

**SOIL TEST CROP RESPONSE CORRELATION  
STUDIES IN INDIAN MUSTARD (*Brassica juncea* L.)**

**By**

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## **CERTIFICATE**

**Mr. BINOY CHHETRI** has satisfactorily prosecuted the course of research and that the thesis entitled "**SOIL TEST CROP RESPONSE CORRELATION STUDIES IN INDIAN MUSTARD**" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

Date :

**(Dr. SHAIK MOHAMMAD)**

Place : Hyderabad

Chairman of the Advisory Committee

## CERTIFICATE

This is to certify that the thesis entitled “**SOIL TEST CROP RESPONSE CORRELATION STUDIES IN INDIAN MUSTARD**” submitted in partial fulfillment of the requirements for the degree of “**MASTER OF SCIENCE IN AGRICULTURE**” of the Acharya N. G. Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Mr. BINOY CHHETRI** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigation have been duly acknowledged by the author of the thesis.

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## **DECLARATION**

I, **BINOY CHHETRI** hereby declare that the thesis entitled **“SOIL TEST CROP RESPONSE CORRELATION STUDIES IN INDIAN MUSTARD”** submitted to Acharya N. G. Ranga Agricultural University for the degree of **MASTER OF SCIENCE IN AGRICULTURE** is the result of original research work done by me. It is further declared that the thesis or any part thereof has not been published earlier in any manner.

Date :

Place : Hyderabad

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## LIST OF SYMBOLS AND ABBREVIATIONS

°C	:	Degree centigrade
%	:	per cent
@	:	At the rate of
a.i.	:	Active ingredient
Ca, Mg, S	:	Calcium, Megnesium and Sulphur
cm <sup>2</sup>	:	Centimetre square
CV	:	Coefficient of variation
DRR	:	Desired rate of return
DS/m	:	desi Siemen per metre
ECe	:	Electrical Conductivity
<i>et al.,</i>	:	and others
Fig.	:	Figure
FK	:	Fertilizer potassium
FP	:	Fertilizer phosphorus
g	:	gram
g/plant	:	gram per plant
h	:	hours (s)

ha	:	hectare
K	:	Potassium
kg	:	kilogram
Kg/ ha	:	kilogram per hectare
KN	:	Fertilizer potassium
m	:	metre
m <sup>2</sup>	:	metre square
N	:	Nitrogen
NMR	:	Nuclear Magnetic Resonance
P	:	Phosphorus
P <sub>2</sub> O <sub>5</sub>	:	Phosphorus
ppm	:	Parts per million
q	:	quintal
SD	:	Standard deviation
SK	:	Soil potassium
SN	:	Soil nitrogen
SP	:	Soil phosphorus
STCR	:	Soil test crop response
<i>viz.,</i>	:	namely
Yield /ha	:	Yield per hectare

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### **ABSTRACT**

A field experiment was conducted on soil test crop response correlation studies in Indian mustard in sequence to the fertility gradient trial at the students' farm, College of Agriculture, Rajendranagar, Hyderabad. The soil was sandy loam in texture, neutral in reaction with 7.1 pH, and normal in electrical conductivity (EC<sub>e</sub>) with 0.138 dS/m. The nutrient status was low in available nitrogen (213.3 kg N / ha), high in phosphorus (70.0 kg P<sub>2</sub>O<sub>5</sub> /ha) and medium in potassium (269.0 kg K<sub>2</sub>O/ ha).

The fertility gradient experiment was conducted by growing fodder sorghum variety SSG 59-3 on 30.06.05 during *Kharif* 2005. The results showed a wide variability in the soil nutrient available status between the strips after the harvest of the crop. This variation was best reflected in the grain yield of 1.51, 6.19 and 9.14 q / ha recorded in 0 X, 1 X and 2 X fertility gradients. The fodder yield was 31.83, 84.21 and 82.78 q / ha in the corresponding gradients.

In the subsequent *rabi* season mustard variety Pusa Jaikisan was sown on 25.11.05 for soil test crop response correlation studies. A total number of 24 treatments involving 21 combination levels of NPK through fertilizers and three controls were executed in each of the three fertility gradients.

The results showed that the vegetative crop growth characteristics *viz*, plant height, number of branches and leaves per plant, dry matter of leaves, stem and the yield components *viz*, number of siliquae per plant, their dry weight, number of seed per siliqua, test weight and seed yield per plant improved substantially by growing the crop in 1 X and 2 X than in the 0 X fertility gradients. The application of NPK through fertilizers to mustard further improved these parameters compared to control and this improvement was more prominent in the 1 X and 2 X than in the 0X fertility gradients. The removal of NPK through the leaves, stem, siliquae, seed and the entire plant was more in the 1 X and 2 X than the 0 X fertility gradient. The application of fertilizers further improved this trend.

The oil content increased by the application of 40 kg N/ha and decreased with further increase up to 120 kg N/ha. Application of 20 kg P<sub>2</sub>O<sub>5</sub>/ha also increased the oil per cent. Oil yield increased by the application of fertilizers up to 80 kg N, 60 kg P<sub>2</sub>O<sub>5</sub> and 40 kg K<sub>2</sub>O / ha.

Mustard produced 5.4 q/ha seed yield by the application of 120 kg N / ha in the 0 X fertility gradient but 80 kg N / ha was sufficient to harvest 6.3 and 5.4 q / ha seed yield in the 1 X and 2 X fertility gradients. Stover yield increased to maximum by the application 120 kg N / ha. The crop produce maximum seed yield of 4.5 q/ha by the application of 60 kg P<sub>2</sub>O<sub>5</sub> / ha in the 0 X fertility gradient. It required only 20 kg P<sub>2</sub>O<sub>5</sub> / ha and yet produced more seed yield of 5.7 q/ha in the 1 X and 2 X fertility gradients. Maximum stover yield was obtained by the application of 60 kg P<sub>2</sub>O<sub>5</sub> / ha.

The crop required 60 kg K<sub>2</sub>O / ha to produce 5.4 q seed yield in the 0 X fertility gradient. But, it produced 6.5 and 5.2 q / ha seed yield by the application of only 20 kg K<sub>2</sub>O / ha in the 1 X and 2 X fertility gradient. Maximum stover yield was obtained by the application of 60 kg K<sub>2</sub>O / ha. Significant correlation coefficients were established between the NPK applied through fertilizers and seed yield. The multiple linear regression explaining the contribution of NPK through soil, fertilizer and interaction was

$$Y = 703.001 + 10.8180 FN - 0.0343 FN^2 - 0.6990 SN + 0.0004 SN^2 - 0.0070 FNSN - 11.575010 FP - 0.0267 FP^2 + 2.7210 SP + 0.0610 SP^2 + 0.1760 FPSP + 10.0180 FK - 0.0907 FK^2 - 4.7030 SK - 0.0047 SK^2 - 0.0071 FKSK \dots R^2 = 0.49$$

The + - - response for linear, quadratic and interaction term was obtained from N and K. Therefore, a ready reckoner of N and K to be applied for soils with different levels of these nutrients to obtain maximum yield, maximum profit and desired rate of return were developed from the fertilizer adjustment equations

$$F N = 157.70 - 0.1025 SN - 14.58 R$$

$$F K_2O = 55.23 - 0.0392 SK - 5.52 R$$

The targeted yield equations developed from the basic parameters were

$$F N = 27.50 T - 0.12 SN$$

$$F P_2O_5 = 10.25 T - 0.19 SP$$

$$F K_2O = 9.02 T - 0.03 SK$$

A ready reckoner was developed for targeted yield goals of 6 and 10 q/ha seed yield of mustard.

The nutrient budgeting recorded higher balance of nitrogen in 0 X and 1 X fertility gradient than the initial value. Phosphorus was build up to more than the initial soil test value in the three gradients. The actual balance of potassium was also more than the initial soil test value in the 0 X and 1 X gradients while it was low in the 2 X fertility gradient.

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## CHAPTER – I

### INTRODUCTION

India heralded a yellow revolution by early 1990s (Hedge 2004). The oil seed production was only 5.2 m t from 10 m ha in 1950 - 51. Nearly 76% of oilseeds area is rainfed in which rapeseed and mustard contribute 28% of total consumption with 13 % share in GDP (The Hindu, survey of Indian agriculture, 2005). The country has a distinction that it occupies third position in the world after USA and China in terms of vegetable oil production. The technology mission in oilseeds initiated in 1980's was one of the most pioneering effort to meet the challenges and complexities in oilseed production witnessing two fold increase in yield within a decade.

The annual per caput consumption of vegetable oil increased from 2.5 kg in 1955-56 to 9.5 kg in 1999-2000. It is estimated that the oilseeds play a significant role in India's agrarian economy since more than 85% of the vegetable oil supply depend upon seven edible oilseeds crops *viz*; groundnut, rapeseed and mustard, soybean, sesamum, sunflower, safflower and niger in addition to non edible oilseeds namely linseed and castor. Mustard is one of the most important edible oilseed crops in the country. It is grown on an area of 5.38 m ha with the

production of 7.5 m t (CMIE Jan., 2006). Judicious fertilizer application to meet the nutrient requirement of the crop is one of the most important agronomic practices to increase the yield.

Biswas and Das (1999) reported that about 3 m t of major plant nutrients are removed by the oilseeds crop with a production of 25 mt. But, they are mostly grown under soil of poor structure with low available nutrients while, the fertilizer addition are barely low. Mandal *et al.* (2002) reported that another inherent biological limitation for low yield of oilseed crops is that 1 g of glucose synthesized through photosynthesis produced 0.83 g starch, 0.04 g protein and only 0.32 g lipid.

Mustard grown in the winter season also requires large quantities of nutrient supplies. Srivastava and Pathak (1980) reported that the crop requires 144 kg N, 35 kg P<sub>2</sub>O<sub>5</sub>, 40 kg K<sub>2</sub>O, 35 kg S, 115 kg Ca and 7 kg Mg/ha. If such huge quantities of nutrients are not replenished the soil impoverish and require more nutrients in due course of time to attain the same yield of yester years with relatively more fertile soils. The interaction of nutrients is also an important consideration.

Mudholkar and Alhawat (1979) observed that mustard responded to produce more yield by the applicaiton of 40 kg P<sub>2</sub>O<sub>5</sub> /ha in the absence of N and up to 80 kg P<sub>2</sub>O<sub>5</sub>/ha when it was

combined with 40 or 80 kg N/ha. The result indicated that the proper application of P may curtail the nitrogen requirement of mustard.

Currently two types of fertilizer recommendations are practiced for different crops in the country. One is general recommendation based on agronomic experiments and other is semi-quantitative approach based on the rating of soil available NPK in the low, medium and high categories (Sharma *et al.*, 1999). But these methods do not take into account the large scale variation in soil fertility from field to field (Suri and Verma, 1999).

