SOIL TEST CROP RESPONSE STUDIES UNDER INTEGRATED PLANT NUTRITION SYSTEM FOR RAINFED BT COTTON IN VERTISOL

THESIS

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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the thesis entitled **"SOIL TEST CROP RESPONSE STUDIES UNDER INTEGRATED PLANT NUTRITION SYSTEM FOR RAINFED BT COTTON IN VERTISOL"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of material used and all the assistance received during the course of investigation have been duly acknowledged.

Place : Akola

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CERTIFICATE

This is to certify that the thesis entitled " Soil Test Crop Response Studies Under Integrated Plant Nutrition System for Rainfed Bt Cotton in Vertisol" submitted in partial fulfillment of the requirement for the degree of " DOCTOR OF PHILOSOPHY" in Agriculture of the Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafied research work carried out by Ramkrushna Mahadeo Ghodpage, under my guidance and supervision. The subject of the thesis has been approved by the student's Advisory Committee.

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CONTENTS

(A) LIST OF TABLES

(B) LIST OF FIGURES

(D) LIST OF ABBREVIATIONS

Symbol		Meaning
%	-	per cent
@	-	at the rate of
^0C	-	degree Celsius
$CaCO_3$	-	Calcium carbonate
CD	-	Critical difference
CEC	-	Cation exchange capacity
CF	-	Contribution from fertilizer(%)
CFYM	-	Contribution from FYM (%)
Cm	-	Centimeter
cv.	-	Cultivars
$dS\ m^{-1}$	-	Deci Siemens per meter
EC	-	Electrical conductivity
et al.	-	*et alia* (and others)
etc.	-	*Etcetera*
$F\ P_20_5$	-	Fertilizer phoshorus
Fig.	-	Figure
FK_20	-	Fertilizer potassium
FYM	-	Farm yard manure
g	-	Gram
ha^{-1}	-	Per hectare
i.e.	-	*id est* (that is)
ICAR	-	Indian Council of Agricultural Research
IPNS	-	Integrated Plant Nutrient System

Kg	-	Kilogram
M	-	Meter
Mg m^{-3}	-	Mega gram per cubic meter
mm	-	Millimeter
Mw	-	Meterological week
NNSS	-	Nutrient Supply system through nature
NR	-	Nutrient requirement (Kg ha^{-1})
NS	-	Non significant
NSCF	-	Nutrient Supply through Chemical Fertilizers
NSOS	-	Nutrient Supply through Organic Source
q	-	Quintal
r	-	Coefficient of correlation
R^2	-	Coefficient of determinant
RDF	-	Recommended dose of fertilizer
Rs.	-	Rupees (Indian currency)
SSP	-	Single super phosphate
STCR	-	Soil Test Crop Response
STV	-	Soil Test Value
t^{-1}	-	Tonnes per haectare
viz.	-	*videlicet* (namely)

(E) GLOSSARY

Absorption : The process by which a substance is taken into and included within another substance, i.e. intake of water by soil, or intake of gases, water, nutrients, or other substances by plants.

Available nutrient : It is diefined as the portion of any essential nutrient or compound in the soil which can be absorbed most readily and easily assimilated by the growing plants.

Buffering capacity of a soil : It is as the power of a soil to resist an abrupt change in soil pH either by the addition of an acid or an alkali forming material of the soil.Buffering capacity varies from soil to soil because of their divergent characteristics like nature and amount of clay, organic matter content, CEC, carbonate, bicarbonate content etc.

Bulk density (soil) : It is defined as the mass (weight) per unit volume of a dry soil (volume of solid and pore space) and it is expressed in M gm^{-3}.

Carbon-Nitrogen(C:N) ratio : It is defined as the ratio of the weight of organic carbon to the weight of total nitrogen in soil or organic material. The ratio of C : N in normal cultivated soil usually varies 10 or 12 : 1.

Cation exchange capacity (CEC) : It is defined as the sum total of exchangeable cations that can be adsorbed by a soil and is expressed in C $mol(p^{+})\ kg^{-1}$. It is one of the important chemical properties of soil and is usually closely related to soil fertility.

Clay : It is a finer fraction of soil separate comprising particles < 0.002 mm in equivalent diameter. The presence of such particles in a soil in different proportion relative to sand and silt particles determines soil textural classes.

Compost : Organic residues or a mixture of organic residues and soil that have been piled and allowed to undergo biological decomposition.

Decomposition : it is a process of breakdown of oranic material (plants, animal and other organic wastes) into simpler compounds or elements by the chemical and biological (by micro-organisms) processes.

Conductivity (electrical) : The reciprocal of the electrical resistivity. The resistivity is the resistance in ohms of a conductor, metallic or electrolytic, which is 1 cm long and has a cross-sectional area of 1 cm^2.

Diffusion coefficient : It is one of the most important factors that controls the movement of ions from the soil to the root.

Farm yard manure : It constitutes the excreta of farm animals with or without an admixture of bedding or litter, fresh or at various stages of further decomposition.

Fertility index (soil) : It is defined as the relative sufficiency expressed as a percentage of the amount of nutrient adequate for optimum yields. It is related with soil test values and crop response.

Fertilizer : Any substance either organic or inorganic of natural or synthetic origin which is applied to a soil to supply certain essential elements for the plant growth and nutrition.

Fertilizer ratio : The fertilizer ratio designtes the relative proportion of three major plant nutrients (N,P and K) , keeping the percentage of N as one in the ratio.

Fertilizer use efficiency : It is defined as the capacity of fertilizer to increase the yield over that of plot without fertilizer application

Fixation (Plant nutrients) : Fixation of plant nutrients in soil may be defined as the process by which readily soluble nutrient elements are converted to less soluble forms by reaction with inorganic or organic components of the soil resulting them to become immobile in the soil.

Integrated nutrient management : It means the supply of nutrients to the plants from various sources of nutrients. Integrated nutrient management is the maintenance of soil fertility and a plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of the benefits from all possible sources of plant nutrients in an integrated manner.

Mechanical Analysis of soils : The analytical procedure by which the soil particles (coarser and finer sand, silt and clay) are separated is called a " mechanical analysis". It is a determination of the particle size distribution.

Mineralization : The conversion of an element from an organic form to an inorganic state as result of microbial decomposition.

Nitrification : It is the process of biological oxidation by which the ammonical form of nitrogen converts to nitrate form of nitrogen through nitrite nitrogen.

Nitrogen fixation : The conversion of elemental dinitrogen (N_2) to organic forms readily usuable in biological process.

Nutrient (functional) : Any mineral element that functions in plant, animal and other organisms, metabolism, whether or not its action is specific.

pH : The pH is defined as the logarithm of the reciprocal of hydrogen ion (H+) activity and it is expressed in g ions l^{-1}.

Shrinkage (soil) : Shrinkage occurs in dry conditions of the soil containing sufficient amount of colloidal particles and causes decrease in volume of the soil with cracks in variable nature.

Soil : The unconsolidated mineral (and organic) material on the surface of the earth in which plants grow. It has formed as result of different soil-froming factors and processes.It differs from the parent material in many physical, chemical, biological and morphological properties.

Soil fertility : It is the quality of soil that enables it to provide essential chemical elements in quantitities and proportions for the growth of specified plants.

Soil health : It is defined as being a state of dynamic equilibrium between flora and fauna and their surrounding soil environment in which all the metabolic activities of the former proceed optimally without hindrence, stress or impedance from the latter.

Soil productivity : It is the capacity of soil for producing a specified plant or sequence of plants under a specified system of management and it is expressed in terms of crop yield.

Soil quality : It is the capacity of a specific kind of soil to function with in ecosystem and land use boundaries, to sustain biological productivity, maintain environmental quality and sustain plant, animal and human health.

Soil structure : Soil structure is defined as the arrangement of soil particles and their aggregates into a certain structural unit.It can be changed.

Soil testing : It may be difined as a tool for rapid soil chemical analysis to assess the available nutrients status and tilth of a soil. Interpretaton of soil test results and making fertilizer recommendations are based on crop response and economic considearation.

Soil texture : Soil texture is defined as the relative percentage of sand, silt and clay particles in a soil mass. It is a basic property of soil and can not be changed or modified.

Sustainable agriculture : It is the successful management of resources to agriculture to satify changing human needs while maintaining or enhancing the environmental and conserving natural resources.

Swelling (soil) : Swelling, a kind of phenomenon occurs when colloidal clay particles are allowed to be placed in contact with moisture due to imbibitions of water. This phenomenon results volume expansion of soil.

Vertisol : One of the ten soil orders (highest category) in the comprehensive soil classification system. It has little horizontion because of extreme argilli-pedoturbation. These are cracking –clay, self mulching mineral soils which turn or invert. Most of the black soils of peninsular India have been placed in this order. Soils of this order are sticky and plastic.

(F) **THESIS ABSTRACT**

a) Title of the thesis	:	SOIL TEST CROP RESPONSE STUDIES UNDER INTEGRATED PLANT NUTRITION SYSTEM FOR RAINFED BT COTTON IN VERTISOL
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ABSTRACT

Field experiment on "soil test crop response studies under integrated plant nutrition system for rainfed Bt cotton in vertisol" was conducted during 2010-11 and 2011-2012 at Research Farm of Department of Soil science &

Agricultural Chemistry,Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola by adopting fertility gradient approach. The three fertility gradients (L_0, L_1 and L_2) were created by using graded doses of N,P and K fertilizers. Soil samples were collected from each fertility gradient and analysed for available NPK.

FYM blocks were prepared across the fertility strips using three levels of FYM (0, 5 and 10 t ha^{-1}) and test crop Bt cotton was grown in these FYM blocks using different combinations of NPK fertilizers (21 treated and 3 control). Plant samples and soil samples from each plot were collected for analysis for available NPK . Seed cotton yield were recorded and the uptake of NPK by plants was calculated. The data on initial soil test values for NPK, yield of seed cotton , uptake of NPK by Bt cotton and fertilizer nutrients applied were used to calculate the basic parameters viz., nutrient requirement (NR), contribution from soil (CS%), contribution from fertilizer (CF%) and per cent contribution from FYM.

An increasing trend of available NPK from low to high fertility gradient was recorded indicating creation of different fertility gradients in the field.The seed cotton yield response was more in medium fertility status of soil, response declined in higher soil fertility strips as compared to low fertility strip gradient.Uptake of nutrients have been increased with the use of FYM and NPK fertilizers together indicated that the efficiency of nutrients contributed from fertilizers was enhanced due to use of FYM and P solubilization from organic source.

Fertilizer prescription equations for present yield target, based on soil testing for rainfed Bt cotton were mathematically computed. The nutrient requirement for production of one quintal seed cotton yield of Bt cotton was 3.11 kg N, 0.92 kg P and 2.60 kg K . The per cent contribution from soil for rainfed Bt cotton was 17.51 N, 60.30 P and 4.77 K. The contribution from fertilizer was 32.68, 14.70 and 66.76 per cent in respect of N, P and K , respectively. While the per cent contribution from fertilizer in presence of FYM was 37.20, 15.50 and 78.9 in respect of N, P and K, respectively. Whereas, per cent contribution of N, P and K from FYM was 4.7, 1.4 and 1.5, respectively.

Making the use of the basic data the fertilizer prescription equations for chemical fertilizers alone and conjointly with FYM were worked out

A) Sole use of chemical fertilizers (Without FYM)

$FN = 9.53\,T - 0.38\,SN$

$FP_2O_5 = 6.26\,T - 2.66\,SP$

$FK_2O = 3.89\,T - 0.07\,SK$

B) Conjoint use of chemical fertilizers and FYM

$FN = 9.67\,T - 0.51\,SN - 0.73\,FYM$

$FP_2O_5 = 6.83\,T - 3.89\,SP -- 0.30\,FYM$

$FK_2O = 3.29\,T - 0.06\,SK - 0.11\,FYM$

Using the equations, ready reckoners were prepared to use fertilizers for rainfed Bt cotton crop for fertilizer use in obtaining targeted crop yields.The nutrient required for rainfed Bt cotton as per fertilizer prescription equation for yield target of 20 q ha^{-1} under STCR- IPNS system was 87:57:47 NPK kg ha^{-1} with the soil test values of 200 kg N, 20 kg P and 300 kg K ha^{-1}. The net saving of 26.85 kg N, 14.70 kg P_2O_5 and 9.55 kg K_2O ha^{-1} was recorded.

The nutrient requirement based on fertilizer prescription equation seems to be more appropriate in respect of reduction in chemical fertilizers and more realistic as compared to recommended dose of fertilizers since it takes in to account the soil and plant nutrients, thus implying its suitability for site specific nutrient management.

CHAPTER – I
INTRODUCTION

1.1 Background Information

Cotton is one of the most important fibre and cash crop widely grown on black cotton soils in Vidarbha. At present genetically modified cotton is widely accepted by Indian farmers. Out of 110.0 lakh ha area, 88 per cent area(96.14 lakh ha) is occupied by Bt cotton hybrids (AICCIP, 2011). Even though the maximum area is under Bt cotton hybids, but the average productivity of India is low (553 kg lint ha^{-1}) as compared to world average 725 kg lint ha^{-1}. India ranks first in the world in respect of area and third in total production of cotton. Cotton is an important fibre crop of global significance, which is cultivated in tropical and sub-tropical regions of more than eighty countries the world over. Maharashtra, Madhya Prasesh, Andra Prasesh, Karnataka, Tamilnadu, Gujrat, Rajasthan, Punjab and Haryana are the major cotton growing states in India.

Maharashtra ranks first in acrage with 35.30 lakh ha.and second in production yielding 67.00 lakh bales next to Gujarat with average productivity of 325 kg lint ha^{-1}. Maharashtra is one of the leading cotton growing states in India under the cotton cultivation which is one third of the country's area of the cotton with the production of 325 kg lint ha^{-1}, which is low as compared to national average 553 kg ha^{-1}. Low productivity is mainly due to maximum area (85 to 90 %) under rainfed condition.Vidarbha accounting 13.14 lakh ha. area with a production of 24.00 lakh bales and productivity of 310 kg lint ha^{-1}.The production of cotton in Maharashtra, which is nearly sixty per cent of the national productivity 553 kg lint ha^{-1} (Anonymous 2010). India accounts for the over 26 per cent of total global production of cotton and accounts for 28.18% of global cotton area.

In India, Bt cotton was cultivated on 0.2 m ha during 2002, which has been increased to 96.14 lakh ha. in the year 2011. India experienced the highest professional growth for any biotech crop globally in 2005 with Bt cotton cultivation elevated 160 per cent. Three Bt cotton hybrids were released in 2002-03, which has increased upto 624 hybrids in 2010. Twenty five companies involved in Bt cotton research (Gawade, 2010)

Maintenance and improvement of soil nutrient levels is having paramount importance for targeted yield through soil test based fertilizer recommendation. Fertilizer is one of the most efficient means of increasing agricultural productivity and profitability. Soils tend to decline in productivity when it is continuously cropped without adopting restorative practices. Application of fertilizers without considering the soil fertility status and nutrient requirement of crops causes adverse effects on soil as well as crops, both in terms of nutrient deficiency and toxicity either by overuse or inadequate utilization. The integration of manures and chemical fertilizers has become a major component in management towards achieving targeted yields of crops.

Soil testing is an efficient tool for determination of soil fertility status and to assess the nutrient requirement of the crop. It is the practical application of soil science getting higher crop production. The targeted yield concept based on soil test and crop response correlation has already been created an improvement in the fertilizer recommendation approaches in which it is assumed that there is a linear relationship between yield and the nutrient uptake by the crop.

Nutrient availability in the soil after the harvest of a crop is much influenced by the initial soil nutrient status, the amount of fertilizer nutrients added and the nature of the crop raise. In the recent years, the concept of integrated nutrient supply involving combined use of organic and chemical fertilizers is being developed. The use of adequate dose of organic manures coupled with chemical fertilizers will ensure optimum growth conditions under intensive cropping system using high yielding varieties. Besides N, P and K, organic manures are the potential source of micronutrients and their judicious application significantly enhances the micronutrients (Mann *et al.* 1977). The combined use of organic and inorganic fertilizers improves the physical condition of soil more effectively than continuous addition of chemical fertilizers (NPK) alone.(Alok Kumar *et al.*,2007).

Poor inherent fertility status of the soils is one of the major reasons for the low productivity in irrigated as well as rainfed agro-eco regions. Greater economy in fertilizer use can be made if fertilizers applied under IPNS on the basis of soil test. Such studies are possible only through inductive cum targeted yield approach (Ramamoorthy *et al.* 1967) which provides scientific basis for balanced fertilization not only among the fertilizer nutrient but also with the available soil nutrients.

Bt cotton, a transgenic plant, produces an insect controlling protein Cry 1 A (c), the gene for which has been derived from the naturally occurring bacterium, *Bacillus thuringiensis* usbsp. Kurstaki (B.t.k.). The cotton hybrids containing Bt gene produces its own toxin for bollworm attack thus significantly reducing chemical insecticide use and providing a major benefit to cotton growers and the environment.

Bt cotton, which confers resistance to Lepidopteron pests of cotton, was first adopted in India as hybrid in 2002 after stringent assessment for bio-safety and profitability. In India, after extensive testing of Bt cotton hybrids (with Cry1 Ac gene) in All India Coordinated Cotton Improvement Project (AICCIP) and farmers field, Government of India has approved commercial cultivation of Bt cotton hybrid with effect from 2002 crop season. In the first year of its (Bt cotton hybrid) release it occupied 38,038 ha. in 2002-03. Notably, India's Bt cotton area in 2006 (3.8 million hectares) exceeded for the first time, that of China's (3.5 million hectares), the third largest cotton producer in the world. Of the 6.3 million hectares of hybrid cotton in India in 2006, which represents 70% of all the cotton area in India, 60% or 3.8 million hectares was Bt cotton - a remarkably high proportion in a fairly short period of five years. The development of Bt cotton in India from the transgenic cotton of Monsanto, USA, underwent a stringent regulatory process before it finally reached farmer fields. Mahyco had obtained Coker 312-Bt (Cry1Ac)-cotton seed from Monsanto USA, in 1996. Feed-safety studies with Bt cotton seed meal were carried out with goats, buffalos, cows, rabbits, birds and fish. The results revealed that the animals fed with Bt-cotton seed meal were comparable to the control animals in various tests and showed no ill-effects. Thus it was concluded that Bt-cotton has potential to improve the lives of cotton farmers through the provision of favourable environmental and economic consequences.(Khadi, 2008).

Yet fertilizer consumption in India is grossly imbalanced since beginning. It is titled more towards N followed by P. Further the decontrol of the phosphatic and potassic fertilizers resulted in more than doubling the prices of phosphatic and potassic fertilizers. Thus, the fertilizer consumption ratio is highly unbalanced (N: P_20_5: K_20, 6 : 2.4 : 1) during 2007-08 as against favourable ratio of 4:2:1 implying thereby that farmers started adding more nitrogen and proportionately less phosphatic and potassic fertilizers. Even till today, the situation is grim as far as fertilizer application by farmers is concerned. In many areas the imbalanced fertilization is the root cause for poor crop yields and soil fertility status, immediate attention to correct the imbalances in nutrient consumptions to prevent further deterioration in soil quality and to breqk the yield barriers. (Muralidharudu *et al.*,2010).

At present requirement of nutrients in crop production are 35 Mt and only 25.15 Mt of fertilizer nutrients are being used, leaving a shortage of 10 Mt. Therefore, combined use of chemical fertilizers and organics becomes essential to meet the nutrient requirement and reduce the negative balance. Also sustaining of the soil productivity and soil health becomes easier with the inclusion of organic sources along with inorganic fertilizers. (Subba Rao *et al.*, 2009). The consumption of fertilizers nutrients (N+ P_20_5+ K_20) in India during the year 1950-51 was 69,800 tonnes only, which increased to an all-time of 25.15 Mt during 2009.. Presently , India ranks third after china and USA as far as the total consumption of fertilizers in the World is concerned (FAI, 2009). Further, India is likely to need about 40-45 Mt of fertilizer nutrients by 2025. On an average fertilizer consumption (kg ha^{-1}) for rainfed cotton in India during 2005-06 was 75.8:18.3:3.6=97.7 Kg NPK ha^{-1} accounting share in fertilizer consumption was 3.3 per cent.

For judicious use of organic manures and chemical fertilizers soil fertility evaluation is the most important attribute, which also enhances sustained agricultural production. Soil testing assesses the available nutrient status of the soil and serves as a source of information from laboratory to the field for reliable fertilizer predictions based on the needs of the crops. It also includes interpretations, evaluation and fertilizer recommendations based on the results of chemical analysis (Sekhon and Tandon, 1985).

To facilitate the desired increase in productivity, the plant needs adequate quantities of essential nutrients in readily available forms. These come mainly from three sources i) nutrient reserve in soil, ii) organic sources such as FYM, crop residues, human waste, biofertilizers, green manures and iii) chemical fertilizers. Imbalanced fertilization with more N, less P and K are common causes of low yields. This has influenced in low nutrient use efficiency and poor quality of crops. (Kanwar and Sekhon, 1998).

Agricultural development is most crucial in the developmental process of any country. It is of prime importance to step up for increased agricultural production by adopting advanced practices like use of improved seeds, judicious use of chemical fertilizers and organic manures, pest and disease control, improved soil tillage methods, etc. The situation becomes more complex in country like India, where with growing population and competing demands, the available land for cultivation is getting shrunk. Therefore, in the absence of any possibility of increasing the availability of cultivable land in the country, the efforts have necessarily to focus on increasing the per hectare yield potential of available land and increasing the intensity of cropping. Crop production under intensified agriculture over the years has resulted in large scale removal of nutrients from the soil, resulting in negative balance and depletion of soil fertility; hence for proper management of soil fertility and productivity, the combined use of organic manures and fertilizers in inevitable.

1.2 Importance of study

The general dose of fertilizer recommendation is based on estimated optimum fertilizer dose derived from multilocation fertilizer trials. However, the adoption of general fertilizer dose results in under usage of fertilizers in low fertility soils and wastage of fertilizers in the case of high fertility soils. This is again arbitrary type of fertilizer recommendation. Under the circumstances, soil test based fertilizer use and crop response have gained a wide scope and importance. Ramamoorthy *et al.* (1967) and Kanwar (1971) established a theoretical but experimental basis for making specific fertilizer recommendations based on soil test crop response. Ramamoorthy and Velayutham (1971) found this approach to be useful tool for fertilizer recommendations. Kadam and Sonar (2006) developed fertilizer prescription equations for onion in vertisols of Maharashtra.

The approach of general fertilizer recommendations related to soil test ratings was in common use though it has its own shortcoming. Because of the changing trend in agriculture, yield target concept and fertilizer recommendations for maximum profit per hectare became more promising. Yield target concept has the added advantage in which targets can be fixed by taking into consideration the resources available. Targeted yield approach has been an unique one in the sense that this method not only indicates soil test based fertilizer dose, but also the levels of yield, the farmers can hope to achieve, if good agronomic practices is followed in raising the crop. From the point of view of soil plant system, this approach is also unique one in the sense that it provides the scientific basis for balanced fertilization not only between the soil and fertilizer nutrients, but also between the soil available nutrients themselves and strike a balance between fertilizing the crop and fertilizing the soil, leading to realization of desired yields and maintenance of soil fertility (Velayutham, 1977).

Targeted yield concept is primarily based on balanced prescription of fertilizer nutrients.Once the actual requirement of of nutrients for given level of yield production known, the needed fertilizer dose can be calculated after considering the per cent efficiencies of soil available and fertilizer nutrients.The recommendation based on this approach are more quantitative, precise and meaningful because they involve both soil and plant analysis with advantage of this approach are , it ensure the achievement of desired yield target with +/- 10% deviation under optimum management conditions, efficient use of fertilizers according to soil fertility and crop need insures high profit and response to applied fertilizers.

The maximum area in Maharashtra state (85 to 90 per cent) is covered by Bt cotton hybrid. It is grown with different fertilizer level and timing of application. Bt cotton hybrid required more appropriate fertilizer for better yield under rainfed condition. Knowledge of an adequate fertilizer not only saves the investment of costly input during the cultivation but also enhances the production through efficient utilization of input. Besides this, monopodial, sympodial, lint yield, number of functional leaf, dry matter per plant also influenced by type of cotton hybrids under different levels of fertilizer.

In Vidarbha farmers are using fertilizer doses with splits application for obtaining higher seed cotton yield under rainfed condition. A significant work has been done by many workers on fertilizer application for higher production of crop. However, work on balanced use of fertilizer, based on soil test crop response approach particularly on rainfed Bt cotton crop in Maharashtra is not taken. It is the need of the hour to conduct soil test crop response correlation studies and derive fertilizer prescription equations for Bt cotton crop by balanced use of fertilizers.

With the above consideration in view, the present investigation on soil test crop response correlation studies on Bt cotton as a test crop was undertaken based on fertility gradient approach of Ramamoorthy *et al.* (1970)

1. 3 Objectives of study

1. To study the response of rainfed Bt cotton to N,P and K fertilization under different fertility gradients
2. To study the nutrient content and uptake by rainfed Bt cotton under different fertility gradients.
3. To develop the fertilizer prescription equations for rainfed Bt cotton.

1. 4 Hypothesis

The STCR approach allows balanced fertilizer use under resource constraints and helps in maintaining soil fertility. When fertilizer availability and resources of the farmers are limited, planning for low yield target(but higher than the yield levels normally obtained by farmers) ensures efficient and economic use of available fertilizers.

In the proposed study the attempt has been made to ascertain the balanced nutrient management of Bt cotton for higher seed cotton yield, generate the soil test based balanced fertilizer recommendation for yield target, maintainance of soil fertility and better field use efficiency under rainfed condition of Vidarbha. For targeted yield and maintainance of soil health, the information on suitable fertilizer dose with its time of application and soil type to Bt cotton hybrid is lacking. Information is very helpful for exploting it's full potentiality of Bt cotton to boost up the yield level and to reduce the cost of cultivation under rainfed condition.

1. 5 Scope and limitations

Through soil test crop response approach, yield target can be fixed by farmers by taking into consideration with different type of resources available in the field. The approach is paramount impotant for making specific fertilizer recommendations based on soil test crop response.

In Vidarbha out of four cultivated species, major area is covered under Gossypium hirsutum particularly Bt cotton hybrid. Many Bt cotton hybrids released for cultivation in this zone but all are not performed well on farmers field. Recently some of hybrids having better yield potential than the existing release or at pre-released stage. However, among the various agronomic practices and balanced nutrient management in Bt cotton hybrid is important to achieve maximum yield. Among the various methods of fertilizer recommendations, the one based on yield targeting is unique as it not only indicates soil test based fertilizer dose but also the level of yield that can be obtained if appropriate practices are followed in raising the crop. Targeted yield approach also provides scientific basis for balanced fertilization not only between the nutrients from the external sources but also with soil available nutrients.

Balanced nutrient management is important factor, which is closely related to crop growth, soil type, development and maturity for obtaining high and sustained productivity in rainfed areas. Judicious use of fertilizers is one of the deciding factors to enhance the final yield performance of Bt cottton genotype. Physical, chemical and biological status of soil can be maintained with balanced and judicious use of organic and inorganic fertilizers.

The probable reasons for low productivity of cotton in Vidarbha region are attributed to its rainfed cultivation, erratic behviour of rainfall and its occurence distribution and frequency, less adaptability of recommended cotton production technologies for different soil type, growing of cotton on marginal and sub-marginal land approach, proper soil and crop management practices and very limited use of required fertilizer are also impotant factors. Moisture status and application of nitrogenous fertilizer are also important factors for rainfed Bt cotton.

Varietal differences on the basic data for targeted yields and how such data can be derived for newer varieties, organic manures and integrated nutrient management on field experiment.

CHAPTER - II
REVIEW OF LITERATURE

A comprehensive review of literature is essential in any research endeavor. It makes the researcher up-to-date with the theoretical knowledge and findings of research in the field of investigation. The main functions of the review of literature are to determine what work, both theoretical and empirical has already been done previously, provide a basis for research frame work, suggest operational definitions of major concepts and provide a basis for interpretation of findings. Present chapter tries to put the chain of thinking of the researcher about the topic of research of various findings related to the topic of research.

Fertilizers play an important role in crop production but their balanced use is imperative to sustain long term crop productivity. Balanced fertilization of crops ensures increased crop production, maintenance of soil fertility, increased nutrient availability and conservation of our precious soil resource. Imbalanced fertilization of crop results in low fertilizer use efficiency, low profit to the farmers, deterioration in soil quality and pollution of soil. Judicious use of inorganic and organic fertilizers in agriculture therefore, is the key to achieve sustained agriculture production with environmental safety.

Literature on fertilizer use with emphasis on soil test crop response correlation, nutrient requirement of Bt cotton, response of fertilizers to nutrient levels, crop yield and uptake of nutrients by Bt cotton under different fertility gradients and to evaluate the basis for making specific fertilizer recommendation for Bt cotton.

The relevant literature has been presented in this chapter under the following heads.

2.1 Fertility gradient approach

2.2 Yield targeting approach

2.3 Soil test crop response correlation based fertilizer use

2.4 Effect of con-joint use of organic manures and chemical fertilizers on yield and yield attributing characters of Bt cotton

2.5 Relationship between nutrient availability, fertilizer application and crop production in Bt cotton

2.6 Effect of con-joint use of organic manures and chemical fertilizers on soil nutrient status

2.7 Nutrient content and uptake by Bt cotton

2.8 Basis for making specific fertilizer recommendation based on nutrient requirement, efficiencies of soil and fertilizer nutrient and soil test values

2.1 Fertility gradient approach

The fertility grading approach (Ramamoorthy and Velayutham, 1971) is aimed at eliminating the influence of three or four factors viz. crop, climate and management by choosing one field over which elaborate treatments are superimposed to obtain crop responses for correlation with soil test values which are artificially created by differential fertilizer treatments before conducting the main experiment with the test crop.

2.2 Yield targeting approach

State general fertilizer recommendations for high potential hybrids had limitation to show more yield responses than the soil test recommendation (Singh et al.,1989). The approach of fertilizer recommendation was proposed by Ramamoorthy et al. (1967), called the fertilizer application for targeted yield, taking into account the relationship between the yield and total uptake of nutrients, efficiency of soil available nutrients and fertilizer nutrients for contributing to the total uptake. As discussed by Ramamoorthy and pathak (1969), this approach provides the real balance in fertilizer use taking into account the crop needs and the soil available nutrients. Among the various methods of formulating fertilizer recommendations, the one based on yield targeting is unique. This method not only indicates soil test based fertilizer dose but also the level of yield. From the point of view of soil plant system, this approach is also unique, which provides the scientific basis for balanced fertilization not only that with soil available nutrients. For a given soil type crop-agroclimatic conditions, the essential basis data required for formulating fertilizer recommendation for targeted yields are NR (Nutrient requirement), CS (Contribution from soil) and CF (Contribution from fertilizer).

The linear relationship between yield and uptake implies that for obtaining a given yield a definite quantity of nutrients must be taken up by the plants. Tandon (1976), Dhillon et al. (1978) and Doharey et al. (1977) indicated the superiority of this approach over generalized fertilizer recommendation from field trials tested for suitable yield targets appropriate to the crops. The fertilizer demonstration trials in the union territory of Delhi showed that fertilizing for targeted yields of wheat increased the net return by 23 per cent and value cost ratio by 18 per cent above generalized recommendations in 32 demonstrations (Tandon, 1976).

Soil testing is the practical application of soil to crop production. Soil testing is both general and specific in the sense to give site specific fertilizer recommendation based on soil analysis of a farm holding and fertility problems and constraints in an area. Scientific fertilizer use based on soil test takes into account the soil fertility status as well as crop needs. In this regard, targeted yield approach (Ramamoorthy et al.,1967) has received considerable attention. Yield targeting is primarily meant for obtaining specific yield through rational fertilizer use. The fertilizer dose based on this takes into account nutrient requirement of the crop, efficiency of nutrient present in the soil and those added through fertilizers.

Ramamoorthy at al. (1967) advocated targeted yield approach for fertilizer recommendation based on soil testing. This approach calls for the fertilizer application for targeted yield, taking into account the relationship between the yield and total uptake of nutrients and the efficiency of soil available and applied fertilizer nutrients for contributing to the total uptake of nutrients.

Ramamoorthy and Pathak (1969) reported that this approach provides the real balance in fertilizer use taking into account the crop needs and the soil available nutrients. Many researchers indicated the superiority of this approach over generalized fertilizer recommendation for suitable yield targets appropriate to the crop (Tandon, 1976).

Randhawa and Velayutham (1982) also reported that targeted yield concept derived a basis for fertilizer recommendation or desired yield targets suited to the constraints in fertilizer availability and credit facilities to the farmers.

Sonar et al.(1989) reported that the present fertilizer recommendations and soil test based fertilizer recommendations are of general nature and they are not site specific and no consideration is given to the financial condition of farmers and has emphasized the use of targeted yield approach for economical and judicious use of fertilizers. This approach also eliminated the limitations of present fertilizer recommendation practices. Under follow-up trial yield targeted (35 and 45 q ha^{-1}) for wheat were easily achieved by the application of fertilizer prescription equation (Tamboli and Sonar, 1998).

Subba Rao and Srivastava (1999) reported that the doses of fertilizer nitrogen required for achieving desired yield target of cotton under two management system viz., fertilizer alone and integrated plant nutrient supply(IPNS) were calculated by adopting targeted yield approach. The per cent efficiencies of soil, fertilizer and FYM to contribute N to cotton are 18.4, 37.0 and 30.6, respectively.

Rao and Srivastava (2000) obtained a three year data for maize-wheat cropping system and examined the extent of fertility build up as a result of continuous fertilization on based targeted yield approach, firstly soil phosphorus and potassium levels improved over the time and showed less phosphorus and potassium requirements to obtain the targets.

Sharma (2007) reported various approaches viz. recommendation based on soil fertility rating, on critical limit, nutrient index, targeted yield and general fertilizer recommendation.

2.3 Soil Test Crop Response Correlation based fertilizer use

The consumption of fertilizer nutrients in the country since the induction of high yielding varieties of crops in 1965-1966 has increased nearly seven times. However, the fertilizer use efficiency as revealed from current estimates of response yardstick realized by the farmers is low. Soil testing has played a great role in promoting judicious and efficient use of fertilizer.

Singh (1969) concluded that the fertilizer applications must be based on soil test to obtain more yield responses.

Ramamoorthy and Velayutham (1971) stated that soil testing could be effectively used for improving fertilizer use efficiency under varying resource conditions and as per the purpose.

Ramamoorthy and Velayutham (1972) brought out the differential nutrient requirements of hybrids/varieties of crop and emphasized the need of providing nutrients as per plant needs to exploit their yield potential.

Bhalerao et al. (1989) reported that to increase the whole efficiency of the fertilizers, they need to be judiciously combined with other complementary inputs, irrigation, insecticides and technical knowledge at a right time and as reasonable prices.

Muralidharudu et al. (2010) stated that the general blanket fertilizer recommendations are static and can't commensurate with variability and changes in soil nutrient status, crop demand and crop management. Therefore, an alternative approach could be that fertilizer is applied based on recommendations emanating from Soil Test Crop Response Correlation (STCR) data. Among the various methods, the one based on yield targeting is unique in the sense that this method not only indicates soil-test based fertilizer dose but also gives the level of yield the farmer can hope to achieve if good agronomic practices are followed in raising the crop.

2.3.1 Nutrient requirement of crop

The nutrient requirement of crop varies according to the respective soil test values and with applied fertilizers, it decreases with increasing test values it decreases with the low available nutrient status of soil.

2.3.2 Contribution from soil

Most plants remove considerable amount of nutrients every season from soil and it becomes necessary to postulate amount of available nutrients in the soil. Bray (1958) revealed that, the roots effectively obtain relatively immobile nutrients like phosphorus from roots surface sorption zone. The surface of these zones represents only small parts of the relatively immobile nutrients present. Nitrogen deficiency is wide spread in Indian soils. The low level of organic matter and hence deficiency of nitrogen in many soils has been attributed primarily to warm climate(Jenney and Raychaudhari,1960) in soils with higher pH values. Sharma and Mishra (1991) studied adsorption of K on soils differing clay mineralogy and found that adsorption rate was the highest in smectite and lower in kaolinitic group of soils.

Patil and Sonar (1992) reported fixation of 55-80 per cent of added K in swell shrink soils of Maharashtra. The percentage of K fixation can be minimized with addition of high levels of potash to maintain the pool of available K in these soils.

2.3.3 Contribution from fertilizer

Motiramani et al. (1964) reported that the clay content in medium black soil has inverse relation with availability of phosphorus which however could be increased through fertilizer application. Swaminathan (1973) reported that the existing farm practices resulted in net deficiency of nitrogen supplying power especially in soils with low organic matter and influence of the fertilizer recommendations need to be explored.

