrogen, phosphorus and potassium for targeted yield were computed as follows:

3.3.8.1 Fertilizer requirement equations without FYM and with FYM

Without FYM

$$FN = (NR/Cf) \times 100T - (Cs/Cf) \times SN$$

$$F\ P_2O_5 = (NR/Cf) \times 100T - (Cs/Cf) \times 2.29 \text{ x } SP$$

$$F\ K_2O = (NR/Cf) \times 100T - (Cs/Cf) \times 1.21\ SK$$

Fertilizer requirement equations for nutrients through conjoint use of organic and inorganic fertilizer sources.

With FYM

$$FN = (NR/Cf^*) \times 100\ T - (CS/Cf^*) \times SN - (Cfym/Cf^*) \times M$$

$$F\ P_2O_5 = (NR/Cf^*) \times 100\ T - (CS/Cf^*) \times 2.29 \text{ x } SP - (Cfym/Cf^*) \times 2.29 \text{ x } M$$

$$F\ K_2O = (NR/Cf^*) \times 100\ T - (CS/Cf^*) \times\times 1.21SK - (Cfym/Cf^*) \times 1.21\ M$$

Where,

FN = Nitrogen Fertilizer dose (kg N ha^{-1})

F P_2O_5 = Phosphorus fertilizer dose (kg $P_2O_5ha^{-1}$)

F K_2O = Potassium fertilizer dose (kg K_2O ha^{-1})

NR =Nutrient requirement of nitrogen, phosphorus and potassium

Cf = Percent contribution of particular nutrient from fertilizer without FYM

Cf* = Percent contribution of particular nutrient from fertilizer with FYM.

CS = Percent contribution of particular nutrient from soil

Cfym = Percent contribution of particular nutrient from FYM

T = Targeted yield (q ha^{-1})

SN = Soil test value for available nitrogen (kg ha^{-1})

SP = Soil test value for available phosphorus (kg ha^{-1})

SK = Soil test value for available potassium (kg ha^{-1})

M = particular nutrient content in organic matter

3.3.9 Multiple regression for maximum yield

Multiple regression approach is used to compute the dose of nutrient (S) required for obtaining the maximum yield of crops under given experimental conditions. This approach can further be extended to compute the economic dose of fertilizer nutrients by applying a constant factor, i.e. cost of produce per unit divided by cost of per unit input (fertilizer) in the original equation. In this approach regression equation of yield with inherent soil nutrients, applied fertilizer nutrients, their quadratic terms and the interaction term of soil and fertilizer nutrients is computed which is given below:

Y= A ± b1 SN ± b2 SN2 ±b3 SP±b4 + SP2 ±b5 SK ±b6 SK2 ± b7 FN ±b8 FN2±b9

FP± b10 FP2±b11 FK± b12 FK2±b13 FNSN±b14 FPSP± b15 FKSK

Where

Y = Crop yield (kg ha^{-1})

A = Intercept (kg ha^{-1})

bi = Regression coefficients (kg ha^{-1})

SN, SP, SK = Available soil nitrogen, phosphorus and potassium (kg ha^{-1}), respectively.

FN, FP, FK = Fertilizer nitrogen, phosphorus and potassium (kg ha^{-1}), respectively.

3.4 Statistical analysis

Test crop data was analyzed as per standard design used in AICRP on soil test crop response correlation. Other statistical analysis were carried out by the method of simple correlation and fitting up the multiple regression equation **(Panse & Sukhatme, 1962).**

Results and Discussion

The results of the present experiment are presented in this chapter along with suitable supporting tables and figures. An attempt is made to discuss results of the investigation with explanations considering experimental evidences wherever possible for noted variations. Also, it has been tried to understand the cause and effect relationship so as to cater information of practical importance to farmers.

4.1 Establishment of soil fertility gradient

Field experiment was conducted according to the technical programme of soil test crop response correlation studies. Since the success of the experiment solely depends on the extent of deliberatly created soil fertility gradient. So, possible large variation in the fertility levels of different strips was created in order to evaluate regression between soil test values of different plots and response of the crop to the applied fertilizer. According to the principle, strip III should be highly enriched in fertility status followed by strip II with medium fertility and strip I with lowest fertility. For this purpose, highest amount of fertilizer nitrogen, phosphorus and potassium was applied in strip III followed by strip II while no fertilizer was applied in strip I.

Initial trial was conducted by growing exhaust crop *i.e.* wheat (var. UP 2526) for grain before the conduct of main experiment on test crop Hybrid maize (*Zea mays* L.) in the preceding crop season. Grain yield and biomass yield of wheat crop is presented in table 4.1.

Table 4.1: Strip wise grain yield and biomass yield of wheat crop

Strip	Symbol	Fertilizer dose ($N-P_2O_5- K_2O$)	Grain yield (q ha^{-1})	Biomass yield (Grain+ Straw) (q ha^{-1})
I	$N_0P_0K_0$	0-0-0	45	29.33
II	$N_1P_1K_1$	100-100-100	120	103
III	$N_2P_2K_2$	200-200-200	140	136

Data on the biomass yield and grain yield clearly showed that fertility gradient has been created successfully since biomass yield and grain yield followed the same pattern as that of applied fertilizer nutrient i.e. strip III > strip II > strip I.

4.2 Soil test values for nitrogen, phosphorus and potassium in test crop experimental plots

Strip wise soil test values of organic carbon, available nitrogen, available phosphorus and available potassium of individual plots are given in appendix II and range and mean of soil test values under different strips are given in table 4.2

Table 4.2: Range and mean* of the soil test values under different strips

Sl. No.	Particular	Strip I	Strip II	Strip III
		Range	Range	Range
1.	Organic carbon (%)	0.156-1.17 (0.51)	0.156-0.858 (0.54)	0.234-1.443 (0.61)
2.	Alkaline $KMnO_4$-N (kg ha^{-1})	50.176-125.44 (93.55)	87.808-137.984 (109.76)	87.808-175.616 (124.39)
3.	Olsen's-P (kg ha^{-1})	10.46-18.43 (14.45)	11.21-18.93 (15.26)	25.67-21.67 (17.70)
4.	NH_4OAc-K (kg ha^{-1})	96.32-165.76 (135.94)	127.68-163.52 (148.02)	127.68-198.24 (165.29)

*Values given in parenthesis are average

Average organic carbon content of experimental field varied from 0.156 to 1.17 per cent with an average of 0.55 per cent. Organic carbon content in strip I ranged from 0.156 to 1.17 per cent with an average of 0.51 per cent. While in strip II the organic carbon content ranged from 0.156 to 0.858 per cent with an average of 0.54 per cent. Range of organic carbon content in strip III varied from0.234 to 1.443 per cent with an average of 0.61per cent. The average value of organic carbon content was lowest in strip I and the highest in strip III.

Available nitrogen extracted by alkaline-$KMnO_4$ method of the experimental field varied from 50.2 to 175.6 kg N $ha^{-1}$with a mean value of 109.2 kg N ha^{-1}. Strip wise variation ranged from 50.176 to 125.44 kg N $ha^{-1}$with an average of 93.55733 kg

N ha^{-1} in strip I, 87.80 to 137.98 kg N ha^{-1} with an average of 109.76 kg N ha^{-1} in strip II and 87.80 to 175.61 kg N ha^{-1} with an average of 124.39 kg N ha^{-1} in strip III. The lowest value was found in strip I while highest in strip III.

Available phosphorus content of the entire experimental field ranged from 10.4 to 21.67 kg P ha^{-1} with a mean value of 15.80 kg P ha^{-1}. Strip wise range varied from 10.46 to 18.43 kg P ha^{-1} with an average value of 14.45 kg P ha^{-1} in strip I, 11.21 to 18.93 kg P ha^{-1} with an average value of 15.26 kg P ha^{-1} in strip II and 25.67 to 21.67 kg P ha^{-1} with an average value of 17.70 kg P ha^{-1} in strip III. Lowest value was reported in strip I while highest in strip III.

Available potassium extracted by neutral normal NH_4OAc method ranged from 96.3 to 198.2 kg K ha^{-1} with a mean of 149.8 kg K $ha^{-1}$for the entire experimental field. Values ranged from 96.32 to 165.76 kg K ha^{-1}in strip I with an average value of 135.94 kg K ha^{-1}, 127.68 to 163.52 kg K ha^{-1} in strip II with an average value of 148.02 kg K ha^{-1} and 127.68 to 198.24 kg K ha^{-1} in strip III with an average value of 165.29 kg K ha^{-1}. The average value of NH_4OAc extractable potassium was highest in strip III and the lowest in strip I.

Nitrogen extracted by using alkaline $KMnO_4$-N was found in the order - strip III> strip II >strip I (Table 8). Similar order was also reported for soil organic carbon content. The phosphorus extracted by using Olsen's method indicated the highest value of Olsen's-P in strip III followed by strip II followed by strip I. Similar trend was also observed for neutral normal NH_4OAC-K in different strips.

Therefore, from the above findings it can be inferred that the organic carbon, alkaline $KMnO_4$ –N, Olsen's-P and neutral normal NH_4O Ac –K content of soil indicates that the fertility gradient was created with the application of differential grades of nitrogen, phosphorus and potassium doses. Similar trend in the results were also suggested by **Chatterjee (2008), Pande (2010) and Upadhyay (2012)** for potato, cabbage and barley crop respectively.

Analysis of variance was also performed by using the soil nutrients i.e soil nitrogen (SN), soil phosphorus (SP) and soil potassium (SK) separately as dependent variables and results thus obtained are given in table 4.3.

Table 4.3: Significance, $R^2$and mean of soil test values of whole plots

Dependent variable	P level	R^2	Mean
SN	<0.01**	0.6606	149.7533
SP	<0.01**	0.7696	36.1815
SK	<0.01**	0.7605	149.7533

The results clearly inferred that the fertility gradient was created properly and it was significant with respect to N, P and K levels. Taking statistical verification of fertility gradient as a base, it can be concluded that the experimental field was suitable for the conduct of soil test crop response studies for the next season test crop. The results are closely in accordance with those reported by **Chatterjee (2010) and Upadhyay (2012)** in Mollisol of Uttarakhand.

4.3 Effect of soil fertility and fertilizers on yield and nutrient uptake of Hybrid maize

4.3.1 Crop yield

4.3.1.1 Grain yield

Strip wise grain yield is given in appendix II and range and mean of grain yield of hybrid maize is given in table 4.4

Grain yield of experiment varied from 7.78 to 105 q ha^{-1} with a mean of 56.48 q ha^{-1}. Highest grain yield was recorded in strip III (66.84) followed by strip II (56.58 q ha^{-1}) and least in strip I (46.02 q ha^{-1}).

Strip wise average grain yield of the treated plots was observed to be in the order of strip III (66.84 q ha^{-1}) > strip II (56.58 q ha^{-1}) > strip I (46.02 q ha^{-1}). In treated plots the grain yield varied from 7.78 to 105 q ha^{-1} in strip I, 14.45 to 88.89 q ha^{-1} in strip II and 21.67 to 93.34 q ha^{-1} in strip III. Grain yield in control plots ranged from 11.12 to 26.12 q ha^{-1} with a mean value of 42.41 q ha^{-1} in strip I, 14.45 to 22.78 q ha^{-1} with a mean value of 38.71 q ha^{-1} in strip II and 21.67 to 41.12 q ha^{-1} with a mean value of 64.82 q ha^{-1} in strip III.

Table 4.4: Range and mean* of yield and total nutrient uptake under different strips

Sl. No.	Particular	Strip I	Strip II	Strip III
		Range	Range	Range
Treated plots				
1.	Grain yield(q ha^{-1})	7.78 - 105 (46.02)	14.45 - 88.89 (56.58)	21.67 - 93.34 (66.84)
2.	Biomass yield (q ha^{-1})	72.23 -344.45 (191.69)	131.12 - 404.45 (232.23)	172.23 - 355.56 (296.19)
3.	Nitrogen Uptake (kg ha^{-1})	13.65-188.45 (95.75)	31.36-211.50 (121.79)	46.52-191.05 (148.93)
4.	Phosphorus Uptake (kg ha^{-1})	4.10-35.74 (19.76)	9.07-41.03 (23.02)	8.60-36.77 (30.14)
5.	Potassium Uptake (kg ha^{-1})	12.25-258.24 (129.73)	23.98-232.67 (156.03)	38.65-262.01 (209.92)
Control plots				
1.	Grain yield(q ha^{-1})	11.12-26.12 (42.41)	14.45-22.78 (38.71)	21.67-41.12 (64.82)
2.	Biomass yield(q ha^{-1})	38.89-171.12 (99.63)	100-196.67 (153.70)	155.56-278.89 (202.23)
3.	Nitrogen uptake(kg ha^{-1})	13.65-67.29 (30.93)	31.36-67.29 (52.13)	46.52-97.78 (65.00)
4.	Phosphorus uptake (kg ha^{-1})	0.85-2.04 (1.36)	1.13-1.82 (1.43)	1.74-3.37 (2.47)
5.	Potassium uptake (kg ha^{-1})	26.20-33.08 (23.84)	23.98-55.03 (40.32)	38.65-84.04 (53.81)

*Values given in parenthesis are mean

In strip I, maximum grain yield of 105 q ha^{-1} was recorded in treatment $N_3P_3K_3OM_2$ and minimum of 7.78 q ha^{-1} in $N_2P_2K_0$ OM_1. In stripII, maximum grain yield of 88.89 q ha^{-1} was recorded in treatment $N_3P_3K_1OM_2$ and minimum of 14.45 q ha^{-1} in treatment $N_0P_0K_0OM_0$. In strip III, maximum grain yield of 93.34 q ha^{-1} was observed with treatment $N_2P_2K_0OM_0$ and minimum of 21.67 q ha^{-1} in treatment $N_0P_0K_0OM_1$ .In general strip wise average grain yield was higher in strip III > strip II >

strip I. These results were in accordance with the results reported by **Thilagam and Natesan (2009) and Katharine, *et al.* (2013)** for cauliflower and cotton crop respectively on Inceptisol.

The above obtained results clearly depict that a wide variability existed in the soil test values and grain yield of treated and control plots, which is a basis and pre-requisite for calculating the basic parameters and developing fertilizer prescription equations for calibrating the fertilizer doses for specific yield targets of hybrid maize**.**

4.3.1.2 Biomass yield (Grain yield + Straw yield)

Strip wise biomass yield is given in appendix II and range and mean of total biomass yield of maize is given in table 4.4.

Biomass yield of experiment varied from 38.89 to 404.45 q ha^{-1} with a mean of 229.02 q ha^{-1}. Highest biomass yield recorded in strip III (284.45 q ha^{-1}) was followed by strip II (222.41 q ha^{-1}) and lowest in strip I (180.19 q ha^{-1}).

Strip wise average biomass yield of the treated plots was in the order of strip III (296.19 q ha^{-1}) > strip II (232.23 q ha^{-1}) > strip I (191.69 q ha^{-1}). In treated plots the biomass yield varied from 72.23 to 344.45 q ha^{-1} in strip I, 131.12 to 404.45 q ha^{-1} in strip II and 172.23 to 355.56 q ha^{-1} in strip III. Biomass yield in control plots ranged from 38.89 to 171.12 qha^{-1} with a mean value of 99.63 q ha^{-1} in strip I, 100 to 196.67 q ha^{-1} with a mean value of 153.70 q ha^{-1} in strip II and 155.56 to 278.89 with a mean value of 202.23 q ha^{-1} in strip III.

In strip I, maximum biomass yield of 344.45 q ha^{-1} was recorded in treatment $N_3P_2K_3OM_2$ and minimum of 38.89 q ha^{-1} in $N_0P_0K_0$ $OM_{1.}$ In strip II, maximum biomass yield 404.45 q ha^{-1} was recorded in treatment $N_3P_3K_1OM_2$ and minimum 100 q ha^{-1} in treatment $N_0P_0K_0OM_1$. In strip III, maximum biomass yield 355.56 q ha^{-1} was observed with treatment $N_2P_1K_1OM_2$ and minimum 155.56 q ha^{-1} in treatment $N_0P_0K_0OM_{1.}$ In general strip wise average biomass yield was higher in strip III > strip II > strip I.

4.3.2 Nutrient uptake

Strip wise values of nitrogen, phosphorus and potassium uptake of individual plot are given in appendix III. Strip wise range and mean values of nutrients uptake are given in table 4.4.

4.3.2.1 Nutrient uptake of grain

4.3.2.1.1 Nitrogen uptake

Grain Nitrogen uptake in experimental field varied from 2.75 to 52.57 kg ha^{-1} with a mean of 26.51 kg ha^{-1}. Highest nitrogen uptake recorded in strip III (31.5 kg ha^{-1}) was followed by strip II (28.11 kg ha^{-1}) and in strip I (19.81 kg ha^{-1}). Strip wise average total nitrogen uptake in treated plots was in the order of strip III (34.45 kg ha^{-1}) > strip II (31.00 kg ha^{-1}) > strip I (21.70 kg ha^{-1}).