These recommendations are also plagued with serious lacuna that they do not consider the balanced proportion of nutrients to be applied through fertilizers to optimize the production and profits with less expenses on chemical fertilizers. Absolutely they do not consider the quantity of nutrients needed by the crops, the efficiency of nutrients supplied by the soil and fertilizers in a given set of soil type and climatic conditions. To overcome such limitation Trough (1960) proposed the prescription method of fertilizers for targeted yield goals.

Ramamoorthy *et al.* (1967) explored further refinements, tested and verified this approach very extensively. They established that the theoretical basis and experimental proof for

the fact that the Liebig's law of minimum operates equally well for N, P and K. Liebig's Law of minimum states that the growth of plants is limited by the plant nutrient element present in the smallest amount, all others being in adequate quantities. From this it follows that the given amount of soil nutrient is sufficient for any one yield of a given percentage of nutrient composition. This method of fertilizer recommendation on the basis of soil test crop response correlation studies is widely adopted in several crops like cereals (Ahmed *et al.*, 1999 and Reddy and Ahmed, 2000), Pulses (Babhulkar *et al.*, 2000) and oilseeds (Reddy and Ahmed, 1999; Ahmed *et al.*, 2000 and Sreedevi *et al.*, 2001).

However, hardly a couple of studies scanned through literature have shown the estimation of nutrient requirement by mustard through this method (Verma and Bhagat, 1996 and Sharma *et al.*, 1999). This approach is widely appreciated for its unique characteristics of considering the balanced nutrient recommendation based on the nutrient requirement by the crop, efficiency of nutrient supply by the soil and fertilizers while making predictions of fertilizer dose to maximize the level of production, profitability, desired rate of returns and targeted yields to be achieved by the farmers to suit their capacity to invest money while restoring the soil health without degradation.

Mustard is a traditional oilseed crop of Rajasthan, UP, Haryana, M.P. and Gujarat covering 80% of the area under this crop in the country. It is a non-tradition crop to Andhra Pradesh. But, its cultivation is increasing in the recent years. Currently it is covering a sizeable area of 4000 ha (CMIE, 2006). Considering its further expansion it is essential to conduct research on fertilizer recommendations so that the farmers will have an option of the level of fertilizer application for targeted yields, maximum production, profitability and desired rate of returns for an array of soils varying wide in their initial level of available nutrients and safeguard the soil health.

In the light of the aforesaid current status of soil research with particular reference to balanced fertilizer recommendations to mustard and maximize the production of mustard, the present investigation was taken up with the following objectives:

- 1) To develop a yield estimation equation for different status of soils.
- 2) To develop targeted yield equations for mustard to provide a ready reckoner to the farmers for different levels of NPK prescription.
- 3) To find out the relationship between the fertilizer doses applied according to targeted yield equation.



## **CHAPTER – II**

### **REVIEW OF LITERATURE**

Literature is gathered in this section on the response of mustard to fertility level in varying agroecological variation and reviewed to gain an understanding on the probable cause-result relationship on crop productivity. This information was used as a tool of guidance for further investigation to cull out information on the relative requirement of NPK fertilizers to be recommended based on the available soil test values in the sandy soil of Southern Telangana agroecological region to mustard variety Pusa Jaikisan.

#### **2.1 Vegetative crop growth characteristics**

##### **2.1.1 Plant height**

Information on the influence of plant height of mustard in relation to the level of fertilizers applied is very useful since this parameter is an important consideration that supports the number of leaves per plant which in turn is the photosynthetic apparatus that supply translocates to the sinks. It is also a logical presumption that the taller the plant more are the number of branches and thereby more number of siliquae which are the important yield components.

The positive role of nitrogen in particular and phosphorus and potassium in general in improving the plant height of mustard was recorded in several investigations. Chauhan *et al.* (1995) reported that mustard responded to increasing level of nitrogen up to 60 kg / ha. This response was recorded on a sandy loam soil at Gurgaon which was detected to have low organic carbon and available nitrogen. On soil of similar texture having a low status of available N and P and medium reserve of available K in the Eastern Madhya Pradesh, Patel and Thakur (1998) also recorded a significant improvement in plant height of mustard with increase in level of fertilization up to 80 kg / ha.

The investigation of Khafi *et al.* (1997) on a differential texture *i.e* clay loam soil measuring low, medium and high in NPK also recorded a linear increase in plant height with increase in the level of nitrogen up to 80 kg/ha.

In contrast to this result, Yadav *et al.* (1995) observed that a liberal dose of 100 kg N/ha was required by mustard to produce a tall crop in sandy loam soil at Madhya Pradesh. But a later investigation conducted for two years in silty loam soil having low, high and medium NPK status, Singh and Singh (2002) observed that the crop required 120 kg N/ha to increase the plant height

significantly over low level. The investigations bring to light that mustard require about 80 to 120 kg N/ha in varying agroecological regions to improve the plant height.

Rana and Singh (1992) reported that the application of 48 kg  $P_2O_5$  / ha in the sandy loam soil increased the plant height significantly.

Mandal and Sinha (2002) observed that the application of 10 t FYM / ha in addition to chemical fertilization with 80 kg N, 40 kg  $P_2O_5$  and 33 kg  $K_2O$  / ha in clay loam soil having low, low and high available NPK status significantly increased the plant height over the chemical fertilizers schedule.

Danial and Nepalia (2003) conducted a field experiment on clay loam soil having medium level of available NPK at Udaipur on response of mustard to combined level of NPK through the fertilizers. They observed that the plant height increased significantly by the application of 60 kg N and 40 kg  $P_2O_5$  / ha while application of 20 kg  $K_2O$  / ha had no significant influence. In a later investigation in sandy loam soil having low level of nitrogen and medium level of both P and K contents in UP, Varshney and Larya (2004) recorded significant improvement in plant height of crop by the application of 20 kg N, 60 kg  $P_2O_5$  and 40 kg  $K_2O$ /ha. The level of nitrogen combined with P and K

brought considerably low to influence the plant height than its requirement of high dose of 80 to 120 kg N/ha in studies limited to the evaluation of response due to this nutrient alone. The trend in requirement of the three nutrients applied in combination varied wide from place to place probably due to the environmental interaction with the genotypes and variability in the soil nutrient status. Therefore, there is a dire need to investigate the level of NPK applied through fertilizers which influence the performance of mustard to the location specific situation.

### **2.1.2 Number of leaves per plant**

An understanding of nutrient requirement for maximum number of leaves per plant is essential to monitor the level of fertilization without leaving the crop under nourished or over nourished.

Kachroo and Kumar (1997), Tomer *et al.* (1997) and Singh and Singh (2002) recorded a significant increased in the number of leaves per plant in mustard with increase in the level of nitrogen up to 100 kg N/ha.

Rana and Singh (1992) reported that the number of leaves per plant increased significantly by the application of 90 kg P<sub>2</sub>O<sub>5</sub> /ha and 45 kg K<sub>2</sub>O / ha was adequate to increase the number of leaves per plant. But Gurjar and Chauhan (1997) recorded

significant increase in number of leaves per plant with successive increase in the level of fertilizers from 0 to 100 kg N and 66 kg  $P_2O_5$  / ha.

### **2.1.3 Number of branches per plant**

Branching is an important parameter of the plant since it bears the siliquae which ultimately produce the seed. Patel and Thakur (1998) observed that the branching of mustard increased significantly with increase in the level of fertilizer application upto 60 kg N/ha. Further increase in the level of this nutrient did not increase the number of branches per plant. But the investigations of Chauhan *et al.* (1995) and Porwel *et al.* (1997) revealed that the branching increased progressively with increase in the level of fertilizer application up to 80 kg N/ha. In a two year investigation, Singh and Singh (2002) recorded a consistent improvement in branching of mustard by the application of 120 kg N/ha.

Working on requirement of phosphorus and potassium, Rana and Singh (1992) observed that the branching of mustard was profuse by the application of 45 kg  $P_2O_5$  / ha. But, the application of potassium had no influence on this parameter.

Varshney and Larya (2004) reported that the application of 20 : 60 : 40 kg /ha NPK was significantly superior to the relatively low level of these nutrients to improve the number of branches

per plant significantly. But the results of Singh *et al.* (2002) showed that the crop needed a higher proportion of nitrogen. The application of 75 kg N, 50 kg P<sub>2</sub>O<sub>5</sub> and 25 kg K<sub>2</sub>O / ha induced prolific branching.

The literature thus shows high inconsistency in the amount of NPK needed to increase the number of branches in mustard in different soil and environmental situations vis-à-vis the inherently different response of mustard genotype tested.

#### **2.1.4 Dry matter per plant**

Kumar *et al.* (2001) studied the influence of nitrogen requirement by mustard crop in Haryana and observed that there was a progressive increase in the dry matter accumulation per plant with increasing level of fertilizers up to 60 N kg/ha. This trend remained similar at flowering, completion of pod formation and at physiological maturity. A later investigation of Singh and Singh (2002) in UP also revealed that mustard accumulated higher level of dry matter with increasing level of fertilizer upto 60 kg N /ha. But the investigation of Kumar *et al.* (2001) showed that a still higher dose of 80 kg N / ha was adequate to maximize the dry matter production recorded at 66 and 108 days after sowing as well as at harvest. But, a much earlier investigation of Yadav *et al.* (1995) had confirmed that the crop needed 100 kg N/ha to

produce high dry matter content. These results establish that a definite quantity of nitrogenous fertilizer application is essential to enhance the dry matter production. But the quantity of nitrogen to be applied for best results ranged from 60 - 100 kg N / ha in different regions.

Working on different level of phosphorus Mudholkar and Ahlawat (1979) recorded significant improvement in dry matter accumulation in the plant by the application of 40 kg P<sub>2</sub>O<sub>5</sub> / ha. But Patel and Shelke (1998) observed that twice this level *i.e.* 80 kg P<sub>2</sub>O<sub>5</sub> / ha was essential to improve the dry matter per plant of mustard significantly. This contradiction indicated that experiments should be conducted to refine the optimum level of phosphorus for a set of agro climatic region and a specific variety of the crop.

Testing the combined role of N and P fertilizers Bhal *et al.*, (1990) and Tomar *et al.*, (1997) observed that the crop responded to produce significantly more dry matter by the application of 120 kg N and 40 kg P<sub>2</sub>O<sub>5</sub> / ha.

Literature is also available on the combined influence of NPK applied through fertilizers on the relative dry matter production per plant of mustard. But the results are highly variable. A low level of 20 kg N / ha along with 60 kg P<sub>2</sub>O<sub>5</sub> and 40

kg K<sub>2</sub>O / ha was detected to be the optimum fertilization level to increase the dry matter of the crop by Varshney and Larya (2004). But Daniel and Nepalia (2003) found that a relatively higher level of 60 kg N combined with relatively low dose of 40 kg P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O / ha was the optimum schedule. The results of the experiment conducted by Shukla *et al.* (2002) showed that for the same level of 40 kg P<sub>2</sub>O<sub>5</sub> and 20 kg K<sub>2</sub>O / ha as investigated by the previous author a high level of 120 kg N/ha was the most balanced nutrient schedule.