Moshi et al. (1975) reported that the phosphate availability was found to be associated with exchangeable calcium and sesquioxide content.

Mandal et al. (1979) reported that addition of phosphatic fertilizers helped to improve the soil phosphorus status and they noticed a decline in soil available phosphorus in plots receiving no phosphatic fertilizers. Subba Rao (1979) observed that the cultivation without fertilizer use indicated appreciable decline in nitrate (31%) and NH_4-N (45%) but addition of 150 per cent NPK fertilizers and FYM maintained the nitrate level in the soil.

The NPK fertilization and high levels of soil test values and improvement in uptake due to FYM application resulted in more nutrient uptake and crop production (Hagin and Tucker, 1982).

El-swaify et al. (1985) found that soil dominant in montmorillonite clay mineral does not have capacity to adsorb appreciable amount of phosphates.

Venkateshwarlu (1976) proposed the high fixation hypothesis based on the fact that vertisols adsorb appreciable proportion of P because of high clay content and all clays have high adsorption capacity. Goswami and Sahrawat (1982) reported the $CaCO_3$ content but the critical factor was the quality of $CaCO_3$, which would affect P availability, its effect on precipitation and as adsorbed phosphorus.

Trivedi and Verma (1989) observed higher K fixation with increasing soil pH, time and applied K concentration. It was also observed that exchangeable K was higher.

Kanwar and Sekhon (1998) reported that imbalanced fertilization with more nitrogen, less phosphorus and potassium are common causes of low yield, low nutrient use efficiency and poor grain quality.

2.3.4 Effect of organics under Soil Test Crop Response Correlation

For improving the scientific based of fertilizer use, the ICAR has initiated a Co-ordinated Project on Soil Test Crop Response Correlation in 1967. This project has worked out soil test basis for efficient fertilizer and nutrient management. Since then the practical approach referred as yield targeting to fetch economical yields for fixed cost of investment, fertilizer allocations under resource constraints, maintenance of soil fertility and evaluation of various soil test methods for their suitability under field conditions were followed. Now, a new and still better concept is introduced in STCR, i.e. use of organic manure in conjunction with mineral fertilizers. This is use for evaluating the extent to which the fertilizer needs of the crops can be shared by the organics and to quantify the reduction in excessive expenditure on agriculture inputs through inclusion of cheap organics available in the vicinity.

Tandon (1974) reported that addition of organic manure in the soil by acting as a chelating agent and increase the nutrient availability by preventing nutrient loss through leaching and volatilization at the same time it increases the biochemical reaction in soil which helps to enhance microflora and microfauna in soil and maintain the soil health.

Singh et al. (1983) reported that a combination of bulky organic matter like FYM and phosphatic and potassium fertilizers had best effect in increasing the P and K availability to the crops.

Gaur et al. (1984) reported that the manure block specific adsorption sites and forms organic P compounds in the manure, which is subsequently mineralized, when added to the soil. The increase in uptake of P with increase in FYM and NPK treatments may be attributed to P solubilization by Phosphate solubilizing bacteria from the organic FYM source.

Perumal and Francis (1985) observed that use of organics (FYM, compost, coirpith) in conjunction with mineral fertilizers resulted in increases the yield , improved physico-chemical and biological properties of soil. The increase in N with the increased application of FYM and better mineralization of nitrogen increased the uptake of nutrients and improvement in the soil condition.

Bhardwaj et al. (1994) revealed that continuous cropping without fertilization leads to the depletion of organic matter, available N, P, K, Fe, Mn, Zn and Cu whereas continuous fertilization had beneficial effect on organic matter and available NPK in the soil.

The IPNS based STCR studies conducted for potato in Entisol by Bhende (2006) revealed that there is considerable saving in chemical fertilizers when the IPNS based fertilizer prescription equation were used for potato.

Another recent study by Jibhkate (2008) for garlic in Inceptisol revealed the utility of IPNS based Soil Test Crop Response equations for fertilizer prescription of garlic and there was significant saving in fertilizers when organic manure was applied in conjunction which improved crop yield and optimized nutrient use and improved post harvest residual soil fertility.

2.4 Effect of co-joint use of organic manures and chemical fertilizers on yield and yield attributing characters of Bt cotton

Jagvir Singh et al.(2000) conducted field experiment for three years on a Vertislol (Typic Ustochrept) under rainfed conditions to evaluate effect of crop productivity changes of cotton. The increase in seed cotton yield due to addition of FYM by 20.4 per cent over NPK alone, showed a positive response of FYM on the crop can be explained on the basis of its nutrient supplying power and effect on improving the physical and biological condition as well as moisture status of soil.

Bastia (2000) reported increased seed cotton yield with increased NPK fertilizer rates from 80:40:40 kg ha^{-1} (1085 kg ha^{-1}) to

140:70:70 kg ha^{-1} (2064 kg ha^{-1}). However, the application of 120:60:60 NPK kg ha^{-1} produced at par yield with that of higher yielded treatment.

A field experiment was conducted on medium to deep black soil at Departmental farm, college of Agriculture, Parbhani to test the validity of targeted yield equation (Khandare *et al.*, 2002). Targeted yields of cotton were in close agreement with actual yields of cotton. Therefore, they concluded that fertilizer prescription equation may be useful to adopt balanced fertilizer dose based on targeted yield concept in cotton.

Halemani et al.(2004) concluded that the application of recommended dose of fertilizer produced highest seed cotton yield (920 kg ha^{-1}) followed by FYM alone @ 10 t ha $^{-1}$ (840 kg ha^{-1}) and these yield were 51-65% more than the control (557 kg ha^{-1}). They also found that among the organics, FYM was the best source which produced significantly superior yield over crop residues, vermicompost, in situ green maturing as well as their combinations and these treatments on par with each other.

Nehra et al. (2004) indicated that Bt cotton hybrid MECH 162 Bt (1095 kg ha^{-1}), MECH 915 Bt (917 kg ha^{-1}) produced significantly highest seed cotton yield in comparison to their respective non Bt hybrid and local variety. Narrow spacing of 67.5 to 60 cm in the sandy loam soil recorded significantly higher seed cotton yield (814 kg ha^{-1}) over wider spacing 100 x 60 cm (727 kg ha^{-1}) this increase in seed yield might be due to more plant population over wider spacing.

Marimuthu et al. (2004) revealed that application of graded levels of N and P significantly influenced the number of sympodial branches, number of bolls and seed cotton yield. Application of 100 per cent recommended dose of N and P recorded higher seed cotton yield (2216 kg ha^{-1}) over 75 per cent of N and P application (2056 kg ha^{-1}). It was mainly due to better nutrient uptake and efficient assimilation of applied N and P fertilizers.

Sharma and Singh (2005) reported that the significant R^2 values of 0.91** and 0.88** obtained for wheat varieties PBW-154 and HD-2643, respectively revealed that prediction of variation in grain yield up to 91% in PBW-154 and 88% in HD-2643 can be explained by variation in soil test values and fertilizer doses.

Rananavare et al. (2006) revealed that, seed cotton yield ha^{-1} was maximum with fertilizer application 50:25:25 Kg NPK ha^{-1}+ Vermicomost applied @ 2 t ha^{-1} compared to other organics source like FYM, sunhemp. Interaction between organic manures and inorganic fertilizer were found significant in respect of seed cotton yield.

Raut et al. (2006) reported that, combination of organic with chemical fertilizers had positive effect on the production of hirsutum cotton. Among the various treatment combination, the application of FYM @ 10 t ha^{-1} + 100 % RDF recorded highest seed cotton yield and found statistically on par with 50 % RDF + sunhemp in situ. The application of FYM @ 10 t ha^{-1} + 100 % RDF gave 17.71 % higher seed cotton yield over recommended dose of fertilizers.

Anonymous (2007) reported that the continuous adoption (four years) of integrated nutrient management practice (N60, P30, K30, Zn45 + 5t FYM ha^{-1} +PSB + 2 % DAP spray) produced 18.2 q ha^{-1} of seed cotton yield which was significantly higher than apply of RDF + 2 t ha^{-1} goat manure + FYM 2 t ha^{-1} (16.2 q ha^{-1}) or FYM alone @ 15 t ha^{-1}(15.3 q ha^{-1}) or under farmer practices (13.7q ha^{-1}). Deletion of K from the recommended NPK dose significantly reduced the seed cotton yield.

Policepatil (2007) conducted field experiment at Main Agricultural Research Station, UAS, Dharwad, during 2006-07 to study the performance of Bt-cotton hybrids as influenced by site specific nutrient management approach for realizing target yields. Experiment consisted three nutrient levels (F_1 - 145:39:99; F_2 -181:49:124; and F_3 - 217:59:148 N P_2O_5 K_2O kg ha^{-1}) for target yields of 2.0, 2.5 and 3.0 t ha^{-1}. Among Bt-cotton hybrids, MRC-6322 recorded significantly higher dry matter production, number of bolls, nutrient uptake and seed cotton yield (3286 kg ha^{-1}). Seed cotton yield increased with increase in the fertilizer levels targeted from 2.0 to 3.0 t ha^{-1}. Improvement in seed cotton yield was in the order of 63.90, 15.60 and 7.30 per cent over their respective target yield levels. Significantly higher seed cotton yield was recorded with F_3 (3219 kg ha^{-1}) level over F_1 (2738 kg ha^{-1}) level. However, F_2 (2891 kg ha^{-1}) level was on par with F_3 level.

Bhalerao et al. (2008) reported that spacing of 90 x 30 cm recorded significantly higher seed cotton yield of var NCS-138 Bt (23.04 qha^{-1}) than 90 x 45 cm. Similarly 90 x 45 cm also recorded significantly more yield than 90 x 60 cm, the highest fertilizer dose (100:50:50 NPK kg ha^{-1}) recorded significantly higher seed cotton yield than RDF (50:25:25 NPK kg ha^{-1}) but it was at par with 150% more dose than RDF (75:37.5:37.5 NPK kg ha^{-1}).

Brar et al. (2008) studied on response of Bt cotton to nutrient combinations and plant geometry in sandy loam soil. They reported that the application of N150:P30:K30:Zn3 gave significantly higher seed cotton yield (33.9 q ha^{-1}) as compared to N150:P0:K0:Zn0 and N150:P30:K0:Zn0 and this increase in yield was to the tune of 14.9 and 14.1 per cent, respectively, which might be owing to better uptake of different nutrients leading to greater dry matter production and its translocation to the sink.

Ramani et al. (2009) indicated that the higher application of NK i.e. 150% RD of N and 150% RD of K_2O significantly increased seed cotton yield over farmers practice by 30 per cent. The improvement was still better when 150 % NK application was coupled with S especially through K-MAG application @ 40 kg S ha^{-1} with an improvement by 19 and 55 per cent over 150% NK and farmers practice, respectively.

Todmal et al. (2009) result revealed that the treatment involving 100% RDF + secondary and micronutrients based on soil test exhibited significantly highest seed cotton yield (17.38 q ha^{-1}) among the all treatments. Lowest seed cotton yield (7.70 q ha^{-1}) was found in absolute control.

Prakash et al. (2009) conducted field experiment on effect of P and K levels on yield and quality of cotton on medium deep black soil during 2005-07. They reported that the seed cotton yield increased from 19.2 q ha^{-1} in control treatment to 23.4 q ha^{-1} in 100 per cent RDF.

Gadhiya et al. (2009) studied the effect of levels of N,P and K on growth , yield and quality of Bt cotton in medium black soil. They reported that application of 40 kg P_2O_5 + 80 kg K_2O ha^{-1} produced the maximum seed cotton yield (2479 kg ha^{-1}). Further it was revealed that maximum seed cotton yield was noted under the application of N 240 kg ha^{-1} (2463 kg ha^{-1}), which was significantly higher than 200 kg N ha^{-1}(2366 kg ha^{-1}) and 160 kg N ha^{-1} (2332 kg ha^{-1}). N application resulted in significant increase in values of yield attributes of Bt cotton, may be due to nitrogen application impact early and vigorous vegetative growth of crop.

Devraj et al. (2009) studies on effect of organic and inorganic source of nutrients on cotton productivity and their residual effect on succeeding crop. The highest seed cotton yield (2401 kg ha^{-1}) was obtained where the application of RDF+ S. When 50 % N was applied through pressmud and 50 % N through urea, then about 5.52 % higher seed cotton yield was obtained over RDF. The highest nutrient uptake N 139.23 kg ha^{-1} ,P 28.46 kg ha^{-1} and K 202.26 kg ha^{-1}) were observed under RDF treatment.

Raghu Rami Reddy et al. (2010) conducted experiment on fertilizer response studies in Bt cotton hybrid in sandy loam soil. They reported that, nitrogen response observed up to 150 kg ha^{-1} only (2928 kg ha^{-1}) with further increase in N level cotton yields was reduced. The per cent increase in seed cotton yield was 9.2 with 60 kg P_2O_5 ha^{-1} and 12.8 with 60 kg K_2O ha^{-1} as compared to their lower level (30 kg ha^{-1}). With excessive nitrogen application, cotton plants may put forwarding excessive growth thus unbalancing between source to sink and lower cotton yields.

Lalitha Kumari et al. (2010) studied long term effect of different manure and fertilizers on productivity of rainfed cotton. Result obtained in vertisol over a period of fifteen years indicated that significantly highest mean seed cotton yield of 13.85 q ha^{-1} was obtained with 100 per cent recommended dose of NPK + FYM @ 10 t ha^{-1} followed by 13.07 q ha^{-1} in the treatment consisting 150 per cent recommended dose of NPK. This treatment record 34 per cent more seed cotton yield over 50 per cent recommended dose of NPK. Increased in yield might be due to the improved physical and chemical properties of soil due to manuring with organics.

Sunitha et al.(2010) conducted field experiment with response of hybrid Bt cotton in clayey soil with nutrient management under rainfed conditions. Result revealed that the application of 180 kg N along with 60 kg P_20_5 and 60 kg K_20 and 120 kg N : 60 Kg P_20_5 : 60 kg K_20 ha^{-1} recorded 57 and 31per cent more seed cotton yield , respectively over 60:60:60 NPK kg ha^{-1}(19.55 q ha^{-1}).

Hosmath et al.(2011) studied the effect of organic and inorganic nutrient management for Bt cotton under rainfed ecosystem on vertisol. They reported pooled result that integrated supply of nutrients through recommended dose of fertilizers (30:15:15) + FYM (7.5 t ha^{-1}) significantly increased Bt cotton yield (1066.3 kg ha^{-1}) and values for yield attributes under rainfed ecosystems. Addition of FYM increased the seed cotton yield by 24.36 per cent over recommended dose of fertilizer which may be due to balanced use of chemical fertilizers coupled with FYM.

Modhvadia et al. (2011) studied the effect of fertilizer management on yield of hybrid Bt cotton in clayey soil. He reported that seed cotton yield showed a constant increase with increasing levels of N, P and K fertilizers. Highest seed cotton yield of Bt cotton 3953 kg ha^{-1} in 2006-07 and 5046 kg ha^{-1} in 2007-08 was recorded with N240 P50 K120, which was significantly higher over rest of the treatment combinations. This might be observed due to adequate and balanced nutrition of plant which might have a favourable influence on the plant growth and development, which ultimately depicted in higher yield.

Pawar et al. (2011) reported that higher fertilizer levels of 200:100:100 and 175: 87.5: 87.5 kg NPK ha^{-1} recorded significantly increase seed cotton yield of 2817 and 2686 kg ha^{-1}, respectively over remaining lower levels of fertilizer application.

Narayana et al. (2011) conducted field experiment for two years under nutrient management for improvement in productivity and fibre quality of Bt cotton. Result revealed that application of RDF based on soil test values plus two sprays of KNO_3 (2%) each at flowering and boll development stage recorded the highest seed cotton yield (4550 kg ha^{-1}) which was closely followed by 75 % inorganic and 25 % in the form of well decomposed FYM (4490 kg ha^{-1}).

Sree Rekha et al.(2012) conducted field experiment for three seasons with response of hybrid Bt cotton in clayey soil with nutrient management under rainfed conditions. Result revealed that the application of 180 kg N along with 60 kg P_20_5 and 60 kg K_20 recorded 9 per cent more seed cotton yield over 150:60:60 NPK kg ha^{-1}(33.21 q ha^{-1}).

2.5 Relationship between nutrient availability, fertilizer application and crop production in Bt cottton

Singh et al. (2000), in a linear correlation coefficient revealed that Olsen-P had positive correlated with relative yield (0.515*), relative P uptake (r=0.456*) and maximum P uptake (r=0.693 **) and negative with maximum yield (r=0.666).

Konde (2002) indicated that the yield of crops was significantly correlated (r^2 = 0.86 **) with the soil available NPK and added nutrients through fertilizers and FYM.

Sonune et al. (2003) revealed that available N (r= 0.885 **) and P (r = 0.831**) exhibited very high correlation with grain yield followed by available K (r = 0.761**).

A significantly value of coefficient of determination (r^2 = 0.70**) indicated the yield of crop was significantly depends upon the available nutrients in the soil and the fertilizer nutrients added (Raut, 2004).

Sharma and Singh (2005) reported that the significant R^2 values of 0.91** and 0.88** obtained for wheat varieties PBW-154 and HD-2643, respectively revealed that prediction of variation in grain yield up to 91% in PBW-154 and 88% in HD-2643 can be explained by variation in soil test values and fertilizer doses.

Milap-Chand et al.(2006) suggested that the variation in yield of rapeseed could be ascribed to changes in soil available and applied fertilizer nutrients with high order of predictability (r^2 = 0.76*).

Gayathri et al.(2009) suggest that the regression equations with R^2 values showing the response of potato to NPK was 0.93** , 0.82** and 0.89** for N, P and K, respectively.

2.6 Effect of co-joint use of organic manures and chemical fertilizers on soil nutrient status

2.6.1 Soil available nitrogen

Jagvir Singh et al. (2000) conducted field experiment for three years on a Vertislol (Typic Ustochrept) under rainfed conditions to evaluate effect of soil fertility and crop productivity changes due to cotton based cropping system. Result revealed that available N status increased slightly due to FYM application in all the treatments. The application of FYM @ 10 t ha^{-1} recorded marginally increased the soil available N 235 kg ha^{-1} over the application of NPK alone (222 kg ha^{-1}) in continuous growing of cotton for three years.

Singh et al. (2001) indicated the continuous conjunctive use of fertilizer nitrogen with organic manure increased the total hydrolysable nitrogen. Conjunctive use of 90 kg N ha^{-1}+ 5 t FYM ha^{-1} or 6 t ha^{-1} green manures increased the total hydrolysable nitrogen from 1256 to 1350 kg ha^{-1} after three years, 1356 to 1395 kg ha^{-1} after five years and 1395 to 1525 kg ha^{-1} after seven years.

Toor et al. (2001) studied the available N release pattern of FYM and poultry manure in sandy loam non-calcareous soil and reported that there was significant increase in available nitrogen with increasing rates of manure.

Tiwari et al. (2002) reported after twenty eight years of continuous intensive cropping along with organic and inorganic fertilization resulted in increased available nitrogen. Highest value of available nitrogen (290 kg ha^{-1}) was recorded by integrating the use of recommended dose of fertilizer with FYM.

Tolanur et al. (2003) reported that the higher nitrogen availability in surface soil (224 kg ha^{-1} and 237 kg ha^{-1}) with the incorporation of subabul along with fertilizer after harvest of pearlmillet and pigeonpea crops. The increase in available nitrogen with subabul and FYM application might be due to the direct addition of nitrogen through FYM and subabul to the available pool of the soil.

Bonde et al. (2004) revealed that availability of nitrogen status was affected due to efficient organic residue and N status of soil enhanced over control upto 120 days. Among organic residues FYM applied @ 5 t ha^{-1} recorded greater value of availability of nitrogen (349.4 kg ha^{-1}) in soil over control(267.6 kg ha^{-1}).The availability of N increased as a result of incorporation of organic residues in soil, which increased the microbial population and enhances mineralization.

More and Hangarge (2003) reported that available N in soil was decline in NSCF (Nutrient Supply through Chemical Fertilizers). It was nearly constant in NSOS (Nutrient Supply through Organic Sources) and NNSS (Nutrient Supply through Nature means natural farming system adopted including no ploughing, harrowing, inter culture operations was done). The highest available N was recorded (255 kg ha^{-1}) with NNSS and NSOS at the end of experimentation over initial value (210 kg ha^{-1}).

Katkar et al.(2007) reported pooled results of five years and they indicated that the highest available nitrogen (193.2 kg ha^{-1}) was recorded in application of FYM @ 10 t ha^{-1} + 100 per cent RDF after the last picking of cotton.

Nawlakhe et al.(2009) reported that the initial available nitrogen of soil was 264.8 kg ha^{-1} and it increased in available nitrogen to the extent of 34.5 kg ha^{-1} when the cotton crop applied 25 kg N+25 kg P205 ha^{-1} through inorganic fertilizer + 25 kg N through FYM under integrated nutrient management in Vertisol.

Todmal et al.(2009) obtained highest residual available nitrogen (210.53 kg ha^{-1}) was recorded in 50 % recommended dose of fertilizer NPK + 50 % N through FYM + micronutrient as per soil test. Whereas, P (12.94 kg ha^{-1}) and K (544.0 kg ha^{-1}) in treatment FYM, Vermicompost and Neemseed cake + in situ incorporation of dhaincha in cotton was recorded highest. The residual available nutrient after harvest of soil indicate that the highest organic carbon, available N, P and K was found 0.59 per cent, 202, 11.9 and 538 kg ha^{-1}, respectively where 1/3 recommended N each through FYM, Vermicompost and Neemseed cake + in situ incorporation of dhaincha in cotton was applied.

Lalitha Kumari et al. (2010) observed that available nitrogen content in the post harvest soils ranged from 184 to 293 kg ha^{-1}. The highest value of 293 kg ha^{-1} was recorded in 150 per cent NPK followed by 289 kg ha^{-1} in 100 per cent recommended dose of NPK + FYM @ 10 t ha^{-1} .There was build up of soil N in all the treated plots over the initial value of 196 kg ha^{-1} in long term effect of different manures and fertilizers application.

2.6.2 Soil available phosphorus

In long term experiment, Tiwari et al., (2002) revealed that the crop use 25 to 30 % of applied P and the rest remains in soil in different form. They also noted that increasing the dose of 50% NPK over control had resulted in 74 % increase in available P. However, when full dose of NPK kg ha^{-1} was applied, the increase ranged from 190 to 200 % while, further increase to 150 % NPK had increased the per cent to 296.

Tiwari et al. (2002) studied the use of recommended dose of fertilizer with FYM resulted in an increase in the available phosphorus content of soil (39.40 kg ha^{-1}). They indicated that integrating fertilizers with manure could enhance the available P of soil.

Tolanur and Badanur (2003) observed that available phosphorus of soil was increased significantly with FYM or subabul in conjunction with 50 per cent RDF over control. The application of FYM increased the available phosphorus, might be because of solubilization of the native phosphorus in the soil through release of various organic acids.

Sonune et al.(2003) noticed maximum available P in treatment receiving 100 % NPK + FYM @ 10 t ha^{-1} which registered 3.72,1.39 and 2.08 folds increase in available P content over control, 100 % NPK and 100% N + FYM , respectively in long term effect of manuring and fertilization on fertility of vertisols.

More and Hangarge (2003) reported that available phosphorus decline slightly with NSCF (Nutrient Supply through Chemical Fertilizers) than INSS(Integrated Nutrient Supply System consisting chemical fertilizers and FYM @ 12.5 t ha^{-1}). It was build up from 12 to 20 kg $ha^{-1}$with INSS than NSCF (Nutrient Supply through Chemical Fertilizers) during the six years of experimentation under cotton-sorghum cropping system.

Bonde et al. (2004) reported that the available phosphorus on soil as affected due to organic residue treatment revealed that the availability of phosphorus was increased upto 90 days only. FYM applied @ 5 t ha^{-1} recorded greater values values (27.21 kg ha^{-1}) of available phosphorus in soil over control (17.84 kg ha^{-1}).

Katkar et al. (2007) reported pooled results of five years and they indicated that the highest available phosphorus (20.7 kg ha^{-1}) was recorded in application of FYM @ 10 t ha^{-1} + 100 per cent RDF which was on par with FYM applied @ 5 t ha^{-1}+ 100 per cent RDF(20.4 kg ha^{-1}) and FYM @ 10 t ha^{-1}+ 50 per cent RDF (20.0 kg ha^{-1}). The application of FYM @ 10 t ha^{-1} alone registered 18.9 kg ha^{-1} available P nutrient in soil. Lowest available phosphorus was recorded in the control treatment (16.1 kg ha^{-1}).

2.6.3 Soil available potassium

Jagvir Singh et al. (2000) reported that soil available potassium were observed (501 kg ha^{-1}) under cotton sole system in a vertisol at the end of three years experimentation. No significant effect was noticed due to addition of FYM on available K status of soil.

Dixit and Gupta (2000) 0bserved that effect of four levels of NPK on soil properties in Inceptisols and noted the available K value of 180, 178, 186, 192 and 195 kg ha^{-1} due to initial, N0 P0 K0, N60 P30 K30, N90 P45 K45 and N120 P60 K60 Kg ha^{-1}, respectively.

Tiwari et al.(2002) noted that the decline in available K was of the same magnitude (60 kg K ha^{-1}) in 150 % NPK and 100% NPK + FYM treatment as compared to initial value (370 kg K ha^{-1}) and relatively lower as compared to other treatments. However, maximum decline was observed in control (225 kg ha^{-1}) and 100 % NPK treatment (225 kg ha^{-1}). Among the inorganic fertilizer, continuous application of N or NP had a depressive effect on the available K content of the soil, which may be due to nutrient imbalance in soil.

More and Hangarge (2003) reported that availability of potassium declined with all the nutrient supply system during six years of the

NSCF. The availability of potassium decreased with NSCF (Nutrient Supply through Chemical Fertilizers) as compared to other nutrient supply systems. The availability of potassium reduced from 350 to 285 kg ha^{-1} with NSCF at the end of experimentation might be due to K fixation and higher uptake of the crop under NSCF.

Sonune et al.(2003) recorded that highest K status (692.1 kg ha^{-1}) in the treatment receiving 100 % NPK + FYM 10 t ha^{-1} and were significantly superior over all other treatments.

Katkar et al.(2007) reported pooled results of five years and they indicated that the highest available potassium (477.7 kg ha^{-1}) was recorded in application of FYM @ 10 t ha^{-1} + 100 per cent RDF which was on par with FYM applied @ 5 t ha^{-1}+ 100 per cent RDF. Lowest available potassium was recorded in the control treatment (453.6 kg ha^{-1}).

Lalitha Kumari et al. (2010) studied on long term effect of different manure and fertilizers on productivity of rainfed cotton. Result obtained in vertisol over a period of fifteen years indicated that significantly highest value of available potassium (732 kg ha^{-1}) was recorded with 100 per cent recommended dose of NPK + gypsum applied @ 500 kg ha^{-1} followed by 717 kg ha^{-1} in the treatment consisting 200 per cent recommended dose of NPK.

2.7 Nutrient content and uptake by Bt cotton

The sources and doses of nutrient applied affected the nutrient content of plant. The literature on the nutrient content and their uptake by Bt cotton is presented in brief.

Rao et al. (1997) reported that, the average nutrient uptake (43.2N: 21.8$P_2 0_5$: 64.7K_2O kg $tonne^{-1}$) removed from the soil by cotton crop to produce one tonne of economic yield under field conditions.

Jagvir Singh et al.(2000) studies conducted for the three years and he indicated that, the total NPK uptake by the cotton removed was 65.3, 70.0 and 142.5 kg N, 16.6, 16.9 and 21.8 kg P and 63.5, 70.0 and 74.0 kg K ha^{-1}, respectively.

Kote et al. (2005) reported that, the nitrogen concentration and uptake by cotton plants at harvest increased significantly by recommended fertilizer dose of 75 % RDF than 50 % RDF. Every higher level of fertilizer application noted significantly increase P and K concentration and uptake over its lower levels. Balanced and optimum dose of NPK increased the concentration and uptake of N,P and K by cotton plants.

Kumawat and jat (2005) found that vermicompost @ 4.5 t ha^{-1} brought significantly highest uptake of NPK over rest of the treatments. Further, the vermicompost @ 1.5 t ha^{-1} was almost equally effective with FYM @ 7.5 and 10 t ha^{-1}. Increasing dose of nitrogen improved significantly the yield attributes, yields, and total uptake of NPK in barley crop.

Chandra Mohan and Chandra Giri (2006) reported that , in general, at all stages of cotton, the recommended dose of NPK (80:40:40 kg ha^{-1}) through inorganic recorded higher uptake of NPK whereas an application of 50 per cent N through sunhemp + 50 per cent through Vermicompost had comparable nutrient uptake.

Das et al. (2006) showed that, N,P and K uptake by plant increased considerably with corresponding increase in nitrogen levels. Largest amount of N, P and K removal was noticed with integrated application of 30 kg N ha^{-1} and FYM @ 12 tonnes ha^{-1} along with Azotobacter which was 31.7, 4.3 and 20.7 kg ha^{-1} higher over no nitrogen application.

Bhavita Gurao et al. (2006) reported that, higher nitrogen uptake was observed in treatment consisting 100 % RDF + 25 % additional N through FYM + spray of 2 % DAP at boll development stage Whereas , lowest N, P and K uptake was noticed in treatment receiving 50 % RDF + 50 % N through FYM.

Dhillon et al. (2006) conducted a field experiment with six fertilizers levels for cotton crop. Results indicated that N and P uptake in plant and seed increased with increasing level of fertilizers. Maximum N and P uptake was recorded under the treatment N80+P30 kg ha^{-1}+ vermicompost 1.25 t ha^{-1} which found significantly at par with recommended application (N80+P30).

Katkar et al.(2007) reported that the highest nitrogen, phosphorus and potassium was recorded with the application of FYM @ 10 t ha^{-1} + 100 % RDF which was at par with FYM @ 10 t ha^{-1} + 50 % RDF + sprayings of 2 % urea and DAP but significantly superior to the rest of the treatments.

More et al. (2003) recorded that, N and P uptake was significantly maximum with fertilizer application of NPK @ 30:75:0 kg ha^{-1} which was at par with 75 % RDF + 5 t FYM ha^{-1} and 75 % RDF + Rhizobium+PSB.

Gadhiya et al. (2009) reported that the highest N (53.58 kg ha^{-1}) and K (50.46 kg ha^{-1}) uptake by Bt cotton stalk were noticed with the application of K 80 kg ha^{-1} which was at par with that of K 40 kg ha^{-1}.The uptake of N and K nutrients were registered higher with the application of 80 kg K ha^{-1} might be due to the higher production of stalk of Bt cotton.

Lalitha Kumari et al. (2010) observed that nitrogen content in cotton leaf varied from 2.68 to 3.23 per cent. It was found that the treatments significantly increased the N content in cotton leaf and highest (3.23 %) was recorded in 100 % RDF + 50 kg $ZnSO_4$ ha^{-1}. The per cent P and K content varied from 0.36 to 0.44 and 1.40 to 1.75 %, respectively.

Deshmukh et al. (2011) recorded the N content and uptake in seed and stalk of Bt cotton increased with increasing fertilizer doses and with increase in FYM levels. The uptake of nitrogen increased from 159.87 kg ha^{-1}

in F_0 block to 173.83 kg ha^{-1} in F_1 and 192.37 kg ha^{-1} in F_2 blocks, which was increased by 6.68 and 18.68 per cent over two F_0 blocks.

Deshmukh et al. (2011) recorded the P content and uptake in seed and stalk of Bt cotton increased with increasing in the levels of P fertilizer doses and with increasing levels of FYM application. The total P uptake in F_0 blocks was 52.00 kg ha^{-1} which was increased to 60.45 kg ha^{-1} in F_1 and 74.39 kg ha^{-1} in F_2 block. This indicated the effect of added P and complementary effect of FYM which two together helped in increasing the uptake of P with increasing FYM application. The mean total uptake of K in Bt cotton in treated plots of two F_0 blocks was 110.38 kg ha^{-1} which was increased to 122.84 kg ha^{-1} in F_1 and 128.66 kg in F_2 blocks. These results indicated an increase in uptake of K with increase in levels of K fertilizers and FYM application.

Bhalerao et al. (2012) reported that highest uptake of nitrogen (77.3 kg ha^{-1}) and phosphorus (35.9 kg ha^{-1}) was recorded with the application of 150 % RDF i.e. 62.5:31.5:31.5 kg NPK ha^{-1}. Increasing in uptake of nutrient was because of increasing trend in biological yield with increasing fertilizer levels.

2.8 Basis for making specific fertilizer recommendation based on nutrient requirement, efficiencies of soil and fertilizer nutrient and soil test values

Ramamoorthy et al. (1967) investigated the fertilizer application for specific yield target of Sonara-64 by obtaining the basic data which include NPK requirement for one quintal of wheat grain was 2.5, 0.8 and 2.1 kg, respectively. While the contribution from soil and fertilizers were 34% N, 41% P_2O_5, 36% K_2O and 37% N, 14% P_2O_5 and 44% K_2O, respectively.

Ramamoorthy and Mahajan (1974) have shown that the yield targets and the required fertilizer dose for such purpose can be calculated from the following equation 1) t = ns/(m-r) 2) Fd = - rms/(m-r). Where t is yield target (q ha^{-1}) n is ratio between per cent contribution from soil and fertilizer nutrient, r is nutrient requirement (kg/100 kg), m is ratio between nutrient requirement and contribution from fertilizer nutrient, s is soil test value (kg ha^{-1}) and Fd is fertilizer dose (kg ha^{-1}).

Dev et al. (1978) reported that the production of one quintal of paddy grain, on an average, the nutrient requirement were 2.11 kg N, 0.75 kg P_2O_5 and 4.41 kg K_2O. The efficiency of soil available nutrients for contribution to production of paddy was 47% from alkaline KMnO4 oxidisable N, 99% from Olsen- P and 200% from ammonium acetate K. Similarly, the efficiency of applied nutrient was 83 % for N, 33 % for P_2O_5 and 167 % for K_2O. On the basis of data , they noted for a target 60 q ha^{-1} of paddy grain yield, the nitrogen requirement was 95 kg N ha^{-1} in a soil with soil test value of 100 kg N ha^{-1} and no fertilizer N was required when the soil tested 300 kg N ha^{-1} or more. Similarly no P fertilizer was required when soil tested 50 kg P ha^{-1} or more.

In a study on fertilizer requirement for yield targeting of sorghum, Sonar et al. (1982) revealed that 3.34, 0.73 and 3.99 kg N, P_2O_5 and K_2O, respectively were required for production of one quintal of sorghum grain (CSH-). while, the contribution from soil and fertilizer of available N, P, K were 16.26, 97.26 and 14.85 and 83.71, 16.92 and 104.44 per cent, respectively.

For yield targeting in *rabi* sorghum (CSH-8), Sonar et al. (1983) found that 2.06 kg N, 0.77 kg P_2O_5 and 2.41 kg K_2O were required to produced one quintal grain yield of *rabi* sorghum. The contribution from applied soil available nutrient was 34 % N, 73 % P and 20 % K. Similarly, the contribution from applied fertilizer was 44 % urea-N, 39 % SSP-P_2O_5 and 73 % murate of potash-K_2O.

Reddy et al. (1991) studied soil test based fertilizer requirement for groundnut in different soil and noted that the nutrient requirement for one quintal of groundnut production in different soil ranged from 3.99 to 6.86 kg N, 1.24 to 2.39 kg P_2O_5 and 1.74 to 4.39 kg K_2O. Highest N requirement was in red soil, P in medium black soil and K in alluvial soil. They further noted that soil N efficiency ranged from 17.0 – 42.8 %, P efficiency 38.0 – 86.7 % and K efficiency from 3.05 – 50.6 %. Fertilizer N efficiency ranged from 45.1 – 149.3 %, P efficiency 20.6– 29.8 % and K efficiency 30.0-65.0 %. Fertilizer N efficiency was more than 100 %, might be due to the contribution from lower soil horizon and priming effect of fertilizer.

In a targeted production of grain yield of sorghum based on nutrient efficiencies and soil test values, Patil et al. (1993) showed that 2.16 kg N, 1.10 kg P_2O_5 and 4.52 kg K_2O required for the production of each quintal of sorghum grain indicating that K requirement of sorghum was highest followed by nitrogen and least in respect of P. In sorghum production, the soil contributed 14.12% N, 96.64% P and 44.28 % K. whereas, 45.88 % N, 42.62 % P and 124.44 % K were contributed from applied fertilizer, indicating that sorghum crop utilized maximum N and K from applied fertilizer and maximum P from soil available form.