In strip I, maximum nitrogen uptake (50.48 kg ha^{-1}) by crop was noted with treatment $N_3P_3K_3OM_2$ and minimum of 2.74 kg ha^{-1} with treatment $N_2P_2K_0$ OM_1. In strip II, maximum nitrogen uptake 51.29 kg ha^{-1} was recorded with treatment $N_3P_3K_1OM_2$ and minimum of 5.88 kg ha^{-1} with treatment $N_0P_0K_0OM_1$. Similarly in strip III, maximum nitrogen uptake 52.57 kg ha^{-1} was recorded with $N_3P_3K_1OM_0$ treatment and minimum of 9.03 kg ha^{-1} with treatment $N_0P_0K_0OM_1$. Thus, from the above results it can be inferred that the uptake of N was higher with higher dose of nitrogen.

Total nitrogen uptake in control plots ranged from 3.92 to 10.04 kg ha^{-1} with a mean of 6.48 kg ha^{-1} in strip I, 5.88 to 11.69 kg ha^{-1} with a mean of 7.86 kg ha^{-1} in strip II and 9.03 to 14.49 kg ha^{-1} with a mean of 11.62 kg ha^{-1} in strip III. Here uptake was observed to be more in strip III followed by strip II followed by strip I.

4.3.2.1.2 Phosphorus uptake

Phosphorus uptake in experimental field varied from 0.68 to 10.20 kg ha^{-1} with a mean of 5.31 kg ha^{-1}. Maximum phosphorus uptake recorded in strip III (6.47 kg ha^{-1}) was followed by strip II (5.36 kg ha^{-1}) and minimum in strip I (4.12 kg ha^{-1}). Strip wise average total phosphorus uptake in treated plots was in the order of strip III (7.03 kg ha^{-1}) > strip II (5.92 kg ha^{-1}) > strip I (4.51kg ha^{-1}).

In strip I, maximum phosphorus uptake (10.20 kg ha^{-1}) by hybrid maize was noted with treatment $N_3P_3K_3OM_2$ and minimum of 0.68 kg ha^{-1} with treatment $N_2P_2K_0OM_1$. In strip II, maximum phosphorus uptake 8.98 kg ha^{-1} was recorded with treatment $N_3P_3K_3OM_0$ and minimum of 1.12 kg ha^{-1} with treatment $N_0P_0K_0OM_0$. Similarly In strip III, maximum phosphorus uptake 9.60 kg ha^{-1} was recorded with $N_3P_2K_2OM_0$ treatment and minimum of 1.73 kg ha^{-1} with treatment $N_0P_0K_0OM_1$. Thus, it can be concluded that the uptake of P was higher with higher dose of phosphorus.

Total phosphorus uptake in control plots ranged from 0.85 to 2.04 kg ha^{-1} with a mean of 1.36 kg ha^{-1} in strip I, 1.13 to 1.82 kg ha^{-1} with a mean of 1.43 kg ha^{-1} in strip II and 1.74 to 3.37 with a mean of 2.47 kg ha^{-1} in strip III. Here uptake was more in strip III followed by strip II and strip I.

4.3.2.1.3 Potassium uptake

Potassium uptake in experimental field varied from 4.99 to 76.93 kg ha^{-1} with a mean of 39.48 kg ha^{-1}. Maximum potassium uptake recorded in strip III (47.32 kg ha^{-1}) was followed by strip II (39.30 kg ha^{-1}) and minimum in strip I (31.82 kg ha^{-1}). Strip wise average total potassium uptake in treated plots was in the order of strip III (50.93 kg ha^{-1}) > strip II (43.04 kg ha^{-1}) > strip I (34.53 kg ha^{-1}).

In strip I, maximum potassium uptake (76.93 kg ha^{-1}) by crop was noted with treatment $N_3P_3K_3OM_2$ and minimum of 4.99 kg ha^{-1} with treatment $N_2P_2K_0OM_1$. In strip II, maximum potassium uptake 72.45 kg ha^{-1} was recorded with treatment $N_3P_3K_1OM_2$ and minimum of 10.23 kg ha^{-1} with treatment $N_0P_0K_0OM_1$. Similarly in strip III, maximum potassium uptake 75.30 kg ha^{-1} was recorded with $N_2P_2K_1OM_2$ treatment and minimum of 13.30 kg ha^{-1} with treatment $N_0P_0K_0OM_1$.

Total potassium uptake in control plots ranged from 6.51 to 20.33 kg ha^{-1} with a mean value of 12.82 kg ha^{-1} in strip I, 10.23 to 18.36 kg ha^{-1} with a mean value of 13.06 kg ha^{-1} in strip II and 13.29 to 34.07 with a mean value of 22.04 kg ha^{-1} in strip III. Here uptake was more in strip III followed by strip II and strip I. Increased uptake of nutrients following an application of NPK fertilizers and FYM was due to added supply of nutrients and proliferous root system developed under balanced nutrient application resulting in more absorption of water and nutrients and adequate soil physical environment **(Grewal and Trehan, 1978; Miller *et al.* 1987)**. **Abusaleha and Shanmulagavelu (1988); Malewar*et al.* (1998); Margay(2002)** reported that the organic and inorganic fertilizers integration has proved superior than individual components with respect to nutrient uptake.

Bahadur *et al.* (2004) also reported that nitrogen uptake by okra increased significantly in treatments which received integrated nutrition.

Increment in potassium uptake was observed in almost all the integrated nutritional treatments over the sole chemical fertilization. Similar results were reported by **Bahadur *et al.* (2004)** in cabbage. This might be due to enhancement in K availability by shifting the equilibrium among the forms of K from relatively exchangeable K to soluble K forms in the soil.

4.3.2.2 Total Nutrient uptake

4.3.2.2.1 Nitrogen uptake

Total Nitrogen uptake by the plant in experimental field varied from 13.65 to 211.51 kg ha^{-1} with a mean of 113.04 kg ha^{-1}. Highest nitrogen uptake recorded in strip III (138.44 kg ha^{-1}) was followed by strip II (113.08 kg ha^{-1}) and in strip I (87.60 kg ha^{-1}). Strip wise average total nitrogen uptake in treated plots was in the order of strip III (148.93 kg ha^{-1}) > strip II (121.79 kg ha^{-1}) > strip I (95.70 kg ha^{-1}).

In strip I, maximum nitrogen uptake (188.45 kg ha^{-1}) by crop was noted with treatment $N_3P_3K_2OM_2$ and minimum of 13.65 kg ha^{-1} with treatment $N_0P_0K_0$ OM_1. In strip II, maximum nitrogen uptake 211.50 kg ha^{-1} was recorded with treatment $N_3P_3K_1OM_2$ and minimum of 31.36 kg ha^{-1} with treatment $N_0P_0K_0OM_1$. Similarly in strip III, maximum nitrogen uptake 191.05 kg ha^{-1} was recorded with $N_3P_3K_1OM_0$ treatment and minimum of 46.52 kg ha^{-1} with treatment $N_0P_0K_0OM_1$. Thus, from the above results it can be inferred that the uptake of N was higher with higher dose of nitrogen.

Total nitrogen uptake in control plots ranged from 13.65 to 41.55 kg ha^{-1} with a mean of 30.93 kg ha^{-1} in strip I, 31.36 to 67.29 kg ha^{-1} with a mean of 52.13 kg ha^{-1} in strip II and 46.52 to 97.78 kg ha^{-1} with a mean of 65.00 kg ha^{-1} in strip III. Here uptake was observed to be more in strip III followed by strip II followed by strip I.

4.3.2.2.2 Phosphorus uptake

Phosphorus uptake in experimental field varied from 4.10 to 41.03 kg ha^{-1} with a mean of 22.99 kg ha^{-1}. Maximum phosphorus uptake recorded in strip III (28.51 kg ha^{-1}) was followed by strip II (21.97 kg ha^{-1}) and minimum in strip I (18.51 kg ha^{-1}). Strip wise average total phosphorus uptake in treated plots was in the order of strip III (30.14 kg ha^{-1}) > strip II (23.02 kg ha^{-1}) > strip I (19.76 kg ha^{-1}).

In strip I, maximum phosphorus uptake (35.74 kg ha^{-1}) by hybrid maize was noted with treatment $N_3P_2K_1OM_2$ and minimum of 4.10 kg ha^{-1} with treatment $N_0P_0K_0OM_1$. In strip II, maximum phosphorus uptake 41.032 kg ha^{-1} was recorded with treatment $N_3P_3K_1OM_2$ and minimum of 9.07 kg ha^{-1} with treatment $N_0P_0K_0OM_1$. Similarly In strip III, maximum phosphorus uptake 36.77 kg ha^{-1} was recorded with $N_3P_3K_1OM_0$ treatment and minimum of 8.60 kg ha^{-1} with treatment $N_0P_0K_0OM_0$. Thus, it can be concluded that the uptake of P was higher with higher dose of phosphorus.

Total phosphorus uptake in control plots ranged from 4.10 to 16.70 kg ha^{-1} with a mean of 9.81 kg ha^{-1} in strip I, 9.07 to 20.60 kg ha^{-1} with a mean of 14.61 kg ha^{-1} in strip II and 8.60 to 28.11 with a mean of 17.08 kg ha^{-1} in strip III. Here uptake was more in strip III followed by strip II and strip I.

4.3.2.2.3 Potassium uptake

Potassium uptake in experimental field varied from 12.25 to 262.01 kg ha^{-1} with a mean of 149.49 kg ha^{-1}. Maximum potassium uptake recorded in strip III (190.42 kg ha^{-1}) was followed by strip II (141.57 kg ha^{-1}) and minimum in strip I (116.50 kg ha^{-1}). Strip wise average total potassium uptake in treated plots was in the order of strip III (209.92 kg ha^{-1}) > strip II (156.03 kg ha^{-1}) > strip I (129.73 kg ha^{-1}).

In strip I, maximum potassium uptake (258.24 kg ha^{-1}) by crop was noted with treatment $N_3P_2K_3OM_2$ and minimum of 12.25 kg ha^{-1} with treatment $N_0P_0K_0OM_1$. In strip II, maximum potassium uptake 232.67 kg ha^{-1} was recorded with treatment $N_3P_3K_1OM_2$ and minimum of 23.98 kg ha^{-1} with treatment $N_0P_0K_0OM_1$. Similarly in strip III, maximum potassium uptake 262.01 kg ha^{-1} was recorded with $N_3P_2K_3OM_1$ treatment and minimum of 38.65 kg ha^{-1} with treatment $N_0P_0K_0OM_0$.

Total potassium uptake in control plots ranged from 26.20 to 33.08 kg ha^{-1} with a mean value of 23.84 kg ha^{-1} in strip I, 23.98 to 55.03 kg ha^{-1} with a mean value of 40.32 kg ha^{-1} in strip II and 38.65 to 84.04 with a mean value of 53.81 kg ha^{-1} in strip III. Here uptake was more in strip III followed by strip II and strip I. Increased uptake of nutrients following an application of NPK fertilizers and FYM was due to added supply of nutrients and proliferous root system developed under balanced nutrient application resulting in more absorption of water and nutrients and adequate soil physical environment **(Grewal and Trehan, 1978; Miller *et al.* 1987)**. **Abusaleha and Shanmulagavelu (1988); Malewar*et al.* (1998); Margay (2002)** reported that the organic and inorganic fertilizers integration has proved superior than individual components with respect to nutrient uptake.

Bahadur ***et al.*** **(2004)** also reported that nitrogen uptake by okra increased significantly in treatments which received integrated nutrition.

Increment in potassium uptake was observed in almost all the integrated nutritional treatments over the sole chemical fertilization. Similar results were reported by **Bahadur** ***et al.*** **(2004)** in cabbage. This might be due to enhancement in K availability by shifting the equilibrium among the forms of K from relatively exchangeable K to soluble K forms in the soil.

4.4 Basic data to calculate nutrient doses through fertilizer for targeted yield of Hybrid maize with and without FYM

In the present investigation basic data generated with target yield of Hybrid maize, nutrient uptake, soil test values, added fertilizer doses and manure are presented in table 4.5.

The nutrient requirement for production of one quintal of Hybrid maize was 2.17 kg of nitrogen, 0.46 kg of phosphorus and 2.74 kg of potassium. Similar trend was also reported by **Upadhyay (2012)** for barley in Mollisol.

Percent contribution of nitrogen, phosphorus and potassium from soil was 33.14, 26.8 and 22.71 respectively. Contribution from fertilizer as percentage of its nutrients content was 62.36, 63.52 and 427.61 with FYM and 58.18, 62.68 and 420.4 without FYM for nitrogen, phosphorus and potassium, respectively. Similar trend was also reported by **Santhi** ***et al.*****(2011)** for beet root in Alfisols.

Percent contribution of nutrients from applied FYM for nitrogen, phosphorus and potassium was 45.21, 14.44 and 39.40 respectively.The data indicated that nutrient contribution from fertilizer along with FYM was greater than without FYM and from soil. The application of FYM might have played an important role for enhancing the microbial population which leads to the higher availability of nutrients and thereby efficiency of added nutrients increased. The organic acids released during the decomposition of added FYM in the soil might played a role in reducing phosphorus fixation **(Jadav** ***et al*****. 2013)**. These findings are in close conformity with those reported by **Selvi** ***et al.*** **(2004), Balasubramaniam** ***et al.*** **(2005), Kadam and Sonar (2006) and Ray** ***et al.*** **(2000).**

The contribution of potassium from fertilizer towards the total uptake of Hybrid maize was more than 100 %, which might be due to the interactive effect of higher doses of N, P_2O_5 and 'priming' effect of starter K_2O doses caused the release of potassium from non-labile pool to labile pool. Similar type of higher efficiency of K fertilizer was also reported by **Santhi *et al.* (2011)** in beet root on Alfisols.

Table 4.5: Basic data for calculating fertilizer doses with and without FYM for targeted yield of Hybrid maize

Particular	Without FYM			With FYM		
	N	P	K	N	P	K
NR (kg q^{-1})	2.17	0.46	2.74	2.17	0.46	2.74
CS (%)*	33.14	26.8	22.71	33.14	26.8	22.71
CF (%)	58.18	62.68	420.4	62.36	63.52	427.61
CFYM (%)	--	--	--	45.21	14.44	39.40

*Soil test values (0-15 cm. depth); alkaline $KMnO_4$-N (kg ha^{-1}), Olsen's-P (kg ha^{-1}) and NH_4OAc-K (kg ha^{-1})

4.5 Fertilizer adjustment equations

Fertilizer adjustment equations for calculating the nutrient requirement with and without FYM were developed with the help of basic data given in table 4.6.

Table 4.6: Fertilizer adjustment equations

Fertilizer dose	Without FYM	With FYM
Nitrogen dose (kg ha^{-1})	FN = 3.6T-0.56SN	FN = 3.36T-0.53SN-0.72FYM
Phosphorus dose (kg ha^{-1})	FP_2O_5 = 0.71T-0.97SP	FP_2O_5=0.70T-0.96SP-0.52FYM
Potassium dose (kg ha^{-1})	FK_2O = 0.64T-0.06SK	FK_2O = 0.63T-0.06SK-0.11FYM

Where T = Yield target (q ha^{-1}) SN = Alkaline $KMnO_4$-N, SP= Olsen's-P (kg ha^{-1}) SK = Amm. Ac.-K (kg ha^{-1})

4.6 N, P, K requirements for different yield targets of Hybrid maize with and without FYM

Fertilizer requirement for nitrogen, phosphorus and potassium at different soil test values for the production of different yield targets of Hybrid maize was calculated from the basic data.

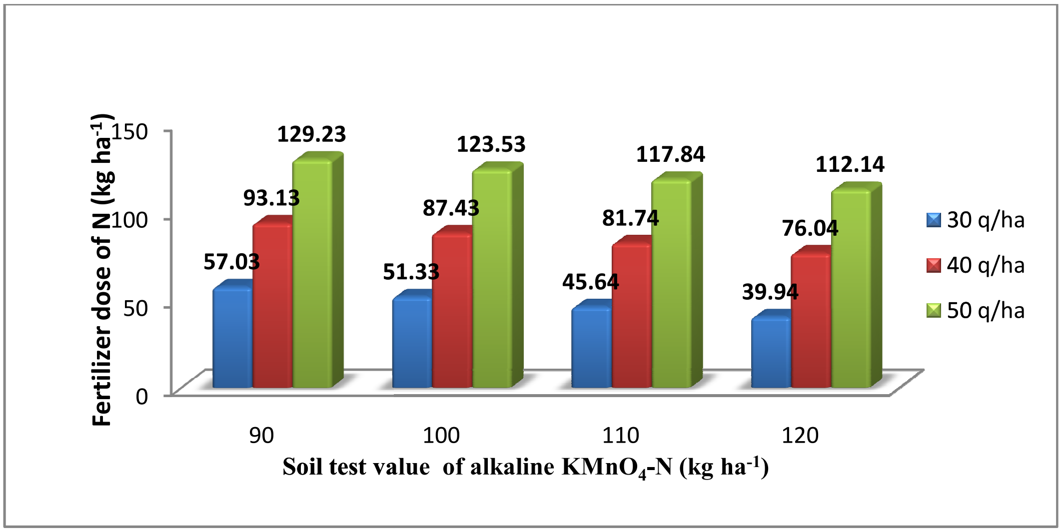
4.6.1 Fertilizer requirement without FYM

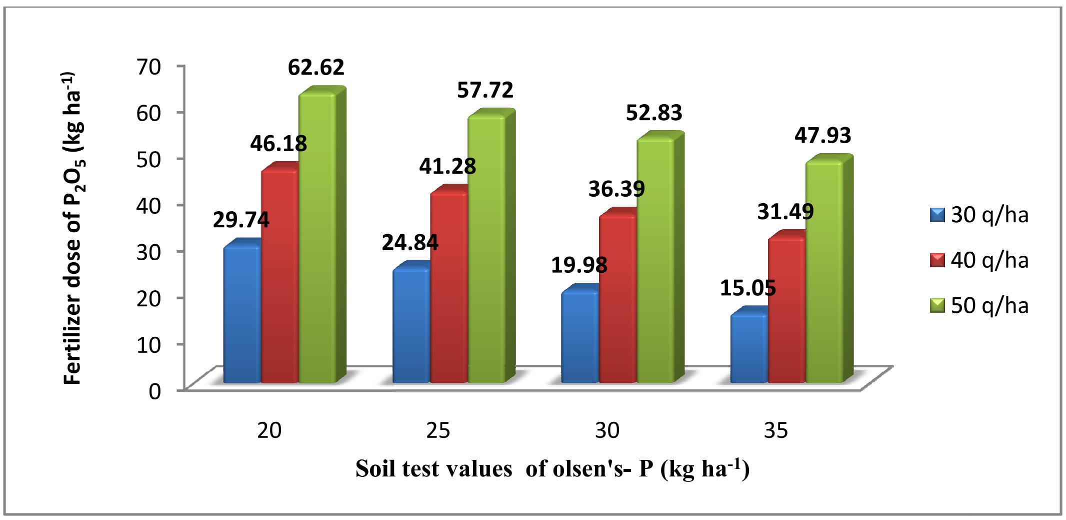
The fertilizer requirement for nitrogen, phosphorus and potassium without FYM at different soil test values for the production of different yield targets are given in table 13 & fig. 4 in the form of ready reckoner and bar diagram, respectively.