## **2.2 Reproductive crop growth characteristics**

### **2.2.1 Number of siliquae per plant**

The relative role of NPK fertilizers application to mustard on the production of siliquae per plant has been shown to be marvellous over control in different experiments. But, there is no consistency in the amount of these nutrients to be applied and varied wide in different locations. An experiment conducted at Gurgaon on sandy loam soil for two years revealed that the application of 80 kg N/ha significantly increased the siliquae per plant over 60 kg N/ha (Chauhan *et al.*, 1995). During the same time an experiment conducted by Yadav *et al.* (1995) in MP Showed that the number of siliquae per plant produced by the application of 100 kg N/ha were significantly more than 50 kg

N/ha consistently during two years of experimentation. However, earlier investigation by Singh and Dixit (1989) at Faizabad revealed that the crop produced significantly more number of siliquae consistently for two years by the application of 120 kg N/ha.

The application of phosphatic fertilizer was also conformed to have a positive role in increasing the number of siliquae per plant. Sharma *et al.* (2002) recorded a significant improvement in this trait by the application of 60 kg P<sub>2</sub>O<sub>5</sub> / ha. An earlier investigation of Rana and Singh (1992) showed that the application of 90 kg P<sub>2</sub>O<sub>5</sub> / ha significantly increased the number of siliquae per plant and that the application of potassium even up to 120 kg K<sub>2</sub>O / ha had no significant influence.

In an experiment conducted on vertisol for two years at Udaipur, Khafi *et al.* (1997) found that the crop responded to produce more number of siliquae per plant by the application of 80 kg N and 30 kg P<sub>2</sub>O<sub>5</sub> / ha. Almost similar fertilizer schedule of 80 kg N and 40 kg P<sub>2</sub>O<sub>5</sub> /ha were also reported to have significant influence in increasing the number of siliquae per plant in the sandy loam soil of Madhya Pradesh (Patel and Thakur, 1998).

Abraham and Lal (2003) observed that the application of 30 kg N, 20 kg P<sub>2</sub>O<sub>5</sub> and 15 kg K<sub>2</sub>O / ha in a sandy loam soil at

Allahabad significantly increased the number of siliquae per plant, Varshney and Larya (2004) recognized the need to apply higher dose of 60 kg P<sub>2</sub>O<sub>5</sub> and 40 kg K<sub>2</sub>O / ha at a low dose of 20 kg N/ha to realize a significant improvement. This result is different from the observation of Sharma *et al.* (1999). These authors recorded a beneficial effect of improving the number of siliquae per plant by enhancing the level of nutrients to 40 kg N / ha and 80 kg P<sub>2</sub>O<sub>5</sub> / ha with a relatively low dose of 20 kg K<sub>2</sub>O / ha. A still contradicting fertilizers schedule recorded by Daniel and Nepalia (2003) was to apply 60: 40 : 20 kg NPK / ha.

The results of research conducted by several investigations showed an enormous variation in the optimum combination of NPK to be applied through the fertilizers to maximize the number of siliquae per plant which is the most reliable index of yield.

### **2.2.2 Number of seeds per siliqua**

Chauhan *et al.* (1995) observed that Indian mustard responded to produce significantly more number of seeds per siliqua by the application of 40 kg N/ha. Increasing the level of this nutrient to 80 kg N/ha was of no advantage. Contrary to this observation, Sharma (1994) and Singh and Singh (2002) recorded significant improvement in the number of seeds per siliqua by the application of 80 kg N / ha. In a two year

investigation Yadav *et al.* (1995) observed that there was a positive response to a still high level of 100 kg N / ha. While, the reports of Bhan (1979), Rathi and Singh (1983) and Singh and Dixit (1989) revealed that the best advantage of increasing the number of seeds per siliqua was by the application of 120 kg N / ha.

Rana and Singh (1992) observed that the application of phosphorus up to 45 kg P<sub>2</sub>O<sub>5</sub> / ha significantly increased the number of seeds per siliqua and further increase in the level of this nutrient up to 90 kg P<sub>2</sub>O<sub>5</sub> / ha had no beneficial effect. But, the investigation of Singh *et al.* (2002) brought to light that the application of phosphorus virtually had no significant influence in increasing the number of seeds per siliqua.

Daniel and Nepalia (2003) observed that the application of nitrogen and phosphorus up to 60 kg N and 40 kg P<sub>2</sub>O<sub>5</sub> / ha significantly increased the number of seeds per siliqua. But the combined application of NPK at 60 : 40 : 20 kg / ha did not bring further beneficial effect. Varshney and Larya (2004) on the other hand observed that the best response was attained by the application 10 kg N, 30 kg P<sub>2</sub>O<sub>5</sub> and 20 kg K<sub>2</sub>O / ha. However, increasing the level of these nutrients by two folds did not show any significant improvement.

### 2.2.3 1000 seed weight

The 1000 seed weight is an important component of yield. The heavier the seed weight more is the seed yield and better market price. Singh and Singh (2002) reported that the test weight of mustard is directly related to the level of nitrogen application up to 60 kg / ha. But the result of Chauhan *et al.* (1995) showed that the crop responded to increase its test weight by the application of 80 kg N /ha. While, Yadav *et al.* (1995) observed that the test weight improved significantly by the application of still high dose of 100 kg N / ha. On the other hand, the report of Singh *et al.* (1985), Kachroo and Kumar (1997) and Shukla *et al.* (2002) revealed that the test weight of this crop can be fairly improved by the application of high level of 120 kg N /ha.

Sharma *et al.* (2002) observed that the test weight of mustard increased significantly by the application of 60 kg P<sub>2</sub>O<sub>5</sub> / ha. Patel and Thakur (1998) recognized the application of both N and P. They observed that the test weight increased significantly with the increase in the rate of application of nitrogen from 20 to 80 kg and P<sub>2</sub>O<sub>5</sub> from 20 to 60 kg / ha. But, Khafi *et al.* (1997) observed that at the same level of 80 kg N, the application of 30 kg P<sub>2</sub>O<sub>5</sub> / ha was the balanced schedule. In contrast, Rana and Singh (1992) observed that there was no advantage of phosphorus application up to 120 kg P<sub>2</sub>O<sub>5</sub> / ha and potassium up

to 90 kg K<sub>2</sub>O / ha. Similarly, the combined application of 20 : 60 : 40 kg NPK / ha as reported to be ineffective in increasing the 1000 seed weight (Varshney and Larya 2004).

Few reports revealed that the advantage of combined application of NPK. Sharma *et al.* (1999) reported that the crop should be fertilized with 40 : 80 : 20 kg NPK / ha to increase the test weight of mustard. Daniel and Nepalia (2003) also confirmed the benefit of combined application of NPK at the rate of 60: 40: 20 / ha. In accordance with this investigation Abharam and Lal (2003) also recorded the need to apply the three nutrients. However, they recorded significant response by applying these fertilizers at high dose of 90 : 60 : 50 kg NPK / ha.

#### **2.2.4 Seed yield per plant**

Mudholkar and Alhawat (1979) reported that the seed yield per plant of mustard increased significantly by the application of 40 kg N/ ha. While, Shukla and Kumar (1992) and Singh and Singh (2002) stated that the seed yield per plant increased significantly with increasing level of nitrogen up to 120 kg N /ha.

Rana and Singh (1992) observed that the application of 90 kg P<sub>2</sub>O<sub>5</sub> / ha increased the seed yield significantly compared to low doses in the sandy loam soil and that the application of

potassium even up to 120 kg K<sub>2</sub>O / ha had no significant influence.

Sharma *et al.* (1999) observed that the seed yield per plant of mustard increased remarkably by the application of 40 kg N, 80 kg P<sub>2</sub>O<sub>5</sub> and 20 kg K<sub>2</sub>O / ha over no fertilizer application. Shukla *et al.* (2002) obtained a progressive increase in seed yield per plant by increasing the level of fertilization to as high as 120 kg N, 40 kg P<sub>2</sub>O<sub>5</sub> and 20 kg K<sub>2</sub>O/ ha.

### **2.3 Nutrient removal**

Bhati and Rathore (1982) reported that the increasing level of nitrogen from 0 to 60 kg / ha significantly increased its uptake by the seed and stover. Further increase in the level of this nutrient up to 80 kg /ha did not influence the uptake either in the seed or stover, Singh and Singh (1998) reported that the nitrogenous fertilizer significantly increased uptake both of nitrogen and phosphorus with the application of 80 kg N/ha. Bishnoi and Singh (1982) reported that the application of 90 kg N/ha increased the uptake of NPK and S with increase in the level of nitrogen application form 0 to 90 kg / ha. The investigation of Singh and Singh (1984), Rana *et al.* (1991) and Yadav *et al.* (1995) indicated that the uptake of NPK by the seeds and stover

increased significantly with increasing level of nitrogen from 0 to 100 kg N/ha.

Jain *et al.* (1995) and Ram and Pareek (2000) reported that the application of 30 kg  $P_2O_5$  / ha significantly increased the uptake of NPK and S in the seed and stover over control or 15 kg  $P_2O_5$  / ha.

Tomar *et al.* (1997) reported that the application of 180 kg N and 80 kg  $P_2O_5$ /ha increased their uptake by seed and stover of mustard.

Sharma *et al.* (1999) found that the highest uptake of NPK was recorded when mustard was fertilized with 80:40:20 kg NPK/ha. Similarly, Singh *et al.* (2002) reported that the application of 75:50:25 kg NPK / ha increased the nutrient uptake.

The highly variable results on the requirement of NPK fertilizers to be applied to mustard reported in literature owe to extreme variability in the genotypes tested, soils and their fertility status, management practices and environmental variation etc.

## **2.4 Seed yield / ha**

Literature on the requirement of fertilizing the crop with NPK is highly inconsistent varying from place to place, variable soils and genotypes tested over years. Manohar (1981) reported

that the seed yield of mustard increased significantly with successive increase in the level of nitrogen up to 60 kg N / ha.

Further increase in the level of this nutrient did not increase the yield. Similar response to the application of 60 kg N/ha was also ascertained by other research workers (Bhati and Rathore 1982, Agarwal and Gupta 1991, Chauhan *et al.*, 1995, Padmani *et al.*, 1994, Ali *et al.*, 1996, Tomar *et al.*, 1997 and Sonali 1999). The trials conducted by Chaniara and Damor (1982) and Singh and Singh (2002) recorded 96% increase in seed yield of mustard by the application of 75 kg N / ha. They further reported that the application of 40 kg P<sub>2</sub>O<sub>5</sub>/ha did not increase the seed yield significantly. Kumar *et al.* (2001) recorded a significant increase in yield with successive increase in level of N up to 80 kg N / ha in one year and up to 60 kg N / ha in the second year. In a two year investigation Yadav *et al.* (1995) recorded a progressive increase in the seed yield of mustard by the application of nitrogen up to 100 kg/ha. A still high level of 120 kg N/ha was recorded to increase the yield by Singh and Rathi (1985), Shukla and Kumar (1992) and Mishra and Virma (1994).