Tamboli et al.(1996) studied fertilizer requirement of chickpea based on targeted yield approach and noted that the chickpea required 4.22 kg N, 2.94 kg P_2O_5 and 2.73 kg K_2O for producing one quintal grain yield. The efficiency of soil available N, P_2O_5 and K_2O was 37, 93 and 7 per cent, respectively, while the per cent efficiency of N, P_2O_5 and K_2O from fertilizer was 80.4, 76.1 and 212, respectively.

Verma et al.(1996) studied on verifications for prescription based fertilizer recommendations for oilseed crops in thermic Typic Hapludalf and hyperthermic typic Ustochrept soil and noted that the amount of nutrients required to produce one quintal of toria, raya and soybean, respectively were 4.5, 6.5 and 6.5 kg N, 0.7, 2.5 and 3.9 kg P_2O_5 and 3.7, 3.0 and 1.5 kg K_2O, respectively. The contribution from soil available N was 5.0 and 5.2 per cent to toria and raya, respectively. The per cent contribution of P_2O_5 and K_20 from soil was 16.1 and 10.8 for soybean, while from fertilizers were 56.0 and 37.0, respectively.

Kadam (1999) studied three approaches for calculating fertilizer prescription equations and concluded that as per whole field approach, the requirement of fertilizer for production of one tonne of onion bulbs was 1.013 kg N, 1.099 kg P_2O_5 and 1.941 kg K_2O. The contribution from soil available nutrient for onion bulb production was 11.25, 55.35 and 7.37 per cent; respectively .While efficiency from fertilizer was 22.21, 21.05 and 60.82 per cent, respectively.

Santhi et al. (1999) conducted the field experiment on Typic Ustorpept to assess the fertilizer requirements under integrated plant nutrition system (IPNS) for rice-rice residual pulse cropping sequence. The quantity of fertilizers that could be adjusted to the levels of the organic manures was evaluated to be 38 kg N, 13 kg P_2O_5 and 33 kg K_2O ha^{-1} with GM (*Sesbania rostrata*), 10 -12 kg P_2O_5 ha^{-1} for fertilizer with PB (*Bacillus megaterium* var. *phosphaticum*), 40 kg N, 26 kg P_2O_5 and 33 kg K_2O ha^{-1} for fertilizer with GM and PB.

Suri and Verma (1999) resulted that the amount of nutrient required for producing one quintal of maize and wheat was 2.3 and 2.3 kg N, 0.8 and 0.6 kg P_2O_5 and 1.6 and 1.7 kg K_2O, respectively. The contribution from soil available N recorded 6.8 and 6.0 % to maize and wheat, respectively. Per cent contribution of P_2O_5 from soil recorded 42.5 for maize and 41.6 for wheat. While, from fertilizer to these crops was 18.5 and 8.5, respectively. Higher efficiency 0f soil P_2O_5 in comparison to added P_2O_5 during maize and wheat growth might be because of hydrolysis of soil Al-P. The contribution of K_2O recorded 6.0 and 12.8 & from soil whereas 71.5 and 68.3 % from fertilizer to maize and wheat, respectively.

In soil test based fertilizer recommendation for maize, Reddy and Ahmad (2000) estimates nutrient requirement values on N, P and K based on yield maximum method were 1.66,1.12 and 1.55 kg q^{-1}, respectively. The per cent nutrient contribution from soil and fertilizer nutrients in an Inceptisols were 10,50 and 17., 40,74 and 105 for N, P and K, respectively under yield maximum method.

Reddy and Ahmad (2000) investigated the field experiment on STCR correlations studies for maize in Inceptisols of jadtiyal in Karimnagar district of Andhra Pradesh during kharif 1995. He reported that the basic data obtained as nutrient requirement (kg q^{-1}) of N, P_2O_5 and K_2O was 1.66, 1.12 and 1.55 respectively for producing one quintal of maize yield in Inceptisols. The per cent contributions from soil and fertilizers were 10, 50 and 17 and 40, 70 and 105 of N, P_2O_5 and K nutrients, respectively under yield maximum method.

Ray et al. (2000) conducted field experiment with different fertility gradient in Gangetic alluvial soil (Typic Ustochrept). He reported that nutrient requirement per quintal of fibre production for jute was observed 2.85, 1.33 and 6.12 kg N, P_2O_5 and K_2O, respectively. Contribution of N, P_2O_5 and K_2O as estimated from soil and fertilizer sources was respectively 22, 86, 44 per cent and 29, 42 and 118 per cent. It is interestingly mentioned that fertilizer contribution of K_2O for jute was observed more than 100 per cent. This higher value of K could be due to the interaction effect of high doses of N,P and primary effect of starter K dose in the treated plots, which might have caused the release of soil potassium from unavailable to available form, resulting in the higher uptake from the native soil sources by the jute crop.

Sharma and Singh (2000) reported that the basic data obtained as nutrient requirement of N, P_2O_5 and K_2O was 2.57, 0.82 and 2.98 kg for one quintal of wheat grain production, respectively. The utilization efficiency of soil available nitrogen, phosphorus and potassium was 25.1, 53.6 and 29.0 per cent while from fertilizer nutrients it was 52.9, 28.1 and 135.6 per cent, respectively.

Bangar (2001) noted that the available N, P and K content in the soil was directly associated with the addition of graded level of fertilizer nutrients in L_0 to L_2 strips. The per cent increase in available nutrients in $L_{1/2}$, L_1 and L_2 strips over L_0 strip was 5.85, 12.87 and 27.49 % for N and 8.87, 0.57 and 19.12 % for P. However, the per cent increase for available K was less. He further noted that the gradient created for available nutrient had direct influence on nutrient uptake in different fertility strips. The nutrient requirement was 2.077, 0.980 and 2.426 for N, P and K (kg q^{-1} sorghum grain), contribution from soil 11.41, 43.09 2.91 % for N, P and K while contribution from fertilizer 21.66, 15.90 and 87.51 % for N, P and K, respectively.

Meena et al. (2001) observed that the nutrient requirement (kg q^{-1}) of N, P and K were 0.26, 0.22 and 0.20, respectively for producing one quintal of onion bulb yield in Alfisols. The contributions % from soil and fertilizer nutrients in an Alfisol was 21.31 and 44.37 for N, 25.38 and 27.71 for P and 5.76 and 48.57 for K, respectively. They also indicated that the fertilizer doses required for attaining a specific yield target of onion yield show decrease with increasing soil test values.

Konde (2002) reported that the nutrient requirement to produce one quintal of wheat was 2.56 kg N, 0.64 kg P_2O_5 and 1.34 kg K_2O. The contribution from soil was 19.42, 66.30 and 6.86 per cent in respect of N, P_2O_5 and K_2O, respectively, contribution from fertilizers with and without FYM as 60.35, 37.18, 62.92 and 58.28, 26.85 and 46.96 per cent in respect of N, P_2O_5 and K_2O, respectively.

Kausadikar et al. (2003) revealed that 7.8 kg N, 0.92 kg P_2O_5 and 4.5 kg K_2O were required to produce one quintal of soybean seed yield. The contribution of N, P_2O_5 and K_2O from soil were 86, 46 and 11 per cent and from fertilizer were 190, 15 and 170 per cent, respectively. They further noted that the low efficiency of soil P_2O_5 and K_2O may be attributed to high fixation and low availability in calcareous heavy textured soil as the experimental soil were alkaline(pH 7.8 and 8.1) in reaction . Similarly the higher efficiency of fertilizer K_2O may be due to fixation of soil K_2O in clayey soils.

At Tamilnadu Agricultural University, Coimbatore, Kalaichelvi and Chinnusamy (2004) studied the influence of STCR based fertilizer nutrients and potassium humate on cotton productivity. They reported that, application of 100 per cent STCR (Soil Test Crop Response) recommended NPK fertilizers recorded more number of sympodial branches, fruiting points, boll setting percentage and boll number over other levels. Higher seed cotton yield was recorded with 100 per cent STCR recommended NPK fertilizer combined with the soil application of potassium humate either 30 kg or 40 kg ha^{-1}.

Raut (2004) stated that for production of one quintal of sorghum grain 2.57 kg N, 0.94 kg P and 4.03 kg K were required. The per cent contribution of soil available nutrients was 13.18, 85.62 and 26.61 per cent N, P and K, respectively. Whereas, the contribution from fertilizer N, P and K was 64.58, 31.75 and 115.67 per cent, respectively.

Sankarnarayanan *et al.* (2004) conducted a field experiment for two years at CICR, Coimbatore with an aim to assess the response of Bt cotton hybrids to N, P and K application (100, 125 and 150 per cent of recommendation level). They reported that, application of 150 per cent of recommendation level of fertilizer registered significantly higher number of bursted bolls per plant, per plant yield and seed cotton (3090 and 1710 kg ha^{-1}) and it was on par with125 per cent of recommendation level of fertilizer for both the years.

Kadam and Sonar (2006) reported that the fertilizer rates based on targeted yield concept upon nutrient requirement, contribution from soil and contribution from fertilizers. Onion crop required 1.314 kg N, 1.172 kg P_2O_5 and 2.04 kg K_2O Mg^{-1} production. Efficiency of soil nutrients was 11.25, 55.35 and 7.37% of N, P_2O_5 K_2O while that of fertilizer N, P_2O_5 K_2O were 21.01, 29.35 and 66.18% respectively. Fertilizer prescription equations were transformed into ready reckoners for requirement of fertilizer NPK for different yield targets of onion on rates increased with increasing yield targets of onion and fertilizer rates decreased with increasing the soil test values. Thus in the targeted yield concept yield potential and soil test values were taken into account while making fertilizer recommendations.

Milap-chand et al.(2004) presented fertility gradient field experimental technique of evolving soil test based fertilizer recommendations for specific yield target of rice. Per cent P contribution from soil decreased with an increase in soil test values and it interacts strogly with other nutrients. The new soil test based fertilizer calibrations in comparison with the existing ones greatly modified the fertilizer recommendations and were commensurate with response behaviour of crops under field conditions.

Milap-chand et al. (2006) conducted soil test response correlations studies with mustard and rapeseed on a Typic Haplustept soil provided correlations of high predictability between grain yield and soil available nutrients and fertilizer nitrogen. Based on yield target, fertilizer adjustment equations for situation and site-specific fertilizer recommenddations for mustard and rapeseed have been evolved. The result showed that the capacity of mustard and rapeseed to exploit soil available pool of N, P and K was similar. Further the data indicated that for the same level of crop production with same level of soil nutrient status, rapeseed required higher amounts of P and K. The efficiency of rapeseed to derive nutrients from applied fertilizer was significantly higher amounts of P and K. The fertilizer doses increased with increase in yield target and decreased increasing soil test values for attaining a yield target. Results clearly showed that the fertilizer requirement varies with the soil test values for the same level of crop production. They also reported that for the production of one tonne rapeseed required 43.7, 9.7 and 37.9 kg N, P and K nutrient, respectively. The per cent soil efficiency was 27.60, 83.80 and 26.80 for N, P and k and fertilizer efficiency found 59.60, 65.20 and 95.25 per cent for N, P and K, respectively.

Mohammad Sajid (2007) conducted field experiment on soil test response correlation studies under integrated nutrient system in vertisol by adopting fertility gradient approach. He reported that the nutrient requirement luction of one tonne of onion bulb was 0.85 kg N, 0.35 kg P and 1.25 k he per cent contribution from soil for onion was 6.34% N, 39.8% P and 8.86% K, respectively, contribution from fertilizer were 15.20% N, 7.54% P and 27.53% K.

Reddy et al. (1991) studied soil test based fertilizer requirement for groundnut in different soil and noted that in presence of FYM for N, P and K were 17.75, 8.08 and 38.42%, respectively. Whereas , per cent contribution of N, P and K from FYM was 5.52, 4.02 and 7.80, respectively.

Srinivasan and Angayarkann (2008) studied STCR fertilizer nitrogen recommendation for a yield target of rice and He noted that nutrient requirement kg ha^{-1}, contribution from soil % and contribution from fertilizer % values for nitrogen were 1.40, 12.53 and 25.42, respectively. The per cent contribution of N from FYM, Azospirillum, FYM+Azospirillum was found 19.50, 21.30 and 22.26.

Bhaskaran et al. (2009) developed STCR based fertilizer equations for rice under soil classified as Typic Haplustaff. In all the STCR treatments, the grain yields achieved were within +/- 10 per cent of targeted yield. The result revealed of the experiment revealed that the application of fertilizers based on STCR-IPNS technology produced the highest grain yield and response ratio. While sustaining the soil organic carbon, available N and P status.

Gayathri et al. (2009) developed soil test based fertilizer prescription equations under integrated plant nutrition system for potato on Ultisoil. The result showed that 0.61 kg N, 0.69 kg P_2O_5 and 0.68 kg K_2O were required for producing one quintal of potato tubers. The per cent contribution of nutrients from soil and fertilizers were found 20.73 and 87.23 for N, 11.96 and 49.83 for P_2O_5 and 19.72 and 94.90 kg K_2O, respectively. Contribution of K_2O from fertilizer towards the total uptake of potato was high, which might be due to the interactive effect of high doses of N, P_2O_5 and priming effect of starter K_2O dose in the treated plots causing the release of soil K from unavailable to available form.

Ganeshamurthy (2009) reported that the blanket recommendation of fertilizers for a crop over large area irrespective of soil type has lead to indiscriminate use of costly inputs. This has also resulted in imbalanced use of fertilizers and environment related problems. He conducted field experiment by following standard Ramamoorthy's approach to develop fertilizer prediction equations for hybrid capsicum on Alfisols. Results obtained in treated plots the yield varied 13.16 to 19.42 t ha^{-1} in L_0, 19.1 to 29.6 t ha^{-1} in $L_{1/2}$, 20.36 to 36.25 t ha^{-1} in L_1 and 21.47 to 37.41 t ha^{-1} in L_2. The nutrient requirement per kg fresh fruit production in hybrid capsicum was 3.109 for N, 0.392 for P_2O_5 and 2.870 for K_2O.

Govardhana and Riazuddin Ahmed (2009) developed a basic data and targeted yield equations for mustard in Alfisols. Using the whole field data, the nutrient requirement of N, P_2O_5 and K_2O were 7.91, 3.71 and 9.21 kg for producing one quintal of mustard seed yield, respectively. The per cent contribution from soil and fertilizer were 2.8 and 33.21 for N, 12.96 and 21.24 for P and 3.34 and 61.59 for K, respectively.

Gulati and Yadav (2009) conducted soil test crop response correlation studies with mustard under integrated plant nutrition system (STCR-IPNS) in Torripsamments of Rajasthan during kharif 2007-08. He found that the nutrient requirement for producing one quintal of mustard was 4.13, 1.31 and 2.53 kg of N, P2O5 and K_2O, respectively. The per cent nutrient utilization efficiencies for mustard from soil and fertilizer nutrients were 20.08 and 32.66 for N, 28.15 and 14.02 for P_2O_5 and 8.65 and 37.69 for K_2O, respectively. Likewise the per cent organic nutrient contribution from FYM was 46.50 for N, 19.65 for P_2O_5 and 30.65 for K_2O, respectively.

Khosa et al. (2009) conducted on farm trials on farmer's fields in rice- wheat cropping system in seven districts of Punjab during 2004 to 2007. In rice, yield target of 70 q ha^{-1} were achieved within +/- 10 per cent variation of the targeted yield of 52 % of the cases without FYM application and 48 % of the cases with FYM application. Result revealed that the yield targets of 45 and 55 q ha^{-1} of wheat were achieved within +/- 10 per cent variation of the targeted yield in 74 and 61 per cent of the trials, respectively .The targets were better achieved in medium to high fertility soils as compared to low fertility soils.

Lalitha et al. (2009) reported that balanced nutrient application is essential to enhance productivity of crop. The yield gaps between the potential and actual yields, in Hassan, Karnataka, appear largely due to non use/low application of potassium. He observed that the farmers obtained only 52.4 q ha^{-1} potato per ha, while the University recommendations yielded 83.1 q ha^{-1}. however, nutrient supplementation based on STCR equations yielded 92.4 q ha^{-1}. The deficiency of potassium was very evident in soil analysis. Similarly, the maize crop yielded 28.9 q ha^{-1} with university recommendations and 36.0 q ha^{-1} with STCR equations against 23.7 q ha^{-1} with farmer's practice.

Pande et al.(2009) investigated experiment during 2008-09 in a Aquic Hapludoll under AICRP on Soil Test Crop Response. With the help of nutrient requirement, soil and fertilizer efficiencies, the fertilizer adjustment equations for cabbage were developed as FN = 1.19 T – 0.92 STV, FP = T – 7.3 STV and FK = 0.96 T – 1.19 STV.

Puri et al. (2009) conducted main field experiment on STCR approach under IPNS on onion under medium black soil. They found that nutrient requirement were 1.9 kg N, 1.54 kg P_2O_5 and 3.78 kg K_2O, respectively for producing one tone of onion. The per cent contribution from soil and fertilizer were found 17, 21 for N, 61 and 77 for P_2O_5 and 18 and 87 for K_2O, respectively. The per cent contribution of N, P_2O_5 and K_2O from FYM were noticed to 11, 70 and 40, respectively. Basic data generated were transformed into fertilizer adjustment equations for N, P_2O_5 and K_2O (kg ha^{-1}). Viz. FN = 9.28 T – 0.80 SN – 0.592 ON, FP_2O_5 = 2.00 T – 0.79 SP – 0.90 OP and FK_2O = 4.34 T – 0.20 SK – 0.450 OK, respectively.

Santhi et al. (2009) studies on soil test based fertilizer prescription for targeted yield of beetroot under integrated plant nutrition system on an Alfisol. Making use of the experimental data on NPK uptake, yield, pre-sowing soil available NPK and fertilizer doses applied, the basic parameters were computed and fertilizer prescription equations developed for beetroot i.FN = 0.64 T – 0.65 SN – 0.96 ON, ii. FP_2O_5 = 0.52 T – 1.58 SP – 0.92 OP and iii.FK_2O = 0.61 T – 0.27 SK – 0.92 OK.

Subba Rao et al. (2009) has quoted a number of approaches are used to make soil test based fertilizer recommendations. viz. Soil test crop response approach, buildup and maintenance of soil fertility, the probability of response approach and soil test based fertilizer recommendation for pre set yield targets. Currently long term demonstrations are being carried out at several STCR centers to obtain the most suitable fertilizer rate to obtain optimum yield and maintain soil fertility.

Yadav and Gulati (2009) conducted soil test crop response correlation studies with pearl millet under integrated plant nutrition system (STCR-IPNS) in Torripsamments of Rajasthan during kharif 2007. He found that the nutrient requirement for producing one quintal of pearl millet was 3.08, 1.49 and 5.18 kg of N, P_2O_5 and K_2O, respectively. The per cent nutrient utilization efficiencies for pearl millet from soil and fertilizer nutrients were found 17.56 and 43.83 for N, 32.41 and 16.09 for P_2O_5 and 15.84 and 66.78 for K_20), respectively. Likewise the per cent organic nutrient contribution from FYM was 27.31 for N, 17.52 for P_2O_5 and 48.25 for K_2O, respectively.

Santhi et al. (2010) conducted a field experiment on Vertic Ustropept soils of Tamilnadu during 2008-09 following Ramamoorthy's Inductive Cum targeted yield model under STCR-IPNS approach. He found that the nutrient requirement for producing one tonne dry root of ashwagandha was 77.6, 31.7 and 113.3 kg of N, P_2O_5 and K_2O. The per cent contribution of nutrients from soil, fertilizer and FYM were 19.03, 31.30 and 23.14 for N; 20.26, 17.30 and 6.38 for P_2O_5; 11.08, 62.53 and 30.39 for K_2O, respectively.

Saranya et al.(2012) conducted a field experiment on Vertic Ustropept following Ramamoorthy's Inductive cum targeted yield model to added fertilizers under IPNS on Ashwagandha. They found that the per cent contribution from soil, fertilizer and FYM were 19.03, 31.30 and 23.14 for N; 20.26, 17.30 and 6.38 for P_20_5; 11.08, 62.53 and 30.39 for K_2O. Result revealed that the contribution by fertilizer K_2O was 3.6 times higher than P_20_5 and twice as that of nitrogen.

CHAPTER - III

MATERIAL AND METHODS

The present investigation entitled "Soil test crop response studies under integrated plant nutrition system for rainfed Bt cotton in Vertisol" was carried out by conducting a field experiment on soil Test Crop Response `correlation based on fertility gradient approach (Ramamoorthy and Velayutham, 1971) at Research Farm of Department of Soil Science and Agricultural Chemistry, Dr. PDKV, Akola during 2010-2011 and 2011-2012. The investigation was undertaken to evaluate the response of rainfed Bt cotton to N, P and K fertilization under different fertility gradients, nutrient content and uptake by rainfed Bt cotton and to develop the fertilizer prescription equations for rainfed Bt cotton.

The details of material used and analytical techniques and methods adopted for this investigation are presented in this chapter.

3.1 Experimental site

The experiment was conducted at Research Farm of Department of Soil Science and Agricultural Chemistry, Dr. PDKV, Akola during 2010-2011 and 2011-2012.

3.1.1 History of experimental field

The experimental field was located at Highway Block of Central Research Station (CRS), Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The research field survey No. SH 75/76 of three hectare was alloted to the Department of Soil Science and Agricultural Chemistry, Dr. PDKV, Akola for research purpose. The research experiement on Bt cotton was conducted in the same field during 2010-11 and 2011-12.

Before conducting the research experiment on Bt cotton in the field survey N0.SH 75/76, Department of Soil Science and Agricultural

Chemistry, Dr. PDKV, Akola , the same field was fallow during 2008-09 and 2009-10, earlier the field survey No. SH 75/76 of three hactare was under cultivation with soybean in kharif season and gram was taken in rabi season for the year 2005-06 , 2006-07 and 2007-08.

3.2 Soil characteristics

The soil of the experimental field was grouped under the order Vertisol, moderately well drained, clayey in texture and developed on weathered basalt, which comprise member of fine, clayey smectitic, hyperthermic family of Typic Haplusterts. The soils were deep black with 100cm depth having swell-shrink property.

The physico-chemical characteristics were determined before the actual start of the experiment. The soil was slightly alkaline in soil reaction pH(1:2.5) 8.23, EC 0.26 dS m^{-1} with low in organic carbon 5.2 g kg^{-1} and calcium carbonate content of 6.82 per cent. Soils of the experimental site were low in available N (163.07 kg ha^{-1}), low in available phosphorus (15.25 kg ha^{-1}) and very high in available potassium (515.2 kg ha^{-1}). The initial status of physico-chemical properties of soil and FYM content are determined in laboratory as per the standard procedure and the results are presented in Table-1.

Table 1 : Initial soil properties of experimental site

Sr. No.	Soil properties (0-20 cm depth)	Values
A) Mechanical analysis		
1	Sand, %	10.02
2	Silt, %	30.77
3	Clay, %	59.21
	Soil order	Vertisol
	Subgroup	Typic Haplusterts
	Textural class	Clay
B) Chemical properties		
4	pH (1:2.5)	8.23
5	EC , dS m^{-1}	0.26
6	Bulk density, Mg m^{-3}	1.43
7	Organic carbon, g kg^{-1}	5.2
8	Calcium carbonate, %	6.82
9	Available N, kg ha^{-1}	163.07
10	Available P, kg ha^{-1}	15.25
11	Available K, kg ha^{-1}	515.2
.C) FYM analysis		
12	Total nitrogen, %	0.57
13	Total phosphorus, %	0.28
14	Total potassium, %	0.60
15	Organic carbon, %	11.59
16	C:N ratio	20.33

3.3 Climate and weather conditions during experimental period

Geographically, Akola district is situated at 20^0 42' N latitude and 77^0 40' E longitude and 309 m above mean sea level altitude. Climatically, the study area of western vidarbha falls in semi arid, sub-tropical zone with an average annual rainfall of 791mm in 41 rainy days and the major share of precipitation is received through South West monsoon during the month of

June to September. The annual rainfall received during the year 2010-11 amounted to 1032 mm in 47 rainy days whereas in 2011-12, the rainfall received was 515.3 mm in 38 rainy days. Winter rains are few and uncertain. The normal mean monthly temperature varies from 40.3 to 45.4 ^{0}C during the hottest month (May), while the mean monthly minimum temperature ranges from 27.2 to 31.2 ^{0}C in the coldest month (December).

In order to have an idea about the climatic conditions prevailed during the period of present experiment the weekly data of weather parameters viz., average maximum and minimum temperatures, rainfall and humidity were recorded and presented in Table 2. It was observed that mean annual maximum and minimum temperature ranges from 28.3 ^{0}C to 36.5 ^{0}C and 20.4 ^{0}C to 25.6 ^{0}C, respectively during the crop growth period. The relative humidity during morning and evening ranged from 36 to 92 per cent and 30 to 72 per cent. The mean pan evaporation ranges from 3.3 to 7.3 mm. The total rainfall received was 1032 mm in 47 rainy days during the year 2010-11 whereas in 2011-12 it was 515.3 mm in 38 rainy days.

3.4 Experimental details and methodology

A field experiment on rainfed Bt cotton to study the nutrient requirement based on targeted yield approach for judicious use of inorganic fertilizers with organic manure was initiated at Research Farm of Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during 2010-2011.

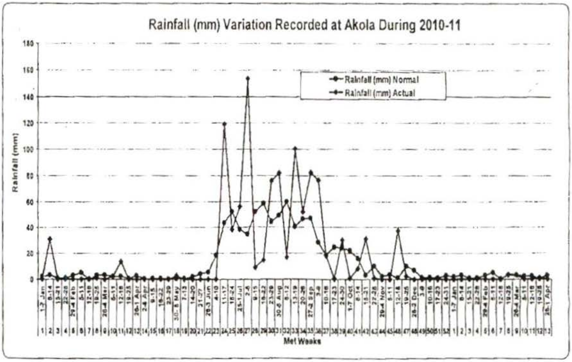
3.4.1 Creation of fertility gradients

A levelled field was selected for experimentation. After collecting composite surface soil sample, the experimental field was divided into three equal strips and three fertility gradients viz., L_0, L_1 and L_2 were created in the field by applying graded doses of N, P and K fertilizers to Maize crop (Table 3) which was taken as an exhaust crop to stabilize the fertility status of experimental field.

Table 2: Monthly Weather data for the year 2010 and 2011 recorded at Meteorological Observatory Department of Agronomy Dr PDKV., Akola																				
Month	T MAX (°C)		T MIN (°C)		BSH (hrs)		Ws (km/hr)		RHI (%)		RHII (%)		Evap (mm)		Rainfall (mm)		CRF (mm)	Rainy Days	
	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A		N	A
2010																			
JANUARY	29.8	28.2	11.4	11.3	8.8	6.7	5.3	1.4	68	79	29	28	4.8	4.1	9.0	30.9	30.9	0.9	2
FEBRUARY	32.5	32.2	13.3	16.1	9.4	5.4	6.2	2.3	57	62	22	25	6.6	5.7	10.2	1.3	32.2	0.8	0
MARCH	37.3	38.6	17.8	20.6	9.6	6.6	7.2	3.6	41	51	19	24	6.0	9.8	9.5	15.9	48.1	0.7	1
APRIL	41.2	42.6	23.2	26.2	10.0	7.5	9.0	6.6	35	39	14	19	13.7	14.9	3.1	2.8	50.9	0.4	1
MAY	42.5	43.5	27.0	29.5	9.9	6.7	14.2	10.3	46	38	18	15	16.8	17.0	16.6	0.0	50.9	1.1	0
JUNE	37.2	37.8	25.6	27.2	7.2	4.9	14.9	9.7	71	67	41	44	10.9	11.4	150.5	173.2	224.1	7.9	5
JULY	32.5	31.4	23.7	24.0	4.5	3.1	11.9	6.2	84	90	61	67	5.5	4.3	212.2	345.3	569.4	12.6	16
AUGUST	30.4	30.1	23.0	23.3	4.1	3.0	11.4	4.2	87	92	68	69	4.4	3.6	215.7	279.2	848.6	9.3	11
SEPTEMBE	32.5	31.6	22.2	23.2	6.6	5.4	7.9	4.0	84	87	57	54	5.0	4.6	111.1	128.1	976.7	7.5	6
OCTOBER	33.7	33.3	18.6	21.4	8.4	5.4	4.8	2.2	76	85	39	43	5.5	5.0	52.3	41.2	1017.9	2.3	4
NOVEMBER	31.6	31.2	14.1	19.8	8.7	5.3	4.7	2.2	70	90	31	48	4.8	4.7	20.0	39.5	1057.4	1.2	1
DECEMBER	28.3	28.3	10.6	12.2	8.8	5.7	4.6	1.5	70	84	30	33	4.3	3.9	8.4	0.0	1057.4	0.9	0
2011																			
JANUARY	29.8	28.6	11.4	9.9	8.8	5.5	5.3	0.9	68	73	29	24	4.8	4.3	9.0	0.0	0.0	0.9	0
FEBRUARY	32.5	32.1	13.3	15.0	9.4	6.2	6.2	1.8	57	62	22	24	6.6	6.3	10.2	3.7	3.7	0.8	1
MARCH	37.3	37.2	17.8	18.9	9.6	7.6	7.2	3.0	41	47	19	16	6.0	9.5	9.5	3.8	7.5	0.7	1

Table 2. Monthly Weather data for the year 2011 and 2012 recorded at Meteorological Observatory Department of Agronomy Dr PDKV., Akola

Month	T MAX (°C)		T MIN (°C)		BSH (hrs)		Ws (km/hr)		RHI (%)		RHII (%)		Evap (mm)		RF (mm)		Rainy Days	
	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A
2011																		
JANUARY, 2011	29.8	28.6	11.6	9.9	8.5	5.5	4.5	0.9	68	73	28	24	4.75	4.3	9.8	0.0	0.8	0.0
FEBRUARY, 2011	32.6	32.1	13.9	15.0	9.0	6.2	5.4	1.8	56	62	22	24	6.62	6.3	7.9	3.7	0.6	1.0
MARCH, 2011	37.2	37.2	18.4	18.9	9.2	7.6	6.4	3.0	43	47	17	16	9.66	9.5	13.1	3.8	1.0	1.0
APRIL, 2011	41.2	39.3	23.6	23.5	9.6	7.5	8.3	4.0	36	48	14	20	13.24	12.2	3.3	28.8	0.4	3.0
MAY, 2011	42.4	42.0	27.4	28.0	9.5	8.0	13.3	11.3	46	51	18	23	16.37	16.8	11.7	15.2	1.2	1.0
JUNE, 2011	37.4	36.5	25.7	25.8	6.7	4.5	14.0	11.3	70	70	41	39	11.12	10.2	142.4	81.2	6.7	6.0
JULY, 2011	32.1	31.7	23.7	24.2	4.2	2.4	11.2	8.2	84	86	61	62	5.60	5.4	200.9	166.2	10.6	12.0
AUGUST, 2011	30.4	30.2	23.0	23.5	3.8	2.6	10.4	5.2	87	90	68	67	4.38	4.0	204.8	126.6	9.8	10.0
SEPTEMBER, 2011	32.2	30.8	22.4	23.0	6.3	4.7	7.2	3.6	85	89	57	61	5.19	4.3	115.7	88.6	6.0	6.0
OCTOBER, 2011	33.5	35.0	18.7	19.2	8.1	6.7	4.0	1.5	77	77	39	29	5.30	5.8	51.1	1.7	2.6	0.0
NOVEMBER, 2011	31.6	32.8	14.3	14.6	8.4	7.6	3.9	1.3	72	66	31	23	4.82	5.6	20.9	0.0	1.0	0.0
DECEMBER, 2011	29.5	30.1	11.3	12.0	8.4	7.4	3.8	1.0	71	70	29	24	4.24	4.7	7.4	0.0	0.6	0.0
2012																		
JANUARY, 2012	29.8	28.6	12	12.9	8.5	6.5	4.5	1.6	68	66	28	27	4.7	4.7	9.8	6.2	6.2	0.8
FEBRUARY. 2012	32.6	32.8	14	14.3	9.0	7.4	5.4	2.1	56	48	22	17	6.6	6.6	7.9	0.0	6.2	0.6
MARCH, 2012	37.2	37.5	18	18.4	9.2	8.1	6.4	3.1	43	35	17	14	9.7	10.5	13.1	0.0	6.2	1.0


Rainfall (mm) Variation Recorded at Akola During 2010-11
Rainfall (mm) Normal
Rainfall (mm) Actual
Rainfall (mm)
Met Weeks

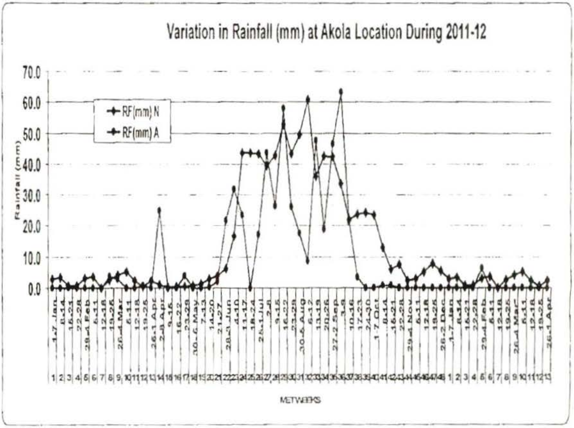

Variation in Rainfall (mm) at Akola Location During 2011-12
RF(mm) N
RF(mm) A
Rainfall (mm)
METWEEKS

Table 3: Fertilizer doses for creation of fertility gradient

Fertility Gradient	N	P_2O_5	K_2O
	------------ kg ha^{-1}	--------------	
L_0	00	00	00
L_1	120	60	60
L_2	240	120	120

3.4.2 Main experiment on Bt cotton as a test crop

After harvest of the maize crop, the field was ploughed and prepared well for planting of Bt cotton as a test crop, without disturbing the three fertility gradient strips.

Three FYM blocks were created across the fertility gradients by applying different levels of FYM as (F_0, F_1 and F_2) i.e. block of no FYM and two blocks of 5 t FYM ha^{-1} and 10 t FYM ha^{-1}. Further blocks were divided into 24 equal plots with 21 NPK treatments and 3 control treatments on randomized basis. Such that, all the 24 treatments were laid along the FYM blocks and also the fertility gradients. Soil samples from each plot at 0-20 depth were collected before sowing of cotton and analyzed for their available NPK status of soil.

Rainfed Bt cotton was taken as a test crop in these FYM blocks and after pickings of cotton, the yield were recorded. Plant samples at square formation, 50% flowering and at harvest stage from each plot were collected and analysed for total N, P and K content and total uptake was computed.

Using the data on yield, nutrient uptake, initial soil nutrient status and fertilizer doses applied, the basic data viz. nutrient requirement, contribution of nutrients from soil, fertilizer and FYM were computed. The basic data generated were used for the development of fertilizer prescription equation for Bt cotton.

3.5 Experimental Details

Location	:	Research Farm of Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.(M.S.)
Soil	:	Vertisol
Season	:	Kharif, 2010
Year of Study	:	2010 and 2011
Crop & variety	:	Bt cotton, NHH-44 (Bt)
Plot size	:	Gross : 5.85 x 5.4 m^2 Net : 4.95 x 3.60 m^2
Spacing	:	90 x 45 cm
Treatments	:	21 treated , 3 Control
Gradients	:	Three strips : L_0, L_1 and L_2
Levels of FYM	:	F_0 = 0·0 t FYM ha^{-1} F_1 = 5 t FYM ha^{-1} F_2 = 10 t FYM ha^{-1}
Experimental Design	:	Fractional Factorial RBD

3.6 Treatments Details:

FYM blocks

F_0 = 0·0 t FYM ha^{-1}

F_1 = 5 t FYM ha^{-1}

F_2 = 10 t FYM ha^{-1}

Table 4: Fertilizer levels to rainfed Bt cotton

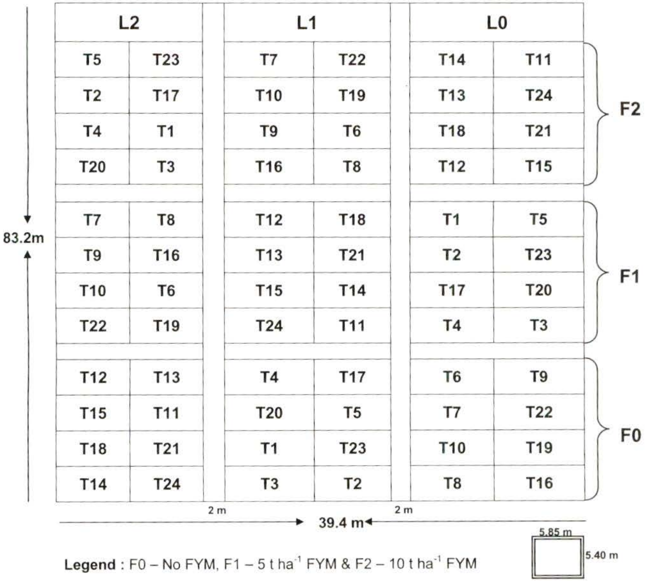
FYM, t ha^{-1}	N	P_2O_5	K_2O
	------------ kg ha^{-1} --------------		
0	25	12.5	12.5
5	50	25	25
10	100	50	50

There were 21 treatment combinations of N, P and K from three levels of nitrogen (25, 50 and 100 kg N ha^{-1}), three levels of phosphorus (12.5, 25 and 50 kg P_2O_5 ha^{-1} and three levels of potassium (12.5, 25 and 50 kg K_2O ha^{-1}). The Bt cotton applied graded doses of N, P and K fertilizers and FYM @ 5 to 10 t ha^{-1}(Table 4) The treatment combinations of NPK presented in Table 5. In addition to these 21 NPK treatment combinations three control/unfertilized plots were also maintained in each strip. All these treatments were superimposed randomly in each strip.