To achieve 40 q ha^{-1} yield target, 93.13 kg nitrogen ha^{-1} was needed at the soil test value of 90 kg alkaline $KMnO_4$-N ha^{-1} nitrogen, whereas for the same yield target at 100 kg soil test value for alkaline $KMnO_4$-N ha^{-1}, only 87.43 kg of nitrogen as fertilizer was required. Further, if the soil test value of nitrogen is 110 kg ha^{-1} then to attain the same yield target 81.74 kg N ha^{-1} whereas for the same target at 120 kg soil test value for alkaline $KMnO_4$-N ha^{-1},76.04 kg N ha^{-1} is needed (Table 4.7 and Fig 4.1).

Table 4.7: N, P, K Requirement for different yield targets of hybrid maize without FYM

Soil test value (kg ha^{-1})	Yield target of Hybrid maize (q ha^{-1})		
	30	**40**	**50**
Alkaline $KMnO_4$-N	**Fertilizer – N (kg ha^{-1})**		
90	57.03	93.13	129.23
100	51.33	87.43	123.53
110	45.64	81.74	117.84
120	39.94	76.04	112.14
Olsen-P	**Fertilizer – P (kg ha^{-1})**		
20	29.74	46.18	62.62
25	24.84	41.28	57.72
30	19.98	36.39	52.83
35	15.05	31.49	47.93
Amm. Ac.-K	**Fertilizer – K (kg ha^{-1})**		
100	16.65	24.37	32.08
110	16.01	23.72	31.43
120	15.36	23.07	30.78
130	14.71	22.42	30.14





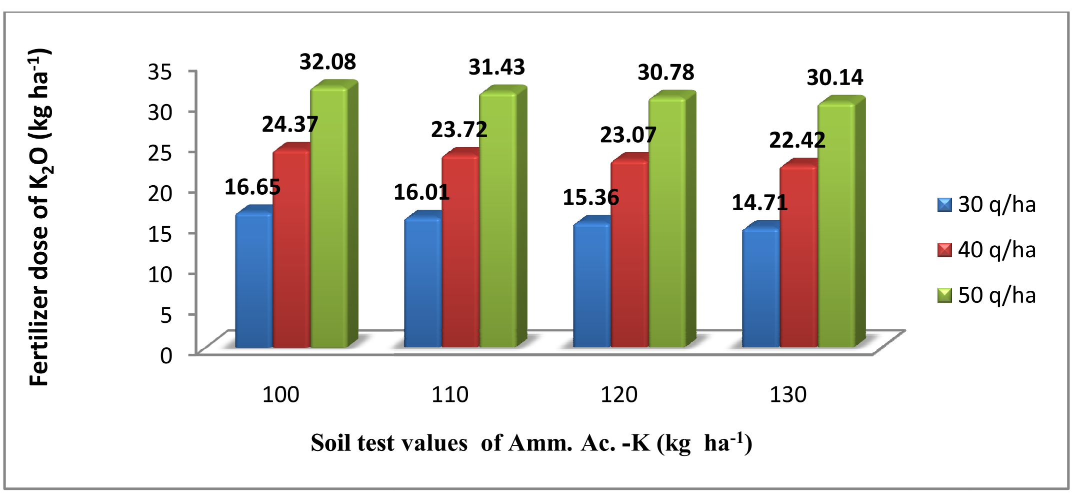


Fig. 4.1: N, P, K Requirement of hybrid maize at different soil test values and yield targets without using FYM

Similarly, fertilizer phosphorus requirement for targeted yield of 40 q ha^{-1} at lower soil test value i.e. 20 kg ha^{-1} of Olsen's phosphorus was 46.18 kg ha^{-1}. At the soil test value of 25 kg of Olsen's-P ha^{-1} to achieve same yield target (40 q ha^{-1}), requirement of fertilizer phosphorus was 41.28 kg ha^{-1}. But, where soil test value reaches 30 kg and 35 kg Olsen's P ha^{-1}, the fertilizer phosphorus need would be 36.39 kg ha^{-1} and 31.49 kg ha^{-1} respectively to meet the yield target of 40 q ha^{-1}(Table 4.7 and Fig 4.1).

Potassium fertilizer requirement for targeted yield of 40 q ha^{-1}, where soil test value of potassium was 100 kg ha^{-1} NH_4OA_C-K, 24.37 kg fertilizer potassium was required. While at 110 kg ha^{-1}, 120 kg ha^{-1} and 130 kg ha^{-1} soil test values of potassium, need of potassic fertilizer for same yield target would be 23.72, 23.07 and 22.42 kg ha^{-1} respectively (Table 4.7 and Fig 4.1).

4.6.2 Fertilizer requirement with combined use of FYM

4.6.2.1 For FYM 5 t/ha

The fertilizer requirement for nitrogen, phosphorus and potassium with combined use of FYM at different soil test values for the production of different yield targets are given in table 14 and fig. 5 in the form of ready recknoner and bar diagram respectively.

To achieve 40 q ha^{-1} yield target, 77.45 kg nitrogen ha^{-1} was needed at the soil test value of 90 kg alkaline $KMnO_4$-N ha^{-1}, whereas for the same yield target at 100 kg soil test value for alkaline $KMnO_4$-N ha^{-1}, 72.13 kg of nitrogen as fertilizer was required. Further, if the soil test value of nitrogen reaches to 110 kg ha^{-1} and 120 kg ha^{-1} then to reach the same yield target 66.82 kg N ha^{-1} and 61.51 kg N ha^{-1} would be needed respectively. (Table 4.8 and Fig 4.2).

Fertilizer phosphorus requirement for target yield of 40 q ha^{-1} where soil test value of phosphorus was 20 kg ha^{-1} of Olsen's phosphorus, 42.31 kg fertilizer phosphorus was required. But, where soil test value reaches 25 kg ha^{-1}, 30 kg ha^{-1} , 35 kg ha^{-1} Olsen's P, the fertilizer phosphorus need would be 37.48 kg ha^{-1} , 32.65 kg ha^{-1}, 27.82 kg ha^{-1} respectively to meet the yield target of 40 q ha^{-1}(Table 4.8 and Fig 4.2).

Potassium fertilizer requirement for target yield of 40 q ha^{-1}, where soil test value of potassium was 100 kg ha^{-1} NH_4OA_C-K, and 22.39 kg fertilizer potassium was required. While at 110 kg ha^{-1} ,120 kg ha^{-1} , 130 kg ha^{-1} soil test values of potassium, need of potassic fertilizer for same yield target would be 21.75 kg ha^{-1}, 21.11 kg ha^{-1}, 20.47 kg ha^{-1}, respectively (Table 4.8 and Fig 4.2).

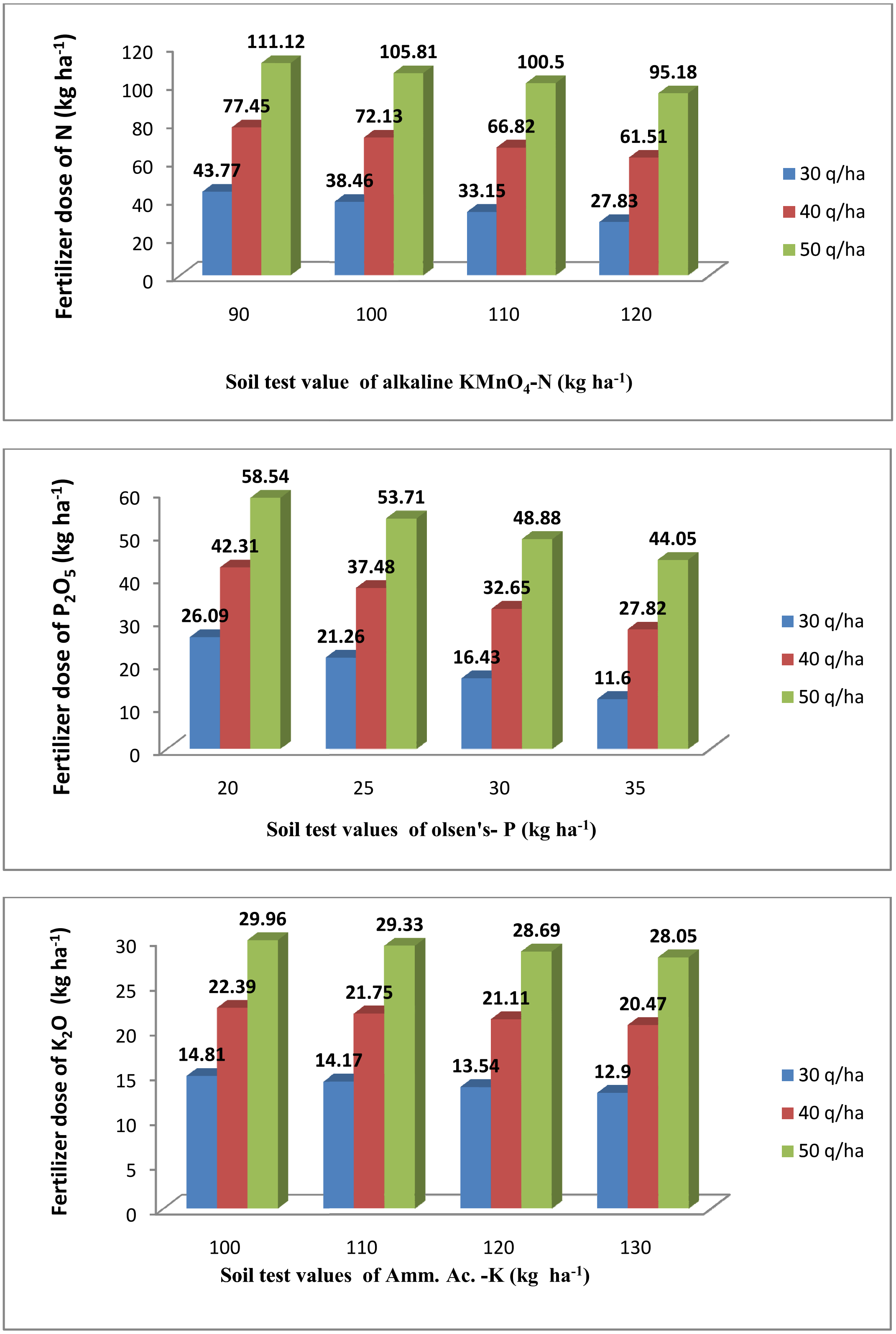


Fig. 4.2: N, P, K Requirement of hybrid maize at different soil test values and yield targets with conjoint use of FYM (5 t/ha)

Table 4.8: N, P, K Requirement for different yield targets of hybrid maize through fertilizer with conjoint use of FYM (5 t/ ha)

Soil Test Values (kg ha^{-1})	Yield Target of Hybrid maize(qha^{-1})		
	30	40	50
Alkaline $KMnO_4$-N	**Fertilizer – N (kg ha^{-1})**		
90	43.77	77.45	111.12
100	38.46	72.13	105.81
110	33.15	66.82	100.5
120	27.83	61.51	95.18
Olsen's P	**Fertilizer – P (kg ha^{-1})**		
20	26.09	42.31	58.54
25	21.26	37.48	53.71
30	16.43	32.65	48.88
35	11.6	27.82	44.05
Amm.Ac.-K	**Fertilizer – K (kg ha^{-1})**		
100	14.81	22.39	29.96
110	14.17	21.75	29.33
120	13.54	21.11	28.69
130	12.9	20.47	28.05

4.6.2.2 For FYM 10 t/ha

To achieve 40 q ha^{-1} yield target, 68.03 kg nitrogen ha^{-1} was needed at the soil test value of 90 kg alkaline $KMnO_4$-N ha^{-1}, whereas for the same yield target at 100 kg soil test value for alkaline $KMnO_4$-N ha^{-1}, 62.71 kg of nitrogen as fertilizer was required. Further, if the soil test value of nitrogen reaches to 110 kg ha^{-1} and 120 kg ha^{-1} then to reach the same yield target 57.40 kg N ha^{-1} and 52.08 kg N ha^{-1} would be needed respectively. (Table 4.9 and Fig 4.3).

Fertilizer phosphorus requirement for target yield of 40 q ha^{-1} where soil test value of phosphorus was 20 kg ha^{-1} of Olsen's phosphorus, 38.95 kg fertilizer phosphorus was required. But, where soil test value reaches 25 kg ha^{-1}, 30 kg ha^{-1} , 35 kg ha^{-1} Olsen's P, the fertilizer phosphorus need would be 34.12 kg ha^{-1} , 29.29 kg ha^{-1}, 24.46 kg ha^{-1} respectively to meet the yield target of 40 q ha^{-1}(Table 4.9 and Fig 4.3).

Potassium fertilizer requirement for target yield of 40 q ha^{-1}, where soil test value of potassium was 100 kg ha^{-1} NH_4OA_C-K, and 20.84 kg fertilizer potassium was required. While at 110 kg ha^{-1} ,120 kg ha^{-1} , 130 kg ha^{-1} soil test values of potassium, need of potassic fertilizer for same yield target would be 20.2 kg ha^{-1}, 19.56 kg ha^{-1}, 18.93 kg ha^{-1}, respectively (Table 4.9 and Fig 4.3).