Ram and Pareek (2002) recorded significant increase in seed yield of mustard by the application of 30 kg P<sub>2</sub>O<sub>5</sub> / ha. Similarly, Sharma *et al.* (2002) observed that the crop required 40

kg P<sub>2</sub>O<sub>5</sub> / ha to produce large quantity of seed yield while, further increase in the level of this nutrient reduced the crop production.

Rana and Singh (1992) reported that the application of phosphorus up to 90 kg P<sub>2</sub>O<sub>5</sub> / ha significantly increased the seed yield while, response to application of potassium was not significant.

Patel and Thakur (1998) observed that the application of 60 kg N and 40 kg P<sub>2</sub>O<sub>5</sub> / ha resulted in an increase in the level of crop production owing to the improvement in plant growth and yield components. Similar findings were recorded by Daniel and Nepalia (2003).

The results of experiments conducted by Khafi *et al.* (1997) revealed that the crop required relatively higher level of 80 kg N along with 30 kg P<sub>2</sub>O<sub>5</sub> / ha to enhance the yield remarkably.

Varshney and Larya (2004) reported that the application of 20: 60: 40 kg NPK/ ha had a similar effect on seed yield as with the application of 10 : 30 : 20 kg NPK / ha. This observation is highly contradictory to the results reported by Ramamurthy and Shivashankar (1996), Tyagi and Rana (1992) and Sharma *et al.* (1999). They recorded substantial increase in seed yield of mustard by the application of 40 : 80 : 20 kg NPK / ha. Singh *et al.* (2002) recorded high yield by the application 60 : 40 : 20 kg

NPK / ha. But Shukla *et al.* (2002) reported that the best fertilizer schedule to optimize the crop production was 120 : 40 : 20 kg NPK / ha. Abraham and Lal (2003) recorded substantial increase in yield by the application of 20 : 50 : 20 kg NPK / ha.

## **2.5 Stover yield**

Bhati and Rathore (1982) reported that the application of 40 kg N / ha increased the stover yield significantly. Gangasaran and Giri (1988), Singh and Dixit (1989) and Sharma (1994) recorded higher stover yield by the application of 80 kg N than the low level of 40 kg N /ha. Dhingra *et al.* (1998) observed that there was no significant improvement in the yield of stover by increasing the level of nitrogen up to 180 kg/ ha in one year while, it increased significantly in the second year. Singh and Singh (2002) recorded consistent increase in stover yield with successive increase in the level of nitrogen up to 120 kg /ha. Further increase in the fertilizer application rate to 160 kg N / ha did not influence the stover yield.

The role of phosphorus in increasing the stover yield of mustard was also confirmed by several investigators. Khafi *et al.* (1997) and Rana and Pareek (2000) recorded significant increase in stover yield in response to the application of 30 kg P<sub>2</sub>O<sub>5</sub> / ha. In a two year study, Patel and Shelke (1998) recorded a consistent and positive response to added level of phosphorus

up to 80 kg P<sub>2</sub>O<sub>5</sub> / ha. Tomar *et al.* (1997) reported that the maximum stover yield was obtained by the application of 180 kg P<sub>2</sub>O<sub>5</sub> / ha.

## **2.6 Oil content (%)**

The research finding on oil content of mustard undisputedly confirmed that the high level of nitrogen application had a negative influence. Singh *et al.* (2002) reported that the oil content of mustard seed reduced with progressive increase in the level of nitrogen up to 100 kg / ha. Similarly, Khan (1980), Shukla and Kumar (1992) and Singh *et al.* (1994) also recorded substantial reduction in oil percent of the seed by nurturing the crop with increasing level of nitrogen up to 120 kg / ha. Such a negative trend leading to reduction in oil content was also recorded with increasing level of nitrogen up to 160 kg / ha by Singh and Rathi (1984).

The role of phosphorus was found to be positive in increasing the oil percentage of mustard seed. Tomar *et al.* (1992) and Ram Pareek (2000) recorded remarkable improvement in oil content of mustard by the application of 30 kg P<sub>2</sub>O<sub>5</sub> / ha. In a later investigation, Sharma *et al.* (2002) observed that the crop was benefited to accumulate more oil content in response to the application of 40 kg P<sub>2</sub>O<sub>5</sub> / ha to the crop.

Kumar (1992) and Singh *et al.* (2002) reported that the oil content in seed increased significantly at low fertility level of 30 : 20 : 10 kg NPK / ha and that each successive increase in the fertility level decreased the oil content remarkably. They explained that this reduction was probably due to the increasing availability of nitrogen which increased the proportion of proteinous substances in the seeds. Similar explanation was propounded by Zubriski and Zimmerman (1974), Mohammad and Rao (1981), Singh *et al.*(1994), Tomar *et al.* (1996), Sreemannarayana *et al.* (1998), Amruthavalli and Reddy (2000), Jat and Giri (2000) and Mandal and Giri (2001). The only exceptional reference of Tomar *et al.* (1997) was that the increasing level of phosphorus up to 80 kg P<sub>2</sub>O<sub>5</sub> / ha decreased the oil content. However, corroborating the results of other investigators, they also found that the high dose of nitrogen at 180 kg / ha severely reduced the oil content.

The results fore warn that the liberal application of nitrogen to increase the seed yield is associated with a negative impact on the oil content. Therefore, it is logical that an optimum nitrogen fertilizer dose should be identified to maximize the oil yield. Application of phosphorus increased the yield and enrich with oil content. Phosphatic fertilizers are more expensive. Therefore,

identification of an optimum economic dose of this nutrient would be the best proposition.

## **2.7 Soil test crop response correlation studies**

Soils vary wide in holding the quantity of available nutrients and differ in their capacity to supply the nutrients to the crop to produce yield. It is a commonly recognized phenomenon that the soil having less quantity of a particular nutrient will exhibit a spectacular response to its application through fertilizers (Biswas and Mukherjee, 1987). Therefore for soils which are deficient in one or more than one nutrient, it is necessity to supply these nutrients through the fertilizers to achieve maximum response by considering their interaction. To overcome the nutrient deficiency, increase the production of crop and realize higher profit the current approaches include fertilizer recommendations based on crop responses to graded levels of nutrients from the crop and location specific agronomic experiments by considering the agro ecological zoning pattern. The other method is fertilizer recommendations based on fertility category of soil. The soil tests are calibrated into different fertility gradient i.e., low, medium and high. The general fertilizer recommendation is made based on the soils rated as medium. For soils testing low or high fertility category, the fertilizer recommendation is increased or decreased by 30 to 50 per cent of the general recommendation (Muhr *et al.*,

1965). This method is subjected to criticism that it does not take into consideration the large scale variation from field to field (Varma and Bhagat, 1996). This principle is also not sound enough as it ignores the quantity of nutrients required by the crop.

Another approach is the fertilizer recommendations based on soil critical limits. In this method, calibration of soil test is done to reduce a critical limit for the soil test value below which there will be a positive or economic response to added fertilizers and above which the response either diminishes at a much faster rate or it is nil (Kate and Nelson, 1965).

The diagnosis recommendation and integrated system is also properly recognized on the premise that the relationship of the nutrients in the plant tissues have a direct bearing on the production of crop than on the nutrients available in the soil as they are subjected to several interactions before they are drawn by the crop. Another comprehensive approach is still soil test crop response.

This approach is based on the three basic requirements i.e., quantity of nutrients required in kg per quintal of economic yield, the percentage contribution of nutrients by the soil and the contribution of nutrients through the fertilizers to optimize the yield. Another added advantage is the estimation of fertilizer

nutrients required to be added for different soil test values of nutrients and targeted yields. This approach is based on the principle of Liebig's law of minimum.

The Liebig's Law of minimum states that a given amount of soil nutrient is sufficient for only one year of a given percentage composition but percentage sufficiency concept of Mitscherlitch-Baule stated that the given amount of soil nutrients is not sufficient for only one yield of a given percentage composition but it can also be just adequate for a wide range of yields. Bray (1954) stated that the relatively immobile nutrients like P and K follow the percentage sufficiency Mitscherltich – Baule and the relatively mobile nutrients like N tend to follow Liebig's law of limiting nutrients. Ramamoorthy *et al.* (1967) established a theoretical basis and experimental proof for the fact that the Liebig's law of minimum operates equally well for N, P and K.

The importance of the associated P and K nutrients in determining the values to make efficiency use of fertilizers was established and it formed the basis for fertilizer recommendation for targeted yields. This tool is likely to have a much wider adaptability to suit the targeted yield goals by a farmer depending upon the investment capacity on nutrients and their availability in the soil, the goals to maximize the production, profit per unit area and profit per rupee invested on the fertilizer nutrients in

proportion to the returns from the produce with maintenance of soil fertility.

Verma and Bhagat (1996) conducted extensive research on prescription based fertilizer recommendation for oilseed crops. They observed that mustard required 6.5 kg N, 2.5 kg P<sub>2</sub>O<sub>5</sub>, and 3.0 kg K<sub>2</sub>O to produce 1q of seeds. The contribution of nutrients by the soil was 5.2 per cent N, 19.1 per cent P<sub>2</sub>O<sub>5</sub> and 3.2 per cent K<sub>2</sub>O. The nutrient contribution from fertilizers was 100, 50 and 79 per cent for N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O respectively.

From these basic requirements, they developed fertilizer adjustment equations for different targeted yields and verified that the precision deviated within the prescribed level of  $\pm 10\%$ . They also confirmed that these estimates were more realistic and close to the actual yields than the yield levels obtained by the farmers following the state recommended fertilizer dose or soil test based fertilizer recommendation.

Sharma *et al.* (1999) conducted a field experiment for two decades from 1975 to 1995 at IARI, New Delhi. They reported that the nutrient requirement for 1 q of seed production of a crop variety is based on the fact that there is a highly significant relationship between nutrient uptake and grain yield. This substantiates the idea that a definite amount of nutrient is

required for each unit of seed production. The nutrient requirement for a given crop variety does not change much and remains fairly constant for a given set of soil - crop - agro climatic conditions. Similarly, utilization efficiency of soil and fertilizer nutrients is also specific for a given set of soil crop agro climatic conditions. The information on these basic parameters provides the basis for quantitative fertilizer recommendations based on soil test for a given yield goals of a crop variety. They reported that the nutrient requirement of N kg/q seed production was high for mustard, medium for bajra and low for wheat. The nutrient requirement of  $P_2O_5$  was high for mustard and bajra but low for wheat. Similarly, the requirement of  $K_2O$  was high for mustard and bajra and low for wheat. Mustard and wheat utilized the soil and fertilizer nitrogen much better than bajra. Phosphorus was best utilized by wheat followed by bajra and mustard. Soil and fertilizer potassium was best utilized by bajra while mustard had the lowest potassium interaction efficiency. They also observed that the variety PR-45 of mustard required less amount of 4.29 kg N, but highest amount of 6.16 kg  $K_2O$  per quintal of seed production. On the other hand, Pusa bold required less quantity of 4.13 kg  $K_2O$  but high quantity of 5.31 kg N and 2.12 kg  $P_2O_5$ . The variety Pusa Jaikisan required less amount of 1.5 kg  $P_2O_5$ . They also stated that the soil available nutrient efficiency ranged from

25.2 to 32.0, 38.3 to 54.3 and 20.2 to 31.7 per cent for N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O respectively. The nutrient efficiency of fertilizers ranged from 56.2 to 77.7, 22.2 to 40.8 and from 58.2 to 116.0 per cent N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O respectively. From this basic information they developed the targeted yield equations and verified that the actual yield was within a variation of  $\pm 10\%$  and fetched more profit compared to the general recommendation.