Table 5: Treatment combinations (21 treated and 3 control)

Sr. No.	Treatment combinations
1	$N_0 P_{25} K_{25}$
2	$N_{25} P_{25} K_{25}$
3	$N_{25} P_{12.5} K_{12.5}$
4	$N_{25} P_{25} K_{12.5}$
5	$N_{25} P_{12.5} K_{25}$
6	$N_{25} P_{50} K_{25}$
7	$N_{50} P_{25} K_0$
8	$N_{50} P_0 K_{25}$
9	$N_{50} P_{25} K_{25}$
10	$N_{50} P_{12.5} K_{25}$
11	$N_{50} P_{50} K_{25}$
12	$N_{50} P_{25} K_{12.5}$
13	$N_{50} P_{25} K_{50}$
14	$N_{50} P_{12.5} K_{12.5}$
15	$N_{50} P_{50} K_{50}$
16	$N_{50} P_{12.5} K_{50}$
17	$N_{100} P_{25} K_{25}$
18	$N_{100} P_{50} K_{50}$
19	$N_{100} P_{50} K_{25}$
20	$N_{100} P_{25} K_{50}$
21	$N_{100} P_{25} K_{12.5}$
22	$N_{00} P_{00} K_{00}$
23	$N_{00} P_{00} K_{00}$
24	$N_{00} P_{00} K_{00}$

The layout of experiment is depicted in fig 1.



Legend : F0 – No FYM, F1 – 5 t ha^{-1} FYM & F2 – 10 t ha^{-1} FYM

L_0, L_1 & L_2 – Fertility gradients

1. NOP25K25
2. N25P25K25
3. N25P12.5K12.5
4. N25P25K12.5
5. N25P12.5K25
6. N25P50K25
7. N5OP25K0
8. N5OP0K25
9. N50P25K25
10. N50P12.5K25
11. N50P50K25
12. N5OP25K12.5
13. N5OP25K50
14. N5OP12.5K12.5
15. N5OP50K50
16. N5OP12.5K50
17. N10OP25K25
18. N10OP50K50
19. N10OP50K25
20. N10OP25K50
21. N10OP25K12.5
22. NOP0K0
23. NOP0K0
24. NOP0K0

Fig 1: Plan of Layout (Main experiment on Bt cotton)

Table 6 : Treatment structure for Bt cotton

Tr. No.	N	P_2O_5	K_2O	Tr. No.	N	P_2O_5	K_2O
1	25	25	25	13	100	50	50
2	50	25	25	14	100	50	25
3	100	25	25	15	100	25	50
4	50	12.5	25	16	00	00	00
5	50	50	25	17	00	00	00
6	50	25	12.5	18	00	00	00
7	50	25	50	19	100	25	12.5
8	25	12.5	12.5	20	50	12.5	50
9	50	12.5	12.5	21	25	50	25
10	25	25	12.5	22	50	25	00
11	25	12.5	25	23	50	00	25
12	50	50	50	24	00	25	25

Table 7 : Fertilizer quantity applied to treatments in main experiment on Bt cotton

Sr. No.	Treatments	Nutrients applied as per treatment combinations (Kg ha^{-1})			Nutrient added (kg plot^{-1})		
		N	P_2O_5	K_2O	Urea	SSP	MOP
1	N0 P2 K2	0	25	25	0	0.494	0.132
2	N1 P2 K2	25	25	25	0.172	0.494	0.132
3	N1 P1 K1	25	12.5	12.5	0.172	0.247	0.066
4	N1 P2 K1	25	25	12.5	0.172	0.494	0.066
5	N1 P1 K2	25	12.5	25	0.172	0.247	0.132
6	N1 P3 K2	25	50	25	0.172	0.988	0.132
7	N2 P2 K0	50	25	0	0.344	0.494	0
8	N2 P0 K2	50	0	25	0.344	0	0.132
9	N2 P2 K2	50	25	25	0.344	0.494	0.132
10	N2 P1 K2	50	12.5	25	0.344	0.247	0.132
11	N2 P3 K2	50	50	25	0.344	0.988	0.132
12	N2 P2 K1	50	25	12.5	0.344	0.494	0.066
13	N2 P2 K3	50	25	50	0.344	0.494	0.264
14	N2 P1 K1	50	12.5	12.5	0.344	0.247	0.066
15	N2 P3 K3	50	50	50	0.344	0.988	0.264
16	N2 P1 K3	50	12.5	50	0.344	0.247	0.264
17	N3 P2 K2	100	25	25	0.688	0.494	0.132
18	N3 P3 K3	100	50	50	0.688	0.988	0.264
19	N3 P3 K2	100	50	25	0.688	0.988	0.132
20	N3 P2 K3	100	25	50	0.688	0.494	0.264
21	N3 P2 K1	100	25	12.5	0.688	0.494	0.066
22	N0 P0 K0	0	0	0	0	0	0
23	N0 P0 K0	0	0	0	0	0	0
24	N0 P0 K0	0	0	0	0	0	0

3.7 Fertilizers used

3.7.1 Organic manure (FYM) used

Well decomposed farm yard manure was obtained from cattle Dairy farm, Akola. A well decomposed FYM was incorporated to F_1 and F_2 blocks @ 5 t ha^{-1} and 10 t ha^{-1}, respectively before 15 days dibbling of cotton seed without disturbing the fertility strips. The FYM was analysed for its total nitrogen, total phosphorus and total potassium contents and found to contain 0.57 per cent N, 0.28 per cent P and 0.60 per cent f K.

3.7.2 Chemical fertilizers used

The sources of fertilizers material for N, P and K were urea, single super phosphate and muriate of potash containing 46.1, 16.08 and 60.2 per cent N, P_2O_5 and K_2O, respectively. The treatment wise quantity of chemical fertilizers was given to plots and presented in Table 7. As per the treatments half dose of nitrogen, full dose of phosphorus and potassium were applied at the time of dibbling of cotton seed. Whereas, remaining half dose of nitrogen was applied 30 days after sowing. The inorganic fertilizers were applied at 10 cm distance from the dibbling of cotton seed at the depth of 5 cm by ring method and covered with the soil.

3. 7.3 Plant protection

Imidacloprid-2000 systemic insecticide was sprayed at 30 and 50 days from sowing for the control of sucking pest. Monocrotophos 36 EC was also sprayed for control of pests.

3. 8 Schedule of field operations

The field operations carried out during the experimental period is given in Table 8. At harvest stage, treatment wise plant samples were collected for further laboratory analysis and analysed for total N, P and K content and total uptake was computed.

Table 8: **Schedule of operational practices followed during the conduct of main experiment on Bt cotton and its details.**

Sr.No.	Particulars		Details	
A	Crop Variety		Bt cotton(NHH-44)	
B.	Location		Research Farm of Department of Soil Science & Agricultural Chemistry, Dr.Panjabrao Deshmukh krishi vidyapeeth, Akola	
C.	Experimental design		Fractional factorial randomized block design	
D.	Treatments		Total No.72	
	Levels of FYM		Three (0, 5 and 10 Mg ha^{-1})	
	Levels of nitrogen		Three (172, 344 and 688 g $plot^{-1}$)	
	Levels of phosphorus		Three (247, 494 and 988 g $plot^{-1}$)	
	Levels of potassium		Three (0.066, 132 and 264 g $plot^{-1}$)	
E.	Plot Size		Gross : 5.85 x 5.4 m^2 Net : 4.95 x 3.60 m^2	
F.	Spacing		90 X 45 cm	
G.	Cultural operation			
			2010	2011
	Ploughing		3.5.2010	12.5.2011
	Harrowing	I	30.5.2010	12.6.2011
		II	14.6.2010	24.6.2011
	Preparation of layout		19.6.2010	--
	Application of FYM		8.6.2010	13.6.2011
H	Sowing			
	Soil sampling before sowing		20.6.2010	
	Sowing		23.6.2010	29.6.2011

			2010	2011
	First dose of chemical fertilizers applied		23.6.2010	29.6.2011
	Gap filling		29.6.2010	6.7.2011
	Thinning		5.7.2010	12.7.2011
	Hoeing	I	14.7.2010	24.7.2011
		II	13.9.2010	--
	Hand weeding	I	22.7.2010	14.7.2011
		II	15.9.2010	27.8.2011
		III	22.10.2010	
	Application of remaining dose of chemical fertilizer		24.7.2010	29.7.2011
	Collection of plant samples		5.8.2010	
			2.9.2010	
			1.10.2010	
I.	Plant protection			
	First spraying		22.7.2010	23.7.2011
	Second spraying		11.8.2010	22.8.2011
J.	Picking			
	First picking		16.11.2010	2.11.2011
	Second picking		1.12.2010	22.11.2011
	Third picking		22.12.2010	22.12.2011
	Fourth picking		21.1.2011	7.1.2012
K.	Collection of soil and plant samples		22.1.2011	23.12.2011

3.9 Laboratory studies

3.9.1 Collection of soil and plant samples

3.9.1.1 Soil analysis

Composite soil samples were collected from 0-20 cm depth from the experimental field before sowing of maize. Strip wise composite soil samples were also collected after the harvest of maize, to check whether the fertility gradients were developed or not. Before incorporation of FYM, plot wise surface samples were collected from each strip. The collected soil samples were air dried in shade on paper sheet, gently ground, mixed and sieved through 2 mm sieve and stored in clean polythene bags duly labelled for laboratory analysis for physico-chemical properties .Soil samples were collected from 0-20 cm depth of each plot after complete picking of Bt cotton and analyzed for pH, EC, organic carbon, available N, P and K.

3.9.1.2 Plant analysis

The treatment wise plant samples were selected randomely from each net plot and cut near the ground surface at square formation, 50 % flowering and at harvest stage. The plants were firstly cleaned with cloths following by rising with detergent 0.02 N HCl and finally with ionized water. After cleaning the collected plant samples were dried in shade and then placed in oven at 65^0 C till the constant weight obtained . These plant samples were ground in electrically operated stainless steel grinder upto maximum fineness. The ground samples stored in polythene bags with proper labelling for chemical analysis. The total nutrient content of plant was determined and uptake was computed by multiplying the respective nutrient conc. in per cent by yield.

Preparation of plant extract

Finally ground and well mixed plant samples of different stages were weighted accurately (0.2 g) transfered into microdigestion tube and 10 ml di-acid mixture was added and digested in microprocessor based digester. After completion of digestion (clean white), the extract was diluted and filtered through whatman filter paper No.42. These extract were used for determination of P and K analysis.

3.10 Methods used for analysis

3.10.1 Plant analysis

Total N was determined by digesting the plant sample in micro-processor based digestion system using Conc. H_2SO_4 and salt misture and distillation with automatic distillation system .P was estimated from di-acid extract by Vanadomolybdate phosphate acid yellow colour method (Piper, 1966) using U.V. based spectrophotometer. K was estimated from di- acid by using flame photometer (Piper, 1966). The methods used for soil and plant analysis of N, P and K are depicted in Table 9.

Table 9: Methods adopted for soil and plant analysis

Sr. No.	Properties	Methods adopted	Reference
A	**Soil analysis**		
1	Mechanical analysis	International pipette method	Piper, 1966
2	Electrical conductivity, dS m^{-1}	In 1:2.5 soil: water suspension by using conductivity meter	Jackson, 1967
3	pH	In 1:2.5 soil : water suspension by using pH meter	Jackson, 1967
4	Free calcium carbonate,%	Rapid titration method	Piper, 1966
5	Organic carbon, g kg^{-1}	Walkley and Black's wet oxidation method	Piper, 1966
6	Available nitrogen kg ha^{-1}	Distillation with alkaline $KMnO_4$	Subbiah and Asija, 1956
7	Available phosphorus kg ha^{-1}	Olsen's method	Jackson, 1967
8	Available potassium kg ha^{-1}	Extraction with neutral N ammonium acetate and then by using flame photometer	Jackson, 1967
B	**Plant analysis**		
1	Total nitrogen	Kjeldahl's method	Jackson, 1967
2	Total phosphorus	Vanadomolybdate yellow colour method for triacid extract	Jackson, 1967
3	Total potassium	Flame photometer method	Jackson 1967
C	**FYM analysis**		
1	Total N	kjeldahl's method	Jackson, 1967
2	Total P	Vanadomolybdate yellow colour method for triacid extract	Jackson, 1967
3	Total K	Flame photometer method	Jackson, 1967

3.11 Data processing

The data on yield, N, P and K uptake, initial soil test values status and NPK fertilizer doses applied to Bt cotton was used for calculating basic parameters viz., nutrient requirement (NR), contribution from soil (CS), and contribution from fertilizer(CF) and contribution from FYM. From these basic parameters fertilizer prescription equations with and without FYM condition were developed for Bt cotton as per the procedure given by Dev et al.(1978).

3.11.1 Whole field approach

In the STCR approach nutrient requirement (NR) and contribution from fertilizer (CF) values were calculated from all the treated plots and contribution from soil (CS) values were calculated from control plots. The NR (Kg q^{-1}), CF(%) and CS(%) values were calculated according to Dev et al (1978). The mean values for NR and CF for NPK were calculated from 63 treated plots (Kg q^{-1}) of Bt cotton production and per cent contribution from fertilizer, respectively. The mean values of soil contribution (CS) for NPK were considered from 9 control plots. From these basic data, the fertilizer adjustment equations were derived.

3.11.2 Basic data required for computation of fertilizer prescription Equation

A) Without FYM application

Nutrient requirement for one quintal production (NR) (kg q^{-1})

$$= \frac{\text{Total uptake of nutrient Straw + Seed (Kg ha}^{-1}\text{)}}{\text{Seed cotton yield (q ha}^{-1}\text{)}}$$

Percent contribution from Soil available nutrients (CS%) (NPK)

$$= \frac{\text{Total uptake of nutrient (NPK,Kg ha}^{-1}\text{) (in control plot)}}{\text{Soil test values for NPK, kg ha}^{-1}\text{ in control plots without FYM}} \times 100$$

$$\text{Contribution from Fertilizer (CF \%)} = \frac{\left(\begin{array}{l}\text{Total uptake of nutrient treated}\\ \text{Plots without FYM, kg ha}^{-1}\end{array}\right) - \left(\begin{array}{l}\text{STV of treated plots}\\ \text{without FYM (kg ha}^{-1})\end{array}\right) \times \%CS/100}{\text{Fertilizer dose (kg ha}^{-1}\text{) in treated plot without FYM}} \times 100$$

The nutrient requirement (NR), contribution from soil nutrients (CS), and contribution from fertilizer nutrients (CF)), were calculated separately for N,P and K as per method prescribed by Dev et al (1978) and average were taken for computing fertilizer adjustment equations.

B) With FYM

$$\% \text{ CFYM} = \frac{\left(\begin{array}{l}\text{Total uptake of nutrient in}\\ \text{control plots with FYM (kg ha}^{-1})\end{array}\right) - \left(\begin{array}{l}\text{STV of control}\\ \text{plots FYM (kg ha}^{-1})\end{array}\right) \times \frac{\%CS}{100}}{\text{Total amount of nutrients added through FYM ,kg ha}^{-1}} \times 100$$

$$\%CF = \frac{\left(\begin{array}{l}\text{Total uptake of nutrient}\\ \text{of treated plots with}\\ \text{FYM (kg ha}^{-1})\end{array}\right) - \text{STV of control plots with FYM} \times \frac{\%CS}{100} - \left(\begin{array}{l}\text{Nutrient added}\\ \text{through FYM}\\ \text{(kg ha}^{-1})\end{array}\right) \times \frac{\%CFYM}{100}}{\text{Fertilizer nutrient added with FYM (kg ha}^{-1})} \times 100$$

The difference in NR irrespective of source of nutrients applied through fertilizers with and without FYM were very small and hence NR was remains same.

3.11.3 Fertilizer prescription equations

The above basic data (NR, CS and CF) were used for generating fertilizer prescription equations both under FYM and without FYM conditions as follows.

A) Fertilizer prescription equations (without FYM)

$$\underset{(\text{Kg ha}^{-1})}{FN} = \frac{NRN}{\% \ CF} \times T - \frac{\%CS}{\% \ CF} \times STV\ (SN)$$

$$\underset{(Kg\ ha^{-1})}{F\ P_2O_5} = \frac{NRP}{\%\ CF} \times T - \frac{\%CS}{\%CF} \times STV\ (SP)$$

$$\underset{(Kg\ ha^{-1})}{F\ K_2O} = \frac{NRK}{\%\ CF} \times T - \frac{\%CS}{\%CF} \times STV\ (SK)$$

B) Fertilizer prescription equations (with FYM)

$$\underset{(Kg\ ha^{-1})}{FN} = \frac{NRN}{\%CF(FYM)} \times T - \frac{\%CS\%}{\%CF(FYM)} \times STV\ (SN) - \frac{CFYM}{\%CF(FYM)} \times \begin{array}{c}\text{Amount of nutrient}\\ \text{added through}\\ \text{one tonne of FYM}\end{array} \times \underset{(t\ ha^{-1})}{FYM}$$

$$\underset{(Kg\ ha^{-1})}{FP_2O_5} = \frac{NRP}{\%\ CF(FYM)} \times T - \frac{\%CS\%}{\%\ CF(FYM)} \times STV(SP) - \frac{CFYM}{\%\ CF(FYM)} \times \begin{array}{c}\text{Amount of nutrient}\\ \text{added through}\\ \text{one tonne of FYM}\end{array} \times \underset{(t\ ha^{-1})}{FYM}$$

$$\underset{(Kg\ ha^{-1})}{FK_2O} = \frac{NRK}{\%CF(FYM)} \times T - \frac{\%CS\%}{\%CF(FYM)} \times STV\ (SK) - \frac{CFYM}{\%\ CF(FYM)} \times \begin{array}{c}\text{Amount of nutrient}\\ \text{added through}\\ \text{one tonne of FYM}\end{array} \times \underset{(t\ ha^{-1})}{FYM}$$

3.11. 4 Yield response approach

In this approach, response of N, P and K in different fertility gradients were assigned treatments codes according to different level of nutrients. The corresponding yield differences were noted and maintaining the yield response relation to each level of N, P and K, the responded plots were selected separately for each nutrient.

3.11. 5 Statistical analysis

The experimental data were subjected to determine the effect due to treatments and other factors. Simple correlations and multiple regression equations were calculated by following the procedure outlined by Snedecor and Cochran (1967). The fertilizer prescription equations for working out the fertilizer requirement for Bt cotton was computed by employing whole field approach.

CHAPTER- IV

RESULTS AND DISCUSSION

Soil test crop response correlation studies were carried out on rainfed Bt cotton crop to develop relationship between soil test values and crop yields by conducting standard experiments based on fertility gradients approarch (Ramamoorthy *et al.*,1967). With a view to derive fertilizer prescription equations for rainfed Bt crop by conjoint use of chemical fertilizer and organic manures for making sound and balanced fertilizer recommendations. The results obtained in the present study are presented and discussed in this chapter under following heads.

4.1 Soil fertility gradient

4.2 Yield of Bt cotton under main experiment of STCR

4.3 Nutrient concentration and uptake by rainfed Bt cotton

4.4 Soil test crop response correlation for yield targeting in Bt cotton

4.5 Major nutrient concentration at square formation and 50 per cent flowering stage by rainfed Bt cotton

4.6 Effect of FYM and chemical fertilizers on chemical properties of soil after picking of Bt cotton

4.1 Soil fertility gradient

Soil fertility gradients were created in one and the same field by applying graded levels of N, P and K fertilizer nutrients. Fodder crop maize (cv.African Tall) was grown to stabilize the nutrients in soil and to bring the fertility of experimental soil to equilibrium condition. Variation in soil available nutrients (N, P and K) in different fertility gradient could be judged from soil test values in three fertility strips viz., L_0, L_1 and L_2.

The data on soil test values for available N, P and K after harvest of maize crop are presented in Table 10.

In fertility gradient experiment, the soil analysis data after harvest of maize crop showed that fertility gradients were created in the L_0, L_1 and L_2 strips.

Table 10. : Range and average soil test values in different fertility gradients after harvest of maize

Sr. No.	Particulars		Fertility gradients		
			L_0	L_1	L_2
1	Available nitrogen (kg ha^{-1})	Range	150.53 to 175.62	163.07 to 188.16	175.60 to 213.25
		Average	162.55	174.05	189.19
2	Available phosphorus (kg ha^{-1})	Range	12.93 to 14.92	15.25 to 17.57	18.56 to 21.22
		Average	13.64	16.33	20.09
3	Available potassium (kg ha^{-1})	Range	492.8 to 548.8	560.0 to 604.8	593.6 to 660.8
		Average	522.19	581.93	632.8

The available nitrogen content was 162.55, 174.05 and 189.19 kg ha^{-1} in L_0, L_1 and L_2 strips, respectively. Available phosphorus was 13.64, 16.33 and 20.09 kg ha^{-1} in L_0, L_1 and L_2 strips, respectively. Available potassium also showed increasing trend as 522.19, 581.93 and 632.8 in the L_0, L_1 and L_2 strips, respectively. This variation revealed the development of fertility gradients in L_0, L_1 and L_2 strips in respect of N, P and K. The soil available nutrient status also reported to be increased from low fertility to high fertility gradient by Bhende (2006). Tamboli *et al.*(1992) reported that artificial fertility gradients were developed by using graded doses of NPK for sugarcane.

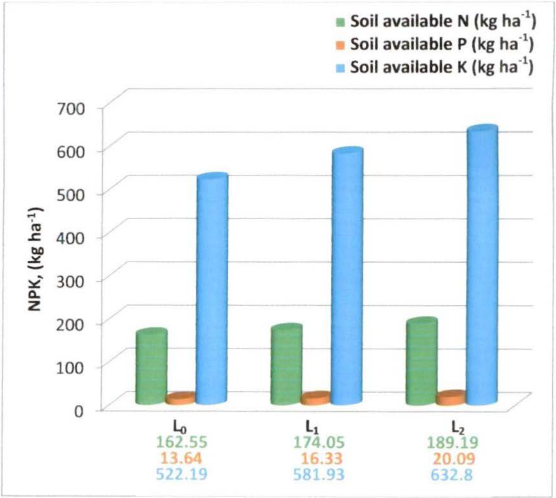


Fig. 2 : Initial NPK status of soil at different fertility gradients.

Saranya *et al.*(2012) reported that N in treated plots increased from 176 kg ha^{-1} in strip I to 270 kg ha^{-1} in strip III with a mean value of 227 kg ha^{-1} . Olsen-P ranged from 16.5 to 50.4 with a mean value of 33.7 kg ha^{-1}, while K status varied from 535 kg ha^{-1} in strip I to 635 kg ha^{-1} in strip III with a mean value of 584 kg ha^{-1}.

4.1.1 Available nitrogen

Variation in soil test values was observed among the gradients for available nitrogen. In L_0 gradient strip, nitrogen content ranged from 150.53 to 175.62 kg ha^{-1}, which gradually increased with increase in fertility gradient from L_0 to L_2. In L_1 strip, nitrogen content ranged from 163.07 to 188.16 with the average value 174.05 kg ha^{-1} and L_2 gradient strip the available nitrogen ranged from 175.60 to 213.25 with a mean value of 189.19 kg ha^{-1}. This clearly indicates that fertility gradient has been developed which did not show considerable variation in available soil nitrogen with increased addition of nitrogen (Table 10, **Fig.2**) from L_0 to L_2. Only 16 per cent increase in soil available nitrogen was observed from L_0 to L_2 fertility gradient.

Mohammad Sajid (2007) reported N content ranged from 150.24 to 209.79 kg ha^{-1} with a mean of 178.29 kg ha^{-1}, which gradually increased with increase in fertility gradient from L_0 to L_2.radients He reported 27.64 % increase in soil available nitrogen from L_0 to L_2 fertility.Katkar et al (2007) also reported that an increase by 10.91 % in available nitrogen content with addition of FYM @ 10 t ha^{-1} over no use of FYM for cotton in Vertisols.

4.1.2 Available phosphorus

The available phosphorus in L_0 fertility gradient strip ranged from 12.93 to 14.92 kg ha^{-1} with a mean of 13.64 kg ha^{-1}. The available phosphorus content of the soil increased with increasing fertility gradients from L_0 to L_2. The range of available phosphorus in L_1 gradient strip was 15.25 to 17.57 with a mean of 16.33 kg ha^{-1}. The available P ranged from 18.56 to 21.22 with a mean of 20.09 kg ha^{-1} was observed in L_2 gradient strip. This has clearly indicated that the fertility gradient was created in respect of available P (Table 10). The magnitude of fertility development in respect of available phosphorus was higher with increased P addition. There was increase in soil available phosphorus content to the tune of 47 per cent as the gradient from L_0 to L_2 gradient. Mohammad Sajid (2007) reported that soil available phosphorus content in different fertility strips increased with increasing level of phosphorus, indicating the fertility gradients has been developed in respect of available phosphorus. Lalitha Kumari et al. (2010) reported that the addition of phosphatic fertilizers helped to improve the soil available P status considerably and they also noticed a decline in soil available P in plots receiving no phosphatic fertilizers. Katkar *et al.* (2007) reported that the application of fertilizer P in adequate amounts to crops invariably raises the available P status of the soil.

4.1.3 Available potassium

Available potassium in different fertility gradients ranged from 492.8 to 548.8 with a mean of 522.19 kg ha^{-1} in L_0 gradient strip. The available K in L_1 gradient strip ranged from 560.0 to 604.8 kg ha^{-1} with a mean value of 581.93 kg ha^{-1} and 593.6 to 660.8 kg ha^{-1} in L_2 gradient strip with an average value of 632.8 kg ha^{-1}. Gadhiya *et al.*(2009) reported that increased status of soil available potassium due the application of K fertilizers.

In present study the soil fertility gradient in respect of K was lowest in L_0 gradient strip, which increased with the application of K fertilizer. The fertility gradient was developed due to addition of N, P and K fertilizer in the soil increasing from L_0 to L_2 strip, because in L_2 gradient strips, the double dose of chemical fertilizer was given against the recommended dose of L_1 strip while in L_0 there was no application of fertilizers and hence, the fertility was build up from L_0 to L_2 as the increased fertilizers doses and it was to the tune of about 21 per cent. The results clearly indicated the development of soil fertility gradients in respect of N, P and K (Table 10).

Plate No. 1. Overview of experiment of Bt Cotton.

Bangar (1991) reported the possibility of development of fertility gradients in respect of NPK with organic manure (FYM) as well as inorganic fertilizers and their combination. He further observed that large variation in respect of nitrogen fertility within the gradient strips.Thus, on the uniform farm the fertility gradients were created which would facilitate for studying response of test crop to applied nutrients.

4. 2 Yield of rainfed Bt cotton under main experiment of STCR

4. 2.1 Bt cotton yield as influenced by organic and chemical fertilizers in FYM blocks

Rainfed Bt cotton was taken as test crop in three blocks **(plate 1).** FYM blocks were created across the fertility gradients. One F_0 block was maintained where no FYM was added and in another two blocks viz., F_1 and F_2 blocks where FYM @ 5 t ha^{-1} and 10 t ha^{-1} were applied, respectively. In these three FYM blocks 24 NPK treatment combinations including 21 treated and 3 controls were randomized across the fertility gradient strips. Conjoint use of FYM and NPK fertilizers in different combinations was carried out in F_1 and F_2 blocks.

4.2.1.1 Seed cotton yield

The perusal of the data on seed cotton yield of Bt cotton (Table 11) in main experiment indicated as increasing trend with increase in the FYM from 0 to 5 and 10 t ha^{-1} **(Fig. 3).** In mean, the seed cotton yield of Bt in treated plots in F_0 block, ranged from 13.13 to 19.97 q ha^{-1}. These results showed that there was an increase in yield with increase in NPK doses, the maximum being with the N_{100} P_{50} K_{50} treatment. **(plate 2).** The average seed cotton yield of control plots of F_0 block was 7 .05 q $ha^{-1.}$

In F_1 block, the same trend of increase in seed cotton yield of Bt was observed with increasing levels of NPK combinations. Due to use of 5 t ha^{-1} of FYM along with NPK treatments, there was an increase in yields ranging from 13.81 to 20.23 q ha^{-1} in treated plots with 8.66 q ha^{-1} average of control plots.

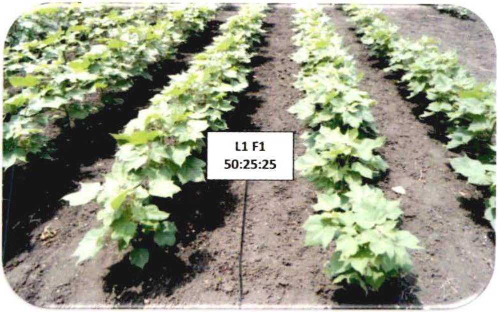


Plate No. 2 : Growth Performance of Bt Cotton under different N doses

(2011-2012)

Table 11 : Seed cotton Yield of rainfed Bt (q ha^{-1}) as influenced by conjoint use of FYM and chemical fertilizers

Sr. No.	Treatments NPK, (Kg ha $^{-1}$)	seed cotton yield (q ha $^{-1}$) 2010-11 FYM blocks			2011-12 FYM blocks			Mean FYM blocks		
		F_0	F_1	F_2	F_0	F_1	F_2	F_0	F_1	F_2
1	$N_0 P_{25} K_{25}$	13.44	12.20	12.93	14.78	15.42	16.14	14.11	13.81	14.54
2	$N_{25} P_{25} K_{25}$	14.46	13.78	16.81	17.03	17.54	18.58	15.75	15.66	17.70
3	$N_{25} P_{12.5} K_{12.5}$	10.75	12.57	12.39	15.51	18.58	17.94	13.13	15.58	15.17
4	$N_{25} P_{25} K_{12.5}$	11.83	14.75	15.10	16.78	16.81	18.83	14.31	15.78	16.97
5	$N_{25} P_{12.5} K_{25}$	11.38	13.53	13.67	16.24	17.60	17.91	13.81	15.57	15.79
6	$N_{25} P_{50} K_{25}$	13.39	15.06	15.87	17.03	17.63	19.44	15.21	16.35	17.66
7	$N_{50} P_{25} K_0$	13.53	15.90	15.67	18.27	18.80	19.60	15.90	17.35	17.64
8	$N_{50} P_0 K_{25}$	13.86	16.84	15.53	16.96	19.47	18.80	15.41	18.16	17.17
9	$N_{50} P_{25} K_{25}$	15.62	14.98	16.91	20.77	18.87	19.28	18.20	16.93	18.10
10	$N_{50} P_{12.5} K_{25}$	14.15	13.12	15.40	18.66	19.18	18.99	16.41	16.15	17.20
11	$N_{50} P_{50} K_{25}$	14.34	17.46	18.13	18.77	18.33	20.04	16.56	17.90	19.09
12	$N_{50} P_{25} K_{12.5}$	13.82	15.59	16.56	17.16	20.83	19.84	15.49	18.21	18.20
13	$N_{50} P_{25} K_{50}$	12.39	16.10	16.56	19.09	21.15	20.86	15.74	18.63	18.71
14	$N_{50} P_{12.5} K_{12.5}$	11.68	12.73	14.32	15.13	19.22	18.74	13.41	15.98	16.53
15	$N_{50} P_{50} K_{50}$	16.24	18.39	18.86	20.73	21.62	20.98	18.49	20.01	19.92
16	$N_{50} P_{12.5} K_{50}$	14.65	13.90	17.72	17.63	18.90	20.32	16.14	16.40	19.02
17	$N_{100} P_{25} K_{25}$	17.73	18.39	18.82	19.91	20.99	21.05	18.82	19.69	19.94
18	$N_{100} P_{50} K_{50}$	18.91	19.48	19.80	21.02	20.92	21.72	19.97	20.20	20.76
19	$N_{100} P_{50} K_{25}$	18.11	18.29	18.53	20.61	20.89	22.16	19.36	20.23	20.35
20	$N_{100} P_{25} K_{50}$	16.38	17.50	18.10	18.42	21.49	22.38	17.40	19.50	20.24
21	$N_{100} P_{25} K_{12.5}$	15.50	17.62	17.81	17.25	21.24	21.46	16.38	19.43	19.64
22	$N_{00} P_{00} K_{00}$	04.36	07.85	08.00	9.49	10.09	10.92	6.93	8.97	9.46
23	$N_{00} P_{00} K_{00}$	05.10	07.15	08.18	8.54	10.45	10.34	6.82	8.80	9.28
24	$N_{00} P_{00} K_{00}$	06.08	07.05	07.16	8.70	9.34	11.87	7.39	8.20	9.52
Mean of treated plot		14.38	15.63	16.45	17.99	19.31	19.76	16.19	17.47	18.11
Mean of control plot		05.18	07.35	07.78	8.91	9.96	11.04	7.05	8.66	9.41

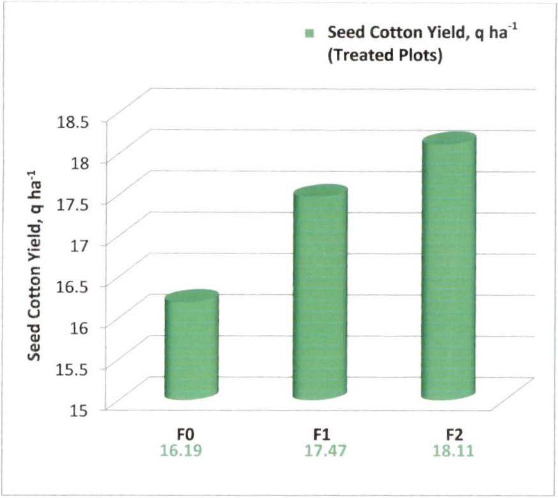


Fig. 3 : Seed cotton yield of rainfed Bt (q ha^{-1}) as influenced by conjoint use of FYM and chemical fertilizers

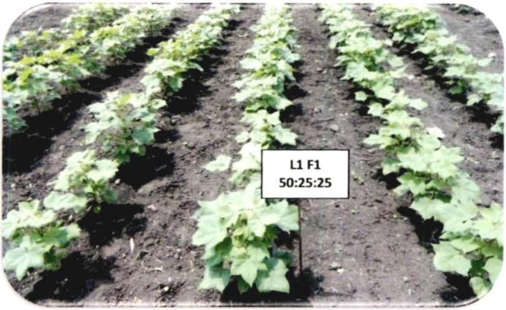
The highest seed cotton yield of 20.23 q ha^{-1} was observed in N_{100} P_{50} K_{25} treatment. This treatment exits in L_1 strip of the F_1 block. The residual fertility in the L_1 strips coupled with FYM used helped to increase the seed cotton yield.

In F_2 block consisting FYM @10 t ha^{-1}, the seed cotton yield ranged from 14.54 to 20.76 q ha^{-1} and the mean of control plots was 9.41 q ha^{-1}. There was an increase in seed cotton yield in control plots in F_2 block than F_0 and F_1 blocks. This shows the beneficial effect of FYM in increasing the seed cotton yield **(plate 3).**

The mean yield of treated plots was 16.19, 17.47 and 18.11 in F_0, F_1 and F_2, respectively, which shows the additional effect of added FYM in combination of NPK treatments. The yield of seed cotton in treated plots of F_1 FYM block increased by 7.91 per cent and 11.86 per cent in F_2 block over F_0 block. The seed cotton yield of control plots of F_1 and F_2 blocks increased by 22.84 and 33.48 per cent , respectively over the yield of control plots of the F_0 block. This has clearly indicated that addition of FYM and in combination with NPK fertilizers helped in increasing the seed cotton yield.