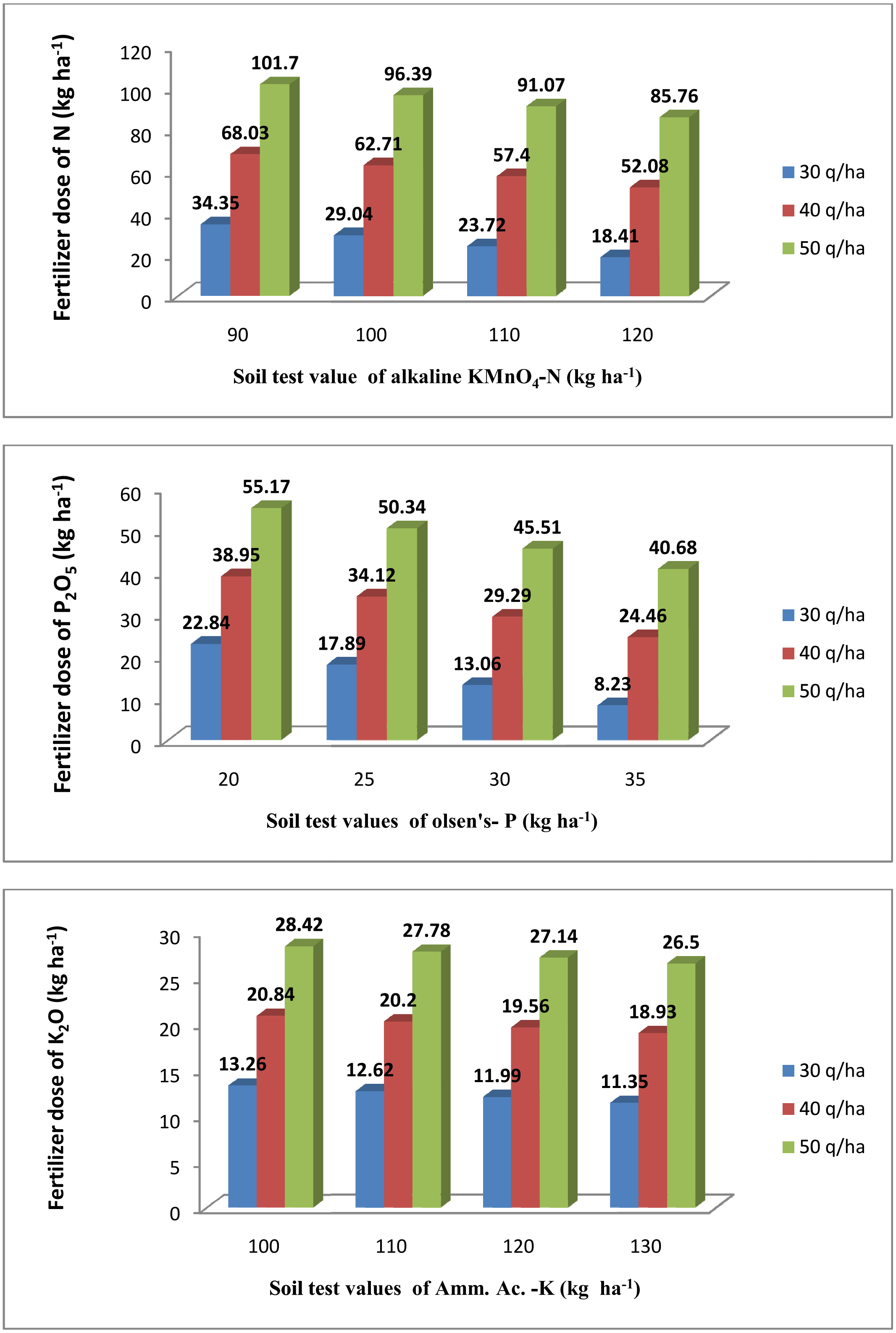


Fig. 4.3: N, P, K Requirement of hybrid maize at different soil test values and yield targets with conjoint use of FYM (10 t/ha)

Table 4.9: N, P, K requirement for different yield targets of Hybrid maize through fertilizer with conjoint use of FYM (10 t/ ha)

Soil Test Values (kg ha^{-1})	Yield Target of Hybrid maize(qha^{-1})		
	30	**40**	**50**
Alkaline $KMnO_4$- N	**Fertilizer – N (kg ha^{-1})**		
90	34.35	68.03	101.7
100	29.04	62.71	96.39
110	23.72	57.4	91.07
120	18.41	52.08	85.76
Olsen's P	**Fertilizer – P (kg ha^{-1})**		
20	22.84	38.95	55.17
25	17.89	34.12	50.34
30	13.06	29.29	45.51
35	8.23	24.46	40.68
Amm.Ac.-K	**Fertilizer – K (kg ha^{-1})**		
100	13.26	20.84	28.42
110	12.62	20.2	27.78
120	11.99	19.56	27.14
130	11.35	18.93	26.5

These results corroborate with the finding of **Santhi *et al.* (2010), Santhi *et al.* (2011) and Jadav *et al.*(2013).** Application of FYM have been found to save N, P and K fertilizer in different crops but its magnitude may vary from crop to crop or from location to location.

4.6.3 Fertilizer equivalence of FYM for Hybrid maize

Fertilizer equivalence of FYM in the present investigation was calculated by taking differences in fertilizer requirement of nutrient in question with and without FYM at a particular soil test value and target yield (Table 4.10). The average saving of fertilizer by 5 tonne FYM was 15.09 kg ha^{-1} N, 3.76 kg ha^{-1} P and 1.95 kg ha^{-1} K in Hybrid maize with in the range of soil test value and yield targets on Mollisol. Also, the fertilizer equilvalence by 10 tonnes FYM was 24.52 kg ha^{-1} N, 7.11 kg ha^{-1} P and 3.50

kg ha^{-1} K in Hybrid maize with in the range of soil test value and yield targets on Mollisol. Table 4.11. These values clearly indicate that the effect of FYM varies with level of soil fertility and yield target. Application of FYM in combination with chemical fertilizers in Hybrid maize has been found to save the use of nitrogen ,phosphorus and potassic fertilizers. Similar type of findings were also reported by **Thilagam and Natesan, (2009); Santhi *et al.* (2011) and Jadav *et al.*(2013)** in cauliflower, beet root and tomato crop respectively.

Table 4.10: Fertilizer equivalence of FYM (5 t ha^{-1}) under varying yield targets and fertility levels of Hybrid maize

Soil test value (kg ha^{-1})	Fertilizer equivalence of FYM @ 5 tonnes/ ha (kg ha^{-1})			
	Yield target (q ha^{-1})			
	30	**40**	**50**	**Mean**
Alkaline$KMnO_4$-N	**Fertilizer- N (kg ha^{-1})**			
90	13.25	15.68	18.10	**15.67**
100	12.87	15.29	17.72	**15.29**
110	12.48	14.91	17.34	**14.91**
120	12.10	14.53	16.95	**14.52**
Mean	**12.67**	**15.10**	**17.5**	**15.09**
Olsen's P	**Fertilizer- P (kg ha^{-1})**			
20	3.64	3.86	4.08	3.86
25	3.58	3.79	4.01	3.79
30	3.51	3.73	3.95	3.73
35	3.45	3.67	3.88	3.66
Mean	**3.54**	**3.76**	**3.98**	**3.76**
Amm.Ac.-K	**Fertilizer -K(kg ha^{-1})**			
100	1.84	1.98	2.11	**1.97**
110	1.83	1.96	2.10	**1.96**
120	1.82	1.95	2.09	**1.95**
130	1.80	1.94	2.08	**1.94**
Mean	**1.82**	**1.95**	**2.09**	**1.95**

Table 4.11: Fertilizer equivalence of FYM (10 t ha^{-1}) under varying yield targetsand fertility levels of Hybrid maize

Soil test value (kg ha^{-1})	Fertilizer equivalence of FYM @ 10 tonnes/ ha (kg ha^{-1})			
	Yield target (q ha^{-1})			
	30	**40**	**50**	**Mean**
AlkalineKMnO$_4$-N	**Fertilizer- N (kg ha^{-1})**			
90	22.67	25.10	27.52	**25.09**
100	22.29	24.72	27.14	**24.71**
110	21.91	24.33	26.76	**24.33**
120	21.52	23.95	26.38	**23.95**
Mean	**22.09**	**24.52**	**26.95**	**24.52**
Olsen's P	**Fertilizer- P (kg ha^{-1})**			
20	6.90	7.23	7.44	**7.19**
25	6.94	7.16	7.38	**7.16**
30	6.88	7.10	7.31	**7.09**
35	6.81	7.03	7.25	**7.03**
Mean	**6.88**	**7.13**	**7.34**	**7.11**
Amm.Ac.-K	**Fertilizer -K(kg ha^{-1})**			
100	3.39	3.52	3.66	**3.52**
110	3.37	3.51	3.65	**3.51**
120	3.36	3.50	3.64	**3.50**
130	3.35	3.49	3.63	**3.49**
Mean	**3.36**	**3.50**	**3.64**	**3.50**

4.6.4 Response to N, P and K on grain yield of Hybrid maize

Response to a nutrient by keeping other nutrient doses at middle doses has been worked out. Grain yield and FYM at different doses of nitrogen was worked out by keeping other nutrients at constant level (recommended and middle) and then their average is calculated. Response to N, P and K is given in table 4.12.

Response per kilogram to 60 , 120 and 150 kg of nitrogen application over control was found to be 21, 19.62 and 26.56 respectively. The maximum response was attained at 180 kg N application. Considering over successive doses, for 0 to 60 kg *i.e.* increment of 60 kg N resulted increase in yield to 21 kg ha^{-1}. So the increase was 21 kg ha^{-1} per kg of N application in this range. Similarly for 60 to 120 kg *i.e.* an increase of 60 kg N resulted increase in yield to the amount of 18.24 kg ha^{-1}. So the increase was 18.24 kg ha^{-1} yield per kg of N application in this range. Similarly for 120 to 180 kg *i.e.* an increase of 60 kg N resulted increase in yield to the amount of 40.44 kg ha^{-1}. So the increase was 40.44 kg ha^{-1} yield per kg of N application in this range. Hence increase of N application from 120 to 180 kg showed highest response at middle doses of P and K.

Table 4.12: Response to N, P and K on grain yield of Hybrid maize

Fertilizer dose (kg ha^{-1})	Grain yield (q ha^{-1})			Average(q ha^{-1})	Response kg $^{-1}$	
	OM_0	OM_5	OM_{10}		Over N_0	Over successive Dose
N_0	36.2	35	27.8	33	-	21
N_{60}	60	17.3	59.5	45.6	21	18.24
N_{120}	57.3	42.3	70	56.54	19.62	40.44
N_{180}	93.4	67.8	81.2	80.8	26.56	-
Average	**61.72**	**40.6**	**59.62**	**53.985**		
P_0	19.5	51.7	75.6	48.94		76
P_{30}	86.7	71.2	57.3	71.74	76	-50.7
P_{60}	57.3	42.3	70	56.54	12.67	3
P_{90}	72.8	27.8	71.7	57.44	9.45	-
Average	**59.07**	**48.25**	**68.65**	**58.66**		
K_0	70.6	7.8	70	49.46	-	-
K_{20}	43.4	32.8	80.6	52.27	14.05	21.35
K_{40}	57.3	42.3	70	56.54	17.7	4.65
K_{60}	26.2	66.2	80	57.47	13.35	-
Average	**49.37**	**37.27**	**75.15**	**53.93**		

Response to 30, 60 and 90 kg phosphorus over control was found 76, 12.67, and 9.45 respectively. The maximum response was attained at 30 kg phosphorus. Considering over successive doses, 0 to 30 kg *i.e.* an increase of 30 kg P resulted increase in yield to the amount of 76 kg ha^{-1}. So the increase was 70 kg ha^{-1} yield per kg of P application in this range. Similarly for 30 to 60 kg *i.e.* increase of 30 kg P resulted decrease in yield to 50.7 kg ha^{-1}. Similarly for 60 to 90 kg *i.e.* increase of 30 kg P resulted increase in yield to 3 kg ha^{-1}. Hence increase in P application from 0 to 30 kg showed highest response at middle doses of N and K.

Response to 20, 40 and 60 kg of potassium application over control was found 14.05, 17.7 and 13.35, respectively. Maximum increase in yield was reported at 40 kg K application. Considering successive doses, from 0 to 20 kg *i.e.* increase of 20 kg K resulted increase in yield to 14.05 kg ha^{-1}. So the increase was 14.05 kg ha^{-1} grain yield per kg of K application in this range. Similarly for 20 to 40 kg *i.e.* increase of 20 kg K resulted increase in yield to 21.35 kg ha^{-1}. Further the increased fertilizer dose showed decreasing trend as it was 4.65 at 40-60 kg application. Hence increase of K application from 20 to 40 kg showed highest response at middle doses of N and P.

4.7 Multiple regression study

Relationship between grain yield as dependent variable and the soil test values, fertilizer doses, FYM doses, interactions between soil test values and fertilizer doses as independent variables were established through a multiple regression equation. Soil test values used for these equations were alkaline $KMnO_4$-N, Olsen-P and neutral normal ammonium acetate-K in kg ha^{-1} Fertilizer doses used in the form of nutrients N, P and K in kg ha^{-1}.

In the present experiment multiple regression equations for different functions with their regression coefficient were developed and described below.

Yield = - 77.7752 + 0.1417 * SN + 1.1004 * SP + 0.2432 * SK + 0.0118 * FN + 1.9499 * FP + 0.1208 * FK + 0.0009 * FN2 - 0.0138 * FP2 - 0.0073 * FK2 + 0.0004 * FNSN - 0.0360 * FPSP + 0.0033 * FKSK - 4.0672 * ON + 4.2668 * OK……………….(1)

R^2= 0.7312**

** Significant at the 0.01 level

* Significant at the 0.05 level

Where,

SN,SP and SK=Soil test value (kg ha^{-1})of nitrogen phosphorus and potassium respectively.

FN, FP and FK = Applied fertilizer dose (kg ha^{-1})of nitrogen phosphorus and potassium respectively.

Y = Grain yield (q ha^{-1}) of Hybrid maize.

The value of coefficient of determination (R^2) obtained in multiple regression equation 0.7312** is highly significant and model fit to the data according to STCR norms, indicates 73 per cent variation in yield can be predicted by complete set of available soil N, P, K and applied fertilizer doses of N, P & K and their interaction. **Sharma *et al.* (2005)** found highly significant R^2 values of 0.88 and 0.91 for multiple regression equations on *Haplustept.*

4.7.1 Fertilizer response type

Generally at a given soil test value the yield will increase up to a limit with increasing dose of fertilizer and beyond that the yield will not increase but decrease, following the "Law of diminishing return" (STCR Report, 1972-73). The fertilizer dose, at which maximum yield increase occurs, decreases with increasing soil test value of the nutrient in question. Eight different types of responses are possible or there are eight ways in which the algebraic symbols (+) and (-) of the linear, quadratic and interaction terms of regression co-efficient could be arranged (STCR coordinator's report, 1972-73). Only in (+ - -) type of response situation site specific optimum fertilizer dose of nutrient in question can be derived by differentiation provided that the three coefficients are significant at least 5% level of significance **(STCR manual, 1985)**.

Types of response identified in the present investigation from above regression equation were given in table 4.13.

Table 4.13: Response type obtained through regression equation (using whole plots)

R^2 value	Nutrient	Response type
0.7312	Nitrogen	+++
	Phosphorus	+--
	Potassium	+-+

Response type '+ - -' is characterized by positive and decreasing response of applied fertilizer nutrients. There is negative correlation between soil and fertilizer nutrients. The law of diminishing return is said to be operates in these studies.

In this particular experiment, the site specific optimum fertilizer dose can be derived for Phosphorus as the response type is " + - -". While the response type '+ - +' showed the optimum fertilizer dose and the maximum yield increase with the increasing soil test value. This is the case with potassium in this particular experiment.

4.8 Suitability of different methods to estimate available nutrients in soil

Various soil test methods evaluated by working out a correlation between soil test values and grain yield of Hybrid maize under field conditions. The relative suitability of different soil test method for a given nutrient was judged from comparison of the magnitude of R^2 values of the regression equations obtained by including alternatively one method each time keeping the methods of other nutrients constant. Generally, the R^2 values above 0.66 are taken as indication of good fit, 0.45 to 0.65 as moderate fit, and below 0.45 as poor fit of the equation **(ICAR, 1974)**.

Data were analyzed to find out multiple regression equation for different functions with selected soil test methods i.e. Olsen's or AB-DTPA method and neutral normal NH_4OA_Cor AB-DTPA method to determine, available phosphorus and potassium in soil, respectively.

4.8.1 Available phosphorus

Evaluation of P fertility status of soil is necessary to make a sound P fertilizer recommendation for optimizing crop yield. Therefore following multiple regression equations have been developed for the evaluation of available phosphorus.

I) Olsen's P

Yield = - 88.1997 + 0.2200 * SN + 1.3809 * SP + 0.1913 * SK + 0.0914 * FN + 2.4697 * FP + 0.1666 * FK + 0.0009 * FN2 - 0.0143 * FP2 - 0.0071 * FK2 - 0.0002 * FNSN - 0.0498 * FPSP + 0.0030 * FKSK……………………………..(I)

R^2 = 0.684**

II) AB-DTPA P

Yield = - 75.6132 + 0.2221 * SN + 1.2233 * SP + 0.2019 * SK + 0.0873 * FN + 2.1771 * FP + 0.2601 * FK + 0.0010 * FN2 - 0.0151 * FP2 - 0.0075 * FK2 - 0.0003 * FNSN - 0.0408 * FPSP + 0.0023 * FKSK……………………………..(I)

R^2= 0.6805**

4.8.2 Available potassium

Numerous methods have been advocated by several workers to measure the available K status of the soils but none of these has been found to be universally applicable. Therefore following multiple regression equations have been developed for the evaluation of available potassium.

(I) Neutral Ammonium Acetate

Yield = - 88.1997 + 0.2200 * SN + 1.3809 * SP + 0.1913 * SK + 0.0914 * FN + 2.4697 * FP + 0.1666 * FK + 0.0009 * FN2 - 0.0143 * FP2 - 0.0071 * FK2 - 0.0002 * FNSN - 0.0498 * FPSP + 0.0030 * FKSK……………………………..(I)

R^2 = 0.6849**

II) AB-DTPA K

Yield = - 81.4268 + 0.2218 * SN + 1.3818 * SP + 0.1556 * SK + 0.0960 * FN + 2.4364 * FP + 0.0017 * FK + 0.0009 * FN2 - 0.0141 * FP2 - 0.0075 * FK2 - 0.0003 * FNSN - 0.0493 * FPSP + 0.0042 * FKSK……………………………..(I)

R^2= 0.6830**

** Significant at the 0.01 level
* Significant at the 0.05 level
Where,

SN, SP and SK = Soil test value (kg ha^{-1})of nitrogen phosphorus and potassium respectively.

OC= Soil test value as organic carbon (%).

FN, FP and FK = Applied fertilizer dose (kg ha^{-1})of nitrogen phosphorus and potassium respectively.

Y = Grain yield (q ha^{-1}) of Hybrid maize.

In the present investigation, on the basis of the R^2 value derived from regression equations, Olsen's method (R^2=**0.684****) was found superior to AB-DTPA method (R^2= **0.6805****). **Pandey (2012)** also reported similar type of results with cabbage crop in Mollisol.