Sreedevi *et al.* (2001) recorded this relationship in sunflower. But Reddy and Ahmed (1999) reported a positive and highly significant contribution of soil available N and P while K had feable association with yield of groundnut.

The information gathered indicated the need to investigate the nutrient requirement of mustard specific to a given agro climatic condition and soil types for a balanced fertilizer application through the STCR approach which has a merit of considering the nutrient need by the crop and the efficiency of soil as well as fertilizers to supply the nutrients.

## CHAPTER-III

### MATERIAL AND METHODS

The experiment entitled “**Soil Test Crop Response Correlation Studies on Indian Mustard**” was conducted during *Rabi*, 2005. The details of the experimental materials used and methods adopted in the present investigation are elucidated in this chapter under appropriate heads.

#### **3.1 Details of the experimental site**

##### **3.1.1 Location**

The present investigation was carried out at the Students' Farm, College of Agriculture, Rajendranagar, Hyderabad. The farm is geographically situated at an altitude of 542.6 m above mean sea level on 18.5°N latitude and 77.53° E longitude and falls under the Southern Telangana agroclimatic region of Andhra Pradesh.

#### **3.2 Climate**

##### **3.2.1 Weather conditions during crop growth**

The data pertaining to various weather elements during crop growth period (25.11.05 to 13.03.2006) of mustard as

recorded at Agricultural Research Institute, Rajendranagar are presented in Appendix 1.

The weekly mean maximum temperature during the crop growth period ranged from 26.9°C to 35.7°C with an average of 30.5°C while the weekly mean minimum temperature ranged from 9.3°C to 20.8°C with an average of 14.6°C. The mean relative humidity ranged from 83.9 to 33.5 percent with an average of 78.2 per cent. The weekly mean sunshine during the crop growth period ranged from 7.0 to 10.4 h with average of 9.1 h per day.

### **3.3 Soil**

Composite soil sample was drawn from 0 to 30 cm depth before the commencement of the experiment. It was analyzed for different physico - chemical properties by adopting standard procedures. The details are presented in Table 1.

The results of physico - chemical analysis revealed that the soil was sandy loam in texture. It was neutral in reaction having 7.10 pH. The nutrient status was low in available nitrogen (213 kg N/ha), rich in phosphorus (70 kg P<sub>2</sub>O<sub>5</sub> / ha) and medium in available potassium (299 kg K<sub>2</sub>O / ha).

### **3.4 Field experiment**

The main aim of the Soil Test Crop Response experiment was to generate a set of data points with a wide range of values for each controllable variable of fertilizer NPK at different levels of the uncontrollable soil available NPK fertility variables. To achieve this objective a fertility gradient experiment was conducted. This was to ensure high heterogeneity between the different fertility gradients and homogeneity within each soil fertility gradient for available soil nutrients, management practices adopted and prevailing climatic conditions.

### **3.5 Layout**

#### **3.5.1 Exhaust crop**

The field was divided into three strips, each strip was 126 m long and 10 m wide. Each strip was separated with 1.5 m wide alleyway all along the length (Fig. 1). These strips were designated as O X, 1 X and 2 X depending upon the quantity of fertilizers added. Fertilizers were not added in the O X gradient. The standard level of 150 kg N / ha was applied in 1 X strip. Phosphorus application was calibrated to the critical value based on its fixation capacity following Waugh and Fitts (1966). The potassium application was calibrated to supply 150 kg exchangeable  $K_2O$ / ha. The 2 X strip was fertilized with two times

the level of these nutrients. The actual dose of NPK applied in each strip is presented in table 2. These fertilizer levels are those recommended by the All India Co-ordinated Research Project on Soil Test Crop Response Correlation Studies.

Table 2 : Fertilizer dose (kg/ha) applied to different strips

Gradient	Nutrient applied (kg/ha)		
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
0 X	0	0	0
1 X	150	75	100
2 X	300	150	200

The exhaust crop of fodder sorghum variety SSG 59-3 was sown on 30.06.2005 in *kharif* season. Half of the nitrogen and entire dose of phosphorus and potassium was applied as basal at sowing. Remaining half of the nitrogen was top dressed a month later. The crop was harvested on 15.11.2005. The grain and fodder yield were recorded from each strip.

### 3.5.2 Test crop

After the harvest of exhaust crop the field was ploughed, harrowed and leveled without disturbing the layout demarcation of the three strips developed for the fertility gradient experiment. Each strip was divided into 24 plots measuring 10 x 4.5 m. These

plots were separated by bunds measuring 45 cm and alternated by feeder channels of 75 cm for irrigation (Fig. 2).

The treatments were a combination of four levels of each N, P and K viz;

Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
N <sub>0</sub> - 0	P <sub>2</sub> O <sub>5</sub> - 0	K <sub>2</sub> O - 0
N <sub>1</sub> - 40	P <sub>2</sub> O <sub>5</sub> - 20	K <sub>2</sub> O - 20
N <sub>2</sub> - 80	P <sub>2</sub> O <sub>5</sub> - 40	K <sub>2</sub> O - 40
N <sub>3</sub> - 120	P <sub>2</sub> O <sub>5</sub> - 60	K <sub>2</sub> O - 60

21 treatment combinations and three controls were selected for Soil Test Crop Response experiment in accordance with the recommendation by the All India Coordinated Research Project on Soil Test Crop Response Correlation Studies ([www.iasires.in](http://www.iasires.in)). These 24 treatments were randomly executed in each of the three strips.

### 3.5.3 Collection of soil samples

Soil samples were collected from the top 30 cm soil depth from the 72 plots of the experiment before sowing and after harvest of mustard by quartering method. They were dried and passed through 2 mm sieve and then kept in polythene bags after proper labeling and used for further analysis.

#### **3.5.4 Seed and sowing**

Indian mustard variety Pusa Jaikisan was sown on 25<sup>th</sup> November 2005. The seeds were dibbled at a spacing of 30 x 10 cm.

#### **3.5.5 Thinning**

The plants were thinned out by leaving one seedling per hill after 15 days of sowing.

#### **3.5.6 Fertilizer application**

The different fertilizers were applied to the plots as per the treatments. One third of nitrogen and full dose of phosphorus and potassium were applied as a basal dose and remaining nitrogen was applied as top dressing at 30 days after sowing.

#### **3.5.7 Weeding**

The herbicide pendimethalin was sprayed as pre-emergence @ 0.75 kg a.i./ha. Hand weeding was done twice at 20 and 40 days after sowing.

#### **3.5.8 Irrigation**

The crop was irrigated at the time of sowing, and remaining five irrigations were given at 25, 40, 55, 70 and 85 days after sowing.

### **3.5.9 Plant protection**

There was an incidence of mustard sawfly at 30 days after sowing and the aphid infestation commenced at 55 days after sowing. The crop was protected from sawfly by spraying chlorpyrifos @ 0.05%. Acephate 75 SP was sprayed @ 0.075% to control the aphids.

### **3.5.10 Harvesting and threshing**

Mustard was harvested at 108 days after sowing on 13.03.06. Threshing was done manually to separate the seeds from the siliquae. The threshed produce was winnowed and seed yield and stover yield from each plot was recorded after drying.

## **3.6 Collection of samples**

### **3.6.1 Soil Sample**

The post harvest soil samples at 30 cm depth from each treatment were collected by quartering method, dried and passed through 2 mm sieve and kept in polythene bags after proper labelling and used for further analysis.

## **3.7 Biometric observations**

Biometric observations on the morpho-physiological parameters were taken on five representative plants in each plot

and the mean values are presented. These observations were made from 45 days after sowing at fortnight intervals. The destructive samples included 5 plants taken from each plot for recording dry weight of stem and leaves.

### **3.7.1 Pre-harvest observations**

#### **3.7.1.1 Plant height (cm)**

The plant height was measured using a linear meter scale from base of the plant to the apex of the terminal bud at 45, 60, 75 days and at harvest and expressed in cm.

#### **3.7.1.2 Number of leaves per plant**

The number of functional leaves per plant was recorded at 45, 60, and 75 days age of the crop.

#### **3.7.1.3 Number of siliquae per plant**

The number of siliquae per plant was recorded at 45, 60, 75 days and at harvest of the crop.

#### **3.7.1.4 Dry matter production**

Dry matter production was recorded at 45, 60, 75 days and at harvest from the destructive samples. Five plants from each plot were cut from the base at each interval. They were shade

dried and later oven dried at 65°C to constant weight and stalk and leaf weigh were recorded.

### **3.7.2 Post harvest observations**

#### **3.7.2.1 Number of seeds per siliqua**

The total number of seeds per siliqua was obtained by counting the seeds from the randomly selected five siliqua and the average number per siliqua was worked out.

#### **3.7.2.2 Seed Yield per plant (g)**

The seed yield per plant collected from five labeled plants was weighed and average was computed and expressed in grams.

#### **3.7.2.3 Thousand seed weight / test weight (g)**

One thousand seeds were selected randomly from the threshed out samples and weight was recorded and expressed in grams.

#### **3.7.2.4 Seed yield per hectare (q/ha)**

The seed obtained from the net plot was thoroughly sun dried, weighed and seed yield expressed in q/ha.

### **3.7.2.5 Stover yield (q/ha)**

The residue obtained from the plot after threshing out the seed was weighed and expressed in q/ha.

### **3.7.2.6 Quality parameters**

The oil content in seeds was determined by using continuous type Nuclear Magnetic Resonance (NMR) Spectrophotometer as suggested by Tiwari *et al.* (1974) and per cent oil content was recorded on the digital display.

### **3.7.2.7 Oil yield**

Oil yield was estimated by multiplying the oil percentage with seed yield/ha and dividing the product with 100.

The soil samples were analyzed for pH, Electrical conductivity, N, P and K by following standard methods as given below:

pH : The pH of the soil was determined in a 1 : 2.5 soil : water suspension using a pH meter with glass electrode assembly Elico model as per the procedure described by Jackson (1973)

ECe : The electrical conductivity of the soil was determined in a 1 : 2.5 soil : water extract using soluble bridge and contents were expressed in dS/m.