The application of N_{100} P_{50} K_{50} and N_{50} P_{25} K_{25} resulted an increase in seed cotton yield to the tune of 183.26,133.26, 120.62 and 158.16, 95.50 and 92.35 per cent in treated plots of F_0, F_1 and F_2, respectively over control treated plots of F_0, F_1 and F_2 blocks. Data further indicated that, application of N_{100} P_{50} K_{50} resulted an increase in seed cotton yield which was 9.73, 19.31 and 14.70 per cent over N_{50} P_{25} K_{25} treated plots of F_0, $F_1$and F_2 blocks,respectively (table11, **plate 4 & 5**) Rananavare et al (2006) observed that , seed cotton yield per hectare was significantly increased from 18.53 to 25.77 per cent with increase in fertilizer level from 25:12.5:12.5 to 50:25:25 kg NPK ha^{-1} over no use of fertilizer. Sankarnarayanan *et al.* (2004) revealed that the application of 150 per cent of recommended level of fertilizer registered significantly higher seed cotton yield of Bt (3090 and 1710 kg ha^{-1}) and it was on par with 125 per cent of recommended level of fertilizer for both the years.

Irrespective of nitrogen level the seed cotton yield was increased with FYM levels. However, the differences between seed cotton yields of F_0 and F_1 level found wider than between the F_1 and F_2 levels. As N



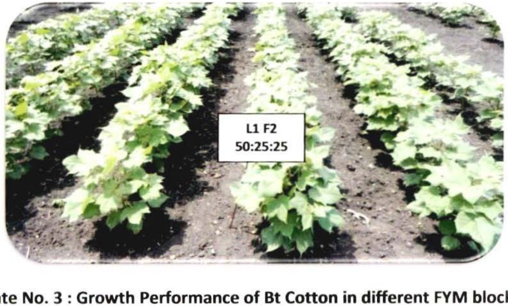


Plate No. 3 : Growth Performance of Bt Cotton in different FYM blocks (2011-2012)

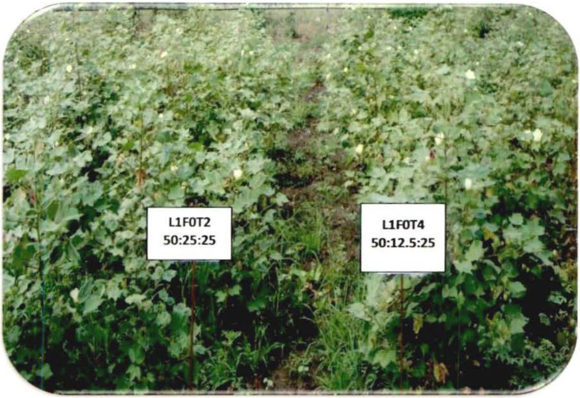


Plate No. 4 : Boll formation of Bt Cotton as influenced by conjoint use of FYM and chemical fertilizers (2010-2011)

and P increases the yield of cotton increases.Thus, the study shows that balanced effect of NP and FYM is more beneficial as compared to their individual effect in increasing the seed cotton yield and FYM reduces the N requirement of the crop. It might be due to enhanced efficiency of N due to use of FYM. Deshmukh *et al.* (2011) reported that average seed cotton yield of Bt in treated plots were 12.99, 13.48 and 13.82 q ha^{-1} in F_0, F_1 and F_2 FYM blocks, respectively, this shows the beneficial effect of FYM in increasing the seed cotton yield. Hosmath et al.(2011) studied the effect of organic and inorganic nutrient management for Bt cotton under rainfed ecosystem on vertisol. They reported pooled result that integrated supply of nutrients through recommended dose of fertilizers (30:15:15) + FYM (7.5 t ha^{-1}) significantly increased Bt cotton yield (1066.3 kg ha^{-1}). Addition of FYM increased the seed cotton yield by 24.36 per cent over recommended dose of fertilizer which may be due to balanced use of chemical fertilizers coupled with FYM. Nehra *et al.* (2004) also emphasized that combined application of FYM and nitrogenous fertilizers was more beneficial for higher seed cotton yield. Regarding phosphorus the seed cotton yield was an increase level with the FYM level. However, the differences between yields at F_0 and F_1 found wider than between the F_1 and F_2 levels . The seed cotton yield increases with increase in P levels but the differences in yield found narrow up to 12.5 kg P ha^{-1} and wide increase in yield has been observed from 12.5 to 50 kg P ha^{-1}.

The seed cotton yield of RCH-2 Bt in the traditional tract of cotton in Akola i.e. 10.18 q ha^{-1} under the 100 % recommended dose of fertilizer indicates that the higher seed cotton yield (20 q ha^{-1}) at 100: 50:50 kg NPK ha^{-1} in F_1 is obtained in the present study at the similar dose of NPK which can be attributed to the integration of chemical fertilizers with FYM resulting into increased efficiency of nutrients causing considerable increase in the yield. However, increasing the fertilizer doses in higher FYM block (F_2 block) was not found that much effective which indicates that combinations of F_1 with optimized combination of NPK were found useful in obtaining the seed cotton yield. Nehra *et al.* (2004) conducted field experiment for two seasons, they reported from the pooled results that the seed cotton yield was 18.03 q ha^{-1} under integrated nutrient management consisting of 100% RDF along with FYM @ 5 t ha^{-1}.

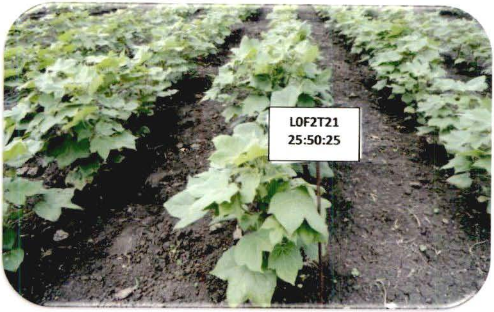


Plate No. 5 : Growth Performance of Bt Cotton as influenced by conjoint use of FYM and chemical fertilizers (2011-2012)

Table 12 : Cotton stalk yield (q ha^{-1}) as influenced by conjoint use of FYM and chemical fertilizers

Sr. No.	Treatments NPK,(Kgha^{-1})	cotton stalk yield (q ha^{-1}) 2010-11 FYM blocks			2011-12 FYM blocks			Mean of two years FYM blocks		
		F_0	F_1	F_2	F_0	F_1	F_2	F_0	F_1	F_2
1	$N_0P_{25}K_{25}$	21.27	20.16	22.16	24.38	25.90	26.47	22.83	23.03	24.31
2	$N_{25}P_{25}K_{25}$	21.49	21.53	26.75	25.70	26.43	30.66	23.60	23.98	28.70
3	$N_{25}P_{12.5}K_{12.5}$	17.95	18.70	20.02	25.01	27.03	28.80	21.48	22.87	24.41
4	$N_{25}P_{25}K_{12.5}$	18.95	23.19	23.97	26.84	26.58	30.91	22.90	24.89	27.44
5	$N_{25}P_{12.5}K_{25}$	22.16	18.83	22.78	26.81	25.08	28.84	24.49	21.96	25.81
6	$N_{25}P_{50}K_{25}$	22.56	23.93	25.66	28.97	29.16	32.46	25.77	26.55	29.06
7	$N_{50}P_{25}K_0$	22.78	24.30	26.09	30.33	30.29	32.51	26.56	27.30	29.30
8	$N_{50}P_0K_{25}$	20.26	25.93	25.04	24.44	30.18	30.27	22.35	28.06	27.66
9	$N_{50}P_{25}K_{25}$	25.70	24.50	26.52	34.06	32.10	32.70	29.88	28.30	29.61
10	$N_{50}P_{12.5}K_{25}$	21.70	21.10	25.26	28.18	30.01	30.68	24.94	25.56	27.97
11	$N_{50}P_{50}K_{25}$	20.89	27.58	27.81	29.85	30.93	31.18	25.37	29.26	29.50
12	$N_{50}P_{25}K_{12.5}$	20.02	26.59	25.40	25.17	32.74	31.90	22.60	29.67	28.65
13	$N_{50}P_{25}K_{50}$	19.04	21.49	24.02	30.01	31.18	32.54	24.53	26.33	28.28
14	$N_{50}P_{12.5}K_{12.5}$	18.83	19.94	20.57	24.72	30.27	29.88	21.78	25.10	25.23
15	$N_{50}P_{50}K_{50}$	25.26	27.74	25.98	33.04	32.76	31.81	29.15	30.25	28.90
16	$N_{50}P_{12.5}K_{50}$	22.14	20.89	25.85	25.67	26.15	28.84	23.91	23.52	27.34
17	$N_{100}P_{25}K_{25}$	27.14	28.83	28.62	31.40	32.87	31.60	29.27	30.85	30.11
18	$N_{100}P_{50}K_{50}$	29.63	30.39	29.47	32.07	34.03	35.15	30.35	32.21	32.31
19	$N_{100}P_{50}K_{25}$	29.69	29.25	29.47	33.11	35.20	34.82	31.40	32.23	32.15
20	$N_{100}P_{25}K_{50}$	27.47	31.02	28.63	30.77	34.26	34.60	29.14	32.64	31.62
21	$N_{100}P_{25}K_{12.5}$	28.42	30.54	28.72	26.58	34.60	33.93	27.50	32.57	31.33
22	$N_{00}P_{00}K_{00}$	10.90	13.58	14.85	20.42	19.94	21.62	15.66	16.76	18.23
23	$N_{00}P_{00}K_{00}$	10.63	14.85	13.96	17.19	21.43	19.21	27.82	18.14	16.58
24	$N_{00}P_{00}K_{00}$	14.21	12.59	13.37	18.04	17.88	19.28	16.13	15.24	16.33
Mean of treated plot		23.02	24.59	27.01	28.42	30.37	31.45	25.72	27.48	29.23
Mean of control plot		11.91	13.67	14.06	18.55	19.75	20.04	15.23	16.71	17.05

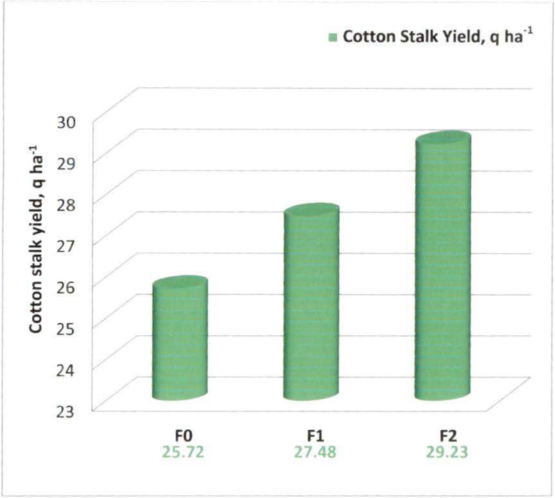


Fig. 4 : Cotton stalk yield (q ha^{-1}) as influenced by conjoint use of FYM and chemical fertilizers.

The seed cotton yield increased with FYM levels and also due to application of potassium. As like N and P the difference between F_0 and F_1 level is wider than between the F_1 and F_2 levels. Potassium application increases the yield of seed cotton. The increase in seed cotton yield due to better supply of nutrients through increasing levels of K application in presence of FYM, favoured the most luxuriant growth and maintenance of crop, which consequently increased the seed cotton yield of Bt. (24.30 q ha^{-1}) reported by Gadhiya *et al.* (2009).

4.2.1.2 Cotton stalk yield

The perusal of the data on cotton stalk yield of Bt cotton (Table 12) in main experiment indicated as increasing trend with increase in the FYM from 0 to 5 and 10 t ha^{-1} **(Fig. 4).** In mean, cotton stalk yield of Bt in treated plots in F_0 block, ranged from 21.48 to 31.40 q ha^{-1}. These results showed that there was an increase in yield with increase in NPK doses, the maximum being with the N_{100} P_{50} K_{25} treatment. The average cotton stalk yield of control plots of F_0 block was 15 .23 q ha^{-1}.

In F_1 block, the same trend of increase in cotton stalk yield of Bt was observed with increasing levels of NPK combinations. Due to use of 5 t ha^{-1} of FYM along with NPK treatments, there was an increase in yields ranging from 21.96 to 32.64 q ha^{-1} in treated plots with 16.71 q ha^{-1} average of control plots. The highest cotton stalk yield of 32.64 q ha^{-1} was observed in N_{100} P_{25} K_{50} treatment. The residual fertility in the L_1 strips coupled with FYM used helped to increase the cotton stalk yield(Table 12).

In F_2 block consisting of FYM @10 t ha^{-1}, the cotton stalk yield ranged from 24.31 to 32.31 q ha^{-1} and the mean of control plots was 17.05 q ha^{-1}. There was an increase in cotton stalk yield in control plots in F_2 block than F_0 and F_1 blocks. This shows the beneficial effect of FYM in increasing the cotton stalk yield.

In mean, cotton stalk yield of treated plots was 25.72, 27.48 and 29.23 in F_0, F_1 and F_2, respectively, which shows the additional effect of added FYM in combination of NPK treatments. The yield of cotton stalk in treated plots of F_1 FYM block increased by 6.84 per cent and 13.65 per cent in F_2 block over F_0 block. The cotton stalk yield of control plots of F_1 and F_2 blocks increased by 9.72 and 11.95 per cent , respectively over the yield of control plots of the F_0 block. This has clearly indicated that addition of FYM alone and in combination with NPK fertilizers helped in increasing the cotton stalk yield.

The application of N_{100} P_{50} K_{25} and N_{50} P_{25} K_{25} resulted an increase in cotton stalk yield to the tune of 106.17, 92.88, 88.56 and 96.19, 69.36 and 73.67 per cent in treated plots of F_0, F_1 and F_2, respectively over control treated plots of F_0, F_1 and F_2 blocks. Deshmukh et al.(2011) observed that , cotton stalk yield to the tune of 81.64, 66.56 and 70.75 per cent in treated plots of F_0, F_1 and F_2 blocks respectively over control treated plots of F_0, F_1 and F_2 blocks. Tamgadge *et al.*(2011) revelaed that significantly highest stalk yield of cotton (35.50 q ha^{-1}) was observed in the treatment receiving 50:25:37.5 kg NPK ha^{-1} in combination with FYM @ 5 ha^{-1} in rainfed condition under vertisols.

4.2.2 Bt cotton yield as influenced by N, P and K fertilization in different fertility gradients

The data on the seed cotton yield in different soil fertility gradients are presented in Table 13 and **fig 5**. The results clearly showed that the seed cotton yield was increased with increasing soil fertility gradients from L_0 to L_2.

The influence of soil fertility on seed cotton yield could be seen from the yield of control plots in different fertility gradients. The average yield of Bt cotton under control plots in different fertility gradients were 8.41, 8.16 and 8.54 q ha^{-1}, respectively from L_0 to L_2 gradients. In case of treated plots, average yield of Bt cotton in different fertility gradients were 16.89, 17.37 and 17.79 q ha^{-1}, respectively. The seed cotton yield in treated plots in L_0 gradient

Table 13 : Seed cotton yield (q ha^{-1}) as influenced by NPK fertilizers in different fertility gradients

Sr. No.	Treatments NPK (Kgha $^{-1}$)	Seed cotton yield (q ha $^{-1}$) 2010-11			2011-12			Mean		
		Fertility gradient			Fertility gradient			Fertility gradient		
		L_0	L_1	L_2	L_0	L_1	L_2	L_0	L_1	L_2
1	$N_0P_{25}K_{25}$	12.93	12.20	13.44	16.14	15.42	14.78	14.54	13.81	14.11
2	$N_{25}P_{25}K_{25}$	13.78	14.46	16.81	17.54	17.03	18.58	15.66	15.75	17.70
3	$N_{25}P_{12.5}K_{12.5}$	10.75	12.39	12.57	15.51	17.94	18.58	13.13	15.17	15.58
4	$N_{25}P_{25}K_{12.5}$	11.83	15.10	14.75	16.78	18.83	16.81	14.31	16.97	15.78
5	$N_{25}P_{12.5}K_{25}$	13.67	13.53	11.38	17.91	17.60	16.24	15.79	15.57	13.81
6	$N_{25}P_{50}K_{25}$	15.87	15.06	13.39	19.44	17.63	17.03	17.66	16.35	15.21
7	$N_{50}P_{25}K_0$	13.53	15.67	15.90	18.27	19.60	18.80	15.90	17.64	17.35
8	$N_{50}P_0K_{25}$	16.84	13.86	15.53	19.47	16.96	18.80	18.16	15.41	17.17
9	$N_{50}P_{25}K_{25}$	14.98	15.62	16.91	18.87	20.77	19.28	16.93	18.20	18.10
10	$N_{50}P_{12.5}K_{25}$	13.12	14.15	15.40	19.18	18.66	18.99	16.15	16.41	17.20
11	$N_{50}P_{50}K_{25}$	17.46	14.34	18.13	18.33	18.77	20.04	17.90	16.56	19.09
12	$N_{50}P_{25}K_{12.5}$	13.82	16.56	15.59	17.16	19.84	20.83	15.49	18.20	18.21
13	$N_{50}P_{25}K_{50}$	12.39	16.56	16.10	19.09	20.86	21.15	15.74	18.71	18.63
14	$N_{50}P_{12.5}K_{12.5}$	11.68	14.32	12.73	15.13	18.74	19.22	13.41	16.53	15.98
15	$N_{50}P_{50}K_{50}$	18.86	18.39	16.24	20.98	21.62	20.73	19.92	20.01	18.49
16	$N_{50}P_{12.5}K_{50}$	13.90	14.65	17.72	18.90	17.63	20.32	16.40	16.14	19.02
17	$N_{100}P_{25}K_{25}$	18.82	17.73	18.39	20.99	19.91	21.05	19.91	18.82	19.72
18	$N_{100}P_{50}K_{50}$	19.80	19.48	18.91	21.72	20.92	21.02	20.76	20.20	19.97
19	$N_{100}P_{50}K_{25}$	18.53	18.29	18.11	22.16	20.89	20.61	20.35	19.59	19.36
20	$N_{100}P_{25}K_{50}$	18.10	17.50	16.38	22.38	21.49	18.42	20.24	19.50	17.40
21	$N_{100}P_{25}K_{12.5}$	15.50	17.81	17.62	17.25	21.46	21.24	16.38	19.64	19.43
22	$N_{00}P_{00}K_{00}$	04.36	08.00	07.85	9.49	10.92	10.09	6.93	9.46	8.97
23	$N_{00}P_{00}K_{00}$	07.15	05.10	08.18	10.45	8.54	10.34	8.80	6.82	9.26
24	$N_{00}P_{00}K_{00}$	07.16	07.05	06.08	11.87	9.34	8.70	9.52	8.20	7.39
Mean of treated plot		15.05	15.60	16.40	18.72	19.13	19.17	16.89	17.37	17.79
Mean of control plot		06.22	06.72	07.37	10.60	9.60	9.71	8.41	8.16	8.54

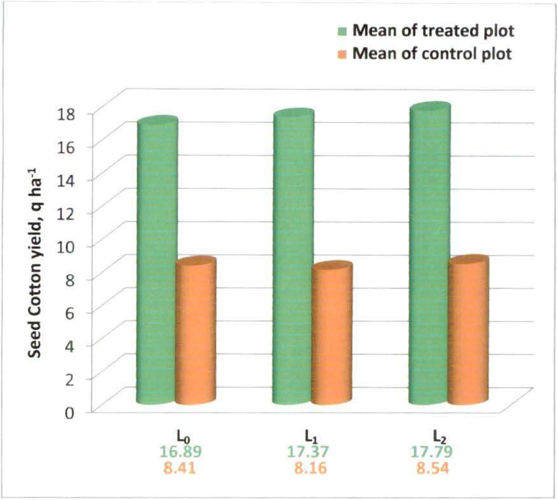


Fig. 5 : Seed cotton yield (q ha^{-1}) as influenced by NPK fertilizers in different fertility gradients.

ranged from 13.13 to 20.76 q ha^{-1}, in L_1 13.81 to 20.20 q ha^{-1} and in L_2 13.81 to 19.97 q ha^{-1}. These results showed that there was relatively more increase in seed cotton yield with an increase in NPK fertilizer application in low fertility gradient as compared to high fertility gradient. Due to addition of FYM in each block, this might have masked the effect of native soil fertility due to its buffering capacity by different gradients.

The FYM applied in different strips has its effect on the availability of nutrients by enhancing the native pool of nutrients in soil in addition to increase the efficiency of applied nutrients through fertilizers. This cause less variability in seed cotton yields among the fertility strips however, the narrow variability in yields due to various gradients was existing.

Therefore, the yield level in different gradient is narrow. However, at low fertility gradients responses were higher to seed cotton yield. Soil, fertilizers and FYM are the sources of supply of plant nutrients to the crop. Therefore, the effect of these three sources of plant nutrients in crop yield is inter linked with each other. The response to applied nutrient to crop is dependent on number of factors, among them fertility status of soil is one of the most important factor (Dave *et al.,* 1990).

The soil test crop response correlation studies carried out on tomato, cabbage, brinjal, okra, French bean, capsicum, onion, green chillies and cauliflower in an Alfisol using fertility gradient and yield goal approach indicated that the response of all vegetables to applied nitrogen, phosphorus and potassium decreased with increasing fertility status of soil. The available N, P and K significantly correlated with yield of all vegetable crops (Hariprakasa Rao and Subramanian, 1994). Milap-Chand *et al.*(2006) reported that soil test crop correlation studies carried out on mustard and rapeseed on an Typic Haplustept soil using four fertility gradients and yield goal approach showed that fertilizer doses increased with increase in yield target and decreased with increasing soil test values for attaining a given yield target. These result clearly showed that fertilizer requirement varies with the soil test values for the same level of crop production and hence balanced fertilization through soil testing becomes essential for crops.

4.2.3 Yield response of Bt cotton to added fertilizers in different fertility gradients

The data on yield response of Bt cotton to added chemical fertilizers in different fertility gradients are given in Table 14 and showed in **Fig.6.**

The data showed that the response of Bt cotton to application of NPK fertilizers was decreased consistently with increasing the fertility gradients from L_0 to L_2.The average response for 21 fertilizer treatment in L_0, L_1 and L_2 fertility gradient were 8.84, 8.88 and 8.44 q ha^{-1} of seed cotton yield, respectively. The highest response (8.88 q ha^{-1}) was recorded at L_1 fertility level which was followed by L_0 the low fertility gradient (8.84 q ha^{-1}) and L_2 fertility gradient becomes 8.44 q ha^{-1}, indicating that the Bt cotton yield responded more in medium fertility status of soil.

Irrespective of FYM strips it was observed that increasing levels of NPK were found to increase the yield of Bt cotton however, the response declined in higher soil fertility strip as compared to low fertility strip gradient.

This is in accordance with the law of diminishing returns. The response of seed cotton yield to the application of N, P and K in their combinations at different levels increased considerably. The highest average response of 13.58 q ha^{-1} was obtained under N_{100} P_{50} K_{50} treatment. While the lowest average response of 4.01 q ha^{-1} was obtained under N_{25} $P_{12.5}$ K_{25} treatment. The average seed cotton yield response in control plots was increased with increasing soil fertility gradients from L_0 to L_1. Average seed cotton yield in control plots were 6.22, 6.72 and 7.37 q ha^{-1} in L_0, L_1 and L_2 fertility gradient, respectively. Panchbhai (2010) also reported that the response of N, P and K fertilizers were decreased with increase in fertility status of soil for banana crop. Kadu *et al.* (2001) reported that the response of onion to addition of NPK fertilizers decreased consistently with increasing fertility gradients from L_0 to L_2.

Table 14. Yield response of Bt cotton to added fertilizers in different fertility gradients (q ha^{-1})

Sr. No.	Treatments NPK, Kg ha^{-1}	Fertility gradients (Response of NPK,q ha^{-1})			Mean
		L_0	L_1	L_2	
1	$N_oP_{25}K_{25}$	6.71	5.48	6.07	6.09
2	$N_{25}P_{25}K_{25}$	7.56	7.74	9.44	8.25
3	$N_{25}P_{12.5}K_{12.5}$	4.53	5.67	5.20	5.13
4	$N_{25}P_{25}K_{12.5}$	5.61	8.38	7.38	7.12
5	$N_{25}P_{12.5}K_{25}$	7.45	6.81	4.01	6.09
6	$N_{25}P_{50}K_{25}$	9.65	8.34	6.02	8.00
7	$N_{50}P_{25}K_o$	7.31	8.95	8.53	8.26
8	$N_{50}P_0K_{25}$	10.62	7.14	8.16	8.64
9	$N_{50}P_{25}K_{25}$	8.76	8.90	9.54	9.07
10	$N_{50}P_{12.5}K_{25}$	6.90	7.43	8.03	7.45
11	$N_{50}P_{50}K_{25}$	11.24	7.62	10.76	9.87
12	$N_{50}P_{25}K_{12.5}$	7.60	9.84	8.22	8.55
13	$N_{50}P_{25}K_{50}$	6.17	9.84	8.73	8.25
14	$N_{50}P_{12.5}K_{12.5}$	5.46	7.60	5.36	6.14
15	$N_{50}P_{50}K_{50}$	12.64	11.67	8.87	11.06
16	$N_{50}P12.5K_{50}$	7.68	7.93	10.35	8.65
17	$N_{100}P_{25}K_{25}$	12.60	11.01	11.02	11.54
18	$N_{100}P_{50}K_{50}$	13.58	12.76	11.54	12.63
19	$N_{100}P_{50}K_{25}$	12.31	11.57	10.74	11.54
20	$N_{100}P_{25}K_{50}$	11.88	10.78	9.01	10.56
21	$N_{100}P_{25}K_{12.5}$	9.28	11.09	10.25	10.21
Average response of treated plot		8.84	8.88	8.44	-
Average response of control plot		6.22	6.72	7.37	-

Hariprakash Rao and Subramanian (1994) reported that the response of N, P and K fertilizers was decreased with increase in fertility status of soil for all vegetable crops.

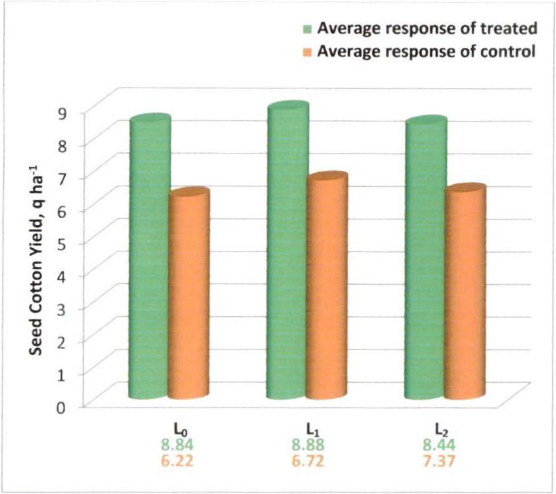


Fig. 6 : Yield response of Bt cotton (q ha^{-1}) to added fertilizers in different fertility gradients

4.3 Nutrient concentration and uptake by rainfed Bt cotton

4.3.1 Nitrogen concentration

Data in respect of nitrogen concentration in seed cotton and cotton stalk as influenced by different treatments are presented in **Appendix I.**

On perusal of the data in **Appendix I**, the mean N concentration in control (N_{00} P_{00} K_{00}) plots in F_0 FYM block was 2.713 and 0.353 in seed cotton and cotton stalk, respectively. The N concentration in seed cotton treated plots ranged from 2.78 to 3.10, 2.81 to 3.11 and 2.80 to 3.12 per cent in F_0, F_1 and F_2 blocks where as in cotton stalk , the concentration of N in treated plots ranged from 0.409 to 0.725, 0.477 to 0.725 and 0.546 to 0.791 per cent in F_0, F_1 and F_2 blocks, respectively. The concentrtion of nitrogen in seed cotton and cotton stalk gradually increased with increase in application of nitrogen application. In F_0 block, the highest N concentration in seed cotton (3.10 %) being observed under $N_{100}P_{25}K_{50}$ and $N_{100}P_{25}K_{12.5}$ followed by 3.08 % in $N_{50}P_{25}K_{50}$ and 3.06 % in $N_{50}P_{25}K_{12.5}$ and $N_{50}P_{12.5}K_{12.5}$, indicating that the N concentration increased with increase in nitrogenous fertilizer along with phosphorus and potassium. Similar trend of N concentration(3.00%) of cotton with an increase in150% RDF was also recorded earlier by Lalitha Kumari *et al.*(2010). The increase in N concentration increased with the application of FYM which may be due to better mineralization of nitrogen, incrreceived the uptake of nutrients and improvement in soil physical condition (Deshmukh *et al.*, 2011).

In F_1 FYM block (5 t ha^{-1}), the N concentration in seed cotton and cotton stalk was ranged from 2.81 to 3.11 and 0.477 to 0.725 per cent , with mean value of 2.997 and 0.630 per cent in treated plots, respectively. N concentration in cotton stalk in treated plots of F_1 and F_2 blocks increased by 24.92 and 37.11 per cent, respectively over the control plots of F_0 block. A increase in N concentration in cotton stalk in control plot may be attributed to the use of FYM.

In F_2 FYM block (10 t ha^{-1}) the N concentration in seed cotton and cotton stalk was ranged from 2.80 to 3.12 and 0.546 to 0.791 per cent , with mean value of 3.009 and 0.693 per cent in treated plots, respectively. N concentration in cotton stalk in treated plots of F_1 and F_2 blocks increased by 7.51 and 18.26 per cent, respectively over the treated plot of F_0 block. An increase in N concentration in treated plot may be attributed to the use of 5 t FYM and 10 t FYM ha^{-1} which helped in efficient use of applied NPK fertilizers and better mineralization of nitrogen. Deshmukh *et al.* (2011) observed that nitrogen concentration in seed cotton and cotton stalk increased with increasing fertilizer doses and with increase in FYM block i.e. 20 t ha^{-1} for rainfed Bt cotton.

4.3.2 Nitrogen uptake by Bt cotton

The data in respect of nitrogen uptake by seed cotton, cotton stalk and total uptake of nitrogen by Bt cotton are presented in table 15 and depicted in **fig 7**. The total uptake of N (91.24 kg ha^{-1}) in seed cotton was observed in $N_{100}P_{25}K_{50}$ treatment of F_1 FYM block where as F_2 FYM block registered highest total uptake of N (96.46 kg ha^{-1}) in N_{100} P_{50} K_{25} treatment. The total uptake of N by Bt cotton showed an increasing trend from F_0 to F_2 FYM blocks. The average total uptake of N in terated plots of F_0 block was 70.40 kg ha^{-1}. and The average total uptake of N in control plots was 30.71 kg ha^{-1}. In F_0 block the uptake of N invariably increased with an increase in nitrogen doses. The highest total uptake of N (96.46 kg ha^{-1}) was recorded in N_{100} P_{50} K_{25} treatment.

The data in table 15 also indicate that the N uptake has been considerably increased with the use of FYM and NPK fertilizers together. This increase in nitrogen uptake might be attributed to the readily available nature of urea N, which also increased the concentration of nitrogen in seed cotton

Table 15: Nitrogen uptake(kg ha^{-1}) by Bt cotton as influenced by conjoint use of chemical fertilizers and FYM (2011-12)

Sr.No	Treatments NPK, (Kg ha^{-1})	Uptake of N, kg ha^{-1}								
		F_0			F_1			F_2		
		Seed cotton	Cotton stalk	Total uptake	Seed cotton	Cotton stalk	Total uptake	Seed cotton	Cotton stalk	Total uptake
1	$N_0P_{25}K_{25}$	41.09	9.97	51.06	43.33	12.35	55.68	45.19	16.28	61.47
2	$N_{25}P_{25}K_{25}$	48.02	12.26	60.28	49.81	12.61	62.42	52.77	18.85	71.62
3	$N_{25}P_{12.5}K_{12.5}$	43.43	11.93	55.36	52.77	12.89	65.66	51.31	15.72	67.03
4	$N_{25}P_{25}K_{12.5}$	48.66	12.80	61.46	48.24	14.51	62.75	54.61	19.00	73.61
5	$N_{25}P_{12.5}K_{25}$	46.28	14.64	60.92	50.16	15.42	65.58	51.22	19.70	70.92
6	$N_{25}P_{50}K_{25}$	48.53	15.82	64.35	50.77	17.93	68.70	55.79	22.17	77.96
7	$N_{50}P_{25}K_0$	55.54	16.56	72.10	57.15	18.63	75.78	59.78	22.20	81.98
8	$N_{50}P_0K_{25}$	49.35	15.03	64.38	58.02	18.56	76.58	55.84	18.62	74.46
9	$N_{50}P_{25}K_{25}$	60.34	20.95	81.39	57.18	21.92	79.10	59.00	22.33	81.33
10	$N_{50}P_{12.5}K_{25}$	56.35	15.39	71.74	58.69	18.46	77.15	58.99	20.95	79.94
11	$N_{50}P_{50}K_{25}$	56.87	18.36	75.23	56.82	21.12	77.94	62.12	23.42	85.54
12	$N_{50}P_{25}K_{12.5}$	52.51	13.74	66.25	62.07	20.13	82.20	61.50	23.96	85.46
13	$N_{50}P_{25}K_{50}$	58.80	17.82	76.62	64.51	20.55	85.06	64.25	23.59	87.84
14	$N_{50}P_{12.5}K_{12.5}$	46.30	15.20	61.50	58.62	19.94	78.56	56.50	21.66	78.16
15	$N_{50}P_{50}K_{50}$	62.60	18.89	81.49	66.16	21.58	87.74	64.20	23.06	87.26
16	$N_{50}P_{12.5}K_{50}$	53.95	15.25	69.20	57.27	17.23	74.50	61.77	19.00	80.77
17	$N_{100}P_{25}K_{25}$	60.33	20.69	81.02	65.07	21.66	86.73	65.04	22.91	87.95
18	$N_{100}P_{50}K_{50}$	63.48	23.25	86.73	64.43	24.67	89.10	67.77	27.80	95.57
19	$N_{100}P_{50}K_{25}$	62.86	24.00	86.86	64.34	25.52	89.86	68.92	27.54	96.46
20	$N_{100}P_{25}K_{50}$	57.10	22.31	79.41	66.40	24.84	91.24	69.15	25.08	94.23
21	$N_{100}P_{25}K_{12.5}$	53.47	17.52	70.99	66.06	25.08	91.14	66.10	26.84	92.94
22	$N_{00}P_{00}K_{00}$	25.62	6.74	32.36	27.75	7.98	35.73	33.63	9.99	43.62
23	$N_{00}P_{00}K_{00}$	23.31	5.67	28.98	29.36	9.90	39.26	29.26	10.14	39.40
24	$N_{00}P_{00}K_{00}$	23.58	7.22	30.80	25.59	8.26	33.85	33.12	8.91	42.03
Meanof treated plot		53.61	16.78	70.40	57.99	19.31	77.31	59.61	21.94	81.55
Meanof control plot		24.17	6.54	30.71	27.57	8.71	36.28	32.00	9.68	41.60

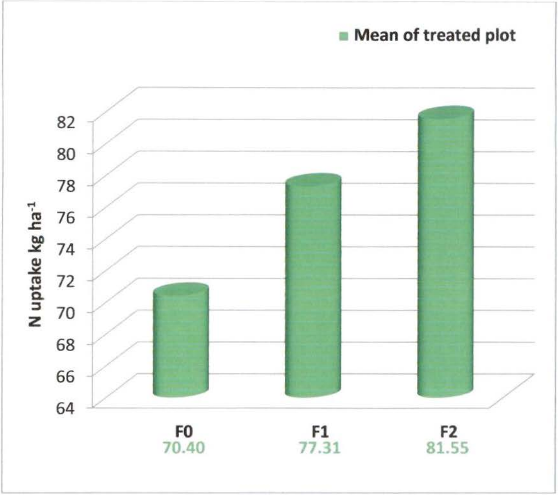


Fig. 7 : Nitrogen uptake by Bt cotton (kg ha^{-1}) as influenced by conjoint use of chemical fertilizers and FYM.

and cotton stalk. Similar observation were also reported earlier by Kumavat *et al.* (2005) and Kote *et al.*(2005). Application of higher dose of N and K in combination increased the nutrient uptake of nitrogen by seed cotton and cotton stalk over lower dose of their combination probably due to grater utilization efficiency of N in presence of adequate K.

Deshmukh *et al.*(2011) also observed that the total nitrogen uptake by Bt cotton was increased by 73.31 per cent with in combination of different NPK levels along with FYM applied @ 10 t ha^{-1} under F_1 block . Due to increased dose of FYM which help in efficient use of applied NPK fertilizers there by increasing uptake of nutrients and improvement in soil physical conditions.

The uptake of N ranged from 43.33 to 66.40 kg ha^{-1} in seed cotton, 12.35 to 25.52 kg ha^{-1} in cotton stalk of F_1 block and the mean total uptake of N in treated plots was 77.31 kg ha^{-1} and that of control plots was 36.28 kg ha^{-1}. In this block also the N uptake increased with the increase in nitrogen application. There was significant response to uptake of N from 56.8 to 77.3 kg ha^{-1} with increased NPK levels from 100% RDF to 150 % RDF(75:37.5:37.5 Kg ha^{-1}), respectively. Increase in uptake of nutrients was because of increasing trend in biological yield with increasing fertilizer levels beyond RDF.(Bhalerao *et al.*, 2012).