Neutral normal NH_4OA_C- K method (R^2 = **0.6849****) was found superior to AB-DTPA K method (R^2=**0.6830****) in case of determination of available potassium as indicated by higher R^2 values. Similar findings were also reported by **(Singh *et al.* 1969 and Sachan *et al.* 1972**) in Mollisol.

Therefore from the above observations, it can be suggested that Olsen's method and neutral ammonium NH_4OA_C method can be taken as indices for determining soil available phosphorus and soil available potassium respectively in Mollisol of Uttarakhand.

4.9 Soil test value prediction

Nutrient availability in the soil after the harvest of a crop is largely influenced by the initial soil nutrient status, the amount of fertilizer nutrients added, crop yield and the nature of the crop raised. But in the present scenerio, the monoculture is replaced by cropping sequence approach. To apply soil test based fertilizer recommendations, the soils are to be tested after each crop, which is not practicable. The predicted soil test values can be utilized for recommending the fertilizer doses for succeeding crop and hence, eliminating the need of soil test after each crop. This provides the way for prescribing the fertilizer recommendations for whole cropping sequence on the basis of initial soil test values. Using a soil test based approach to nutrient management requires index measurement related to crop yield, the effective nutrient supply during the growth period, regular monitoring of soil test values and well developed service infrastructure with excellent quality control (**Dobermann *et al.*, 2003**) which is not feasible in farmer's point of view. So it has become necessary to predict the soil test values after the harvest of a crop. It is done by post-harvest soil test value predicting equations using vital soil test values, applied fertilizer dose and the obtained nutrients uptake or yield. By using the soil test value of the post harvest samples as a dependent variable and initial soil test value, applied fertilizer doses and yield or uptake as independent variables the following linear polynomial equations were derived. The functional relationship is as follows:-

Table 4.14: Prediction equation of postharvest soil nutrient based on yield and uptake of Hybrid maize

S,No	Prediction equation	R2 Value
1. Based on yield	PHN = - 9.3972 + 0.6124 * SN + 0.3250 * FN - 0.0123 * Y*	0.5395**
	PHP = 7.4910 + 0.1871 * SP + 0.1629 * FP + 0.0468 * Y	0.4768**
	PHK = 125.0024 + 0.1634 * SK + 0.3551 * FK + 0.0926 * Y	0.2711**
2.Based on uptake	PHN = - 6.9759 + 0.5605 * SN + 0.2839 * FN + 0.0803 * UN	0.5463**
	PHP = 7.3058 + 0.0387 * SP + 0.1388 * FP + 0.2479 * UP	0.6105**
	PHK = 128.4252 + 0.1170 * SK + 0.1785 * FK + 0.0889 * UK	0.3592**

** Regression is significant at the 0.01 level (2-tailed)
* Regression is significant at the 0.05 level (2-tailed)

Where,

FN = Fertilizer Nitrogen,

FP= Fertilizer Phosphorus,

FK= Fertilizer Potassium

SN = Soil Nitrogen,

SP=Soil Phosphorus.

SK= Soil Potassium,

PHN = Post Harvest Soil Nitrogen,

PHP= Post Harvest Soil Phosphorus

PHK = Post Harvest Soil Potassium,

Y= Yield.

Since, the value of R^2 is less which indicates that the difference between predicted and actual values of soil parameters are not much different. Hence, it infers that our prediction resembles the actual values and we can predict soil test values on the basis of post harvest analysis of soil samples.

The predicted values of the post harvest soil samples for N,P, and K are given below:

Table 4.15: Predicted Post harvest Soil test values obtained for nitrogen, phosphorus and potassium in experimental plots on yield basis

Strip I

Plot No.	Treatment	Alkaline $KMnO_4$ -N (kg ha^{-1})	Olsen's P (kg ha^{-1})	NH_4OAC-K (kg ha^{-1})
1.	$N_2P_3K_{2\ OM1}$	112.93	17.52	161.72
2.	$N_2P_2K_{2\ OM1}$	112.07	16.99	162.88
3.	$N_0P_0K_{0\ OM1}$	75.51	10.34	148.72
4.	$N_2P_2K_{0\ OM1}$	113.18	14.54	148.04
5.	$N_2P_2K_{3\ OM0}$	117.76	15.87	168.78
6.	$N_1P_2K_{1\ OM0}$	97.50	16.71	157.32
7.	$N_2P_0K_{2\ OM0}$	109.61	11.33	160.03
8.	$N_3P_2K_{1\ OM0}$	129.96	17.58	158.38
9.	$N_3P_3K_{2\ OM2}$	128.38	19.96	165.54
10.	$N_1P_1K_{2\ OM2}$	88.58	14.11	160.85
11.	$N_3P_2K_{3\ OM2}$	133.95	18.07	172.32
12.	$N_0P_2K_{2\ OM2}$	49.24	15.01	155.13
13.	$N_2P_3K_{3\ OM2}$	98.77	19.67	167.34
14.	$N_0P_0K_{0\ OM2}$	61.61	11.64	146.45
15.	$N_3P_1K_{1\ OM2}$	133.08	16.54	161.66
16.	$N_3P_3K_{3\ OM2}$	133.54	21.83	175.35
17.	$N_1P_1K_{1\ OM0}$	89.81	14.54	156.32
18.	$N_0P_0K_{0\ OM0}$	77.51	11.15	149.68
19.	$N_2P_2K_{1\ OM0}$	106.57	16.16	155.58
20.	$N_2P_1K_{1\ OM0}$	130.62	13.52	161.63
21.	$N_3P_2K_{2\ OM1}$	127.83	18.19	164.33
22.	$N_1P_2K_{2\ OM1}$	91.51	15.08	160.20
23.	$N_3P_3K_{1\ OM1}$	147.51	19.87	165.30
24.	$N_2P_1K_{2\ OM1}$	130.23	15.37	170.49

Strip II

Plot No.	Treatment	Alkaline $KMnO_4$-N (kg ha^{-1})	Olsen's P (kg ha^{-1})	NH_4OAC-K (kg ha^{-1})
1.	$N_1P_1K_{1\ OM1}$	94.02	14.27	156.69
2.	$N_0P_0K_{0\ OM1}$	83.67	11.25	151.43
3.	$N_2P_2K_{1\ OM1}$	128.65	16.32	160.46
4.	$N_2P_1K_{1\ OM1}$	128.00	14.05	160.02
5.	$N_3P_3K_{3\ OM0}$	148.16	21.42	177.55
6.	$N_3P_3K_{2\ OM0}$	148.51	19.58	168.99
7.	$N_1P_1K_{2\ OM0}$	108.06	15.72	169.25
8.	$N_0P_0K_{0\ OM0}$	87.13	11.14	152.14
9.	$N_2P_2K_{0\ OM2}$	111.73	17.64	153.62
10.	$N_1P_2K_{2\ OM2}$	96.47	17.57	165.57
11.	$N_3P_2K_{2\ OM2}$	134.52	18.07	167.39
12.	$N_3P_3K_{1\ OM2}$	134.43	20.66	162.18
13.	$N_2P_1K_{2\ OM2}$	113.26	14.77	164.63
14.	$N_0P_0K_{0\ OM2}$	77.43	12.09	150.35
15.	$N_2P_3K_{2\ OM2}$	116.51	19.76	166.88
16.	$N_2P_2K_{2\ OM2}$	120.65	17.59	167.83
17.	$N_0P_2K_{2\ OM0}$	75.20	15.54	162.86
18.	$N_3P_2K_{3\ OM0}$	126.24	18.30	171.49
19.	$N_3P_1K_{1\ OM0}$	36.77	16.14	160.57
20.	$N_2P_3K_{3\ OM0}$	116.67	19.13	171.58
21.	$N_1P_2K_{1\ OM1}$	101.35	17.23	160.35
22.	$N_2P_0K_{2\ OM1}$	122.24	12.51	166.50
23.	$N_2P_2K_{3\ OM1}$	122.07	17.41	173.76
24.	$N_3P_2K_{1\ OM1}$	140.03	18.92	162.77

Strip III

Plot No.	Treatment	Alkaline $KMnO_4$-N (kg ha^{-1})	Olsen's P (kg ha^{-1})	NH_4OAC-K (kg ha^{-1})
1.	**$N_0P_0K_{0\ OM1}$**	102.82	11.11	157.02
2.	**$N_3P_3K_{2\ OM1}$**	169.53	21.17	176.52
3.	**$N_0P_2K_{2\ OM1}$**	90.31	16.00	166.78
4.	**$N_1P_1K_{2\ OM1}$**	111.60	14.84	169.34
5.	**$N_2P_2K_{0\ OM0}$**	125.44	18.60	157.34
6.	**$N_0P_0K_{0\ OM0}$**	92.43	12.87	154.99
7.	**$N_1P_2K_{2\ OM0}$**	119.10	18.57	171.66
8.	**$N_3P_2K_{2\ OM0}$**	146.03	18.22	171.64
9.	**$N_3P_2K_{1\ OM2}$**	151.55	18.67	166.96
10.	**$N_2P_2K_{3\ OM2}$**	137.67	19.04	179.26
11.	**$N_2P_0K_{2\ OM2}$**	121.26	14.66	168.52
12.	**$N_1P_1K_{1\ OM2}$**	121.74	16.34	167.28
13.	**$N_1P_2K_{1\ OM2}$**	114.99	17.98	164.58
14.	**$N_2P_2K_{1\ OM2}$**	126.69	18.51	164.52
15.	**$N_0P_0K_{0\ OM2}$**	88.17	12.95	154.97
16.	**$N_2P_1K_{1\ OM2}$**	137.56	17.83	168.22
17.	**$N_3P_3K_{1\ OM0}$**	144.00	21.74	164.95
18.	**$N_2P_3K_{2\ OM0}$**	129.53	20.84	170.46
19.	**$N_2P_2K_{2\ OM0}$**	126.98	18.02	168.29
20.	**$N_2P_1K_{2\ OM0}$**	127.99	16.85	171.38
21.	**$N_3P_3K_{3\ OM1}$**	144.22	20.91	175.16
22.	**$N_3P_1K_{1\ OM1}$**	143.45	16.44	163.74
23.	**$N_3P_2K_{3\ OM1}$**	142.01	18.86	175.80
24.	**$N_2P_3K_{3\ OM1}$**	107.47	18.54	166.00

Predicted Post harvest Soil test values obtained for nitrogen, phosphorus and potassium in experimental plots on uptake basis

Strip I

Plot No.	Treatment	Alkaline $KMnO_4$ -N (kg ha^{-1})	Olsen's P (kg ha^{-1})	NH_4OAC-K (kg ha^{-1})
1.	$N_2P_3K_{2\ OM1}$	109.32	17.64	159.59
2.	$N_2P_2K_{2\ OM1}$	107.68	14.69	158.18
3.	$N_0P_0K_{0\ OM1}$	71.96	8.80	145.76
4.	$N_2P_2K_{0\ OM1}$	106.72	13.48	147.77
5.	$N_2P_2K_{3\ OM0}$	112.92	14.70	162.78
6.	$N_1P_2K_{1\ OM0}$	96.37	15.32	156.61
7.	$N_2P_0K_{2\ OM0}$	109.09	12.75	158.84
8.	$N_3P_2K_{1\ OM0}$	128.45	17.32	159.83
9.	$N_3P_3K_{2\ OM2}$	132.70	21.87	168.07
10.	$N_1P_1K_{2\ OM2}$	89.20	14.37	161.95
11.	$N_3P_2K_{3\ OM2}$	136.69	20.41	176.68
12.	$N_0P_2K_{2\ OM2}$	53.22	15.17	153.62
13.	$N_2P_3K_{3\ OM2}$	100.69	19.94	169.09
14.	$N_0P_0K_{0\ OM2}$	61.64	12.05	144.99
15.	$N_3P_1K_{1\ OM2}$	133.27	16.99	162.99
16.	$N_3P_3K_{3\ OM2}$	135.81	21.43	176.30
17.	$N_1P_1K_{1\ OM0}$	89.71	13.65	155.45
18.	$N_0P_0K_{0\ OM0}$	75.76	10.05	147.39
19.	$N_2P_2K_{1\ OM0}$	104.41	15.50	155.82
20.	$N_2P_1K_{1\ OM0}$	126.60	13.57	157.91
21.	$N_3P_2K_{2\ OM1}$	123.32	16.78	163.08
22.	$N_1P_2K_{2\ OM1}$	88.37	13.70	155.12
23.	$N_3P_3K_{1\ OM1}$	141.92	17.36	159.09
24.	$N_2P_1K_{2\ OM1}$	126.58	13.97	165.39

Strip II

Plot No.	Treatment	Alkaline $KMnO_4$-N (kg ha^{-1})	Olsen's P (kg ha^{-1})	NH_4OAC-K (kg ha^{-1})
1.	**$N_1P_1K_{1\ OM1}$**	94.26	13.86	155.97
2.	**$N_0P_0K_{0\ OM1}$**	80.91	10.17	148.37
3.	**$N_2P_2K_{1\ OM1}$**	123.42	14.25	157.80
4.	**$N_2P_1K_{1\ OM1}$**	124.45	13.26	157.81
5.	**$N_3P_3K_{3\ OM0}$**	146.09	18.88	173.66
6.	**$N_3P_3K_{2\ OM0}$**	145.41	18.41	166.76
7.	**$N_1P_1K_{2\ OM0}$**	108.53	14.31	165.77
8.	**$N_0P_0K_{0\ OM0}$**	86.94	11.43	150.63
9.	**$N_2P_2K_{0\ OM2}$**	113.20	16.94	157.48
10.	**$N_1P_2K_{2\ OM2}$**	99.91	18.30	168.15
11.	**$N_3P_2K_{2\ OM2}$**	134.84	18.95	169.22
12.	**$N_3P_3K_{1\ OM2}$**	140.20	23.47	168.58
13.	**$N_2P_1K_{2\ OM2}$**	115.62	16.09	170.70
14.	**$N_0P_0K_{0\ OM2}$**	77.38	13.14	149.95
15.	**$N_2P_3K_{2\ OM2}$**	117.39	20.83	166.62
16.	**$N_2P_2K_{2\ OM2}$**	121.40	17.96	168.98
17.	**$N_0P_2K_{2\ OM0}$**	76.85	15.14	157.34
18.	**$N_3P_2K_{3\ OM0}$**	127.91	17.84	169.19
19.	**$N_3P_1K_{1\ OM0}$**	136.98	16.01	161.00
20.	**$N_2P_3K_{3\ OM0}$**	115.95	19.80	169.05
21.	**$N_1P_2K_{1\ OM1}$**	102.44	16.20	160.09
22.	**$N_2P_0K_{2\ OM1}$**	121.51	12.31	162.64
23.	**$N_2P_2K_{3\ OM1}$**	120.95	16.48	169.70
24.	**$N_3P_2K_{1\ OM1}$**	141.56	18.79	164.27

Strip III

Plot No.	Treatment	Alkaline $KMnO_4$-N (kg ha^{-1})	Olsen's P (kg ha^{-1})	NH_4OAC-K (kg ha^{-1})
1.	$N_0P_0K_{0\ OM1}$	99.71	11.45	153.35
2.	$N_3P_3K_{2\ OM1}$	169.01	20.82	178.20
3.	$N_0P_2K_{2\ OM1}$	92.19	16.20	162.63
4.	$N_1P_1K_{2\ OM1}$	114.53	15.88	171.05
5.	$N_2P_2K_{0\ OM0}$	125.61	18.76	161.19
6.	$N_0P_0K_{0\ OM0}$	90.63	10.26	151.38
7.	$N_1P_2K_{2\ OM0}$	118.52	17.98	170.87
8.	$N_3P_2K_{2\ OM0}$	146.83	19.46	174.35
9.	$N_3P_2K_{1\ OM2}$	151.50	19.26	168.57
10.	$N_2P_2K_{3\ OM2}$	140.38	18.23	177.46
11.	$N_2P_0K_{2\ OM2}$	124.43	16.16	174.67
12.	$N_1P_1K_{1\ OM2}$	127.56	18.38	172.14
13.	$N_1P_2K_{1\ OM2}$	118.36	19.89	169.48
14.	$N_2P_2K_{1\ OM2}$	130.99	20.34	171.54
15.	$N_0P_0K_{0\ OM2}$	90.64	15.00	154.63
16.	$N_2P_1K_{1\ OM2}$	140.66	18.14	172.87
17.	$N_3P_3K_{1\ OM0}$	147.35	22.61	170.61
18.	$N_2P_3K_{2\ OM0}$	130.48	20.31	170.79
19.	$N_2P_2K_{2\ OM0}$	125.75	16.52	167.37
20.	$N_2P_1K_{2\ OM0}$	131.71	18.10	174.13
21.	$N_3P_3K_{3\ OM1}$	143.70	21.85	177.57
22.	$N_3P_1K_{1\ OM1}$	143.05	17.09	164.74
23.	$N_3P_2K_{3\ OM1}$	143.86	20.51	178.59
24.	$N_2P_3K_{3\ OM1}$	107.79	20.78	174.25

Summary and Conclusion

SUMMARY AND CONCLUSION

The present investigation was carried out during the year 2017-18 on an Aquic Hapludoll at D_7 block of Norman E. Borlogue Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar. The experiment was conducted in two phases. In first phase soil fertility gradient was developed by dividing experimental field into three strips where graded dose of fertilizers was applied in these strips and exhaust crop wheat (var. UP2526) for grain was grown. In second phase test crop Hybrid maize (var.P3377) was grown by further dividing each strip in 24 plots for 21 treatments and 3 control plots. Response to selected combinations of three levels of FYM (0, 5 and 10 t ha^{-1}), four levels of each nitrogen (0, 60, 120 and 180 kg N ha^{-1}), phosphorus (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) and potassium (0, 20, 40 and 60 kg K_2O ha^{-1}) at different fertility levels was studied to develop dependable equation for computing nutrient doses for target yield on the basis of initial soil fertility. Salient experimental findings of this investigation are summarized below:

1. Fertility gradient was developed by using differential fertilizer doses and growing a gradient stabilizing crop (Wheat var.UP2526) for grain. Organic carbon ranged from 0.156 to 1.17 with 0.55 per cent mean, Alkaline $KMnO_4$ extractable nitrogen ranged from 50.2 to 175.6 with 109.2 kg N ha^{-1} mean, Olsen's phosphorus ranged from 10.4 to 21.67 with 15.80 kg P ha^{-1} mean and neutral normal NH_4OAc extractable potassium ranged from 96.3 to 198.2 with 149.8 kg ha^{-1} mean in the surface soil. Fertility gradient was established significantly with respect to N, P and K. Variation among the fertility gradient strips as well as the variability within the strip *i.e.* among treatments was significant at 1% level.