Mechanical analysis : The mechanical composition of soil was determined by the Hydrometer method and the contents of sand, silt and clay were expressed in per cent

Nitrogen : Available nitrogen was determined by the alkaline permanganate method as given by Subbaiah and Asija (1956) and is expressed in kg/ha

Phosphorus : Olsen's method : The available P was extracted using 0.5 m NaHCO<sub>3</sub>, pH 8.5 at a soil : solution ratio of 1 : 20 after shaking for 30 minutes and employing stannous chloride (SnCl<sub>2</sub>) blue color method using a Klett-Summerson photo electric colorimeter.

Potassium : Neutral normal ammonium acetate method; The

available potassium was extracted with neutral normal ammonium acetate at a soil : solution ratio of 1.5 and then estimated using a flame photometer as given by Hanway and Heidal (1952).

### **3.8 Balance sheet of soil available NPK**

The balance sheet of available nutrients viz; N, P and K after harvest of the crop was worked out by the following formula (Masthan, 1996).

$$X = a - [(b + c) - d]$$

Where,

X = N, P, K (kg) gain or loss at the end of the season

a = Actual balance of available N, P, K (kg) at the end of the season

b = initial status of available N, P, K (kg/ha)

c = Addition of N, P, K (kg/ha) through fertilizers

d = quantity of N, P, K (kg/ha) removed by the crop

### **3.9 Plant analysis**

The plant samples collected for dry matter estimation were separated into stalks, leaves and siliquae at each stage and

powdered in an electric grinding machine. The finely ground material was used for chemical analysis.

### **3.9.1 Major nutrients (NPK)**

The nitrogen content in mustard plant samples were estimated by modified microkjeldhal method (Piper, 1966) after digesting the organic matter by  $H_2SO_4$  and  $H_2O_2$ .

The plant material was digested in triacid mixture of 9 : 4 : 1 ( $HNO_3$  :  $H_2SO_4$  :  $HClO_4$ ) following Piper (1966). Phosphorus content in the plant digest was determined by Vanado – Molybdophosphoric yellow colour method as described by Jackson (1958) using spectrophotometer at 420 nm. Potassium content was determined with ELICO-Flame photometer (Piper, 1966). The nutrient concentration was expressed in percentage. The removal of N, P and K by the plant parts of mustard crop was computed as follows.

Removal of nutrients (kg/ha) = Nutrient content / 100 x Total dry matter (kg/ha)

### **3.9 Multiple regression analysis**

Multiple regression approach is used to calculate the dose of nutrient(s) required to obtain the maximum yield of crops under given set of experimental conditions. It can further be used to

calculate the economic dose of fertilizer nutrients by incorporating a constant factor i.e., per unit cost of produce divided by unit cost of input fertilizer in the original equation. In this approach yield is regressed with soil and fertilizer nutrients, their quadratic terms and the interaction term of soil and fertilizer nutrients.

### 3.9.1 Conditions for application

Soil test crop response calibration for economic yield of a crop is possible only when the response to added nutrients follow the law of diminishing returns. There are eight different response types signified by the signs for the linear and quadratic terms of the added fertilizer and the interaction term between the fertilizer and soil test value. The following eight response types are recognized, but except the last, first seven types are non-ideal for derivation of soil test based fertilizer recommendation.

- (i) - - + (ii) - - - (iii) + + + (iv) + + - (v) - + + (vi) - + -  
 (vii) + - + and (viii) + - -

The quadratic function was fitted with combination of (i) linear terms of soil and fertilizer nutrients (ii) quadratic terms of soil and fertilizer nutrients and (iii) interaction between soil and fertilizer nutrients.

Through numerous experiments, it has been realized that for high order of predictability the coefficient of determination should be equal to or more than 66%. Also the partial regression coefficients obtained from the relationship should be statistically significant i.e. they should be different from zero at least at five per cent level of significance.

The three basic parameters required to calculate the targeted yield were worked out by following the procedure laid out by Ramamoorthy *et al.* (1967) as follows.

**Nutrient requirement of N, P and K for grain production**

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

**Per cent contribution of nutrient from soil**

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

### Per cent contribution of nutrient from fertilizers

$$\left[ \begin{array}{c} \text{Nutrient} \\ \text{Uptake} \end{array} \right] - \left[ \begin{array}{cc} \text{Av soil} & \% \text{ contribution} \\ \text{test value} & \text{x of nutrients} \\ \text{Kg/ha} & \text{from soil/100} \end{array} \right]$$

% Contribution of nutrients from fertilizers =  $\frac{\text{fertilizer nutrient applied kg/ha}}{\text{fertilizer nutrient applied kg/ha}} \times 100$

### 3.10 Derivation of fertilizer adjustment equations

The fertilizer adjustment equation of N, P and K can be derived by using multiple equation of yield as computed above. They are derived by partially differentiating yield with respect to each fertilizer nutrient. The fertilizer adjustment equations can be derived for attaining maximum yield, maximum profit and desired rate of return. The adjustment equations of fertilizer nitrogen can be given as

$$FN = \beta_7 / 2\beta_8 - \beta_{11} / 2\beta_8 \times SN \quad \text{Maximum Yield}$$

$$FN = \beta_7 / 2\beta_8 - \beta_{11} / 2\beta_8 \times SN - 1 / 2\beta_8 \times R \quad \text{Maximum profit}$$

$$FN = \beta_7 / 2\beta_8 - \beta_{11} / 2\beta_8 \times SN - 1 / 2\beta_8 \times 2 \quad \text{Desired Rate of Return}$$

Where, DRR is desired rate of return. Similarly, phosphorus and potassium fertilizer adjustment equations can be derived by using the above multiple regression equation.

$\beta_7$ ,  $\beta_8$  and  $\beta_{11}$  are regression coefficients.

## LAYOUT OF THE MAIN EXPERIMENT

Strip I			Strip II			Strip III					
0 X			1 X			2 X					
N	P	K	N	P	K	N	P	K			
*	1	2	1	*	3	2	2	*	3	2	3
	2	2	2		2	1	1		3	2	1
	0	0	0		1	2	1		3	3	1
	2	1	2		1	1	2		3	1	1
	2	3	2		2	3	3		2	2	0
	2	2	1		3	3	3		2	0	2
	2	2	3		0	0	0		0	2	2
	1	1	1		3	3	2		0	0	0
*	3	2	2	*	3	2	3	*	1	2	2
	2	1	1		3	2	1		2	2	2
	1	2	1		3	3	1		0	0	0
	1	1	2		3	1	1		2	1	2
	2	3	3		2	2	0		2	3	2
	3	3	3		2	0	2		2	2	1
	0	0	0		0	2	2		2	2	3
	3	3	2		0	0	0		1	1	1
*	3	2	3	*	1	2	2	*	3	2	2
	3	2	1		2	2	2		2	1	1
	3	3	1		0	0	0		1	2	1
	3	1	1		2	1	2		1	1	2
	2	2	0		2	3	2		2	3	3
	2	0	2		2	2	1		3	3	3
	0	2	2		2	2	3		0	0	0
	0	0	0		1	1	1		3	3	2

4.5 m

\* Leave enough space in between each gradient

N (kg/ha)

P<sub>2</sub>O<sub>5</sub> (kg/ha)

K<sub>2</sub>O (kg/ha)

N<sub>0</sub> - 0

P<sub>0</sub> - 0

K<sub>0</sub> - 0

N<sub>1</sub> - 40

P<sub>1</sub> - 20

K<sub>1</sub> - 20

N<sub>2</sub> - 80

P<sub>2</sub> - 40

K<sub>2</sub> - 40

N<sub>3</sub> - 120

P<sub>3</sub> - 60

K<sub>3</sub> - 60



## **CHAPTER – IV**

### **RESULTS**

The results of the investigation “Soil test crop response (STCR) correlation studies in Indian mustard” are tabulated and inferences are drawn for a coherent understanding of the crop performance in this section.

#### **4.1 FERTILITY GRADIENT EXPERIMENT**

##### **4.1.1 Chemical properties of soil**

The composite soil sample drawn from a depth of 0-30 cm before the sowing of fodder sorghum had 7.10 pH and ECe of 0.138 dS/m (Table 4a). Available nutrient content was 213 kg N, 70 kg P<sub>2</sub>O<sub>5</sub> and 299 kg K<sub>2</sub>O/ha. The cultivation of fodder sorghum SSG 59-3 as an exhaust crop with or without the application of fertilizers substantially influenced the chemical properties of soil after its harvest. The pH raised to 7.56 and the ECe reduced enormously to as low as 0.05 dS/m by growing the crop on native soil fertility without the addition of fertilizers. The available N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O content also reduced to 181, 47 and 250 kg/ha respectively. The addition of 150, 75 and 100 kg recommended level of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O/ha increased the pH to 7.26 and reduced the ECe to 0.04 dS/m after the harvest of the crop. But

the level of available nutrients increased to 238 kg N, and 372 kg K<sub>2</sub>O/ha, while the available P<sub>2</sub>O<sub>5</sub> was reduced to 52 kg/ha.

The application of twice the recommended level of fertilizers did not bring a perceptible change in the pH or E<sub>Ce</sub> compared to the recommended level. But, the level of available nutrients increased to 401 kg N, 57 kg P<sub>2</sub>O<sub>5</sub> and 391 kg K<sub>2</sub>O/ha. Still the available P<sub>2</sub>O<sub>5</sub> was less than the initial value.

#### **4.1.2 Grain and fodder yield of sorghum**

The data on grain and fodder yield of sorghum in the gradient strips are furnished in Table 4b. The crop produced extremely low grain yield of 1.51 and fodder yield of 31.83 q/ha without the application of fertilizers. The production triggered to as high as 6.19 q grain and 84.2q fodder by the application of 150, 75 and 100 kg recommended level of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O/ha. The high dose of twice the recommended level of fertilizers increased the grain yield to 9.14 q/ha. But, the fodder yield of 82.78 q/ha was equivocal to that of the recommended level.

## **4.2 SOIL TEST CROP RESPONSE CORRELATION STUDIES IN INDIAN MUSTARD**

### **4.2.1 Vegetative crop growth**

#### **4.2.1.1 Plant height**

The data on plant height of mustard in response to the graded levels of fertilizers applied under different fertility gradients of the soil are presented in Table 5. The mean plant height of mustard was less at 45, 60, 75 and 90 days after sowing in the 0 X fertility gradient compared to its vigorous growth in 1 X as well as 2 X fertility gradients during the corresponding sampling stages.