The silimar trend in N uptake was observed in F_2 block, but the magnitude of N uptake was more in all the treated and control plots than that of respective F_1 and F_0 blocks. The range of total uptake of N in treated plots of F_2 blocks was 61.47 to 96.46 kg ha^{-1} with a mean value of 81.55 kg ha^{-1}.

The perusal of data in table 15 showed that total N uptake by Bt cotton in treated plots irrespective of fertility gradients and different levels of NPK showed increase from 70.40 kg ha^{-1} (F_0 block) to 77.31 kg ha^{-1} (F_1 block) and further to 81.55 kg ha^{-1}(F_2 block) with 9.81per cent increase in N uptake in treated plots from F_0 to F_1 block and 15.84 per cent increase from F_0 to F_2 block indicating the influence of integrated nutrient management by conjoint use of FYM and chemical fertilizers, However, the increase in uptake from F_1 to F_2 was relatively lower i.e 5.48 per cent indicating that the 5 t ha^{-1} FYM was more helpful to increase the growth of plant and further increase to 10 t ha^{-1} FYM recorded relatively lower response. The balanced supply of NPK and conjuction with FYM was observed to enhance the nitrogen uptake by seed cotton and cotton stalk as compared to treatments of levels of NPK.

In general the uptake of nitrogen was low in F0 block than that of F_1 and F_2 blocks, which was depicted in **fig 7**.This shows that increase in nitrogenous fertilizers with P, K and FYM dose together helped in increasing nitrogen uptake of Bt cotton. Katkar *et al.*(2007) reported that the N uptake were significantly enchanced due to increasing levels of fertilizers along with FYM application in cotton.

The increase in nitrogenous fertilizers with P and K and increase in the FYM dose together helped in increasing nitrogen uptake in Bt cotton. Application of FYM helped in nitrification process resulting in the availability of N from the soil applied N and FYM that eventually helped to register higher and comparable N uptake as that of sole use of nitrogenous fertilizer. Raju *et al.*(2008) reported that the N uptake by rainfed cotton was to the tune of 71.9 kg ha^{-1}, phosphorus 18.1 kg ha^{-1} and potassium 79.5 kg ha^{-1} under the integrated nutrient management treatment. Dhillon *et al.*(2006) also reported that the total N uptake by cotton was to the tune of 93.4 kg ha^{-1} under the application of NPK with vermicompost applied @ 2.5 t ha^{-1}.

4.3.3 Phosphorus concentration

The data in respect of per cent P concentration in seed cotton and cotton stalk are presented in **Appendix II.** The P concentration in seed cotton and cotton stalk increased with increasing levels of phosphorus application. The P concentration in seed cotton ranged from 0.707 to 0.822, the highest being 0.822 per cent in N_{100} P_{50} K_{25} while the P concentration in cotton stalk ranged from 0.239 to 0.307.

In F_1 FYM block (5 t ha^{-1}), P concentration in seed cotton ranged from 0.707 to 0.828 per cent, 0.250 to 0.318 per cent in cotton stalk.

the highest being at higher P level along with N and K application.This increase in P concentration might be due to FYM application and increasing levels of applied N, P and K fertilizers. It indicates that phosphorus take place at the important stages of growth and in the parts of plant. Similar result have been reported by Lalitha Kumari *et al.* (2010) and Dev Raj *et al.* (2007).

The P concentration in F_2 FYM block(10 t ha^{-1}) ranged from 0.730 to 0.828 per cent, 0.261 to 0.329 per cent in seed cotton and cotton stalk, respectively. The mean P concentration of seed cotton and cotton stalk in control plot was 0.667 and 0.254 per cent, respectively. There was an increase in P concentration by 8.15 and 8.84 per cent in seed cotton and 15.81 and 12.86 per cent in stalk cotton in F_1 and F_2 blocks over the F_0 block, but an increase in P concentration in control plots of F_1 and F_2 blocks was 12.50 and 17.13 per cent in cotton stalk, respectively, over the control plots of F_0 block.This increase in P content in control plots of F_1 and F_2 blocks may be attibuted to FYM application which helped in increasing the uptake of native P. Release of organic acids might have helped in solubilising inorganic P which increased the P availability and thereby the concentration of P plants. This clearly indicates the role of FYM in exploiting the acitive P as observed by Mandal *et al.(1979)*. Similar observations regarding increase in P content (0.36 to 0.44%) were recorded by Lalitha kumari *et al.*(2010) and Dhillon *et al.*(2006).

Table 16: **Phosphorus uptake (kg ha^{-1}) by Bt cotton as influenced by conjoint use of chemical fertilizers and FYM** (2011-12)

Sr.No	Treatments NPK, (Kg ha $^{-1}$)	Uptake of P, kg ha^{-1}								
		F_0			F_1			F_2		
		Seed cotton	Cotton stalk	Total uptake	Seed cotton	Cotton stalk	Total uptake	Seed cotton	Cotton stalk	Total uptake
1	$N_0P_{25}K_{25}$	10.54	5.83	16.37	11.61	6.48	18.09	12.15	7.23	19.38
2	$N_{25}P_{25}K_{25}$	12.14	7.02	19.16	13.20	6.90	20.10	13.47	8.37	21.84
3	$N_{25}P_{12.5}K_{12.5}$	11.06	6.83	17.89	13.25	7.05	20.30	13.10	7.52	20.62
4	$N_{25}P_{25}K_{12.5}$	12.45	6.71	19.16	12.37	7.26	19.63	14.18	9.12	23.30
5	$N_{25}P_{12.5}K_{25}$	11.58	6.70	18.28	12.85	6.55	19.40	13.07	7.87	20.94
6	$N_{25}P_{50}K_{25}$	12.82	7.56	20.38	14.30	9.27	23.57	15.76	10.32	26.08
7	$N_{50}P_{25}K_o$	13.66	7.92	21.58	14.59	8.27	22.86	14.99	10.34	25.33
8	$N_{50}P_0K_{25}$	11.99	5.84	17.83	13.76	7.55	21.31	13.84	9.29	23.13
9	$N_{50}P_{25}K_{25}$	15.53	8.89	24.42	14.76	9.12	23.88	15.08	10.04	25.12
10	$N_{50}P_{12.5}K_{25}$	13.84	6.73	20.57	15.23	8.19	23.42	15.17	9.76	24.93
11	$N_{50}P_{50}K_{25}$	15.22	8.15	23.37	15.07	9.50	24.57	16.47	10.26	26.73
12	$N_{50}P_{25}K_{12.5}$	13.52	6.87	20.39	16.41	10.05	26.46	15.60	10.50	26.10
13	$N_{50}P_{25}K_{50}$	14.28	7.83	22.11	16.90	9.57	26.47	16.67	10.71	27.38
14	$N_{50}P_{12.5}K_{12.5}$	11.32	6.18	17.50	15.26	8.93	24.15	15.31	8.81	24.12
15	$N_{50}P_{50}K_{50}$	16.81	9.75	26.56	17.53	10.42	27.95	17.37	10.52	27.89
16	$N_{50}P_{12.5}K_{50}$	13.19	6.70	19.89	14.56	7.71	22.27	16.23	9.17	25.40
17	$N_{100}P_{25}K_{25}$	15.23	9.26	24.49	17.02	10.09	27.11	17.43	10.05	27.48
18	$N_{100}P_{50}K_{50}$	17.17	9.84	27.01	17.32	10.45	27.27	17.98	11.18	29.16
19	$N_{100}P_{50}K_{25}$	16.94	10.16	27.10	17.30	10.81	28.11	18.21	11.07	29.28
20	$N_{100}P_{25}K_{50}$	14.62	9.45	24.07	17.30	10.89	28.19	18.02	11.00	29.02
21	$N_{100}P_{25}K_{12.5}$	13.78	7.84	21.62	17.59	11.00	28.59	17.40	11.57	28.97
22	$N_{00}P_{00}K_{00}$	6.00	4.63	10.63	6.61	4.77	11.38	7.22	5.41	12.63
23	$N_{00}P_{00}K_{00}$	5.45	3.71	9.16	6.73	5.36	12.09	6.90	4.80	11.70
24	$N_{00}P_{00}K_{00}$	5.66	3.68	9.34	6.12	4.27	10.39	7.99	5.03	13.02
Meanof treated plot		13.70	7.72	21.42	15.15	8.86	24.01	15.59	9.75	25.34
Meanof control plot		5.70	4.01	9.71	5.49	4.80	11.29	7.37	5.08	12.45

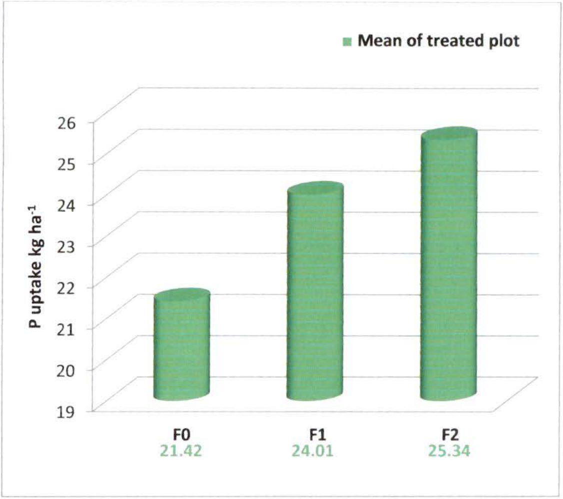


Fig. 8 : Phosphorus uptake by Bt cotton (kg ha^{-1}) as influenced by conjoint use of chemical fertilizers and FYM.

4.3.4 Phosphorus uptake by Bt cotton

A close look to the data presented in table 16 and depicted in **fig 8** indicated that the uptake of phosphorus by seed cotton and cotton stalk increased from F_0 to F_2 blocks. The average uptake of P by seed cotton and cotton stalk in F_0 block was 21.42 kg ha^{-1}, which was increased to 24.01 and 25.34 kg ha^{-1} in F_1 and F_2 blocks, respectively. The total uptake of P by Bt cotton in F_0 block ranged from 16.37 to 27.10 kg ha^{-1} in treated plots and average P uptake in control plots was 9.71 kg ha^{-1}. The data in table16 indicate that an increase in Phosphorus uptake with the increasing doses of Phosphorus fertilizers.

In the F_1 and F_2 blocks similar trend of increase in total P uptake was observed with increase in P fertilizer doses. The range of P uptake in treated plots was 18.09 to 28.59 kg ha^{-1} and 19.38 to 29.28 kg ha^{-1} in F_1 and F_2 blocks, respectively. The average total uptake in treated plot was 24.01 kg ha^{-1} in F_1 block, which increased to 25.34 kg ha^{-1} in F_2 block. This increase in total uptake in treated plots of F_1 block was 12.09 per cent and 18.30 per cent in F_2 block over the F_0 block. However, there was an increase in total P uptake by 16.27 and 28.22 per cent in F_1 and F_2 blocks over F_0 block in the control plots.

An increase in uptake of P with increase in FYM with NPK treatments can be attributed to P solubilization from organic source. A combination of FYM and phosphatic and potassic fertilizer had best effect in increasing organic matter, in the manure blocking specific adsorption sites and formation of organic P compounds in the manure, which are subsequently mineralized when added to the soil. Milap-Chand *et al.(*2004) opined that the effect of nitrogen fertilizer in influencing Phosphorus supply to plants due to better root proliferation and by mining more soil volume.Dhillon *et al.*(2006) reported that P uptake in plant and seed cotton increased with increasing level of fertilizer. Maximum total P uptake (29.7 kg ha^{-1}) was recorded under the treatment consisting N_{80}+P_{30}+vermincompost @1.25 t ha^{-1} and found significantly better over the other treatments. Dev Raj *et al.*(2007) also reported that significantly increased the P uptake from 9.03 to 12.01 kg ha^{-1} with the FYM application @ 5 t ha^{-1} along with levels of NPK fertilizers.

4.3.5 Potassium concentration

The data in respect of per cent K concentration of seed cotton and cotton stalk as influenced by different treatments are presented in **Appendix III.** The per cent K concentration in treated plots of F_0 block ranged from 0.569 to 0.767 in seed cotton, 1.43 to 1.76 per cent in cotton stalk. The mean K concentration of seed cotton and cotton stalk in control plots of F_0 block was 0.489 and 1.443 per cent, respectively. The K concentration in seed cotton and cotton stalk was increased with an increase in the K fertilizer doses.

The K concentration in treated plots of F_1 and F_2 blocks ranged from 0.594 to 0.792 and 0.643 to 0.792 per cent in seed cotton and 1.47 to 1.80 and 1.52 to 1.80 per cent in cotton stalk , respectively. The per cent K concentration in treated plots of F_1 and F_2 blocks increased by 2.28 and 7.09 per cent in seed cotton and 3.11 and 5.59 per cent in cotton stalk, respectively over the treated plots of the F_0 block. The plant nutrient content varied from (1.67 to 1.75 %) of rainfed cotton increased significantly with the increasing fertilizer levels in combination with FYM @ 10 t ha^{-1} application.(Lalitha Kumari *et al.* 2010). Konde (2002) also reported the similar observation regarding increase in the K concentration in straw of soybean due to increase in the doses of chemical fertilizer K and FYM.

4.3.6 Potassium uptake by Bt cotton

The data are presented in table 17 and fig 9 showed that the total uptake of K by Bt cotton increased with increase in K fertilizer doses and also the yields in all the FYM blocks. It is seen that the total uptake of K

Table 17: Potassium uptake (kg ha^{-1}) by Bt cotton as influenced by conjoint use of chemical fertilizers and FYM (2011-12)

Sr. No	Treatments NPK, (Kg ha^{-1})	Uptake of K, kg ha^{-1}								
		F_0			F_1			F_2		
		Seed cotton	Cotton stalk	Total uptake	Seed cotton	Cotton stalk	Total uptak	Seed cotton	Cotton stalk	Total uptak
1	$N_0P_{25}K_{25}$	8.41	35.84	44.25	9.16	38.07	47.33	10.38	40.23	50.61
2	$N_{25}P_{25}K_{25}$	10.54	39.06	49.60	10.86	40.17	51.03	11.95	49.36	61.31
3	$N_{25}P_{12.5}K_{12.5}$	9.21	35.76	44.97	11.50	41.08	52.58	11.10	43.78	54.88
4	$N_{25}P_{25}K_{12.5}$	10.39	39.45	49.84	10.40	40.40	50.80	12.11	46.98	59.09
5	$N_{25}P_{12.5}K_{25}$	10.05	40.75	50.80	11.32	40.38	51.70	11.96	50.76	62.72
6	$N_{25}P_{50}K_{25}$	10.95	44.03	54.98	11.34	46.95	58.29	13.96	57.13	71.09
7	$N_{50}P_{25}K_0$	10.39	43.37	53.76	11.64	46.04	57.68	13.09	53.97	67.06
8	$N_{50}P_0K_{25}$	11.75	37.17	48.90	13.49	50.10	63.59	13.03	50.25	63.28
9	$N_{50}P_{25}K_{25}$	12.86	54.84	67.70	12.61	54.89	67.50	14.79	55.92	70.71
10	$N_{50}P_{12.5}K_{25}$	12.46	45.37	57.83	12.81	51.32	64.13	14.09	52.46	66.55
11	$N_{50}P_{50}K_{25}$	12.07	49.55	61.62	12.70	54.44	67.14	13.89	56.12	70.01
12	$N_{50}P_{25}K_{12.5}$	11.46	41.78	53.24	13.39	55.98	69.37	13.25	54.55	67.80
13	$N_{50}P_{25}K_{50}$	12.75	52.82	65.57	14.13	56.12	70.25	14.98	58.57	73.55
14	$N_{50}P_{12.5}K_{12.5}$	9.36	41.03	50.39	12.84	48.73	61.57	12.52	49.60	62.12
15	$N_{50}P_{50}K_{50}$	15.38	58.15	73.53	16.04	58.99	75.03	16.62	57.26	73.88
16	$N_{50}P_{12.5}K_{50}$	12.66	43.90	56.56	14.50	44.72	59.22	15.58	50.76	66.34
17	$N_{100}P_{25}K_{25}$	13.80	53.69	67.49	14.55	54.56	69.11	16.14	54.04	70.18
18	$N_{100}P_{50}K_{50}$	16.12	56.44	72.56	15.52	61.25	76.77	16.66	63.27	79.93
19	$N_{100}P_{50}K_{25}$	15.29	56.62	71.91	16.50	60.19	76.69	17.00	61.28	78.28
20	$N_{100}P_{25}K_{50}$	13.67	54.15	67.82	17.02	60.30	77.32	17.72	62.28	80.00
21	$N_{100}P_{25}K_{12.5}$	12.38	40.40	52.78	14.72	55.71	70.43	15.41	54.63	70.04
22	$N_{00}P_{00}K_{00}$	4.46	29.20	33.66	5.03	30.31	35.34	5.94	32.86	38.80
23	$N_{00}P_{00}K_{00}$	4.26	25.27	29.53	5.43	31.50	36.93	5.38	29.20	34.58
24	$N_{00}P_{00}K_{00}$	4.34	25.80	30.14	4.86	26.28	31.14	6.46	27.57	34.03
Meanof treated plot		12.00	45.90	57.90	13.19	50.49	63.68	14.10	53.49	67.59
Mean of control plot		4.35	26.76	31.11	5.11	29.36	34.47	5.92	29.88	35.80

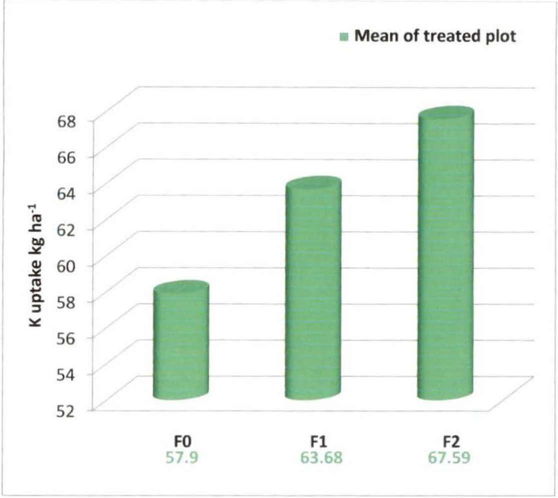


Fig. 9 : Potassium uptake by Bt cotton (kg ha^{-1}) as influenced by conjoint use of chemical fertilizers and FYM.

ranged from 44.25 to 73.53 kg ha^{-1} in treated plot in F_0 block. The average total uptake of K in treated plots in F_0 block was 57.90 kg ha^{-1}, while those of control plots was 31.11 kg $ha^{-1.}$ An increase in total K uptake was observed in F_1 and F_2 blocks which ranged from 47.33 to 77.32 and 50.61 to 80.00 kg ha^{-1} for treated plots, respectively.

The average total uptake of treated plots was 63.68 and 67.59 kg ha^{-1} in F_1 and F_2 blocks, respectively and the average K uptake of control plot in F_1 and F_2 blocks was 34.47 and 35.80 kg ha^{-1}, respectively. The data also indicated that an increase in K uptake in F_1 block by 9.98 per cent in treated plots over the treated plots of F_0 block and in increase by 16.74 per cent in K uptake in the treated plots of F_2 block over the F0 block. The data in table17 revealed that potassium uptake was increased with increase in K fertilizer doses along with increase in N, P and FYM application.

Gadhiya *et al.* (2009) reported that there was an improvement in uptake of K in cotton stalk (50.46 kg ha^{-1}) with increased doses of K from 0 to 80 kg ha^{-1}. Tamgadge *et al.*(2011) also revealed on three year data that application of RD+37.5 kg K_20 ha^{-1} recorded significantly highest uptake of potassium i.e. 71.80 kg ha^{-1} followed by RD+25 kg K_20 ha^{-1} (70.2 kg ha^{-1}) under rainfed cotton in vertisols. Among the major nutrients, average nutrients uptake removal by seed cotton was 44.5 kg N, 28.3 kg P_20_5 and 74.7 kg K_20 per tonne to produce one tonne of economic yield under field condition in India reported by Rao *et al.* (1997). Dev Raj *et al.*(2007) reported that an increase in uptake of K due to increased application of NP and K fertilizers along with FYM applied @ 5 t ha^{-1}. Jagvir Singh *et al.*(2000) also reported that application of FYM @10 t ha^{-1} with recommended dose of NPK in general, increased NPK absorption by the cotton crop and to mineralize in the soil.

Table 18: **Total uptake by Bt cotton (kg ha^{-1}) as influenced by conjoint use of FYM and chemical fertilizers.**

Sr. No	Fertilizers, NPK, kg ha^{-1}	Total N uptake	Total P uptake	Total K uptake
1	$N_oP_{25}K_{25}$	56.07	17.95	47.36
2	$N_{25}P_{25}K_{25}$	64.77	20.37	53.98
3	$N_{25}P_{12.5}K_{12.5}$	62.68	19.60	50.81
4	$N_{25}P_{25}K_{12.5}$	65.94	20.70	53.24
5	$N_{25}P_{12.5}K_{25}$	65.81	19.54	55.07
6	$N_{25}P_{50}K_{25}$	70.34	23.61	61.45
7	$N_{50}P_{25}K_o$	76.62	23.26	59.50
8	$N_{50}P_0K_{25}$	71.81	20.76	58.59
9	$N_{50}P_{25}K_{25}$	80.61	24.47	68.64
10	$N_{50}P_{12.5}K_{25}$	76.28	22.97	62.84
11	$N_{50}P_{50}K_{25}$	79.57	24.89	66.26
12	$N_{50}P_{25}K_{12.5}$	77.97	24.32	63.47
13	$N_{50}P_{25}K_{50}$	83.17	25.32	69.79
14	$N_{50}P_{12.5}K_{12.5}$	72.74	21.92	58.03
15	$N_{50}P_{50}K_{50}$	85.50	27.47	74.15
16	$N_{50}P_{12.5}K_{50}$	74.82	22.52	60.71
17	$N_{100}P_{25}K_{25}$	85.23	26.36	68.93
18	$N_{100}P_{50}K_{50}$	90.47	27.98	76.42
19	$N_{100}P_{50}K_{25}$	91.06	28.16	75.63
20	$N_{100}P_{25}K_{50}$	88.29	27.09	75.05
21	$N_{100}P_{25}K_{12.5}$	85.02	26.39	64.42
22	$N_{00}P_{00}K_{00}$	37.24	11.55	31.60
23	$N_{00}P_{00}K_{00}$	35.88	10.98	29.73
24	$N_{00}P_{00}K_{00}$	35.56	10.92	29.41
Mean of treated plot		76.42	23.60	63.06
Mean of control plot		36.23	11.15	33.79

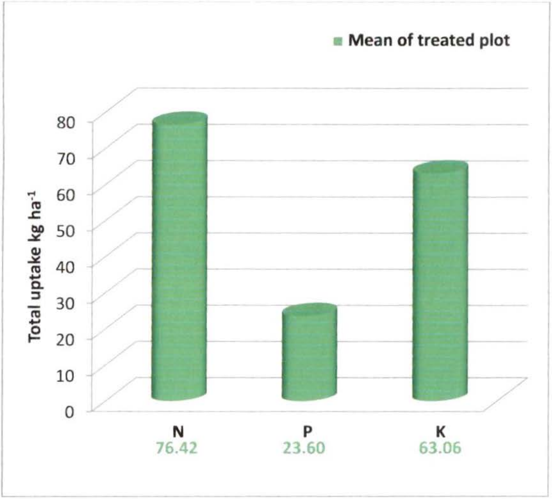


Fig. 10 : Total uptake by Bt cotton (kg ha^{-1}) as influenced by conjoint use of FYM and chemical fertilizers.

The total uptake (table 18, **fig 10**) of nitrogen and phosphorus were higher in seed cotton followed by cotton stalk .However, Potassium uptake was higher in cotton stalk than nitrogen and phosphorus. Similar trend in uptake was reported by Gadhiya *et al*.(2009).

The data in table 18 revealed that potassium uptake as that of N and P was increased with an increase in K fertilizer doses along with nitrogen and phosphorus with increase in FYM application. Similar result have also been reported by Deshmukh *et al*.(2011) and Dave *et al*.(1990).

It is seen that the average total uptake of N ranged from 56.07 to 91.06 kg ha^{-1} in treated plot with mean value 76.42 kg ha^{-1}, while those of mean value of control plots was 36.23 kg ha^{-1}. In case of ,average total uptake of P ranged from 17.95 to 28.16 kg ha^{-1} in treated plot with mean value 23.60 kg ha^{-1} , while those of mean value of control plots was 11.15 kg ha^{-1}. and average total uptake of K ranged from 47.36 to 76.42 kg ha^{-1} in treated plot with mean value 63.06 kg ha^{-1} , while those of mean value of control plots was 33.79 kg ha^{-1}.

4.4 Soil test crop response correlation for yield targeting in Bt cotton (yield prediction of Bt cotton)

In multiple regression analysis more than one factor are utilized for developing a relationship that affect the yield and therefore, it is supposed to be more realistic than linear relationship. Different types of functions viz., quadratic, square root, are employed for developing regression equations depending upon the nature of the data. To express natural processes like crop growth, generally quadratic type of function has been found to be superior to other functions as it gives the closest possible fit to the experiment data as revealed by the highest R^2 values (Willcox, 1954). This model also provides a practical estimate of the nutrient level and plant growth relationship, because it reaches "Y" maximum equal to 100 with increasing levels of inputs of other experimental models, there is no decrease on the curve (Peck *et al.*,1976). The performance of this model was also reported by Bangar (1991).

In the present investigation the data on Bt cotton yield, soil and fertilizer nutrients from 63 treated plots have been utilized for fitting multiple regression equations based on quadratic function.

4. 4.1 Basic parameters

The data generated during the field experimentation were used for calculating the nutrient requirement (in kg/quintal of Bt cotton), per cent contribution of nutrients from soil and per cent contribution of nutrients from applied fertilizer for the production of Bt cotton. These parameters are calculated as per the principle and methodology prescribed by All India Co-ordinated Project on Soil Test Crop Response Correlation Studies, ICAR, New Delhi.

The average nutrient requirement to produce one quintal of Bt cotton were worked out together with per cent contribution of individual nutrient from the soil and also from applied fertilizer nutrients has been worked out and presented in table19.

Table 19: Basic data for Bt cotton

Parameters	**Major Nutrients**		
	N	**P**	**K**
NR, kg q^{-1}	3.11	0.92	2.60
CS,%	17.51	60.30	4.77
	Without FYM		
CF,%	32.68	14.70	66.76
	With FYM		
CF,%	37.20	15.50	78.9
CFYM,%	4.7	1.4	1.5

4.4.2 Nutrient requirement of Bt cotton (Whole field method)

The data in respect of nutrient requirement of Bt cotton is presented in table19. It could be seen from the result of the present investigation that for production of one quintal of seed cotton yield of Bt , nutrient required were 3.11 kg N, 0.92 kg P and 2.60 kg K, indicating that N requirement of Bt cotton was highest followed by K and least in case of P. STCR studies on rapeseed reported that for the production of one tonne rapeseed nutrient required were 43.7, 9.7 and 37.9 kg N, P and K nutrient, respectively (Milap-Chand *et al.*, 2006) .Yadav *et al.(*2009) also conducted STCR correlation studies with pearl millet (Var RBH-121) under integrated plant nutrition system(STCR-IPNS) during kharif 2007, he reported that the nutrient requirement for producing one quintal of pearl millet was found to be 3.08, 1.49 and 5.18 kg N, P_20_5 and K_20, respectively. Kausadikar *et al.* (2003) reported that for production of one tonne of soybean seed yield, nutrient required were 7.8 kg N, 0.92 kg P_20_5 and 4.5 kg K_20.

4.4.3 Per cent contribution from soil

The data on per cent contribution from soil to seed cotton yield of Bt is given in table 19. The per cent contribution from soil in respect of N for Bt cotton 17.51 per cent, for phosphorus it was 60.30 per cent and for potassium 4.77 percent. It is apparent from the result that the per cent contribution from soil in respect of phosphorus was higher as compare to N and K, this might be due to addition of FYM which might have helped in increasing the solubility of phosphorus in soil which resulted by better sorption of P nutrient. The result in present investigation is in close consonance with the results reported earlier by Bangar (2001). He reported that the contribution from soil 11.41, 43.09 and 2.91 per cent for N, P and K, respectively while working on sorghum crop. Subba Rao et al.(1999) reported that the per cent efficiencies of soil, fertilizer and FYM to contribute N to cotton are 18.4, 37.0 and 30.6, respectively. Gulati *et al.*(2009) conducted STCR correlation studies with mustard under integrated plant nutrient system(STCR-IPNS) during rabi 2007-08, he reported that the per cent nutrient utilization efficiencies from soil were found to be 20.08, 28.15 and 8.65 for N, P_20_5 and K_20, respectively.

4.4.4 Per cent contribution from fertilizers

The data in respect of per cent contribution of N, P and K from applied fertilizer to rainfed Bt cotton is presented in table19. It could be seen from the results that the per cent contribution from applied fertilizer was found to be 32.68, 14.70 and 66.76 in respect of N, P and K, respectively.

The estimated contribution from fertilizer clearly revealed the fact that the magnitude of contribution by fertilizer K_20 was 4.5 times higher than P_20_5 and twice as that of N. With regards to N and K_20, comparatively more contribution was recorded from fertilizers than from the soil. However, in case of P_20_5 , the contribution was more from soil than from fertilizer.The application of N at important stage of crop growth with sufficient moisture resulted better utilization of applied N, which also indicated by the relatively higher response ratio recorded for fertilizer N than P_20_5.These observations of the present investigation are in close agreement with those reported earlier by Santhi *et al.*(2010). Perusal of the data indicates that the fertilizer nitrogen was found to be more efficient (32.68 %) as compared to that of soil available nitrogen towards the seed cotton yield of Bt. The higher contribution of fertilizer nitrogen might be due to its water soluble nature, mobile and readily available. In respect of phosphorus fertilizer, phosphorus was comparatively less efficient in contributing phosphorus (14.70%) to the seed cotton production when compared with that of soil available phosphorus (60.30%). Similar observations were also reported by Yadav *et al.*,(2009). It reported that the per cent nutrient utilization efficiencies for pearl millet from fertilizer nutrient were found to be 43.83 for N, 16.09 for P_20_5 and 66.78 for K_20.

The potassium contribution from applied fertilizer was found to be higher (66.76%) as compared to the soil available K (4.77%). These results of present investigation are in conformity with the findings of Puri *et al.*(2009).

4.4.5 Per cent contribution from fertilizer in presence of FYM

The per cent contribution from fertilizer in presence of FYM was increased. The data presented in table 19 showed that, the contribution from fertilizer was increased from 32.68 to 37.20 per cent in N, 14.70 to 15.50 per cent in presence of P and 66.76 to 78.90 per cent K in presence of FYM. The data on contribution from without FYM and FYM revealed that the contribution of nutrients preferably N was higher from the combined addition of FYM and inorganic fertilizers rather than applying alone. In combine addition, the FYM would have provided enough carbon,the source of energy for build-up of bacterial population, physical and chemical condition, nutrient availability, which in turn would have enchanced the contribution of N. The finding are in close conformity with those reported by Santhi *et al.*(2002). The contribution of fertilizers in respect of P and K may be accounted for priming effect i.e. by application of fertilizer NPK in combination with FYM, hence, the more and more nutrients brought into available pool and hence more uptake and more contribution from the fertilizers (Venkateshwarlu, 1976).

4.4.6 Nutrient contribution from FYM

The integration of organic and chemical fertilizers leads to built up of soil fertility increasing production and concomitant care of nutrient balances in soil.

In respect of per cent contribution of FYM, the data presented in table19 revealed that, the contribution of N, P and K were 4.7, 1.4 and 1.5 per cent, respectively.

The fertilizer coefficients were 0.73, 0.30 and 0.11 for N, P_20_5 and K_20, respectively. The coefficient when multiplied by tonnes of FYM gives the contribution of nutrient from FYM and this value when deducted from the equation, the reduced dose of chemical fertilizer is computed as the contribution from the fertilizer (CF) and from FYM is taken into account.

4.4.7 Fertilizer prescription equations for yield targeting in Bt cotton

The basic data for Bt cotton by using chemical fertilizers with and without FYM (table19) were transformed with the help of NR (kg q^{-1}), CS (%), CF (%) and CFYM (%) coefficients into workable fertilizer adjustment equations for different yield targets based on soil test values and are given below.

1. Without FYM (Use of chemical fertilizers alone)

$FN = 9.53\ T - 0.38\ SN$

$FP_2O_5 = 6.26\ T - 2.66\ SP$

$FK_2O = 3.89\ T - 0.07\ SK$

Where, F and S indicate the fertilizer and soil nutrients, respectively (kg ha^{-1}) and T indicates yield target (q ha^{-1}).

2. With FYM (Conjoint use of chemical fertilizers and FYM)

$FN = 9.67\ T - 0.51\ SN - 0.73\ FYM$

$FP_2O_5 = 6.83\ T - 3.89\ SP -- 0.30\ FYM$

$FK_2O = 3.29\ T - 0.06\ SK - 0.11\ FYM$

Where, FN, FP_2O_5 and FK_2O is fertilizer N, P_2O_5 and K_2O in kg ha^{-1}, T is yield target in q ha^{-1} and SN, SP and SK are soil available N, P and K, kg ha^{-1} and FYM is Farm Yard manure in t ha^{-1}

These relationships were further used to compute fertilizer dose for different yield targets of rainfed Bt cotton and varying soil test values. Ready reckoners were prepared for fertilizer N, P_2O_5 and K_2O requirements and presented in table 20, 21 and 22 for sole use of chemical fertilizer and in table 23, 24 and 25 for conjoint use of organic manure and chemical fertilizers.

4.4.8 Multiple regression equation for rainfed Bt cotton

Yield predictions from soil NPK, fertilizer NPK, FYM and interactions were derived separately for treated and control plots and are given below

Multiple regression equation for treated plots

$$Y = 1497.96 + 0.070095\ FN^{**} - 0.000247\ FN^2 + 0.086644\ FP^{*} - 0.000897\ FP^2 + 0.104350\ FK^{*} - 0.001245\ FK^{2*} - 0.807798\ SN + 0.002241\ SN^2 + 6.235900\ SP - 0.185916\ SP^2 - 5.091112\ SK^{**} + 0.00441\ SK^2 - 0.2274495\ FNSN - 0.42889\ FPSP - 0.108644\ FKSK + 0.332095\ FYM^{**} - 0.014366\ FYM^2$$

$R^2 = 0.895$

Multiple regression equation for control plots

$$Y = -93.46106 + 0.260545\ SN + 2.34020\ SP^{*} + 0.200264\ SK^{*} - 0.000813\ SN^2 - 0.059608\ SP^{2*} - 0.0001678\ SK^{2*}$$

*Significance at 5%, **Significance at 1% **$R^2 = 0.98$**

Where SN, SP and SK are soil available NPK, kg ha^{-1} in control plots and Y is yield in q ha^{-1}.

A significant value of coefficient of determination of R^2 (0.89 **) value indicated that the variation in the yield of the treated plots is significantly depending upon the available nutrient in the soil in presence of applied fertilizer nutrients. The data obtained from the equation and the R^2 value (0.89 **), the assorted treatments for 0-20 cm depth indicate that 89 per cent variation in seed cotton yield of Bt cotton obtained by using soil test values, fertilizer dose and FYM. This also suggests a scope for explaining the factors other than the soil test values, fertilizer doses, FYM, which affect the seed cotton yield.The R^2 value of 0.895** indicated good fit for multiple regression equations. Bangar(1990) reported that R^2 values for multiple regression equations above 0.66 indicated good fit, 0.65 to 0.45 as moderate fit and below 0.45 as poor fit. R^2 value of 0.83 was reported in the regression studies to develop the yield targeting equation for onion(Mohammad Sajid, 2007). Similarly, R^2 values of 0.99 , 0.86 were also reported by Kadam(1999) for onion and Konde(2002) for soybean.

4.4.9 Nutrient requirement of Bt cotton for different yield target and soil test values

The fertilizer adjustment equations computed for prescription of fertilizer dose were used to calculate fertilizer requirement of Bt cotton for different yield targets in the form of ready reckoners presented in Table 20, 21 and 22 for application of sole use of chemical fertilizers and in table 23, 24 and 25 for conjoint use of chemical fertilizers and FYM.

From the equations for sole use of chemical fertilizer (table 20, 21 and 22), it could be seen from these ready recknoers that for 20 q ha^{-1} yield target of seed cotton yield of Bt with soil test values of 200 kg N, 20 kg P_20_5 and 300 K_20 ha^{-1} requires 114.60, 72.00 and 56.80 kg ha^{-1} N, P_20_5 and K_20, respectively. But with the conjoint use of FYM and chemical fertilizer (table 23, 24 and 25) for the same yield target and soil test values, the nutrient requirement comes to 87.75 kg N, 57.30 kg P_20_5 and 47.25 kg K_20 ha^{-1}. Thus about 26.85 kg N ha^{-1}, 14.70 kg P_20_5 ha^{-1} and 9.55 kg K_20 ha^{-1} can be saving of fertilizer by combine use of FYM and inorganic fertilizers over sole use of chemical fertilizer (table 26).