2. Average grain yield of Hybrid maize varied from 7.78 to 105 with 56.48 q ha^{-1} mean. Average grain yield of Hybrid maize was recorded in order of strip III (66.84 q ha^{-1}) followed by strip II (56.58 q ha^{-1}) and strip I (46.02 q ha^{-1}).

3. Average biomass yield of Hybrid maize varied from 38.89 to 404.45 q ha^{-1} with 229.02 mean. Average biomass yield of Hybrid maize was recorded in order of strip III (284.45 q ha^{-1}) followed by strip II (222.41 q ha^{-1}) and strip I (180.19 q ha^{-1}).

4. Average uptake of nitrogen by grain varied from 2.75 to 52.57 with 26.51 kg ha^{-1} mean. Average uptake of nitrogen was recorded highest in strip III (31.5 kg ha^{-1}), followed by strip II (28.11 kg ha^{-1}) and strip I (19.81 kg ha^{-1}).

5. Average uptake of phosphorus by grain varied from 0.68 to 10.20 kg ha^{-1} with 5.31 kg ha^{-1} mean. Average uptake of phosphorus recorded highest in strip III (6.47 kg ha^{-1}), followed by strip II (5.36 kg ha^{-1}) and strip I (4.12 kg ha^{-1}).

6. Average uptake of potassium by grain varied from 4.99 to 76.93 kg ha^{-1} with 39.48 kg ha^{-1} mean. Average uptake of potassium was recorded highest in strip III (47.32 kg ha^{-1}), followed by strip II (39.30 kg ha^{-1}) and strip I (31.82 kg ha^{-1}).

7. Average uptake of nitrogen by whole plant varied 13.65 to 211.51 kg $ha^{-1}$with 113.04 kg ha^{-1} mean. Average uptake of nitrogen was recorded highest in strip III (138.44 kg ha^{-1}), followed by strip II (113.08 kg ha^{-1}) and strip I (87.60 kg ha^{-1}).

8. Average uptake of phosphorus by whole plant varied from4.10 to 41.03 kg ha^{-1} with 22.99 kg ha^{-1} mean. Average uptake of phosphorus recorded highest in strip III (28.51 kg ha^{-1}), followed by strip II (21.97 kg ha^{-1}) and strip I (18.51 kg ha^{-1}).

9. Average uptake of potassium by grain varied from 12.25 to 262.01 kg ha^{-1} with 149.49 kg ha^{-1} mean. Average uptake of potassium was recorded highest in strip III (190.42 kg ha^{-1}), followed by strip II (141.57 kg ha^{-1}) and strip I (116.50 kg ha^{-1}).

10. Basic parameters viz. nutrient requirement for the production of one quintal of Hybrid maize grain (NR) and contribution of soil (CS), fertilizer (CF) and FYM (CFYM) in terms of N, P and K was calculated with the help of above data.

11. One quintal grain yield of Hybrid maize was produced with 2.17 kg nitrogen, 0.46 kg phosphorus and 2.74 kg potassium.

12. Contribution of soil to supply nitrogen, phosphorus and potassium for the crop was 33.14, 26.8 and 22.71 per cent, respectively.

13. Contribution from applied FYM for nitrogen, phosphorus and potassium was 45.21, 14.44 and 39.40 percent respectively.

14. Contribution from fertilizer was 62.36, 63.52 and 427.61 percent applied with FYM and 58.18, 62.68 and 420.4 percent without FYM for nitrogen, phosphorus and potassium, respectively.

15. On the basis of basic data (NR, CS, CF and CFYM), fertilizer adjustment equations were developed and requirement of nitrogen, phosphorus and potassium was calculated for different yield targets of Hybrid maize at different soil test values with the application of chemical fertilizer alone and with combined use of FYM.

16. Fertilizer doses to be applied decreased with increasing soil test values for a particular yield target. However, for a particular soil test value fertilizer doses to be applied increased with increasing target yields.

17. The value of fertilizer equivalence was found highest at higher yield level while it decreased with increasing soil test values. Average saving of fertilizer by 5 tonne FYM was 15.09 kg ha^{-1} N, 3.76 kg ha^{-1} P and 1.95 kg ha^{-1} K within the range of soil test values and yield targets and average saving of fertilizer by 10 tonne FYM was 24.52 kg ha^{-1} N, 7.11 kg ha^{-1} P and 3.50 kg ha^{-1} K within the range of soil test values and yield targets

18. Multiple regression equation was developed by connecting grain yield of Hybrid maize being used as dependent and soil test value, applied fertilizer doses and their interaction as independent variables. From the R^2 (0.7312**) value, it is clear that 73 per cent variation in grain yield may be predicted. Ideal '+ - -' response type for linear and quadratic interaction term for phosphorus while '+ + +' response type was observed for nitrogen and '+ - +' for potassium..

19. From the present study, it may be suggested that Olsen's method for soil available phosphorus and neutral ammonium NH_4OA_C method for soil available potassium could be taken as indices for determining P and K in Mollisol of Uttarakhand. AB-DTPA as an universal extractant could be adopted by soil testing laboratories for extraction as it extracts both P and K and various micronutrients too from the soil.

Thus, the present investigation provides a strong basis for the fertilizer recommendations based on target yield concept which can effectively work up to 30 and 50 q ha^{-1} yield targets in Hybrid maize grown on Mollisols of Uttarakhand. Besides, target yield based fertilizer recommendations not only provide balanced nutrition to crop, but also are able to sustain the crop productivity and soil health. Resource poor farmers could also fetch good profitability by applying fertilizers based on site specific target yield concept.

For the optimum utilization of both renewable and non- renewable resources and the concern for quality of soil health and environment, the research on soil testing needs more emphasis and modifications to meet the future challenges.

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Appendices

APPENDIX-I

Initial Soil test values obtained for nitrogen, phosphorus and potassium in experimental plots

Strip I

Plot No.	Treatment	Alkaline $KMnO_4$-N (kg ha^{-1})	Olsen's P (kg ha^{-1})	NH_4OAC-K (kg ha^{-1})	Organic carbon (%)
1.	$N_2P_3K_{2\ OM1}$	100.35	12.45	136.64	0.78
2.	$N_2P_2K_{2\ OM1}$	75.26	17.44	135.52	0.78
3.	$N_0P_0K_{0\ OM1}$	125.44	12.45	138.88	0.39
4.	$N_2P_2K_{0\ OM1}$	87.80	12.95	136.64	0.39
5.	$N_2P_2K_{3\ OM0}$	112.89	15.44	144.48	0.15
6.	$N_1P_2K_{1\ OM0}$	87.80	18.43	143.36	0.42
7.	$N_2P_0K_{2\ OM0}$	75.26	15.69	131.04	0.23
8.	$N_3P_2K_{1\ OM0}$	100.35	15.69	133.28	0.54
9.	$N_3P_3K_{2\ OM2}$	75.26	12.70	131.04	1.17
10.	$N_1P_1K_{2\ OM2}$	112.89	15.94	128.8	0.42
11.	$N_3P_2K_{3\ OM2}$	87.80	15.69	140	0.39
12.	$N_0P_2K_{2\ OM2}$	125.44	10.46	96.32	0.85
13.	$N_2P_3K_{3\ OM2}$	87.80	14.95	114.24	0.54
14.	$N_0P_0K_{0\ OM2}$	100.35	15.69	116.48	0.46
15.	$N_3P_1K_{1\ OM2}$	112.89	15.19	138.88	0.50
16.	$N_3P_3K_{3\ OM2}$	125.44	16.19	140	0.50
17.	$N_1P_1K_{1\ OM0}$	75.26	15.44	131.04	0.58
18.	$N_0P_0K_{0\ OM0}$	100.35	15.69	142.24	0.39
19.	$N_2P_2K_{1\ OM0}$	100.35	12.70	126.56	0.19
20.	$N_2P_1K_{1\ OM0}$	75.26	10.96	165.76	0.97
21.	$N_3P_2K_{2\ OM1}$	75.26	17.44	129.92	0.39
22.	$N_1P_2K_{2\ OM1}$	50.17	13.45	133.28	0.19
23.	$N_3P_3K_{1\ OM1}$	87.80	10.71	162.4	0.58
24.	$N_2P_1K_{2\ OM1}$	87.80	12.95	165.76	0.35
	Mean	**93.55**	**14.45**	**135.94**	**0.51**

Contd..

Strip II

Plot No.	Treatment	Alkaline $KMnO_4$-N (kg ha^{-1})	Olsen's P (kg ha^{-1})	NH_4OAC-K (kg ha^{-1})	Organic carbon (%)
1.	$N_1P_1K_{1\ OM1}$	112.89	15.94	137.76	0.78
2.	$N_0P_0K_{0\ OM1}$	137.98	15.94	152.32	0.39
3.	$N_2P_2K_{1\ OM1}$	125.44	16.19	162.4	0.62
4.	$N_2P_1K_{1\ OM1}$	112.89	16.19	161.28	0.70
5.	$N_3P_3K_{3\ OM0}$	125.44	18.43	163.52	0.35
6.	$N_3P_3K_{2\ OM0}$	137.98	15.69	163.52	0.39
7.	$N_1P_1K_{2\ OM0}$	112.89	16.19	161.28	0.78
8.	$N_0P_0K_{0\ OM0}$	125.44	15.94	157.92	0.78
9.	$N_2P_2K_{0\ OM2}$	112.89	13.95	135.52	0.78
10.	$N_1P_2K_{2\ OM2}$	137.98	16.19	142.24	0.78
11.	$N_3P_2K_{2\ OM2}$	125.44	13.45	141.12	0.39
12.	$N_3P_3K_{1\ OM2}$	100.35	13.95	141.12	0.39
13.	$N_2P_1K_{2\ OM2}$	87.80	13.20	137.76	0.15
14.	$N_0P_0K_{0\ OM2}$	87.80	18.93	142.24	0.42
15.	$N_2P_3K_{2\ OM2}$	100.35	13.45	143.36	0.19
16.	$N_2P_2K_{2\ OM2}$	87.80	13.70	150.08	0.19
17.	$N_0P_2K_{2\ OM0}$	100.35	11.21	138.88	0.39
18.	$N_3P_2K_{3\ OM0}$	100.35	13.70	127.68	0.39
19.	$N_3P_1K_{1\ OM0}$	87.80	18.43	144.48	0.54
20.	$N_2P_3K_{3\ OM0}$	112.89	13.45	143.36	0.58
21.	$N_1P_2K_{1\ OM1}$	112.89	15.94	150.08	0.78
22.	$N_2P_0K_{2\ OM1}$	87.80	13.95	152.32	0.85
23.	$N_2P_2K_{3\ OM1}$	87.80	13.70	152.32	0.58
24.	$N_3P_2K_{1\ OM1}$	112.89	18.43	150.08	0.78
	Mean	**109.76**	**15.26**	**148.02**	**0.54**

Contd….

Strip III

Plot No.	Treatment	Alkaline $KMnO_4$-N (kg ha^{-1})	Olsen's P (kg ha^{-1})	NH_4OAC-K (kg ha^{-1})	Organic carbon (%)
1.	$N_0P_0K_{0\ OM1}$	87.80	13.95	183.68	0.78
2.	$N_3P_3K_{2\ OM1}$	100.35	19.18	198.24	0.78
3.	$N_0P_2K_{2\ OM1}$	112.89	13.95	163.52	0.39
4.	$N_1P_1K_{2\ OM1}$	112.89	13.70	166.88	1.17
5.	$N_2P_2K_{0\ OM0}$	137.98	18.93	157.92	0.39
6.	$N_0P_0K_{0\ OM0}$	100.35	21.42	166.88	0.58
7.	$N_1P_2K_{2\ OM0}$	112.89	21.42	179.2	0.46
8.	$N_3P_2K_{2\ OM0}$	175.61	11.21	160.16	1.09
9.	$N_3P_2K_{1\ OM2}$	150.52	14.20	169.12	0.39
10.	$N_2P_2K_{3\ OM2}$	125.44	18.93	178.08	0.19
11.	$N_2P_0K_{2\ OM2}$	125.44	19.43	151.2	0.23
12.	$N_1P_1K_{1\ OM2}$	125.44	18.68	183.68	0.39
13.	$N_1P_2K_{1\ OM2}$	100.35	18.43	172.48	0.78
14.	$N_2P_2K_{1\ OM2}$	112.89	15.94	160.16	0.85
15.	$N_0P_0K_{0\ OM2}$	125.44	18.93	160.16	0.78
16.	$N_2P_1K_{1\ OM2}$	100.35	21.67	178.08	0.78
17.	$N_3P_3K_{1\ OM0}$	163.07	19.18	156.8	0.39
18.	$N_2P_3K_{2\ OM0}$	125.44	18.93	164.64	0.39
19.	$N_2P_2K_{2\ OM0}$	137.98	19.18	160.16	0.78
20.	$N_2P_1K_{2\ OM0}$	137.98	16.94	162.4	0.39
21.	$N_3P_3K_{3\ OM1}$	112.89	19.18	156.8	0.89
22.	$N_3P_1K_{1\ OM1}$	137.98	16.44	155.68	0.39
23.	$N_3P_2K_{3\ OM1}$	137.98	16.44	153.44	0.70
24.	$N_2P_3K_{3\ OM1}$	125.44	18.43	127.68	0.78
	Mean	**124.39**	**17.70**	**165.29**	**0.61**

APPENDIX-II

Post harvest Soil test values obtained for nitrogen, phosphorus and potassium in experimental plots

Strip I

Plot No.	Treatment	Alkaline $KMnO_4$-N (kg ha^{-1})	Olsen's P (kg ha^{-1})	NH_4OAC-K (kg ha^{-1})	Organic carbon (%)
1.	$N_2P_3K_{2\ OM1}$	125.44	18.68	157.92	0.78
2.	$N_2P_2K_{2\ OM1}$	137.98	16.19	153.44	0.62
3.	$N_0P_0K_{0\ OM1}$	87.80	8.72	151.20	0.74
4.	$N_2P_2K_{0\ OM1}$	137.98	16.19	155.68	0.66
5.	$N_2P_2K_{3\ OM0}$	112.89	11.71	160.16	0.39
6.	$N_1P_2K_{1\ OM0}$	62.72	12.21	153.44	0.35
7.	$N_2P_0K_{2\ OM0}$	125.44	9.47	155.68	0.58
8.	$N_3P_2K_{1\ OM0}$	150.52	11.21	153.44	0.31
9.	$N_3P_3K_{2\ OM2}$	112.89	21.17	157.92	0.58
10.	$N_1P_1K_{2\ OM2}$	62.72	16.69	146.72	0.58
11.	$N_3P_2K_{3\ OM2}$	100.35	18.68	164.64	0.74
12.	$N_0P_2K_{2\ OM2}$	50.17	19.18	157.92	1.01
13.	$N_2P_3K_{3\ OM2}$	62.72	21.42	175.84	0.58
14.	$N_0P_0K_{0\ OM2}$	37.63	11.96	146.72	0.97
15.	$N_3P_1K_{1\ OM2}$	112.89	16.69	170.24	0.97
16.	$N_3P_3K_{3\ OM2}$	100.35	21.67	164.64	0.89
17.	$N_1P_1K_{1\ OM0}$	62.72	11.21	153.44	0.50
18.	$N_0P_0K_{0\ OM0}$	50.17	8.97	142.24	0.39
19.	$N_2P_2K_{1\ OM0}$	62.72	11.46	142.24	0.5
20.	$N_2P_1K_{1\ OM0}$	62.72	9.71	153.44	0.31
21.	$N_3P_2K_{2\ OM1}$	125.44	16.19	155.68	0.66
22.	$N_1P_2K_{2\ OM1}$	137.98	17.44	157.92	0.58
23.	$N_3P_3K_{1\ OM1}$	137.98	18.68	145.60	0.81
24.	$N_2P_1K_{2\ OM1}$	137.98	13.95	146.72	0.39
	Mean	**98.26**	**14.98**	**155.12**	**0.60**

Contd..