The crop grown without the application of nitrogen in 0 X fertility gradient attained a mean plant height of 48.9 cm at 45 days after sowing in the previously unfertilized strips of the soil. The plant height was 84.0 cm at 60 days after sowing. It was 92.1 cm and 98.8 cm at 75 and 90 days after sowing respectively. The unfertilized crop grown in the 1 X soil fertility strip attained a remarkably tall height of 79.5, 100.4, 106.9 and 111.1 cm at 45, 60, 75 and 90 days after sowing. The growth was almost similar in the 2 X fertility gradient as in 1 X during the corresponding stages of crop growth. The application of nitrogenous fertilizer at 40 kg N/ha remarkably increased the mean plant height in the

0 X, 1 X and 2 X fertility gradients during every stage of crop growth. The plant height increased further in response to an increase in the level of fertilization up to 80 kg N/ha in 0 X fertility gradient. But, the 1 X and 2 X fertility gradients, the application of high level of 80 and 120 kg N/ha did not increase the plant height over the response due to 40 kg N/ha.

Mustard exhibited considerable variation in the plant height without the application of phosphorus in the previously unfertilized than the fertilized strips. It attained very low plant height of 63.9, 90.0, 97.1 and 104.2 cm at 45, 60, 75 and 90 days after sowing in the 0 X fertility gradient. It grew tall to a height of 90.3, 103.6, 108.7 and 112.8 cm during the corresponding stages of crop growth in 1 X fertility gradient. The response was almost similar in 2 X fertility gradient. The crop responded to grow tall due to the application of 20 kg P<sub>2</sub>O<sub>5</sub> /ha at every stage of sampling in all the three fertility gradients. The plant was tall in 1 X and 2 X fertility gradients compared to 0X gradient. However the plant height did not improve by increasing the dose of phosphorus from 40 to 60 kg P<sub>2</sub>O<sub>5</sub> /ha in any of the three fertility gradients.

The mean plant height of mustard was also influenced by the level of K fertilizer applied to the soil in different fertility gradients created by the previous exhaust crop of sorghum. The crop attained tall height of 89.1, 102.5, 107.9 and 113.7 cm at 45,

60, 75, 90 days after sowing without the addition of potassium in the 1 X fertility gradient compared to its low growth with a mean height of 63.2, 89.6, 98.9 and 105.8 cm during the corresponding growth stages in the 0 X strip. There was not much variation in the plant height of mustard in the 2 X than in the 1 X fertility gradient at any stage of crop growth. Application of 20 kg K<sub>2</sub>O/ha in 0 X, 1 X and 2 X fertility gradients increased the plant height of the crop substantially at every stage of its growth. The application of 40 or 60 kg K<sub>2</sub>O/ha did not induce a distinct response to further improve the plant in any of the three fertility gradients.

#### **4.2.1.2 Number of branches per plant**

The data on mean number of branches per plant at the time of harvest in response to the application of graded levels of N P K under different fertility gradients of the soil is presented in Table 6. The variable fertility gradients showed an edge with a mean of 3.4 and 3.1 branches per plant in the 1 X and 2 X compared to 3.0 branches per plant in the 0 X fertility gradient.

Mustard produced 2.4 branches per plant in the 0 X fertility gradient without the application of nitrogen. The application of 40 kg N/ha increased the number of branches per plant to 3.1 and further to 3.3 branches per plant by the application of 80 kg N/ha. Branching also improved from a mean of 3.3 per plant in mustard

grown without the application of nitrogen to 3.5 by the application of 80 kg N/ha in 1 X fertility gradient. Similarly, more number of 3.2 branches per plant were produced by mustard fertilized with 80 kg N/ha compared to 3.0 branches per plant without the application of this nutrient in the 2 X fertility gradient.

Mustard fertilized with 20 kg  $P_2O_5$  / ha produced more number of 3.2, 3.5 and 3.2 branches per plant in the 0 X, 1 X and 2 X fertility gradient than the less number of 2.6, 3.4 and 3.0 branches per plant in control in the respective fertility gradients.

Mustard fertilized with 20 kg  $K_2O$ /ha in the 0 X fertility gradient produced more number of 3.4 branches per plant compared to 2.5 branches produced by the plant without the application of potassium. However, there was no improvement in the number of branches per plant by the application of 20 kg  $K_2O$  / ha in the 1 X and 2 X fertility gradients.

#### **4.2.1.3 Number of leaves per plant**

The data on number of leaves per plant of mustard in response to graded levels of fertilizers under different fertility gradients of soil is presented in table 7.

On an average mustard produced 13.1 leaves per plant at 45 days after sowing in the 0X fertility gradient. They reduced to

9.8 and 3.5 per plant subsequently at 60 and 75 days after sowing. Relatively large number of 18.3, 10.8 and 4.7 leaves per plant were recorded during the corresponding stages in the 1 X fertility gradient. Similarly, more number of 19.6, 11.3 and 5.5 leaves were recorded in the 2 X fertility gradient.

Mustard grown without the application of nitrogen produced more number of 11.6 leaves at 45 days, 8.7 at 60 days and 4.9 leaves at 75 days after sowing compared to less number of 7.9 leaves at 45 and 60 days and 4.4 leaves at 75 days in the 0 X strip. It responded to produce still more number of 13.6, 10.2 and 4.5 leaves per plant in the 2 X strip. There was a progressive increase in the number of leaves per plant at 45 days age of the crop with increase in the level of nitrogen by increments of 40 up to 120 kg N/ha in 0 X and 1 X fertility gradients. The number of leaves substantially increased with the level of fertilization up to 80 kg N/ha in the 2 X fertility gradient. More number of leaves were retained on the plant at 60 and 75 days age of the crop with increase in the level of nitrogen in all the three fertility gradients.

Mustard grown without the application of phosphorus in the 1 X strip produced 14.3 leaves per plant at 45 days, retained 9.9 leaves at 60 days and 4.9 leaves per plant at 75 days after sowing. In the 2 X strip, the crop had 14.9, 11.5 and 5.1 leaves per plant during the corresponding stages. But, the crop had less

number of 10.1, 9.3 and 4.7 leaves per plant during the respective stages in the 0 X strip. Maximum number of 16.5 leaves per plant were recorded at 45 days age of the crop in response to the application of 40 kg  $P_2O_5$  / ha in the 0 X fertility gradient. While, a maximum of 21.0 leaves per plant were recorded by the application of 60 kg  $P_2O_5$  / ha in the 1 X strip. Maximum number of 22.3 leaves per plant were recorded by the application of 40 kg  $P_2O_5$  / ha to mustard grown in 2 X gradient.

The soil fertility gradient showed considerable variation in the number of leaves per plant of mustard without the application of potassium at different stages of crop growth. It had less number of 11.4, 9.0 and 4.4 leaves per plant at 45, 60 and 75 days after sowing in the 0 X strip. There were more number of 14.3, 10.6 and 4.6 leaves per plant during the respective stages in the 1 X fertility gradient. A still high number of 16.0, 9.8 and 5.0 leaves per plant were recorded in the 2 X fertility gradient. Application of potassium increased the production of leaves in all the three fertility gradients. The crop required 20 kg  $K_2O$ /ha to produce maximum number of leaves per plant. There was no advantage of increasing the level of fertilization to 40 or 60 kg  $K_2O$ /ha.

#### 4.2.1.4. Leaf dry weight per plant

The data on dry matter of leaves per plant of mustard in response to different levels of fertilizers in variable grades of soil fertility is presented in table 8. Maximum mean leaf dry matter of 4.1 g per plant was produced at 45 days in 2 X fertility gradient. The crop grown in 1 X fertility gradient had a mean leaf dry weight of 3.6 g per plant. Least mean leaf dry weight of 2.8 per plant was registered in 0 X fertility gradient. The leaf dry weight was relatively less at 60 than at 45 days in the three fertility gradients.

The fertility gradient of the soil had a remarkable influence on the leaf dry matter per plant of mustard. In the 0 X fertility gradient, mustard grown without the application of nitrogen accumulated low dry matter content of 1.9 g per plant at 45 days and 1.7 g per plant at 60 days of sowing. A larger dry matter content of 2.2 and 1.8 g per plant was recorded in the 1 X fertility gradient while still a higher quantity of 3.0 and 2.4 g leaf dry matter was recorded in the 2 X fertility gradient during the corresponding stages. This trend was also *akin* in the three fertility gradients by the application of 40, 80 and 120 kg N/ha to mustard.

Mustard grown without the application of phosphorus produced 3.0 and 2.5 g leaf dry matter per plant in 2 X strip while

it was 3.0 and 2.0 g at 45 and 60 days after sowing in the 1 X strip. Leaf dry matter content of 2.3 and 1.7 g per plant was recorded in the 0 X fertility gradient. The application of phosphorus at 40 kg P<sub>2</sub>O<sub>5</sub> / ha maximized the leaf dry matter content in each of three strips. The response to this level of fertilization was more in the 2 X and 1 X than in 0 X fertility gradient.

The residual fertility from the previous fertility gradients also had a remarkable influence on leaf dry matter in response to the omission or application of potassium. The leaves accumulated 3.1 g leaf dry matter / plant at 45 days and 2.6 g at 60 days in the 2 X strip. The leaf dry matter was 2.6 and 2.0 g per plant during the respective stages in the 1 X gradient while it was only 2.4 and 1.8 g per plant in the 0 X gradient. The leaf dry matter increased by the application of 20 kg K<sub>2</sub>O/ha in each of the three strips.

#### **4.2.1.5 Dry matter of stem per plant**

The mean dry weight of stem per plant increased progressively from 4.8 g at 45 days to 8.4 g at 90 days after sowing in 0 X fertility gradient (Table 9). More stem dry matter per plant was recorded in the 1 X and 2 X fertility gradients. It increased from 4.9 g per plant at 45 days to 10.7 g per plant at 90

days in the 1 X and from 5.2 to 10.2 g per plant in the 2 X fertility gradient.

Omission of nitrogenous fertilizer to mustard in 0 X fertility gradient rendered the crop to accumulate low dry matter content of 3.1, 4.2, 4.6 and 6.3 g per plant in the stem than 4.4, 5.1, 5.5 and 9.1 g in the 1 X fertility gradient. This dry weight was also more in the 2 X than in the 0 X fertility gradient.

The crop recorded a progressive increase in the accumulation of stem dry matter per plant with increase in the level of fertilizer up to 120 kg N/ha in the 0 X and 1 X fertility gradients. While, this improvement was limited up to 80 kg N/ha in the 2 X fertility gradient. In all the fertilizer treatments, the stem dry matter per plant was more in 1 X and 2 X than in 0 X fertility gradient.

The fertility of previous crop had a remarkable influence on the stem dry matter content of mustard grown with or without the application of phosphorus. The stem dry matter of mustard grown without the application of phosphorus in the 0 X fertility gradient had a least dry matter of 3.4 g per plant. It increased with advance in age of the crop up to 7.3 g per plant. The performance of the crop improved in the 1 X and 2 X fertility gradients. The stem dry matter increased from 4.9 g per plant at 45 days to 8.6 g

at 90 days in the 1 X fertility gradient and from 5.2 to 8.2 g in the 2 X fertility gradient. The application of 40 kg  $P_2O_5$  / ha enhanced the stem dry matter in the three fertility gradients. The responses were of a higher magnitude in the 2 X and 1 X than in 0X fertility gradient.