Wheareas,for 15 q ha^{-1} yield target of seed cotton yield of Bt with soil test values of 200 kg N, 20 kg P_20_5 and 300 K_20 ha^{-1} requires 66.95, 40.70 and 37.35 kg ha^{-1} N, P_20_5 and K_20, respectively. But with the conjoint use of FYM and chemical fertilizer (table 23, 24 and 25) for the same yield target and soil test values, the nutrient requirement comes to 39.40 kg N, 23.15 kg P_20_5 and 30.80 kg K_20 ha^{-1}. Thus about 27.55 kg N ha^{-1}, 17.55 kg P_20_5 ha^{-1} and 6.55 kg K_20 ha^{-1} can be saving of fertilizer by combine use of FYM and inorganic fertilizers over sole use of chemical fertilizer (table 26).

Table 20: Nitrogen requirement (kg ha^{-1}) of Bt cotton under sole use of chemical fertilizers as per the N status of soil

Sr. No.	Soil available N Kg ha^{-1}	Nitrogen requirement (kg ha^{-1})	
		Yield target (q ha^{-1}) 15	Yield target (q ha^{-1}) 20
1	120	97.35	145.00
2	130	93.55	141.20
3	140	89.75	137.40
4	150	85.95	133.60
5	160	82.15	129.80
6	170	78.35	126.00
7	180	74.55	122.20
8	190	70.75	118.40
9	200	66.95	114.60
10	210	63.15	110.80
11	220	59.35	107.00
12	230	55.55	103.20
13	240	51.75	99.40
14	250	47.95	95.60
15	260	44.15	91.80

Table 21: Phosphorus requirement (kg ha^{-1}) of Bt cotton under sole use of chemical fertilizers as per the P status of soil

Sr. No.	Soil available P Kg ha^{-1}	Phosphorus requirement (kg ha^{-1})	
		Yield target (q ha^{-1}) 15	Yield target (q ha^{-1}) 20
1	10	67.30	98.60
2	11	64.64	95.94
3	12	61.98	93.28
4	13	59.32	90.62
5	14	56.66	87.96
6	15	54.00	85.30
7	16	51.34	82.64
8	17	48.68	79.98
9	18	46.02	77.32
10	19	43.36	74.66
11	20	40.70	72.00
12	21	38.04	69.34
13	22	35.38	66.68
14	23	32.72	64.02
15	24	30.06	61.36

Table 22: Potassium requirement (kg ha^{-1}) of Bt cotton under sole use of chemical fertilizers as per the K status of soil

Sr. No.	Soil available K Kg ha^{-1}	Potassium requirement (kg ha^{-1})	
		Yield target (q ha^{-1}) 15	Yield target (q ha^{-1}) 20
1	100	51.35	70.80
2	120	49.95	69.40
3	140	48.55	68.00
4	160	47.15	66.60
5	180	45.75	65.20
6	200	44.35	63.80
7	220	42.95	62.40
8	240	41.55	61.00
9	260	40.15	59.60
10	280	38.75	58.20
11	300	37.35	56.80
12	320	35.95	55.40
13	340	34.55	54.00
14	360	33.15	52.60
15	380	31.75	51.20

Table 23: Nitrogen requirement (kg ha^{-1}) of Bt cotton under conjoint use of FYM and chemical fertilizers as per the N status of soil

Sr. No.	Soil available N Kg ha^{-1}	Nitrogen requirement (kg ha^{-1})	
		Yield target (q ha^{-1}) 15	Yield target (q ha^{-1}) 20
1	100	90.40	138.75
2	120	80.20	128.55
3	140	70.00	118.35
4	160	59.80	108.15
5	180	49.60	97.95
6	200	39.40	87.75
7	220	29.20	77.55
8	240	19.00	67.35
9	260	8.80	57.15
10	280	-1.40	46.95
11	300	-11.60	36.75
12	320	-21.80	26.55
13	340	-32.00	16.35
14	360	-42.20	6.15
15	380	-52.40	-4.05

Table 24: **Phosphorus requirement (kg ha^{-1}) of Bt cotton under conjoint use of FYM and chemical fertilizers as per the P status of soil**

Sr. No.	Soil available P Kg ha^{-1}	Phosphorus requirement (kg ha^{-1})	
		Yield target (q ha^{-}) 15	Yield target (q ha^{-1}) 20
1	10	62.05	96.20
2	11	58.16	92.31
3	12	54.27	88.42
4	13	50.38	84.53
5	14	46.49	80.64
6	15	42.60	76.75
7	16	38.71	72.86
8	17	34.82	68.97
9	18	30.93	65.08
10	19	27.04	61.19
11	20	23.15	57.30
12	21	19.26	53.41
13	22	15.37	49.52
14	23	11.48	45.63
15	24	7.59	41.74

Table 25: Potassium requirement (kg ha^{-1}) of Bt cotton under conjoint use of FYM and chemical fertilizers as per the K status of soil

Sr. No.	Soil available K Kg ha^{-1}	Potassium requirement (kg ha^{-1})	
		Yield target (q ha^{-1}) 15	Yield target (q ha^{-1}) 20
1	100	42.80	59.25
2	120	41.60	58.05
3	140	40.40	56.85
4	160	39.20	55.65
5	180	38.00	54.45
6	200	36.80	53.25
7	220	35.60	52.05
8	240	34.40	50.85
9	260	33.20	49.65
10	280	32.00	48.45
11	300	30.80	47.25
12	320	29.60	46.05
13	340	28.40	44.85
14	360	27.20	43.65
15	380	26.00	42.45

Table 26: Saving in chemical fertilizers by using STCR-IPNS fertilizer prescription equation

Soil test value : N-200, P-20, K-300 kg ha^{-1}

Yield target : 15 q ha^{-1} and 20 q ha^{-1}

Yield target (15 q ha^{-1})		
	Without FYM (Chemical fertilizer alone)	With FYM (STCR-IPNS)
Fertilizer prescription STCR equation (kg ha^{-1})	N : P_2O_5 : K_2O 66.95 : 40.70 : 37.35	N : P_2O_5 : K_2O 39.40 : 23.15 : 30.80
Saving of chemical fertilizer (kg ha^{-1})		N : P_2O_5 : K_2O 27.55 : 17.55 : 6.55
Total Cost	Rs. 3,996/-	Rs. 13,573/-
Saving of chemical fertilizer		Rs. 1,432/-

Yield target (20 q ha^{-1})		
	Without FYM (Chemical fertilizer alone)	With FYM (STCR-IPNS)
Fertilizer prescription STCR equation(kg ha^{-1})	N : P_2O_5 : K_2O 114.60 : 72.00 : 56.80	N : P_2O_5 : K_2O 87.75 : 57.30 : 47.25
Saving of chemical fertilizer (kg ha^{-1})		N : P_2O_5 : K_2O 26.85 : 14.70 : 9.55
Total Cost	Rs.6,760	Rs. 16,396/-
Saving of chemical fertilizer		Rs. 1,364/-

N 27.55 kg ha^{-1} = 60 kg Urea
P 17.55 kg ha^{-1} = 110 kg SSP
K 6.55 kg ha^{-1} = 11 kg MOP

Cost of Urea @ Rs.5.96, SSP @ Rs. 8.00 & MOP @ Rs. 17.24 kg^{-1}
FYM @ Rs.2200 $tonne^{-1}$

The total cost of chemical fertilizers required as per the equation based on use of only chemical fertilizers for yield target of 15 q ha^{-1} and 20 q ha^{-1} comes out to Rs. 3,996/- and Rs. 6,760/-, respectively (table 26). The IPNS based equation use of FYM @ 5 t ha^{-1} was found to be Rs.13,573/-and Rs.16,396/- for 15 and 20 q ha^{-1}, respectively.which reduce the chemical fertilizer by Rs.1,432/- under yield target 15 q ha^{-1} and Rs.1,364/- under yield target 20 q ha^{-1}. It thus become clear that the use of FYM can be advantageously used for reducing the cost on chemical fertilizers and the on farm available crop residues and waste can be used by the farmers for preparation of FYM in order to substitute partially the considerable quantity of chemical fertilizers.Besides this the residual effect of FYM over the succeeding years and the enhancement in soil qualities is the added advantage in addition to supply of nutrient to the crop.Thus it becomes apparent that the organics added as per the IPNS based equation need to be viewed in respect of their role as a soil conditioner in spite of nutrient supply.

Apart from saving in fertilizer requirement and additional advantage of organics is for improvement in soil physical, chemical and microbiological properties of soils is of great significance reported by Gaur *et al.*(1984). It is evident from the data that the fertilizer N, P_20_5 and K_20 requirements decreased with increase in soil test values. The finding are in close conformity with those reported by santhi et al.(2002). Similar observation was also reported earlier by Konde (2002).The considerable saving in fertilizers by using IPNS based STCR equation for banana has also been reported by Panchbhai (2010). Conjoint use of manure and chemical fertilizers for additional benefit and improvement in yield can be recommended to the cultivators by the targeted yield concept.

It was observed that for a given soil test values the quantity of nutrients required increased as the target was increased. The nutrient required also increased along with the decrease in available nutrients.

The recommended dose of fertilizer to Bt cotton by Dr. PDKV, Akola is 60:30:30 NPK kg ha^{-1}. The nutrient requirement of Bt cotton as per fertilizer prescription equation for yield target of 15 comes to 66.95, 40.70 and 37.35 NPK kg ha^{-1} for generalized soil test values (200:20:300 NPK kg ha^{-1}) which is slightly higher as compared to the recommended dose of chemical fertilizer to rainfed Bt cotton. This nutrient requirementis reduced to 39.40 kg N, 23.15 kg P_20_5 and 30.80 kg K_20 ha^{-1} after using STCR-IPNS equation thus indicating a saving of 27.55 kg N, 17.55 Kg P_20_5 and 6.55 kg K_20 ha^{-1} fertilizer nutrients(table26) which can significantly reduce the cost on chemical fertilizers.

It would be more prudent approach for fertilizer prescription to Bt cotton if the soil test crop response correlation based fertilizer prescription equation developed in present study are used since the nutrient requirement is derived here taking into account the soil nutrient status as well as the plant need considering the efficiency of nutrient contribution from soil, fertilizer and FYM. Accordingly the fertilizer dose comes out to 66.95, 40.70 and 37.35 NPK kg ha^{-1} for generalized soil test values (200:20:300 NPK kg ha^{-1}). It was thus observed that by considering the commonly observed soil test values of Vertisol in the study area the fertilizer dose prescribed here is comparable to the recommended dose of fertilizer (RDF). This suggests that the fertilizer prescription equations can be used for the soils of varying fertility status for obtaining the variable yield target of Bt cotton depending upon the resources of the farmer.

The nutrient requirement in kg ha^{-1} for yield target of 15 q ha^{-1} comes to 66.95, 40.70 and 37.35 NPK kg ha^{-1}which is slightly higher as compared to the recommended dose of chemical fertilizers to the rainfed Bt cotton. The nutrient requirement based on fertilizer prescription equation seems to be more appropriate in respect of reduction in chemical fertilizers and more realistic as compared to general recommended dose of fertilizers since it takes into account the soil and plant nutrients, thus implying its suitability for site specific nutrient management.

4. 5 Major nutrient concentration at square formation and 50 per cent flowering stage by rainfed Bt cotton

The data pertaining to the nutrient concentration at square formation and 50 per cenr flowering stage as influenced by different levels of chemical fertilizers and FYM are presented in table 27 and 28, the data reveals that, the NPK concentration was variable in different chemical fertilizer levels and FYM . The major nutrient concentration (NPK) at square formation stage by rainfed Bt cotton as influenced by different inorganic fertilizers and FYM blocks are depicted in **Appendix IV, V and VI**

On perusal of the data in table 27, the mean N concentration at square formation stage in treated plots ranged from 1.620 to 1.847 with a mean value of 1.771 where as in mean value under control was 1.587. For the value of P and K concentration in treated plots ranged from 0.670 to 0.709 and 1.936 to 2.077 with a mean value of 0.694 and 2.003, respectively. The mean value of concentration of P and K under control plots becomes 0.665 and 1.797, respectively. The concentration of nutrients found gradually increased with increase in application of inorganic fertilizers and FYM. The highest concentration of N (1.847 %) and P(0.709%) at square formation stage was observed under $N_{100}P_{50}$ K_{25} where as K registerd under $N_{100}P_{25}K_{50}$, indicating that the N concentration increased with increase in nitrogenous fertilizer along with phosphorus and potassium. Similar trend of N concentration (3.00%) of cotton with an increase in 150% RDF was recorded earlier by Lalitha Kumari *et al.*(2010). Application of high levels of K increased the content of the plant and thereby Nuptake (Krishnan and Lourdraj,1997).The increase in N concentration increased with the application of FYM which may be due to better mineralization of nitrogen. Krishnan and Lourdraj (1997) recorded similar observation at square formation and peak flowering stage of cotton, he further resulted the total uptake of nutrient in cotton at square formation and peak flowering stage.

Table 27: **Nutrient concentration (%) in Bt cotton at square formation stage as influenced by conjoint use of chemical fertilizers and FYM**

Sr. No.	Treatments NPK, Kg ha^{-1}	Nutrient concentration (%)		
		N	P	K
1	$N_0P_{25}K_{25}$	1.620	0.680	1.955
2	$N_{25}P_{25}K_{25}$	1.747	0.691	1.980
3	$N_{25}P_{12.5}K_{12.5}$	1.666	0.686	1.967
4	$N_{25}P_{25}K_{12.5}$	1.729	0.694	1.961
5	$N_{25}P_{12.5}K_{25}$	1.693	0.670	1.973
6	$N_{25}P_{50}K_{25}$	1.756	0.709	1.986
7	$N_{50}P_{25}K_0$	1.720	0.691	1.936
8	$N_{50}P_0K_{25}$	1.693	0.683	1.936
9	$N_{50}P_{25}K_{25}$	1.783	0.701	1.998
10	$N_{50}P_{12.5}K_{25}$	1.793	0.678	1.992
11	$N_{50}P_{50}K_{25}$	1.810	0.709	2.042
12	$N_{50}P_{25}K_{12.5}$	1.811	0.694	1.986
13	$N_{50}P_{25}K_{50}$	1.811	0.701	2.054
14	$N_{50}P_{12.5}K_{12.5}$	1.801	0.678	1.974
15	$N_{50}P_{50}K_{50}$	1.847	0.708	2.042
16	$N_{50}P_{12.5}K_{50}$	1.783	0.683	2.047
17	$N_{100}P_{25}K_{25}$	1.801	0.696	2.069
18	$N_{100}P_{50}K_{50}$	1.838	0.701	2.048
19	$N_{100}P_{50}K_{25}$	1.847	0.709	2.044
20	$N_{100}P_{25}K_{50}$	1.801	0.704	2.077
21	$N_{100}P_{25}K_{12.5}$	1.838	0.704	2.017
22	$N_{00}P_{00}K_{00}$	1.593	0.667	1.793
23	$N_{00}P_{00}K_{00}$	1.575	0.667	1.799
24	$N_{00}P_{00}K_{00}$	1.593	0.663	1.800
Mean of treated plots		1.771	0.694	2.003
Mean of control plots		1.587	0.665	1.797

The data pertaining to the nutrient concentration at 50 per cent flowering stage as influenced by different levels of chemical fertilizers and FYM is presented in table 28, the data reveals that, the NPK concentration was variable in different chemical fertilizer and FYM levels . The major nutrient concentration at 50 per cent flowering stage by rainfed Bt cotton as influenced by different inorganic fertilizers and FYM blocks are depicted in **Appendix VII, VIII and IX.**

On perusal of the data in Table 28, the mean N concentration at 50 per cent flowering stage in treated plots ranged from 1.327 to 1.552 with a mean value of 1.472 where as in mean value under control was 1.366. For the value of P and K concentration in treated plots ranged from 0.523 to 0.564 and 1.791 to 2.013 with a mean value of treated plots 0.538 and 1.900, respectively. The mean value of concentration of P and K under control plots becomes 0.495 and 1.661, respectively. The concentration of nutrients found gradually increased with increase in application of inorganic fertilizers and FYM. The highest concentration of N (1.552 %) at 50 per cent flowering stage was observed under $N_{100}P_{50}K_{25}$, indicating that the N concentration increased with increase in nitrogenous fertilizer. Similar trend of N concentration (3.00%) of cotton with an increase in 150% RDF was recorded earlier by Lalitha Kumari *et al.*,(2010). The increase in N concentration increased with the application of FYM which may be due to better mineralization of nitrogen.

Table 28: **Nutrient concentration (%) in Bt cotton at 50 per cent flowering stage as influenced by conjoint use of chemical fertilizers and FYM**

Sr. No.	Treatments NPK, Kg ha^{-1}	Nutrient concentration (%)		
		N	P	K
1	$N_0P_{25}K_{25}$	1.327	0.523	1.791
2	$N_{25}P_{25}K_{25}$	1.444	0.533	1.824
3	$N_{25}P_{12.5}K_{12.5}$	1.372	0.526	1.792
4	$N_{25}P_{25}K_{12.5}$	1.435	0.542	1.791
5	$N_{25}P_{12.5}K_{25}$	1.417	0.523	1.850
6	$N_{25}P_{50}K_{25}$	1.471	0.556	1.856
7	$N_{50}P_{25}K_0$	1.426	0.538	1.791
8	$N_{50}P_0K_{25}$	1.426	0.510	1.856
9	$N_{50}P_{25}K_{25}$	1.489	0.543	1.889
10	$N_{50}P_{12.5}K_{25}$	1.444	0.517	1.889
11	$N_{50}P_{50}K_{25}$	1.462	0.560	1.955
12	$N_{50}P_{25}K_{12.5}$	1.507	0.526	1.935
13	$N_{50}P_{25}K_{50}$	1.507	0.560	2.013
14	$N_{50}P_{12.5}K_{12.5}$	1.489	0.517	1.903
15	$N_{50}P_{50}K_{50}$	1.525	0.564	1.994
16	$N_{50}P_{12.5}K_{50}$	1.489	0.515	1.962
17	$N_{100}P_{25}K_{25}$	1.534	0.551	1.955
18	$N_{100}P_{50}K_{50}$	1.534	0.553	1.994
19	$N_{100}P_{50}K_{25}$	1.552	0.559	1.981
20	$N_{100}P_{25}K_{50}$	1.543	0.545	1.994
21	$N_{100}P_{25}K_{12.5}$	1.534	0.526	1.896
22	$N_{00}P_{00}K_{00}$	1.354	0.492	1.667
23	$N_{00}P_{00}K_{00}$	1.363	0.497	1.661
24	$N_{00}P_{00}K_{00}$	1.381	0.496	1.654
Mean of treated plots		1.472	0.538	1.900
Mean of control plots		1.366	0.495	1.661

4.6 Effect of FYM and chemical fertilizers on chemical properties of soil after pickings of Bt cotton

The data pertaining to the fertility status of soil as influenced by different levels of chemical fertilizers and FYM presented in (table 29.30 and 31), the data reveals that, the available NPK status was variable in different fertility gradient and FYM strips (**Fig 11, 12 and 13).** However, it was observed that, it relatively better under the conjoint use of chemical fertilizers and FYM.

It was observed an increase in available N, P and K status of soil to the tune of 6.88, 11.71 and 9.38 in F_1 block and 12.75, 22.72 and 17.19 per cent in F_2 block of treated plots, respectively over treated plots of F_0 block. Similarly, an increase in available N, P and K status of soil to the tune of 3.58, 21.28 and 13.96 in F_1 block and 6.62, 31.88 and 18.40 per cent in F_2 block of control plots, respectively over control plots of F_0 block.

The available N status of soil ranged from 175.6 to 220.8, 183.2 to 235.8 and 195.7 to 238.3 kg ha^{-1} and mean of available N status in treated plots was 197.6, 211.2 and 222.8 kg ha^{-1} in F_0, F_1 and F_2 blocks, respectively and that of control plots was 164.7,170.6 and 175.6 kg ha^{-1} in F_0, F_1 and F_2 blocks, respectively. There was an increase in available N status of soil in F_1 and F_2 blocks than F_0 block. This shows the beneficial effect of FYM in increasing the fertility status of soil. More *et al.*(2003) reported that the highest available N was recorded (255 kg ha^{-1}) with integrated nutrient supply system comprising NPK 80:40:40 kg ha^{-1} along with organic source FYM applied @12.5 t ha^{-1} at the end of experimentation over initial value (210 kg ha^{-1}). Das *et al.(*2006) reported that the available N in soil after harvest of cotton crop were recorded 224.6 kg ha^{-1} in control plot, 234.2 kg ha^{-1} in 60 kg N ha^{-1} and 240.7 kg ha^{-1} in FYM applied @12 t ha^{-1}. Dev Raj *et al.* (2007) reported that the application of FYM , the available nutrient status in post harvest soil was slightly more than without FYM application.

Table 29: Chemical properties of soil after picking of Bt cotton (F0 block) as influenced by conjoint use of chemical fertilizers and FYM

Sr. No.	Treatments NPK,(Kgha^{-1})	pH	EC dSm^{-1}	OC, g kg^{-1}	Available N, kg ha^{-1}	Available P, kg ha^{-1}	Available K, kg ha^{-1}
1	$N_oP_{25}K_{25}$	8.34	0.24	5.20	175.6	16.91	526.4
2	$N_{25}P_{25}K_{25}$	8.28	0.26	5.39	180.6	18.47	537.6
3	$N_{25}P_{12.5}K_{12.5}$	8.22	0.27	5.05	180.6	18.16	537.6
4	$N_{25}P_{25}K_{12.5}$	8.24	0.27	5.20	185.7	19.41	537.6
5	$N_{25}P_{12.5}K_{25}$	8.39	0.28	5.36	183.1	19.10	549.0
6	$N_{25}P_{50}K_{25}$	8.33	0.30	5.20	188.2	18.79	549.0
7	$N_{50}P_{25}K_o$	8.30	0.24	4.97	185.7	18.16	526.4
8	$N_{50}P_0K_{25}$	8.23	0.25	4.97	190.7	17.54	537.6
9	$N_{50}P_{25}K_{25}$	8.28	0.27	5.35	198.2	19.10	537.6
10	$N_{50}P_{12.5}K_{25}$	8.33	0.25	5.20	195.7	19.41	548.8
11	$N_{50}P_{50}K_{25}$	8.22	0.26	5.36	195.7	20.67	560.0
12	$N_{50}P_{25}K_{12.5}$	8.31	0.23	5.20	198.2	19.73	560.0
13	$N_{50}P_{25}K_{50}$	8.26	0.30	5.35	205.7	19.41	571.2
14	$N_{50}P_{12.5}K_{12.5}$	8.30	0.29	4.97	198.2	20.04	560.0
15	$N_{50}P_{50}K_{50}$	8.40	0.28	5.51	208.2	21.29	560.0
16	$N_{50}P_{12.5}K_{50}$	8.29	0.25	5.20	198.2	20.98	571.2
17	$N_{100}P_{25}K_{25}$	8.36	0.30	5.51	210.7	21.61	560.0
18	$N_{100}P_{50}K_{50}$	8.39	0.36	5.66	218.3	22.86	560.0
19	$N_{100}P_{50}K_{25}$	8.39	0.28	5.36	218.3	23.80	571.2
20	$N_{100}P_{25}K_{50}$	8.40	0.31	5.66	220.8	23.80	571.2
21	$N_{100}P_{25}K_{12.5}$	8.37	0.27	5.20	218.3	22.23	560.0
22	$N_{00}P_{00}K_{00}$	8.20	0.25	5.05	165.5	13.78	515.2
23	$N_{00}P_{00}K_{00}$	8.24	0.24	5.20	165.5	13.46	504.0
24	$N_{00}P_{00}K_{00}$	8.18	0.26	5.05	163.0	14.09	504.0
Mean of treated plot		8.31	0.274	5.27	197.6	20.07	552.01
Mean of control plot		8.21	0.250	5.10	164.7	13.77	507.7

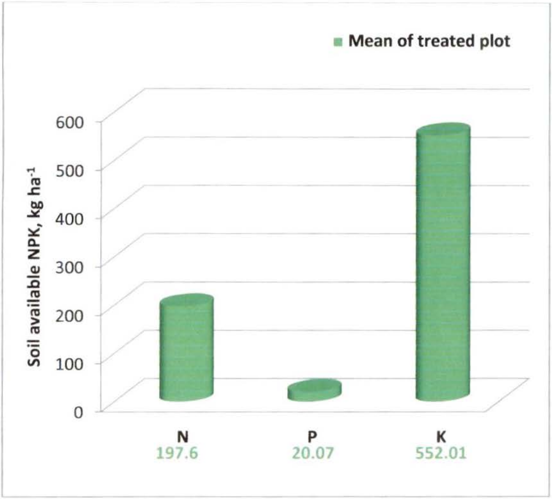


Fig. 11 : Available NPK status of soil in treated plot of F0 block.

Table 30: **Chemical properties of soil after picking of Bt cotton (F1 block) as influenced by conjoint use of chemical fertilizers and FYM**

Sr. No.	Treatments NPK,(Kgha^{-1})	pH	EC dSm^{-1}	OC, g kg^{-1}	Available N, kg ha^{-1}	Available P, kg ha^{-1}	Available K, kg ha^{-1}
1	$N_oP_{25}K_{25}$	8.32	0.22	5.32	183.2	18.16	582.4
2	$N_{25}P_{25}K_{25}$	8.29	0.24	5.47	190.7	20.04	582.4
3	$N_{25}P_{12.5}K_{12.5}$	8.26	0.26	5.32	188.2	20.04	593.6
4	$N_{25}P_{25}K_{12.5}$	8.20	0.27	5.32	198.2	21.29	582.4
5	$N_{25}P_{12.5}K_{25}$	8.37	0.27	5.18	188.2	21.92	593.6
6	$N_{25}P_{50}K_{25}$	8.33	0.31	5.32	195.7	22.23	593.6
7	$N_{50}P_{25}K_o$	8.32	0.23	5.18	198.2	19.41	582.4
8	$N_{50}P_0K_{25}$	8.27	0.22	5.03	213.3	19.73	582.4
9	$N_{50}P_{25}K_{25}$	8.23	0.25	5.32	218.3	21.29	605.0
10	$N_{50}P_{12.5}K_{25}$	8.29	0.25	5.32	210.7	22.23	605.0
11	$N_{50}P_{50}K_{25}$	8.21	0.28	5.47	218.3	23.17	605.0
12	$N_{50}P_{25}K_{12.5}$	8.29	0.23	5.25	220.8	22.54	593.6
13	$N_{50}P_{25}K_{50}$	8.25	0.27	5.35	223.3	23.17	605.0
14	$N_{50}P_{12.5}K_{12.5}$	8.32	0.26	5.25	213.3	23.49	605.0
15	$N_{50}P_{50}K_{50}$	8.37	0.24	5.47	223.3	23.17	616.0
16	$N_{50}P_{12.5}K_{50}$	8.32	0.25	5.32	210.7	22.54	616.0
17	$N_{100}P_{25}K_{25}$	8.31	0.32	5.47	220.8	24.11	627.2
18	$N_{100}P_{50}K_{50}$	8.35	0.30	5.47	230.8	24.42	627.2
19	$N_{100}P_{50}K_{25}$	8.30	0.28	5.32	235.8	26.62	627.2
20	$N_{100}P_{25}K_{50}$	8.35	0.30	5.62	230.8	26.93	638.4
21	$N_{100}P_{25}K_{12.5}$	8.37	0.28	5.20	223.3	24.42	616.0
22	$N_{00}P_{00}K_{00}$	8.20	0.24	5.32	168.1	16.91	582.4
23	$N_{00}P_{00}K_{00}$	8.25	0.23	5.18	170.6	16.91	582.4
24	$N_{00}P_{00}K_{00}$	8.16	0.23	5.18	173.1	16.28	571.2
Mean of treated plot		8.31	0.262	5.33	211.23	22.42	603.8
Mean of control plot		8.20	0.233	5.23	170.6	16.70	578.6

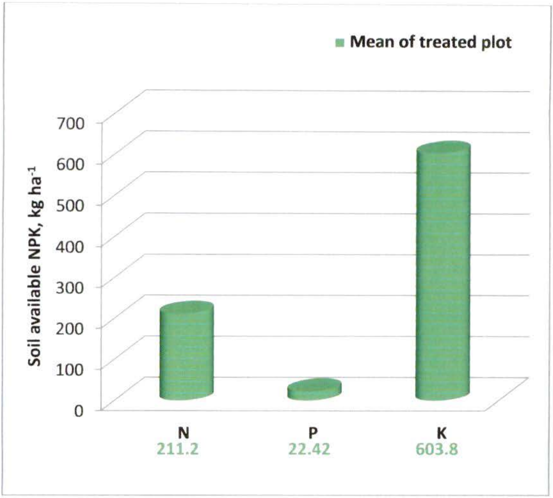


Fig. 12 : Available NPK status of soil in treated plot of F1 block.

Table 31: Chemical properties of soil after picking of Bt cotton (F2 block) as influenced by conjoint use of chemical fertilizers and FYM

Sr. No.	Treatments NPK,(Kgha^{-1})	pH	EC dSm^{-1}	OC, g kg^{-1}	Available N, kg ha^{-1}	Available P, kg ha^{-1}	Available K, kg ha^{-1}
1	$N_0P_{25}K_{25}$	8.31	0.22	5.30	195.7	20.98	616.0
2	$N_{25}P_{25}K_{25}$	8.28	0.24	5.45	205.7	22.54	616.0
3	$N_{25}P_{12.5}K_{12.5}$	8.22	0.26	5.45	200.7	22.86	627.2
4	$N_{25}P_{25}K_{12.5}$	8.22	0.27	5.30	213.3	23.80	638.4
5	$N_{25}P_{12.5}K_{25}$	8.28	0.28	5.30	205.7	24.11	627.2
6	$N_{25}P_{50}K_{25}$	8.30	0.30	5.32	218.3	24.11	649.6
7	$N_{50}P_{25}K_0$	8.30	0.24	5.30	210.7	22.86	627.2
8	$N_{50}P_0K_{25}$	8.23	0.25	5.30	223.3	21.61	627.2
9	$N_{50}P_{25}K_{25}$	8.24	0.25	5.45	228.3	23.17	649.6
10	$N_{50}P_{12.5}K_{25}$	8.30	0.26	5.30	228.3	23.17	627.2
11	$N_{50}P_{50}K_{25}$	8.27	0.29	5.45	230.8	25.36	649.6
12	$N_{50}P_{25}K_{12.5}$	8.30	0.23	5.30	230.8	24.11	638.4
13	$N_{50}P_{25}K_{50}$	8.24	0.24	5.45	228.3	25.68	649.6
14	$N_{50}P_{12.5}K_{12.5}$	8.29	0.27	5.30	228.3	26.30	660.8
15	$N_{50}P_{50}K_{50}$	8.35	0.26	5.45	235.8	25.99	672.0
16	$N_{50}P_{12.5}K_{50}$	8.33	0.29	5.30	220.8	25.36	660.8
17	$N_{100}P_{25}K_{25}$	8.32	0.28	5.45	228.3	26.62	649.6
18	$N_{100}P_{50}K_{50}$	8.35	0.29	5.75	238.3	26.62	683.2
19	$N_{100}P_{50}K_{25}$	8.31	0.28	5.30	238.3	27.24	672.0
20	$N_{100}P_{25}K_{50}$	8.34	0.30	5.45	238.3	27.87	683.2
21	$N_{100}P_{25}K_{12.5}$	8.31	0.25	5.30	230.8	25.99	660.8
22	$N_{00}P_{00}K_{00}$	8.20	0.20	5.30	178.1	18.16	593.6
23	$N_{00}P_{00}K_{00}$	8.15	0.21	5.15	173.0	17.85	604.8
24	$N_{00}P_{00}K_{00}$	8.19	0.24	5.30	175.6	18.47	604.8
Meanoftreated plot		8.29	0.264	5.38	222.8	24.63	646.9
Meanofcontrol plot		8.18	0.216	5.25	175.6	18.16	601.1

The mean pH value was observed in F_0, F_1 and F_2 blocks of treated plots was 8.31,8.31 and 8.29 while in control plots it was recorded average pH value was 8.21, 8.20 and 8.18, respectively. The mean EC value

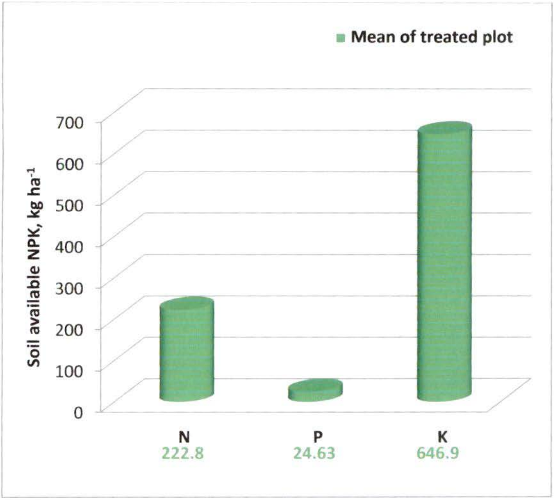


Fig. 13 : Available NPK status of soil in treated plot of F2 block.

in F_0, F_1 and F_2 blocks of treated plots was 0.274, 0.262 and 0.264, respectively. The mean value of organic carbon content was observed in F_0, F_1 and F_2 blocks of treated plots was 5.27, 5.33 and 5.38 g kg^{-1} while in control plots it was recorded average organic carbon content was 5.10, 5.23 and 5.25, respectively. More *et al.* (2003) observed that decreased pH value from 8.00 to 7.85 with the application of nutrient through organic sources under cotoon-sorghum rotation in Typic Haplusterts.

The available P status of soil ranged from 16.91 to 23.80, 18.16 to 26.93 and 20.98 to 27.87 kg ha^{-1} and mean of available P status in treated plots was 20.07, 22.42 and 24.63 kg ha^{-1} in F_0, F_1 and F_2 blocks, respectively and that of control plots was 13.77,16.70 and 18.16 kg ha^{-1} in F_0, F_1 and F_2 blocks, respectively. There was an increase in available P status of soil in F_1 and F_2 blocks of treated plots than F0 block. This shows the beneficial effect of FYM in combination of chemical fertilizers which helps in increasing the fertility status of soil.Tamgadge *et al.*(2011) observed that the fertility status of soil was significantly highest (available P 17.13 kg ha^{-1}) with application of recommended dose of fertilizer along with FYM 5 ha^{-1}.Lalitha Kumari *et al.*(2010) reported that available P in soil 30 kg ha^{-1} was noticed with the application of 150% NPK application.

The available K status of soil ranged from 526.4 to 571.2, 582.4 to 638.4 and 616.0 to 672 kg ha^{-1} and mean of available K status in treated plots was 552.01, 603.8 and 646.9 kg ha^{-1} in F_0, F_1 and F_2 blocks, respectively and that of control plots was 507.7, 578.6 and 601.1 kg ha^{-1} in F_0, F_1 and F_2 blocks, respectively. There was an increase in available K status of soil in F_1 and F_2 blocks than F_0 block in treated and control plots. This shows the beneficial effect of FYM in increasing the fertility status of soil. Gadhiya *et* al (2009) observed that available K in soil after harvest of Bt cotton was significantly influenced by application of different level chemical fertilizer. Jagvir Singh *et al.* (2000) reported that soil available potassium were observed (501 kg ha^{-1}) under cotton sole system in a vertisol at the end of three years experimentation.

CHAPTER-V

SUMMARY AND CONCLUSIONS

The present investigation entitled "Soil test crop response studies under integrated plant nutrition system for rainfed Bt cotton in Vertisol" was undertaken based on the fertility gradient approach by conducting main experiment for rainfed Bt cotton on Vertisol at Research Farm of Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola(M.S.) during 2010-2011 and 2011-2012. The investigation was undertaken to evaluate the response of rainfed Bt cotton to N, P and K fertilization under different fertility gradients, nutrient content and uptake by rainfed Bt cotton and to develop the fertilizer prescription equations for rainfed Bt cotton.

The basic data obtained from the experiments were used to compute fertilizer prescription equations with and without FYM conditions. The fertilizer requirement of rainfed Bt cotton was calculated from these equations for different yield targets from varying soil test values.

The three fertility gradients (L_0, L_1 and L_2) were created by applying graded doses of NPK fertilizers so as to get a wide range in soil fertility and fodder maize was grown as an exhaust crop to bring the soil in equilibrium fertility conditions. After maize the field was prepared for rainfed Bt cotton on the same fertility gradients.