Strip II

Plot No.	Treatment	Alkaline $KMnO_4$-N (kg ha^{-1})	Olsen's P (kg ha^{-1})	NH_4OAC-K (kg ha^{-1})	Organic carbon (%)
1.	$N_1P_1K_{1\ OM1}$	100.35	14.70	170.24	0.50
2.	$N_0P_0K_{0\ OM1}$	87.80	9.71	169.12	0.81
3.	$N_2P_2K_{1\ OM1}$	112.89	16.69	157.92	0.74
4.	$N_2P_1K_{1\ OM1}$	112.89	14.95	157.92	0.58
5.	$N_3P_3K_{3\ OM0}$	125.44	14.70	173.6	0.46
6.	$N_3P_3K_{2\ OM0}$	125.44	14.20	169.12	0.23
7.	$N_1P_1K_{2\ OM0}$	87.80	9.22	157.92	0.58
8.	$N_0P_0K_{0\ OM0}$	75.26	8.72	143.36	0.19
9.	$N_2P_2K_{0\ OM2}$	125.44	19.18	172.48	1.36
10.	$N_1P_2K_{2\ OM2}$	112.89	19.43	163.52	0.78
11.	$N_3P_2K_{2\ OM2}$	137.98	21.17	163.52	0.78
12.	$N_3P_3K_{1\ OM2}$	163.07	23.66	160.16	0.97
13.	$N_2P_1K_{2\ OM2}$	125.44	19.18	163.52	0.89
14.	$N_0P_0K_{0\ OM2}$	100.35	13.70	146.72	0.74
15.	$N_2P_3K_{2\ OM2}$	125.44	22.17	174.72	0.58
16.	$N_2P_2K_{2\ OM2}$	125.44	19.93	163.52	0.78
17.	$N_0P_2K_{2\ OM0}$	75.26	12.21	165.76	0.19
18.	$N_3P_2K_{3\ OM0}$	125.44	14.20	162.4	0.50
19.	$N_3P_1K_{1\ OM0}$	125.44	12.21	156.8	0.39
20.	$N_2P_3K_{3\ OM0}$	112.89	19.68	162.4	0.39
21.	$N_1P_2K_{1\ OM1}$	100.35	19.68	173.6	0.66
22.	$N_2P_0K_{2\ OM1}$	150.52	12.70	161.28	0.58
23.	$N_2P_2K_{3\ OM1}$	163.07	17.44	164.64	0.62
24.	$N_3P_2K_{1\ OM1}$	188.16	18.18	166.88	0.58
	Mean	**120.21**	**16.15**	**163.38**	**0.62**

Contd….

Strip III

Plot No.	Treatment	Alkaline $KMnO_4$-N (kg ha^{-1})	Olsen's P (kg ha^{-1})	NH_4OAC-K (kg ha^{-1})	Organic carbon (%)
1.	$N_0P_0K_{0\ OM1}$	100.35	12.70	161.28	0.31
2.	$N_3P_3K_{2\ OM1}$	150.52	22.92	198.24	0.39
3.	$N_0P_2K_{2\ OM1}$	100.35	20.18	164.64	0.39
4.	$N_1P_1K_{2\ OM1}$	112.89	19.93	164.64	0.74
5.	$N_2P_2K_{0\ OM0}$	125.44	22.67	157.92	0.19
6.	$N_0P_0K_{0\ OM0}$	100.35	12.70	157.92	0.27
7.	$N_1P_2K_{2\ OM0}$	100.35	16.69	162.4	0.58
8.	$N_3P_2K_{2\ OM0}$	137.98	16.19	169.12	0.42
9.	$N_3P_2K_{1\ OM2}$	175.61	18.93	164.64	0.58
10.	$N_2P_2K_{3\ OM2}$	150.52	21.67	208.32	1.05
11.	$N_2P_0K_{2\ OM2}$	150.52	16.44	168	1.05
12.	$N_1P_1K_{1\ OM2}$	125.44	21.17	142.24	1.36
13.	$N_1P_2K_{1\ OM2}$	125.44	21.17	164.64	0.97
14.	$N_2P_2K_{1\ OM2}$	150.52	18.93	175.84	1.56
15.	$N_0P_0K_{0\ OM2}$	87.80	16.19	163.52	0.78
16.	$N_2P_1K_{1\ OM2}$	150.52	21.17	175.84	0.85
17.	$N_3P_3K_{1\ OM0}$	137.98	18.68	182.56	0.19
18.	$N_2P_3K_{2\ OM0}$	125.44	18.68	162.4	0.39
19.	$N_2P_2K_{2\ OM0}$	125.44	13.70	151.2	0.58
20.	$N_2P_1K_{2\ OM0}$	125.44	13.70	162.4	0.39
21.	$N_3P_3K_{3\ OM1}$	150.52	21.17	202.72	0.58
22.	$N_3P_1K_{1\ OM1}$	150.52	18.68	173.6	0.62
23.	$N_3P_2K_{3\ OM1}$	150.52	22.67	202.72	0.85
24.	$N_2P_3K_{3\ OM1}$	137.98	24.66	213.92	0.66
	Mean	**131.18**	**18.82**	**172.94**	**0.65**

APPENDIX-III
Nutrient content in grain of hybrid maize in different experimental plots
Strip I

Plot No.	Treatment	N %	P %	K %
1.	$N_2P_3K_{2\ OM1}$	1.05	0.199	1.52
2.	$N_2P_2K_{2\ OM1}$	0.7	0.203	1.37
3.	$N_0P_0K_{0\ OM1}$	0.77	0.166	1.28
4.	$N_2P_2K_{0\ OM1}$	0.77	0.191	1.4
5.	$N_2P_2K_{3\ OM0}$	0.77	0.166	1.44
6.	$N_1P_2K_{1\ OM0}$	0.98	0.195	1.56
7.	$N_2P_0K_{2\ OM0}$	0.91	0.174	1.17
8.	$N_3P_2K_{1\ OM0}$	0.98	0.187	1.72
9.	$N_3P_3K_{2\ OM2}$	0.98	0.208	1.7
10.	$N_1P_1K_{2\ OM2}$	0.84	0.170	1.7
11.	$N_3P_2K_{3\ OM2}$	0.98	0.191	1.15
12.	$N_0P_2K_{2\ OM2}$	0.77	0.195	1.58
13.	$N_2P_3K_{3\ OM2}$	1.12	0.208	1.62
14.	$N_0P_0K_{0\ OM2}$	0.84	0.170	1.7
15.	$N_3P_1K_{1\ OM2}$	0.84	0.183	1.58
16.	$N_3P_3K_{3\ OM2}$	1.05	0.212	1.6
17.	$N_1P_1K_{1\ OM0}$	0.77	0.170	1.72
18.	$N_0P_0K_{0\ OM0}$	0.77	0.166	1.63
19.	$N_2P_2K_{1\ OM0}$	1.05	0.191	1.59
20.	$N_2P_1K_{1\ OM0}$	0.84	0.187	1.22
21.	$N_3P_2K_{2\ OM1}$	0.91	0.220	1.81
22.	$N_1P_2K_{2\ OM1}$	0.91	0.203	1.14
23.	$N_3P_3K_{1\ OM1}$	1.12	0.208	1.25
24.	$N_2P_1K_{2\ OM1}$	0.91	0.191	1.28
	Mean	**0.90**	**0.190**	**1.48**

Contd..

Strip II

Plot No.	Treatment	N %	P %	K %
1.	$N_1P_1K_{1\ OM1}$	1.05	0.199	1.2
2.	$N_0P_0K_{0\ OM1}$	0.77	0.174	1.34
3.	$N_2P_2K_{1\ OM1}$	1.19	0.203	1.4
4.	$N_2P_1K_{1\ OM1}$	1.12	0.203	1.37
5.	$N_3P_3K_{3\ OM0}$	1.05	0.224	1.8
6.	$N_3P_3K_{2\ OM0}$	1.19	0.224	1.43
7.	$N_1P_1K_{2\ OM0}$	0.98	0.191	1.56
8.	$N_0P_0K_{0\ OM0}$	0.91	0.170	1.6
9.	$N_2P_2K_{0\ OM2}$	1.05	0.208	1.65
10.	$N_1P_2K_{2\ OM2}$	0.98	0.212	1.74
11.	$N_3P_2K_{2\ OM2}$	1.05	0.228	1.19
12.	$N_3P_3K_{1\ OM2}$	1.26	0.216	1.78
13.	$N_2P_1K_{2\ OM2}$	0.84	0.203	1.82
14.	$N_0P_0K_{0\ OM2}$	1.12	0.174	1.76
15.	$N_2P_3K_{2\ OM2}$	1.19	0.216	1.68
16.	$N_2P_2K_{2\ OM2}$	1.05	0.212	1.59
17.	$N_0P_2K_{2\ OM0}$	0.91	0.212	1.17
18.	$N_3P_2K_{3\ OM0}$	1.19	0.203	1.5
19.	$N_3P_1K_{1\ OM0}$	1.26	0.203	1.62
20.	$N_2P_3K_{3\ OM0}$	1.26	0.224	1.44
21.	$N_1P_2K_{1\ OM1}$	0.91	0.178	1.39
22.	$N_2P_0K_{2\ OM1}$	1.19	0.178	1.4
23.	$N_2P_2K_{3\ OM1}$	0.84	0.195	1.15
24.	$N_3P_2K_{1\ OM1}$	1.19	0.203	1.37
	Mean	**1.06**	**0.202**	**1.48**

Contd….

Strip III

Plot No.	Treatment	N %	P %	K %
1.	$N_0P_0K_{0\ OM1}$	0.91	0.174	1.34
2.	$N_3P_3K_{2\ OM1}$	1.05	0.187	1.46
3.	$N_0P_2K_{2\ OM1}$	1.05	0.183	1.35
4.	$N_1P_1K_{2\ OM1}$	1.05	0.203	1.48
5.	$N_2P_2K_{0\ OM0}$	0.91	0.224	1.51
6.	$N_0P_0K_{0\ OM0}$	0.84	0.170	1.39
7.	$N_1P_2K_{2\ OM0}$	0.77	0.216	1.48
8.	$N_3P_2K_{2\ OM0}$	1.05	0.224	1.51
9.	$N_3P_2K_{1\ OM2}$	1.05	0.212	1.6
10.	$N_2P_2K_{3\ OM2}$	1.12	0.208	1.19
11.	$N_2P_0K_{2\ OM2}$	1.05	0.187	1.71
12.	$N_1P_1K_{1\ OM2}$	0.98	0.203	1.74
13.	$N_1P_2K_{1\ OM2}$	0.84	0.216	1.69
14.	$N_2P_2K_{1\ OM2}$	1.19	0.216	1.78
15.	$N_0P_0K_{0\ OM2}$	0.77	0.178	1.81
16.	$N_2P_1K_{1\ OM2}$	0.98	0.208	1.85
17.	$N_3P_3K_{1\ OM0}$	1.26	0.228	1.8
18.	$N_2P_3K_{2\ OM0}$	1.26	0.224	1.66
19.	$N_2P_2K_{2\ OM0}$	0.91	0.224	1.18
20.	$N_2P_1K_{2\ OM0}$	1.19	0.212	1.52
21.	$N_3P_3K_{3\ OM1}$	1.05	0.237	1.48
22.	$N_3P_1K_{1\ OM1}$	0.98	0.212	1.39
23.	$N_3P_2K_{3\ OM1}$	1.05	0.216	1.41
24.	$N_2P_3K_{3\ OM1}$	0.77	0.228	1.15
	Mean	**1.00**	**0.208**	**1.52**

APPENDIX-IV

Nutrient content in plants of hybrid maize in different experimental plots

Strip I

Plot No.	Treatment	N %	P %	K %
1.	$N_2P_3K_{2\ OM1}$	0.7	0.187	1.04
2.	$N_2P_2K_{2\ OM1}$	0.91	0.174	1.3
3.	$N_0P_0K_{0\ OM1}$	0.56	0.187	0.33
4.	$N_2P_2K_{0\ OM1}$	0.91	0.195	0.85
5.	$N_2P_2K_{3\ OM0}$	0.91	0.191	1.4
6.	$N_1P_2K_{1\ OM0}$	0.98	0.195	1.18
7.	$N_2P_0K_{2\ OM0}$	0.98	0.178	0.92
8.	$N_3P_2K_{1\ OM0}$	0.98	0.191	1.02
9.	$N_3P_3K_{2\ OM2}$	0.98	0.174	0.93
10.	$N_1P_1K_{2\ OM2}$	0.84	0.183	1.31
11.	$N_3P_2K_{3\ OM2}$	0.91	0.187	1.4
12.	$N_0P_2K_{2\ OM2}$	0.91	0.174	0.94
13.	$N_2P_3K_{3\ OM2}$	0.7	0.166	1.29
14.	$N_0P_0K_{0\ OM2}$	0.42	0.195	0.17
15.	$N_3P_1K_{1\ OM2}$	0.91	0.187	0.93
16.	$N_3P_3K_{3\ OM2}$	0.98	0.191	1.52
17.	$N_1P_1K_{1\ OM0}$	0.91	0.183	0.94
18.	$N_0P_0K_{0\ OM0}$	0.77	0.178	0.35
19.	$N_2P_2K_{1\ OM0}$	0.91	0.195	1.19
20.	$N_2P_1K_{1\ OM0}$	0.91	0.174	0.79
21.	$N_3P_2K_{2\ OM1}$	0.7	0.191	1.31
22.	$N_1P_2K_{2\ OM1}$	0.91	0.178	1.18
23.	$N_3P_3K_{1\ OM1}$	0.77	0.166	0.93
24.	$N_2P_1K_{2\ OM1}$	0.77	0.166	1.31
	Mean	**0.842**	**0.183**	**1.02**

Contd..

Strip II

Plot No.	Treatment	N %	P%	K%
1.	$N_1P_1K_{1\ OM1}$	0.98	0.187	1.06
2.	$N_0P_0K_{0\ OM1}$	0.63	0.191	0.34
3.	$N_2P_2K_{1\ OM1}$	0.98	0.158	1.27
4.	$N_2P_1K_{1\ OM1}$	1.12	0.178	1.04
5.	$N_3P_3K_{3\ OM0}$	1.12	0.166	1.57
6.	$N_3P_3K_{2\ OM0}$	1.05	0.170	1.32
7.	$N_1P_1K_{2\ OM0}$	1.05	0.187	1.39
8.	$N_0P_0K_{0\ OM0}$	0.84	0.178	0.43
9.	$N_2P_2K_{0\ OM2}$	0.98	0.162	1.01
10.	$N_1P_2K_{2\ OM2}$	0.91	0.195	1.33
11.	$N_3P_2K_{2\ OM2}$	0.77	0.158	1.18
12.	$N_3P_3K_{1\ OM2}$	0.91	0.183	0.91
13.	$N_2P_1K_{2\ OM2}$	0.98	0.170	1.48
14.	$N_0P_0K_{0\ OM2}$	0.49	0.199	0.39
15.	$N_2P_3K_{2\ OM2}$	0.77	0.212	1.08
16.	$N_2P_2K_{2\ OM2}$	0.98	0.203	1.48
17.	$N_0P_2K_{2\ OM0}$	1.12	0.220	1.06
18.	$N_3P_2K_{3\ OM0}$	1.19	0.199	1.48
19.	$N_3P_1K_{1\ OM0}$	1.12	0.191	0.96
20.	$N_2P_3K_{3\ OM0}$	0.77	0.216	1.38
21.	$N_1P_2K_{1\ OM1}$	1.12	0.199	1.27
22.	$N_2P_0K_{2\ OM1}$	1.12	0.183	1.12
23.	$N_2P_2K_{3\ OM1}$	0.91	0.162	1.46
24.	$N_3P_2K_{1\ OM1}$	1.12	0.195	1.12
	Mean	**0.95**	**0.185**	**1.13**

Contd….