Three FYM blocks were created across the fertility gradients by applying different levels of FYM as (F_0, F_1 and F_2) i.e. block of no FYM (F_0) and two blocks of 5 t FYM ha^{-1} (F_1) and 10 t FYM ha^{-1}(F_2). Further blocks were divided into 24 treatment combinations including 21 treated treatments and 3 control treatments on randomized basis. The treatment consisted of selected combinations of 3 levels of N (100 , 50 and 25 kg ha^{-1}), 3 levels of P (50, 25 and 12.5 kg ha^{-1}) and 3 levels of K (50, 25 and 12.5 kg ha^{-1}).

The data generated during the present investigation in respect of initial soil test values, seed cotton yield, nutrient uptake by the rainfed Bt cotton crop and fertilizer doses were used to compute the nutrient requirement, per cent contribution from soil (CS), per cent contribution of nutrients from the added fertilizers (CF), per cent contribution from fertilizers in presense of FYM and also the contribution from the added FYM. Finally these basic data were used to formulate fertilizer prescription equations for calculating fertilizer doses for any yield target based on initial soil test values under with and without FYM conditions.

5.1 Creation of soil fertility gradients

The fertility gradients created by growing exhaust crop of maize revealed that different fertility gradients in respect of soil available NPK were formed in the experimental field. The available nitrogen, phosphorus and potassium content in the three fertility gradients were found to be increased with increase in the fertilizer levels.The average increase in available nitrogen content over control (L_0) were 11.5, 26.64 kg ha^{-1} in L_1 and L_2 fertility gradients strip, respectively.The average increase in available phosphorus content over control (L_0) were 2.69, 6.45 kg ha^{-1} in L_1 and L_2 fertility gradients strip, respectively. Similar trend was also recorded in case of available potassium content with average increase of 59.74 and 110.61 kg ha^{-1} in L_1 and L_2 fertility gradients strip, respectively..The results clearly indicated the development of soil fertility in respect of N, P and K.

5.2 Yield of rainfed Bt cotton under main experiement of STCR

The seed cotton yield of rainfed Bt cotton showed increasing trend from F_0 to F_2 FYM blocks. The average seed cotton yield of rainfed Bt cotton in 2 year mean treated plots of F_0 was 16.19 q ha^{-1} which was increased to the extent of 17.47 q ha^{-1} in F_1 and 18.11 q ha^{-1} in F_2 blocks.The highest seed cotton yield of Bt cotton was obtained in the treatment where the NPK fertilizer was applied in balanced proportion as compared to individual application. The average seed cotton yield in control plots of F_0

blocks (no FYM) was 7.05 q ha^{-1}, which also increased to 8.66 q ha^{-1} in F_1 and 9.41 q ha^{-1} in F_2 blocks, which clearly indicated the significant role of FYM in increasing the seed cotton yield.The seed cotton yield increases with increase in P levels but the differences in yield found narrow up to P applied @ 2.5 kg ha^{-1} and wide increase in yield has been observed from P @ 12.5 to 50 kg ha^{-1}.

5.3 Nutrient concentration and uptake of rainfed Bt cotton

The nitrogen, phosphorus and potassium concentration in cotton seed and cotton stalk increased with increase in FYM levels. Similar trend was also observed in the uptake of nutrients. The mean total uptake of nitrogen in treated plot was increased from 70.40 kg ha^{-1} in F_0 block to 77.31 kg ha^{-1} in F_1 and 81.55 kg ha^{-1} in F_2 blocks, which was inceased by 9.81 and 15.84 per cent respectively.In control plots, the same trend of increase in uptake of N was recorded.

The balanced supply of NPK and conjunction with FYM was observed to enhance the nitrogen uptake by seed cotton and cotton stalk of rainfed Bt cotton as compared to treatments of levels of NPK.

As like the nitrogen uptake, phosphorus uptake of Bt cotton was also increased. The P uptake increased with increase in the levels of P fertilizer doses and N and K within the FYM blocks and increase with increasing levels of FYM application.The average total P uptake of Bt cotton in treated plots of F_0 blocks was 21.42 kg ha^{-1}, which was increased to 24.01 kg ha^{-1} and 25.34 kg ha^{-1} in F_1 and F_2 block, respectively.This indicated the effect of added P and complimentary effect of FYM which together helped in increasing the uptake of P with increasing FYM application.

The total K uptake increased with increasing in the levels of K fertilizers doses.The total K uptake in F_0 block was 57.90 kg ha^{-1} which was increased to 63.68 kg ha^{-1} in F_1 block and 67.59 Kg ha^{-1} in F_2 block. An increase in K uptake in F_1 blocks by 9.98 per cent in the treated plots over F_0

blocks and an increase by 16.73 per cent in K uptake in F_2 blocks over the F_0 blocks were recorded.This indicated that K uptake as that of N and P was increased with increase in K fertilizer doses along with N and P as increase in FYM application.

5.4 Major nutrient concentration at square formation and 50 per cent flowering stage

The concentration of nutrients found gradually increased with increase in application of inorganic fertilizers and FYM. The mean N concentration at square formation stage in treated plots recorded 1.771 where as in mean value under control was 1.587. For P and K concentration in treated plots recorded the value of 0.694 and 2.003, respectively. The mean value of concentration of P and K under control plots becomes 0.665 and 1.797, respectively. The highest concentration of N (1.847 %) and P(0.709%) at square formation stage was observed under $N_{100}P_{50}$ K_{25} , indicating that the N concentration increased with increase in nitrogenous fertilizer along with phosphorus and potassium.

The mean value of N concentration at 50 per cent flowering stage in treated plots recorded 1.472 where as in mean value under control was 1.366. The average value of P and K concentration in treated plots recorded 0.538 and 1.900, respectively. Where as control plots becomes 0.495 per cent P and 1.661 per cenr K. The highest concentration of N (1.552 %) at 50 per cent flowering stage was observed under $N_{100}P_{50}$ K_{25}.

5.5 Basic parameters for fertilizer prescription equations

The basic data of rainfed Bt cotton i.e. nutrients requirement(NR), per cent contribution of nutrients from soil (CS), per cent contribution of applied nutrients from applied fertilizer alone(CF), per cent contribution of nutrient from applied fertilizer in presence of FYM, CF (FYM) and per cent contribution from applied FYM derived on the basis of seed cotton yield, initial soil test values, nutrient uptake and applied fertilizer and

FYM to Bt cotton indicates that for production of one quintal of seed cotton yield of Bt cotton 3.11 kg N, 0.92 kg P and 2.60 kg K were required. While the per cent contribution from soil in respect of N, P and K was 17.51, 60.30 and 4.77, respectively. The contribution from fertilizer was 32.68, 14.70 and 66.76 per cent in respect of N, P and K , respectively, While the per cent contribution from fertilizer in presence of FYM was 37.20, 15.5 and 78.9 in respect of N, P and K, respectively, Whereas, per cent contribution of N, P and K from FYM was 4.7, 1.4 and 1.5, respectively.Since the contribution from fertilizer and FYM is taken into account based on coefficient developed the dose of chemical fertilizer is reduced in the equation based on IPNS.

5.6 Fertilizer prescription equations for rainfed Bt cotton

The fertilizer prescription equations for rainfed Bt cotton with sole use of chemical fertilizers and with conjoint use of FYM and fertilizers were computed from the basic data on NR, CS and CF. The fertilizer prescription equations for rainfed Bt cotton are as follows

Sole use of chemical fertilizers (Without FYM)

$FN = 9.53\ T - 0.38\ SN$

$FP_20_5 = 6.26\ T - 2.66\ SP$

$FK_20 = 3.89\ T - 0.07\ SK$

Conjoint use of chemical fertilizers and FYM)

$FN = 9.67\ T - 0.51\ SN - 0.73\ FYM$

$FP_20_5 = 6.83\ T - 3.89\ SP -- 0.30\ FYM$

$FK_20 = 3.29\ T - 0.06\ SK - 0.11\ FYM$

Where, FN, FP_20_5 and FK_20 is fertilizer N, P_20_5 and K_20 in kg ha^{-1}, T is yield target in q ha^{-1} and SN, SP and SK are soil available N, P and K , kg ha^{-1} and FYM is farm yard manure in t ha^{-1}

5.7 Nutrient requirement of rainfed Bt cotton

The use of fertilizer by fertilizer prescription equation using conjoint application of FYM and chemical fertilizers indicated that, there was a net saving of fertilizers with different yield targets varying soil test values. From the present investigation it is seen that there was net saving of 26.85 kg N, 14.70 kg P_2O_5 and 9.55 kg K_2O ha^{-1}. When the fertilizer prescription equation based on IPNS involving use of chemical fertilizers and FYM was used for the yield target of 20 q ha^{-1} with the soil test values of 200 kg N, 20 kg P and 300 kg K ha^{-1}. It was also observed that with increase in soil test values there was decrease in fertilizer requirement and vice-versa.

5.8 Soil nutrient status after picking of Bt cotton

The post-harvest soil analysis reveals that the available status was variable in different fertility gradients and FYM strips. However, it was observed that it was relatively better under the conjoint use of NPK and FYM. The mean of available N status in treated plots was 197.6, 211.2 and 222.8 kg ha^{-1} in F_0, F_1 and F_2 blocks, respectively whereas control plots recorded 164.7,170.6 and 175.6 kg ha^{-1} in F_0, F_1 and F_2 blocks, respectively. While ,mean of available P status in treated plots registered 20.07, 22.42 and 24.63 kg ha^{-1} in F_0, F_1 and F_2 blocks, respectively and control plots was 13.77,16.70 and 18.16 kg ha^{-1} in F_0, F_1 and F_2 blocks, respectively. Whereas, the mean value of available K status in treated plots was 552.01, 603.8 and 646.9 kg ha^{-1} in F_0, F_1 and F_2 blocks, respectively.

CONCLUSIONS

Based on the data generated during the course of present investigation on soil test crop response studies for rainfed Bt cotton by conjoint use of FYM and cheimical fertilizers with targeted yield approach, the following conclusions are drawn

1. The fertility gradient can be created artificially by applying graded dose of N, P and K fertilizers.
2. The yield response was higher in low fertility gradient and lower in high fertility gradient indicating dependence of crop response on soil nutrient status
3. The higher concentration, seed cotton yield and nutrient uptake was observed under the conjoint use of NPK combinations and FYM indicated that the efficiency of nutrients contributed from fertilizers was enhanced due to use of FYM.
4. The fertilizer prescription equation with and without FYM were developed for rainfed Bt cotton by using basic data, NR,CS, CF and CFYM.

Fertilizer prescription equation

Without FYM

$FN = 9.53\,T - 0.38\,SN$

$FP_20_5 = 6.26\,T - 2.66\,SP$

$FK_20 = 3.89\,T - 0.07\,SK$

With FYM

$FN = 9.67\,T - 0.51\,SN - 0.73\,FYM$

$FP_20_5 = 6.83\,T - 3.89\,SP -- 0.30\,FYM$

$FK_20 = 3.29\,T - 0.06\,SK - 0.11\,FYM$

5. The nutrient required for rainfed Bt cotton as per fertilizer prescription equation for yield target of 20 q ha^{-1} under STCR- IPNS system was

87:57:47 kg ha^{-1} with the soil test values of 200 kg N, 20 kg P and 300 kg K ha^{-1}.

6. The IPNS based fertilizer prescription equations developed for rainfed Bt cotton are useful for fertilizer recommendations to the farmers considerinrg their financial conditions. The targeted yield approach with FYM is more beneficial for making fertilizer recommendations to rainfed Bt cotton on Vertisol of Maharashtra as compared to only chemical fertilizer through general recommended dose owing to saving in chemical fertilizers, improvement in soil health and achieving higher seed cotton yield.
7. Based on IPNS-STCR experimentation it can be concluded that the combined use of FYM with chemical fertilizer nutrients(NPK) against their sole use, resulted in increasing the contribution from fertilizer and enhancing nutrient use efficiency which is reflected in increased nutrient concentration, nutrient uptake and seed cotton yield of rainfed Bt in Vertisol.

Implication

The results generated in this investigation will be helpful in improving the Bt cotton productivity and targeting the seed cotton yield with the resources available and sustaining the soil fertility by using the balanced fertilizer based on STCR-IPNS system.

CHAPTER - VI

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APPENDICES

Appendix I. Nitrogen concentration (%) in Bt cotton as influenced by conjoint use of FYM and chemical fertilizers 2011-12

Sr. No.	Treatments NPK, (Kg ha $^{-1}$)	FYM blocks					
		F_0		F_1		F_2	
		Seed cotton	Cotton stalk	Seed cotton	Cotton stalk	Seed cotton	Cotton stalk
1	$N_0P_{25}K_{25}$	2.78	0.409	2.81	0.477	2.80	0.615
2	$N_{25}P_{25}K_{25}$	2.82	0.477	2.84	0.477	2.84	0.615
3	$N_{25}P_{12.5}K_{12.5}$	2.80	0.477	2.84	0.477	2.86	0.546
4	$N_{25}P_{25}K_{12.5}$	2.90	0.477	2.87	0.546	2.90	0.615
5	$N_{25}P_{12.5}K_{25}$	2.85	0.546	2.85	0.615	2.86	0.683
6	$N_{25}P_{50}K_{25}$	2.85	0.546	2.88	0.615	2.87	0.683
7	$N_{50}P_{25}K_0$	3.04	0.546	3.04	0.615	3.06	0.683
8	$N_{50}P_0K_{25}$	2.91	0.615	2.98	0.615	2.97	0.615
9	$N_{50}P_{25}K_{25}$	2.91	0.615	3.03	0.683	3.06	0.683
10	$N_{50}P_{12.5}K_{25}$	3.02	0.546	3.06	0.615	3.08	0.683
11	$N_{50}P_{50}K_{25}$	3.03	0.615	3.10	0.683	3.10	0.751
12	$N_{50}P_{25}K_{12.5}$	3.06	0.546	2.98	0.615	3.10	0.751
13	$N_{50}P_{25}K_{50}$	3.08	0.594	3.05	0.659	3.08	0.715
14	$N_{50}P_{12.5}K_{12.5}$	3.06	0.615	3.05	0.659	3.02	0.715
15	$N_{50}P_{50}K_{50}$	3.02	0.594	3.06	0.659	3.06	0.725
16	$N_{50}P_{12.5}K_{50}$	3.06	0.594	3.03	0.659	3.04	0.659
17	$N_{100}P_{25}K_{25}$	3.03	0.659	3.10	0.659	3.09	0.725
18	$N_{100}P_{50}K_{50}$	3.02	0.725	3.08	0.725	3.12	0.791
19	$N_{100}P_{50}K_{25}$	3.05	0.725	3.08	0.725	3.11	0.791
20	$N_{100}P_{25}K_{50}$	3.10	0.725	3.09	0.725	3.09	0.725
21	$N_{100}P_{25}K_{12.5}$	3.10	0.659	3.11	0.725	3.08	0.791
22	$N_{00}P_{00}K_{00}$	2.70	0.330	2.75	0.400	2.82	0.462
23	$N_{00}P_{00}K_{00}$	2.73	0.330	2.81	0.462	2.83	0.528
24	$N_{00}P_{00}K_{00}$	2.71	0.400	2.74	0.462	2.79	0.462
Mean of treated plot		2.976	0.586	2.997	0.630	3.009	0.693
Mean of control plot		2.713	0.353	2.767	0.441	2.813	0.484

Appendix II. Phosphorus concentration (%) in Bt cotton as influenced by conjoint use of FYM and chemical fertilizers 2011-12

Sr. No.	Treatments NPK, (Kg ha $^{-1}$)	FYM blocks					
		F_0		F_1		F_2	
		Seed cotton	Cotton stalk	Seed cotton	Cotton stalk	Seed cotton	Cotton stalk
1	$N_0P_{25}K_{25}$	0.713	0.239	0.753	0.250	0.753	0.273
2	$N_{25}P_{25}K_{25}$	0.713	0.273	0.753	0.261	0.725	0.273
3	$N_{25}P_{12.5}K_{12.5}$	0.713	0.273	0.713	0.261	0.730	0.261
4	$N_{25}P_{25}K_{12.5}$	0.742	0.250	0.736	0.273	0.753	0.295
5	$N_{25}P_{12.5}K_{25}$	0.713	0.250	0.730	0.261	0.730	0.273
6	$N_{25}P_{50}K_{25}$	0.753	0.261	0.811	0.318	0.811	0.318
7	$N_{50}P_{25}K_0$	0.748	0.261	0.776	0.273	0.765	0.318
8	$N_{50}P_0K_{25}$	0.707	0.237	0.707	0.250	0.736	0.307
9	$N_{50}P_{25}K_{25}$	0.748	0.261	0.782	0.284	0.782	0.307
10	$N_{50}P_{12.5}K_{25}$	0.742	0.273	0.794	0.273	0.799	0.318
11	$N_{50}P_{50}K_{25}$	0.811	0.273	0.822	0.307	0.822	0.329
12	$N_{50}P_{25}K_{12.5}$	0.788	0.273	0.788	0.307	0.811	0.329
13	$N_{50}P_{25}K_{50}$	0.748	0.261	0.799	0.307	0.799	0.329
14	$N_{50}P_{12.5}K_{12.5}$	0.748	0.250	0.794	0.295	0.817	0.298
15	$N_{50}P_{50}K_{50}$	0.811	0.295	0.811	0.318	0.828	0.318
16	$N_{50}P_{12.5}K_{50}$	0.748	0.261	0.765	0.295	0.799	0.318
17	$N_{100}P_{25}K_{25}$	0.765	0.295	0.811	0.307	0.828	0.318
18	$N_{100}P_{50}K_{50}$	0.817	0.307	0.828	0.307	0.828	0.318
19	$N_{100}P_{50}K_{25}$	0.822	0.307	0.828	0.307	0.822	0.318
20	$N_{100}P_{25}K_{50}$	0.794	0.307	0.805	0.318	0.805	0.318
21	$N_{100}P_{25}K_{12.5}$	0.799	0.295	0.828	0.318	0.811	0.307
22	$N_{00}P_{00}K_{00}$	0.632	0.227	0.655	0.239	0.661	0.250
23	$N_{00}P_{00}K_{00}$	0.638	0.216	0.644	0.250	0.667	0.250
24	$N_{00}P_{00}K_{00}$	0.650	0.204	0.655	0.239	0.673	0.261
Mean of treated plot		0.724	0.272	0.783	0.315	0.788	0.307
Mean of control plot		0.640	0.216	0.651	0.243	0.667	0.254

Appendix III. Potassium concentration (%) in Bt cotton as influenced by conjoint use of FYM and chemical fertilizers 2011-12

Sr. No.	Treatments NPK, (Kg ha $^{-1}$)	FYM blocks					
		F_0		F_1		F_2	
		Seed cotton	Cotton stalk	Seed cotton	Cotton stalk	Seed cotton	Cotton stalk
1	$N_0P_{25}K_{25}$	0.569	1.47	0.594	1.47	0.643	1.52
2	$N_{25}P_{25}K_{25}$	0.619	1.52	0.619	1.52	0.643	1.61
3	$N_{25}P_{12.5}K_{12.5}$	0.594	1.43	0.619	1.52	0.619	1.52
4	$N_{25}P_{25}K_{12.5}$	0.619	1.47	0.619	1.52	0.643	1.52
5	$N_{25}P_{12.5}K_{25}$	0.619	1.52	0.643	1.61	0.668	1.76
6	$N_{25}P_{50}K_{25}$	0.643	1.52	0.643	1.61	0.718	1.76
7	$N_{50}P_{25}K_0$	0.569	1.43	0.619	1.52	0.668	1.66
8	$N_{50}P_0K_{25}$	0.693	1.52	0.693	1.66	0.693	1.66
9	$N_{50}P_{25}K_{25}$	0.619	1.61	0.668	1.71	0.767	1.71
10	$N_{50}P_{12.5}K_{25}$	0.668	1.61	0.668	1.71	0.742	1.71
11	$N_{50}P_{50}K_{25}$	0.643	1.66	0.693	1.76	0.693	1.80
12	$N_{50}P_{25}K_{12.5}$	0.668	1.66	0.643	1.71	0.668	1.71
13	$N_{50}P_{25}K_{50}$	0.668	1.76	0.668	1.80	0.718	1.80
14	$N_{50}P_{12.5}K_{12.5}$	0.619	1.66	0.668	1.61	0.668	1.66
15	$N_{50}P_{50}K_{50}$	0.742	1.76	0.742	1.80	0.792	1.80
16	$N_{50}P_{12.5}K_{50}$	0.718	1.71	0.767	1.71	0.767	1.76
17	$N_{100}P_{25}K_{25}$	0.693	1.71	0.693	1.66	0.767	1.71
18	$N_{100}P_{50}K_{50}$	0.767	1.76	0.742	1.80	0.767	1.80
19	$N_{100}P_{50}K_{25}$	0.742	1.71	0.742	1.71	0.767	1.76
20	$N_{100}P_{25}K_{50}$	0.742	1.76	0.792	1.76	0.792	1.80
21	$N_{100}P_{25}K_{12.5}$	0.718	1.52	0.693	1.61	0.718	1.61
22	$N_{00}P_{00}K_{00}$	0.470	1.43	0.499	1.52	0.544	1.33
23	$N_{00}P_{00}K_{00}$	0.499	1.47	0.520	1.47	0.520	1.33
24	$N_{00}P_{00}K_{00}$	0.499	1.43	0.520	1.47	0.544	1.38
Mean of treated plot		0.663	1.610	0.678	1.660	0.710	1.700
Mean of control plot		0.489	1.443	0.513	1.486	0.536	1.490

Appendix IV: Nitrogen concentration(%) in Bt cotton at square formation stage as influenced by conjoint use of FYM and chemical fertilizers 2011-12

Sr. No.	Treatments NPK, (Kg ha $^{-1}$)	Nitrogen concentration (%)			
		F0	F_1	F_2	Mean
1	$N_0P_{25}K_{25}$	1.602	1.629	1.629	1.620
2	$N_{25}P_{25}K_{25}$	1.765	1.711	1.765	1.747
3	$N_{25}P_{12.5}K_{12.5}$	1.657	1.657	1.684	1.666
4	$N_{25}P_{25}K_{12.5}$	1.738	1.711	1.738	1.729
5	$N_{25}P_{12.5}K_{25}$	1.684	1.684	1.711	1.693
6	$N_{25}P_{50}K_{25}$	1.765	1.738	1.765	1.756
7	$N_{50}P_{25}K_0$	1.711	1.711	1.738	1.720
8	$N_{50}P_0K_{25}$	1.684	1.684	1.711	1.693
9	$N_{50}P_{25}K_{25}$	1.792	1.765	1.792	1.783
10	$N_{50}P_{12.5}K_{25}$	1.765	1.792	1.820	1.793
11	$N_{50}P_{50}K_{25}$	1.765	1.792	1.874	1.810
12	$N_{50}P_{25}K_{12.5}$	1.820	1.792	1.820	1.811
13	$N_{50}P_{25}K_{50}$	1.820	1.820	1.792	1.811
14	$N_{50}P_{12.5}K_{12.5}$	1.792	1.820	1.792	1.801
15	$N_{50}P_{50}K_{50}$	1.820	1.847	1.874	1.847
16	$N_{50}P_{12.5}K_{50}$	1.765	1.792	1.792	1.783
17	$N_{100}P_{25}K_{25}$	1.792	1.792	1.820	1.801
18	$N_{100}P_{50}K_{50}$	1.820	1.820	1.874	1.838
19	$N_{100}P_{50}K_{25}$	1.847	1.820	1.874	1.847
20	$N_{100}P_{25}K_{50}$	1.792	1.792	1.820	1.801
21	$N_{100}P_{25}K_{12.5}$	1.820	1.847	1.847	1.838
22	$N_{00}P_{00}K_{00}$	1.575	1.602	1.602	1.593
23	$N_{00}P_{00}K_{00}$	1.548	1.575	1.602	1.575
24	$N_{00}P_{00}K_{00}$	1.602	1.575	1.602	1.593
Mean of treated plot		1.763	1.763	1.787	1.771
Mean of control plot		1.575	1.584	1.602	1.587

Appendix V. Phosphorus concentration (%) in Bt cotton at square formation stage as influenced by conjoint use of FYM and chemical fertilizers 2011-12

Sr. No.	Treatments NPK, (Kg ha $^{-1}$)	Phosphorus concentration (%)			
		F_0	F_1	F_2	Mean
1	$N_0P_{25}K_{25}$	0.675	0.675	0.689	0.680
2	$N_{25}P_{25}K_{25}$	0.683	0.699	0.691	0.691
3	$N_{25}P_{12.5}K_{12.5}$	0.683	0.683	0.691	0.686
4	$N_{25}P_{25}K_{12.5}$	0.691	0.699	0.691	0.694
5	$N_{25}P_{12.5}K_{25}$	0.668	0.668	0.675	0.670
6	$N_{25}P_{50}K_{25}$	0.706	0.714	0.706	0.709
7	$N_{50}P_{25}K_0$	0.683	0.691	0.699	0.691
8	$N_{50}P_0K_{25}$	0.668	0.691	0.691	0.683
9	$N_{50}P_{25}K_{25}$	0.699	0.699	0.706	0.701
10	$N_{50}P_{12.5}K_{25}$	0.668	0.668	0.699	0.678
11	$N_{50}P_{50}K_{25}$	0.706	0.714	0.706	0.709
12	$N_{50}P_{25}K_{12.5}$	0.691	0.691	0.699	0.694
13	$N_{50}P_{25}K_{50}$	0.699	0.706	0.699	0.701
14	$N_{50}P_{12.5}K_{12.5}$	0.668	0.675	0.691	0.678
15	$N_{50}P_{50}K_{50}$	0.714	0.706	0.704	0.708
16	$N_{50}P_{12.5}K_{50}$	0.675	0.683	0.691	0.683
17	$N_{100}P_{25}K_{25}$	0.691	0.699	0.699	0.696
18	$N_{100}P_{50}K_{50}$	0.691	0.706	0.706	0.701
19	$N_{100}P_{50}K_{25}$	0.706	0.706	0.714	0.709
20	$N_{100}P_{25}K_{50}$	0.706	0.699	0.706	0.704
21	$N_{100}P_{25}K_{12.5}$	0.699	0.699	0.714	0.704
22	$N_{00}P_{00}K_{00}$	0.668	0.652	0.683	0.667
23	$N_{00}P_{00}K_{00}$	0.660	0.668	0.675	0.667
24	$N_{00}P_{00}K_{00}$	0.652	0.668	0.668	0.663
Mean of treated plot		0.689	0.694	0.700	0.694
Mean of control plot		0.660	0.662	0.675	0.665

Appendix VI: Potassium concentration (%) in Bt cotton at square formation stage as influenced by conjoint use of FYM and chemical fertilizers 2011-12

Sr. No.	Treatments NPK, (Kg ha $^{-1}$)	Potassium concentration (%)			
		F_0	F_1	F_2	Mean
1	$N_0P_{25}K_{25}$	1.942	1.942	1.980	1.955
2	$N_{25}P_{25}K_{25}$	1.980	1.980	1.980	1.980
3	$N_{25}P_{12.5}K_{12.5}$	1.961	1.980	1.961	1.967
4	$N_{25}P_{25}K_{12.5}$	1.924	1.980	1.980	1.961
5	$N_{25}P_{12.5}K_{25}$	1.961	1.961	1.998	1.973
6	$N_{25}P_{50}K_{25}$	1.961	1.980	2.017	1.986
7	$N_{50}P_{25}K_0$	1.924	1.942	1.942	1.936
8	$N_{50}P_0K_{25}$	1.924	1.924	1.961	1.936
9	$N_{50}P_{25}K_{25}$	2.017	1.961	2.017	1.998
10	$N_{50}P_{12.5}K_{25}$	1.980	1.980	2.017	1.992
11	$N_{50}P_{50}K_{25}$	2.017	2.036	2.073	2.042
12	$N_{50}P_{25}K_{12.5}$	1.942	1.980	2.036	1.986
13	$N_{50}P_{25}K_{50}$	1.980	2.092	2.092	2.054
14	$N_{50}P_{12.5}K_{12.5}$	1.961	1.980	1.980	1.974
15	$N_{50}P_{50}K_{50}$	1.980	2.073	2.073	2.042
16	$N_{50}P_{12.5}K_{50}$	2.036	2.036	2.068	2.047
17	$N_{100}P_{25}K_{25}$	2.068	2.073	2.068	2.069
18	$N_{100}P_{50}K_{50}$	1.998	2.073	2.073	2.048
19	$N_{100}P_{50}K_{25}$	2.068	2.036	1.998	2.044
20	$N_{100}P_{25}K_{50}$	2.073	2.068	2.092	2.077
21	$N_{100}P_{25}K_{12.5}$	1.998	2.017	2.036	2.017
22	$N_{00}P_{00}K_{00}$	1.793	1.793	1.793	1.793
23	$N_{00}P_{00}K_{00}$	1.793	1.775	1.830	1.799
24	$N_{00}P_{00}K_{00}$	1.775	1.812	1.812	1.800
Mean of treated plot		1.985	2.004	2.021	2.003
Mean of control plot		1.787	1.793	1.812	1.797

Appendix VII: Nitrogen concentration (%) in Bt cotton at 50 per cent flowering stage as influenced by conjoint use of FYM and chemical fertilizers 2011-12

Sr. No.	Treatments NPK, (Kg ha $^{-1}$)	Nitrogen concentration (%)			
		F_0	F_1	F_2	Mean
1	$N_0P_{25}K_{25}$	1.318	1.318	1.345	1.327
2	$N_{25}P_{25}K_{25}$	1.426	1.453	1.453	1.444
3	$N_{25}P_{12.5}K_{12.5}$	1.372	1.372	1.372	1.372
4	$N_{25}P_{25}K_{12.5}$	1.426	1.426	1.453	1.435
5	$N_{25}P_{12.5}K_{25}$	1.399	1.426	1.426	1.417
6	$N_{25}P_{50}K_{25}$	1.453	1.480	1.480	1.471
7	$N_{50}P_{25}K_0$	1.426	1.426	1.426	1.426
8	$N_{50}P_0K_{25}$	1.426	1.399	1.453	1.426
9	$N_{50}P_{25}K_{25}$	1.480	1.507	1.480	1.489
10	$N_{50}P_{12.5}K_{25}$	1.453	1.426	1.453	1.444
11	$N_{50}P_{50}K_{25}$	1.453	1.453	1.480	1.462
12	$N_{50}P_{25}K_{12.5}$	1.507	1.507	1.507	1.507
13	$N_{50}P_{25}K_{50}$	1.507	1.480	1.534	1.507
14	$N_{50}P_{12.5}K_{12.5}$	1.480	1.480	1.507	1.489
15	$N_{50}P_{50}K_{50}$	1.507	1.534	1.534	1.525
16	$N_{50}P_{12.5}K_{50}$	1.480	1.507	1.480	1.489
17	$N_{100}P_{25}K_{25}$	1.480	1.561	1.561	1.534
18	$N_{100}P_{50}K_{50}$	1.534	1.534	1.534	1.534
19	$N_{100}P_{50}K_{25}$	1.534	1.561	1.561	1.552
20	$N_{100}P_{25}K_{50}$	1.534	1.561	1.534	1.543
21	$N_{100}P_{25}K_{12.5}$	1.561	1.507	1.534	1.534
22	$N_{00}P_{00}K_{00}$	1.345	1.372	1.345	1.354
23	$N_{00}P_{00}K_{00}$	1.372	1.345	1.372	1.363
24	$N_{00}P_{00}K_{00}$	1.345	1.399	1.399	1.381
Mean of treated plot		1.464	1.472	1.481	1.472
Mean of control plot		1.354	1.372	1.372	1.366

Appendix VIII. Phosphorus concentration (%) in Bt cotton at 50 per cent flowering stage as influenced by conjoint use of FYM and chemical fertilizers 2011-12

Sr. No.	Treatments NPK, (Kg ha $^{-1}$)	Phosphorus concentration (%)			
		F_0	F_1	F_2	Mean
1	$N_0P_{25}K_{25}$	0.512	0.526	0.531	0.523
2	$N_{25}P_{25}K_{25}$	0.536	0.526	0.536	0.533
3	$N_{25}P_{12.5}K_{12.5}$	0.531	0.522	0.526	0.526
4	$N_{25}P_{25}K_{12.5}$	0.536	0.545	0.545	0.542
5	$N_{25}P_{12.5}K_{25}$	0.517	0.522	0.531	0.523
6	$N_{25}P_{50}K_{25}$	0.554	0.550	0.564	0.556
7	$N_{50}P_{25}K_0$	0.540	0.536	0.540	0.538
8	$N_{50}P_0K_{25}$	0.503	0.512	0.517	0.510
9	$N_{50}P_{25}K_{25}$	0.545	0.540	0.545	0.543
10	$N_{50}P_{12.5}K_{25}$	0.508	0.517	0.526	0.517
11	$N_{50}P_{50}K_{25}$	0.559	0.564	0.559	0.560
12	$N_{50}P_{25}K_{12.5}$	0.522	0.526	0.531	0.526
13	$N_{50}P_{25}K_{50}$	0.550	0.564	0.568	0.560
14	$N_{50}P_{12.5}K_{12.5}$	0.512	0.522	0.517	0.517
15	$N_{50}P_{50}K_{50}$	0.564	0.568	0.559	0.564
16	$N_{50}P_{12.5}K_{50}$	0.508	0.517	0.522	0.515
17	$N_{100}P_{25}K_{25}$	0.559	0.545	0.550	0.551
18	$N_{100}P_{50}K_{50}$	0.545	0.550	0.564	0.553
19	$N_{100}P_{50}K_{25}$	0.550	0.559	0.568	0.559
20	$N_{100}P_{25}K_{50}$	0.554	0.536	0.545	0.545
21	$N_{100}P_{25}K_{12.5}$	0.517	0.526	0.536	0.526
22	$N_{00}P_{00}K_{00}$	0.480	0.498	0.498	0.492
23	$N_{00}P_{00}K_{00}$	0.480	0.503	0.508	0.497
24	$N_{00}P_{00}K_{00}$	0.484	0.498	0.508	0.496
Mean of treated plot		0.534	0.537	0.542	0.538
Mean of control plot		0.481	0.499	0.505	0.495

Appendix IX: Potassium concentration (%) in Bt cotton at 50 per cent flowering stage as influenced by conjoint use of FYM and chemical fertilizers 2011-12

Sr. No.	Treatments NPK, (Kg ha $^{-1}$)	Potassium concentration (%)			
		F0	F_1	F_2	Mean
1	$N_0P_{25}K_{25}$	1.765	1.765	1.844	1.791
2	$N_{25}P_{25}K_{25}$	1.746	1.805	1.922	1.824
3	$N_{25}P_{12.5}K_{12.5}$	1.746	1.785	1.844	1.792
4	$N_{25}P_{25}K_{12.5}$	1.726	1.785	1.863	1.791
5	$N_{25}P_{12.5}K_{25}$	1.765	1.863	1.922	1.850
6	$N_{25}P_{50}K_{25}$	1.765	1.863	1.942	1.856
7	$N_{50}P_{25}K_0$	1.726	1.785	1.863	1.791
8	$N_{50}P_0K_{25}$	1.785	1.863	1.922	1.856
9	$N_{50}P_{25}K_{25}$	1.824	1.922	1.922	1.889
10	$N_{50}P_{12.5}K_{25}$	1.805	1.922	1.942	1.889
11	$N_{50}P_{50}K_{25}$	1.903	1.981	1.981	1.955
12	$N_{50}P_{25}K_{12.5}$	1.903	1.922	1.981	1.935
13	$N_{50}P_{25}K_{50}$	1.981	2.020	2.040	2.013
14	$N_{50}P_{12.5}K_{12.5}$	1.883	1.903	1.922	1.903
15	$N_{50}P_{50}K_{50}$	1.962	2.020	2.001	1.994
16	$N_{50}P_{12.5}K_{50}$	1.981	1.942	1.962	1.962
17	$N_{100}P_{25}K_{25}$	1.942	1.942	1.981	1.955
18	$N_{100}P_{50}K_{50}$	1.962	2.020	2.001	1.994
19	$N_{100}P_{50}K_{25}$	1.962	1.942	2.040	1.981
20	$N_{100}P_{25}K_{50}$	1.962	1.981	2.040	1.994
21	$N_{100}P_{25}K_{12.5}$	1.863	1.903	1.922	1.896
22	$N_{00}P_{00}K_{00}$	1.667	1.667	1.667	1.667
23	$N_{00}P_{00}K_{00}$	1.648	1.648	1.687	1.661
24	$N_{00}P_{00}K_{00}$	1.628	1.667	1.667	1.654
Mean of treated plot		1.855	1.901	1.945	1.900
Mean of control plot		1.648	1.661	1.674	1.661

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