Strip III

Plot No.	Treatment	N%	P%	K%
1.	$N_0P_0K_{0\ OM1}$	0.56	0.191	0.38
2.	$N_3P_3K_{2\ OM1}$	1.05	0.178	1.41
3.	$N_0P_2K_{2\ OM1}$	1.05	0.220	1.11
4.	$N_1P_1K_{2\ OM1}$	1.05	0.191	1.49
5.	$N_2P_2K_{0\ OM0}$	0.91	0.203	1.07
6.	$N_0P_0K_{0\ OM0}$	0.91	0.145	0.46
7.	$N_1P_2K_{2\ OM0}$	0.84	0.203	1.43
8.	$N_3P_2K_{2\ OM0}$	0.84	0.166	1.26
9.	$N_3P_2K_{1\ OM2}$	0.98	0.195	1.12
10.	$N_2P_2K_{3\ OM2}$	1.12	0.166	1.53
11.	$N_2P_0K_{2\ OM2}$	0.84	0.183	1.36
12.	$N_1P_1K_{1\ OM2}$	1.05	0.195	1.13
13.	$N_1P_2K_{1\ OM2}$	0.91	0.203	1.16
14.	$N_2P_2K_{1\ OM2}$	0.98	0.203	1.3
15.	$N_0P_0K_{0\ OM2}$	0.7	0.208	0.42
16.	$N_2P_1K_{1\ OM2}$	0.98	0.183	1.17
17.	$N_3P_3K_{1\ OM0}$	0.91	0.178	1.05
18.	$N_2P_3K_{2\ OM0}$	0.84	0.174	1.2
19.	$N_2P_2K_{2\ OM0}$	0.98	0.153	1.46
20.	$N_2P_1K_{2\ OM0}$	1.05	0.216	1.49
21.	$N_3P_3K_{3\ OM1}$	0.91	0.212	1.62
22.	$N_3P_1K_{1\ OM1}$	0.98	0.195	1.07
23.	$N_3P_2K_{3\ OM1}$	0.98	0.208	1.56
24.	$N_2P_3K_{3\ OM1}$	0.7	0.178	1.56
	Mean	**0.92**	**0.189**	**1.20**

APPENDIX-V

Yield and nutrient uptake in experimental plots
Strip I

Plot No.	Treatment	Grain yield(q ha^{-1})	Straw yield(q ha^{-1})	N-uptake (kg ha^{-1})	P-uptake (kg ha^{-1})	K-uptake (kg ha^{-1})
1.	$N_2P_3K_2$ $_{OM1}$	27.77	122.22	70.27	17.76	103.89
2.	$N_2P_2K_2$ $_{OM1}$	42.22	66.66	57.67	12.41	89.54
3.	$N_0P_0K_0$ $_{OM1}$	11.11	27.77	13.65	4.10	12.24
4.	$N_2P_2K_0$ $_{OM1}$	7.77	64.44	37.95	8.25	37.87
5.	$N_2P_2K_3$ $_{OM0}$	26.11	102.77	60.37	12.75	95.93
6.	$N_1P_2K_1$ $_{OM0}$	32.22	84.44	74.22	14.81	94.97
7.	$N_2P_0K_2$ $_{OM0}$	19.44	152.77	106.58	19.53	102.86
8.	$N_3P_2K_1$ $_{OM0}$	61.66	182.77	119.92	23.30	144.58
9.	$N_3P_3K_2$ $_{OM2}$	78.88	226.66	188.45	34.80	206.65
10.	$N_1P_1K_2$ $_{OM2}$	32.22	167.77	86.57	18.68	140.76
11.	$N_3P_2K_3$ $_{OM2}$	72.22	272.22	175.54	35.77	258.24
12.	$N_0P_2K_2$ $_{OM2}$	27.77	144.44	77.34	15.46	89.87
13.	$N_2P_3K_3$ $_{OM2}$	63.88	213.88	119.23	26.64	206.73
14.	$N_0P_0K_0$ $_{OM2}$	26.11	145	41.55	16.70	33.08
15.	$N_3P_1K_1$ $_{OM2}$	87.22	238.33	140.79	29.37	172.70
16.	$N_3P_3K_3$ $_{OM2}$	105	195	164.59	32.48	253.90
17.	$N_1P_1K_1$ $_{OM0}$	43.33	138.88	77.31	15.86	98.21
18.	$N_0P_0K_0$ $_{OM0}$	15.55	73.33	37.58	8.64	26.20
19.	$N_2P_2K_1$ $_{OM0}$	43.33	145.55	79.58	16.42	108.37
20.	$N_2P_1K_1$ $_{OM0}$	39.44	127.22	82.20	16.25	80.23
21.	$N_3P_2K_2$ $_{OM1}$	67.77	114.44	79.47	20.85	152.05
22.	$N_1P_2K_2$ $_{OM1}$	17.22	86.11	45.03	9.04	58.07
23.	$N_3P_3K_1$ $_{OM1}$	85	28.33	84.41	16.92	97.95
24.	$N_2P_1K_2$ $_{OM1}$	71.11	98.88	82.06	17.56	130.87
	Mean	**46.01**	**134.16**	**87.59**	**18.51**	**116.49**

Contd….

Strip II

Plot No.	Treatment	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	N- uptake (kg ha^{-1})	P-uptake (kg ha^{-1})	K- uptake (kg ha^{-1})
1.	$N_1P_1K_{1\ OM1}$	35.55	126.66	87.08	16.62	95.23
2.	$N_0P_0K_{0\ OM1}$	16.66	83.33	31.36	9.07	23.98
3.	$N_2P_2K_{1\ OM1}$	32.77	98.33	66.05	10.83	83.47
4.	$N_2P_1K_{1\ OM1}$	30	110	86.69	14.19	85.03
5.	$N_3P_3K_{3\ OM0}$	87.22	123.88	128.52	21.84	193.27
6.	$N_3P_3K_{2\ OM0}$	58.88	162.22	120.06	20.35	149.15
7.	$N_1P_1K_{2\ OM0}$	65.55	106.66	100.56	18.43	141.01
8.	$N_0P_0K_{0\ OM0}$	14.44	150	67.29	14.18	41.95
9.	$N_2P_2K_{0\ OM2}$	70	178.88	126.49	22.04	148.56
10.	$N_1P_2K_{2\ OM2}$	59.44	190.55	126.22	27.16	192.86
11.	$N_3P_2K_{2\ OM2}$	81.11	252.22	144.78	30.21	206.30
12.	$N_3P_3K_{1\ OM2}$	88.88	315.55	211.51	41.03	232.67
13.	$N_2P_1K_{2\ OM2}$	57.22	241.66	141.00	26.05	227.39
14.	$N_0P_0K_{0\ OM2}$	22.77	173.88	57.75	20.60	55.03
15.	$N_2P_3K_{2\ OM2}$	71.66	217.22	123.92	30.48	174.17
16.	$N_2P_2K_{2\ OM2}$	70	185.55	126.95	26.21	191.86
17.	$N_0P_2K_{2\ OM0}$	36.11	110.55	74.53	15.21	75.65
18.	$N_3P_2K_{3\ OM0}$	85	145	152.26	25.71	190.14
19.	$N_3P_1K_{1\ OM0}$	65.55	184.44	147.95	24.93	143.02
20.	$N_2P_3K_{3\ OM0}$	58.33	172.77	105.91	26.30	167.96
21.	$N_1P_2K_{1\ OM1}$	53.33	120	102.90	18.75	125.43
22.	$N_2P_0K_{2\ OM1}$	51.66	142.77	112.64	18.04	117.61
23.	$N_2P_2K_{3\ OM1}$	66.11	167.22	105.63	20.21	163.49
24.	$N_3P_2K_{1\ OM1}$	79.44	220.55	165.85	28.81	172.40
	Mean	**56.57**	**165.83**	**113.08**	**21.96**	**141.56**

Contd….

Strip III

Plot No.	Treatment	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	N-uptake (Kg ha^{-1})	P-uptake (kg ha^{-1})	K- uptake (kg ha^{-1})
1.	$N_0P_0K_{0\ OM1}$	21.66	133.88	46.52	14.55	38.74
2.	$N_3P_3K_{2\ OM1}$	78.88	232.22	171.57	29.53	232.20
3.	$N_0P_2K_{2\ OM1}$	35	137.22	93.59	19.05	102.79
4.	$N_1P_1K_{2\ OM1}$	56.66	183.33	136.24	25.15	193.07
5.	$N_2P_2K_{0\ OM0}$	70.55	190.55	124.69	28.60	160.83
6.	$N_0P_0K_{0\ OM0}$	29.44	142.77	50.72	8.60	38.65
7.	$N_1P_2K_{2\ OM0}$	60	171.11	99.93	25.06	174.76
8.	$N_3P_2K_{2\ OM0}$	93.33	251.11	161.15	32.63	238.94
9.	$N_3P_2K_{1\ OM2}$	91.11	222.22	156.69	31.37	195.77
10.	$N_2P_2K_{3\ OM2}$	80	242.22	167.84	26.46	216.83
11.	$N_2P_0K_{2\ OM2}$	75.55	268.88	156.89	32.75	254.36
12.	$N_1P_1K_{1\ OM2}$	68.88	262.22	181.27	34.43	216.70
13.	$N_1P_2K_{1\ OM2}$	59.44	240.55	144.91	33.23	201.58
14.	$N_2P_2K_{1\ OM2}$	80.55	269.44	176.00	35.46	240.90
15.	$N_0P_0K_{0\ OM2}$	41.11	237.77	97.78	28.11	84.04
16.	$N_2P_1K_{1\ OM2}$	88.88	266.66	171.38	33.03	232.29
17.	$N_3P_3K_{1\ OM0}$	91.11	253.33	191.05	36.77	234.89
18.	$N_2P_3K_{2\ OM0}$	72.77	210.55	138.38	27.54	193.02
19.	$N_2P_2K_{2\ OM0}$	57.22	176.11	110.80	19.54	160.47
20.	$N_2P_1K_{2\ OM0}$	86.66	174.44	169.33	33.57	233.59
21.	$N_3P_3K_{3\ OM1}$	73.33	215.55	145.58	33.68	246.09
22.	$N_3P_1K_{1\ OM1}$	80	206.66	145.28	29.59	170.34
23.	$N_3P_2K_{3\ OM1}$	86.11	256.11	171.07	36.05	262.01
24.	$N_2P_3K_{3\ OM1}$	25.78	277.55	113.85	29.47	247.05
	Mean	**66.83**	**217.60**	**138.43**	**28.50**	**190.41**

APPENDIX VI

Weather data from 2017-2018

SMW	Max. temperature	Min. temperature	R.H. (0712 hrs)	R.H. (1412 hrs)	Rainfall(mm)	Sunshine (hr/day)
44	28.4	14.7	89.9	52.6	0	4.4
45	28.7	12.8	93.9	51.6	0	4.8
46	27.9	11.3	86	40.1	0	6.9
47	26.1	8.6	92.6	43.1	0	7.3
48	24.7	7.8	92	47.9	0	7.1
49	23.3	10.9	93.1	60.4	0	3.7
50	23.1	11.4	93.9	65.9	2.8	5
51	21.3	8.3	95.3	63.9	0	5.6
52	22.5	7.2	96	65.6	0	6.2
1	15.2	6	94.9	81.4	0	2.5
2	12.9	5.3	95.1	79	0	1.2
3	20.2	4.2	93.3	65.1	0	5.5
4	18.6	6.4	93.6	70	6.8	3.6
5	20.6	6.9	94.4	60.1	0	5.8
6	23.2	5.6	95.3	50.4	0	6.4
7	23	9.2	92.7	60.7	4	6.1
8	26.9	11.5	89.4	50.9	0	7.7
9	28.7	11.5	90.9	44.3	0	7.5
10	29.5	10.7	91.9	39	0	8.8
11	31.1	11.8	81.3	43.6	0	8.5
12	31.9	12.7	82.9	40	0	9
13	33.6	14.5	78.3	46.7	0	8.2
14	33.4	18.7	78.4	52.3	29.2	8
15	31.3	16.2	80.6	48.6	13	6.4
16	37.2	17.2	73	19	0	9.4
17	36.2	19.5	65	36	0	9.2
18	35.1	21.9	69	40	2.8	9

VITA

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Advisor	:	**Dr. Ajaya Srivastava**			

ABSTRACT

A field experiment was conducted during the year 2017-18 in an Aquic Hapludoll at D_7 block of Norman E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar under AICRP on soil test crop response (STCR) correlation to develop fertilizer adjustment equation for computing nutrient doses for target yield of hybrid maize on the basis of initial soil fertility. Response of hybrid maize to selected combination of three levels of FYM (0, 5 and 10 t ha^{-1}), four levels of nitrogen (0, 60, 120 and 180 kg ha^{-1}), four levels of phosphorus (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) and four levels of potassium (0, 20, 40 and 60 kg K_2O ha^{-1}) of hybrid maize at different fertility levels was studied.

Chemical analysis was performed to estimate organic carbon, available nitrogen, phosphorus and potassium status in the soil. Nutrient requirement to produce one quintal of hybrid maize grain was found to be 2.17 kg, 0.46 kg, and 2.74 kg of N, P and K, respectively. Per cent contribution of N, P and K was 33.14, 26.80 and 22.71 from soil and 45.21, 14.44 and 39.40 from FYM, 58.18, 62.68 and 420.4 from chemical fertilizer and 62.36, 63.52 and 427.61 from combined use of chemical fertilizer with FYM. Fertilizer adjustment equations were developed with and without FYM with the help of basic data.

Coefficient of determination (R^2) was found highly significant (0.7312**) between grain yield, soil test values, added fertilizers and interaction between soil and fertilizer.

Suitability of soil test methods was also evaluated by R^2 value of multiple regression equation and concluded that Olsen's and Normal neutral NH_4OAC methods are suitable for the determination of phosphorus and potassium, respectively, for Hybrid maize crop grown on Mollisol of Uttarakhand.

Findings could be used as guide for efficient fertilizer management for hybrid maize grown in Mollisol of Uttarakhand, which provides not only balanced nutrition to crop but also may fetch good profitability.

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Advisor

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प्रमुख विषय	**:** मृदा विज्ञान	**विभाग**	**:** मृदा विज्ञान

शोध का शीर्षक **:** ''मक्के की उपज एवं भलीभांति वृद्धि हेतु मृदा परीक्षण एवं फसल अनुक्रिया आधारित सामन्वित पौध पोषक तत्वों की आपूर्ति का अनुकूलन।''

सलाहकार **:** **डॉ0** अजय श्रीवास्तव

सारांश

अखिल भारतीय समन्वित अनुसन्धान परियोजना के अर्न्तगत प्रारम्भिक मृदा उर्वरता एवं पोषक तत्वों की मात्रा के आधार पर मक्के की लक्षित उपज हेतु पोषक तत्वों की मात्रा के आंकलन के लिए उर्वरक समायोजन समीकरण के विकास हेतु वर्ष 2017–18 के दौरान गो0ब0 पन्त कृषि एवं प्रौ0 विश्वविद्यालय,पन्तनगर के नार्मन ई0 बोरलाग फसल अनुसंधान केन्द्र के डी$_7$ खण्ड में एक क्षेत्रीय प्रयोग सम्पन्न किया गया।

मक्के में फसल अनुकिया का अध्ययन नाइट्रोजन के चार (0, 60, 120 एवं 180 किग्रा हे0^{-1}), फास्फोरस के चार (0, 30, 60 एवं 90 किग्रा हे0^{-1}), पोटेशियम के चार (0, 20, 40 एवं 60 किग्रा हे0^{-1}) तथा गोबर की खाद के तीन (0, 5, एवं 10 टन हे0^{-1}), स्तरों से चयनित संयोजनों के साथ किया गया।

प्रायोगिक क्षेत्र की मृदा में जैविक कार्बन, क्षारीय पोटेशियम परमैंनेट– नाइट्रोजन, ओल्सन–फास्फोरस एवं सामान्य उदासीन अमोनियम एसिटेट–पोटेशियम की मात्रा का आंकलन करने के लिए रासायनिक परिक्षण किया गया। मक्के के प्रति कुन्तल उत्पादन के लिये पोषक तत्व नाइट्रोजन, फास्फोरस एवं पोटेशियम की मात्रा क्रमशः 2.17 किग्रा, 0.46 किग्रा एवं 2.74 किग्रा पायी गयी। मृदा द्वारा नाइट्रोजन, फास्फोरस एवं पोटेशियम के उपयोग की क्षमता क्रमशः 33.14, 26.80 एवं 22.71; गोबर की खाद से प्राप्त पोषक तत्वो के उपयोग की क्षमता क्रमशः 45.21, 14.44 और 39.40 प्रतिशत, रासायनिक उर्वरक से क्रमशः 58.18, 62.68 और 420.40 प्रतिशत तथा गोबर की खाद के साथ रसायनिक उर्वरकों के प्रयोग से क्रमशः 62.36, 63.52 और 427.61 प्रतिशत पायी गयी।

उपरोक्त मौलिक आंकड़ों की सहायता से उर्वरकों के तथा गोबर की खाद के संयुक्त प्रयोग पर आधारित उर्वरक समायोजन समीकरणों को विकसित किया गया। मक्के की बीज उपज, मृदा परीक्षण मानों, प्रयोग में लाये गये उर्वरक और मृदा एंव उर्वरकों की अनुक्रिया के मध्य निर्धारित गुणांक (R^2) सार्थक (0.7312 **) पाया गया।

बहुलक प्रतिगमन गुणांक के (R^2) मान के द्वारा मृदा परीक्षण विधियों की उपयुक्तता का भी मूल्यांकन किया गया और यह निष्कर्ष प्राप्त हुआ कि उत्तराखण्ड के मॉलीसाल में मक्के की फसल के लिए ओलसन फास्फोरस तथा सामान्य उदासीन अमोनियम एसीटेट विधियां क्रमशः उपलब्ध फास्फोरस व पोटाश के निर्धारण के लिए उपयुक्त है।

उत्तराखण्ड की मॉलीसाल में उगाये गये मक्के में प्रभावी उर्वरक प्रबन्धन हेतु प्रस्तुत निष्कर्षों को मार्गदर्शक की तरह प्रयोग में लाया जा सकता है जो न केवल फसल को सन्तुलित पोषण प्रदान कर सकता है बल्कि इससे किसान अच्छा लाभ भी प्राप्त कर सकते है।

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सलाहकार

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लेखिका