Dry matter accumulation in stem of mustard also varied with the graded dose of potassium applied to the crop grown in different fertility gradients. The fertility gradient without the application of potassium to mustard exhibited a remarkable variation in the pattern of dry matter accumulation of mustard. The crop had a very low dry matter content in the stem ranging from 3.4 g per plant at 45 days after sowing to 7.5 g at 90 days after sowing in the 0 X fertility gradient. The stem dry matter improved considerably to 4.4 g per plant at 45 days and 8.7 g per plant at 90 days in the 1 X fertility gradient. The response was almost similar in the 2 X as in the 1 X fertility gradient. The application of 20 kg  $K_2O$ /ha enhanced the dry matter per plant of stem compared to control at every stage of crop growth in each of the three fertility gradients. This fertilizer effect was superior in 1 X and 2 X than in 0 X strip.

#### **4.2.1.6 Number of siliquae per plant**

Mustard exhibited a spectacular response to the residual fertility gradient as well as the level of NPK fertilizers during the growing season on the number of siliquae per plant (Table 10). The mean number of siliquae per plant increased progressively from 45 to 90 days after sowing in each of the three fertility gradients. There was a mean of 22.7 siliquae per plant at 45 days age of the crop in the 0 X fertility gradient. They increased to 39.1 at 60 days 51.8 at 75 days and 79.8 at 90 days after sowing. The crop produced more number of 27.3, 39.9, 56.5 and 104.6 siliquae per plant at 45, 60, 75 and 90 days after sowing in the 1 X fertility gradient. The crop grown in the 2 X fertility gradient produced still more number of 31.5, 51.1, 69.7 and 108.1 siliquae per plant during the respective crop growth stages.

The number of siliquae per plant were influenced both by the level of nutrients applied to mustard and the residual influence of the soil fertility gradients created by growing the exhaust crop. Mustard grown on 0 X fertility gradient without the application of nitrogen produced less number of 6.9, 24.8, 33.4 and 44.1 siliquae per plant compared to the more number of 10.7, 21.4, 41.9 and 74.4 siliquae per plant at 45, 60, 75 and 90 days after sowing in the 1 X fertility gradient. The response was further magnified in 2 X fertility gradient by producing more number of

28.3, 47.6, 57.0 and 76.2 siliquae per plant at 45, 60, 75 and 90 days after sowing,. The crop responded to produce more number of siliquae per plant with increasing level of nitrogen in each of three fertility gradients. The magnitude of this response was more in 2 X than in 1 X fertility gradient.

Mustard grown on the residual fertility of 2 X gradient without the application of phosphorus produced 24.5, 48.1, 56.2 and 82.9 siliquae per plant at 45, 60, 75 and 90 days after sowing. The crop grown in 1 X fertility gradient had 16.0, 27.8, 42.1 and 83.8 siliquae per plant at corresponding crop growth stages. The number reduced sharply to 14.3, 28.1, 36.4 and 52.0 siliquae per plant in the 0 X fertility gradient. Considerable increase in the number of siliquae were recorded by the application of 20 kg  $P_2O_5$  / ha in the three fertility gradients. The same level of 20 kg  $P_2O_5$  /ha with the residual influence from 2 X fertility gradient was more prominent than the 1 X and was least in the 0 X fertility gradient.

The application of 20 kg  $K_2O$ /ha to mustard in the 0X fertility gradient enabled the crop to produce substantially more number of siliquae per plant than its cultivation without the application of potassium. In the 1 X fertility gradient the crop produced more siliquae per plant due to different levels of potassium application. This improvement was more progressive

in the 2 X fertility gradient under any level of potassium applied to the crop.

#### **4.2.1.7 Siliquae dry weight per plant**

The data on dry matter per plant of siliquae in mustard as influenced by different levels of fertilizers under varying fertility gradient of the soil is presented in table 11. The mean dry weight increased progressively from 2.8 g at 60 days to 4.8 g at 75 days and 10.8 g per plant at 90 days after sowing in the 0 X fertility gradient. The crop accumulated more mean siliquae dry weight of 3.0, 6.0 and 13.3 g per plant at 60, 75 and 90 days after sowing in the 1 X fertility gradient. The dry weight was 3.3, 6.9 and 12.5 g per plant in the 2 X fertility gradient.

The dry weight of silique per plant was greatly influenced by the level of fertilizers applied to mustard and the residual effect of fertility gradients. The crop grown in the 0 X fertility gradient without the application of N, P and K invariably accumulated less dry matter in siliquae per plant at 60, 75 and 90 days compared to that in the 1 X fertility gradient. The application of fertilizers enhanced the siliquae dry matter content at different stages of the crop growth in the three fertility gradients. The crop required 40 kg N, 20 kg P<sub>2</sub>O<sub>5</sub> and 20 kg K<sub>2</sub>O/ha for substantial improvement in the dry weight of siliquae per plant. The 1 X and 2 X fertility

gradients were superior to 0 X fertility gradient. They manifested substantial improvement in the dry matter accumulation in the siliquae per plant under each level of fertilizer applied to the crop.

#### **4.2.1.8 Yield attributes of mustard**

The data on yield attributes of mustard in response to different levels of fertilizers and fertility gradient of the soil is presented in table 12. The results indicated that the mean number of seeds per siliqua, test weight of the seeds and seed yield per plant were more in the 1 X and 2 X fertility gradients. The values of all these parameters were low without the application of N, P or K through the fertilizers to mustard grown on different fertility gradients. This effect was more severe in 0 X than 1 X or 2 X fertility gradients. There were 10.2 seeds per pod and test weight of 1000 seed was 4.9 g in mustard grown without the addition of nitrogen in the 0 X fertility gradient. Also, a low seed yield of 4.5 g/plant was realized from this fertility gradient compared to 5.8 g from 1 X and 5.1 g from 2 X fertility gradient. These yield components increased with increase in the level of fertilization up to 120 kg N/ha in each of the three fertility gradients. Similarly, the application of phosphorus at 40 kg P<sub>2</sub>O<sub>5</sub> /ha benefitted the crop to produce more number of seeds per siliquae with higher test weight and more seed yield per plant. This influence was more prominent in 1 X and 2 X than 0 X fertility gradient. The

application of 20 kg K<sub>2</sub>O/ha also increased the number of seeds per siliquae, test weight and seed yield per plant compared to control. The test weight and seed yield per plant were more in the 1 X and 2 X fertility gradients at the same level of 20 kg K<sub>2</sub>O/ha applied to mustard.

#### **4.2.1.9 Nutrient removal by leaves**

The data on N, P and K removed through the leaves of mustard in response to different levels of nutrients applied to the crop grown in different fertility gradients of soil is presented in Table 13.

Mustard grown in 2 X fertility gradient removed more NPK than in 1 X fertility gradient. The removal of these nutrients through the leaves was least in the O X fertility gradient. The leaves removed a mean of 25.1, 6.3 and 21.7 kg NPK per hectare in the 1 X fertility gradient and a mean of 17.3, 4.5 and 14.4 kg NPK/ha in the O X fertility gradient at 45 days after sowing. Relatively low quantities of nutrients were recovered in the leaves at 60 days than at 45 days after sowing.

Mustard grown in O X fertility gradient without the application of nitrogen removed 8.4 kg N, 2.3 kg P and 7.1 kg K/ha at 45 days after sowing. In the 1 X fertility gradient, it removed 13.1 kg N, 3.4 kg P and 11.1 kg K/ha. The leaves

removed still larger quantity of 18.6 kg N, 6.3 kg P and 15.9 kg/ha by growing the crop in 2 X fertility gradient. Such trends were also evinced by the application of graded levels of nitrogen to mustard in the three fertility gradients.

The leaves removed substantially large quantity of 21.1 kg N, 4.7 kg P and 17.2 kg K/ha by the application of 120 kg N/ha in the O X fertility gradient. The nutrient removal enhanced to 33.3 kg N, 6.7 kg P and 28.1 kg K/ha for the same level of nitrogen applied to mustard grown in the 1 X fertility gradient. The response was more prominent in the 2 X fertility gradient. The leaves removed 38.8 kg N, 10.8 kg P and 31.0 kg K/ha. Such trends were also recorded at 60 days after sowing.

Mustard grown in the O X fertility gradient without the application of phosphorus removed 11.8 kg N, 2.9 kg P and 9.8 kg K/ha at 45 days after sowing. It removed 11.4 kg N, 2.4 kg P and 9.8 kg K/ha at 60 days after sowing. In the 1 X gradient the leaves removed 13.1 kg N, 3.4 kg P and 11.1 kg K /ha at 45 days after sowing. The removal of this nutrient was also more in the 2 X than in the O X fertility gradient.

The application of 40 kg  $P_2O_5$ /ha to mustard enhanced the removal of NPK under the three fertility gradients. Similarly the leaves removed more quantity of NPK in the 1 X and 2 X than in

O X fertility gradient in instances whether potassium was applied or not to the mustard crop in the three fertility gradients.

#### **4.2.1.10 Nutrient removal by stem**

The data on NPK removed by the stem of mustard in response to different levels of fertilizer application in different fertility gradients of soil is presented in table 14.

The crop removed a large mean quantity of 49.9 kg N, 14.4 kg P and 42.2 kg K/ha through the stem at 45 days after sowing. It removed low quantity of 19.6 kg N, 5.1 kg P and 25.7 kg K/ha at 60 days after sowing. It removed further low quantity of 16 kg N, 4.6 kg P and 18.2 kg K/ha at 75 days after sowing. The crop removed slightly more quantity of 20.1 kg N/ha at 90 days after sowing, while the removal of 4.4 kg P and 18.4 kg K/ha was almost similar as at 75 days after sowing. The mean quantity of NPK removed at different stages of crop growth was more in 1 X and 2 X than in 0 X fertility gradient. The stem removed low quantity of N, P and K without the application of these nutrients to mustard crop in each of three fertility gradients. This reduction was more severe in the 0 X than 1 X and 2 X fertility gradients. The application of 80 kg N to mustard increased the removal of N, P and k throughout the crop growth period. This effect was more prominent in the 1 X and 2 X fertility gradients. Similarly, the

application of 40 kg  $P_2O_5$ /ha and 60 kg  $K_2O$ /ha influenced the crop to remove more NPK through the stem than the control at different stages of crop growth. More nutrients were removed at any given level of fertilizer application in the 2 X than in 1 X and 0 X fertility gradient.

#### **4.2.1.11 Nutrients removal by siliquae**

The data on NPK removed by the siliquae per plant of mustard treated with different level of fertilizers under the different fertility gradients of soil is presented in table 15. The siliquae removed more NPK at 75 days than at 60 days after sowing. The siliquae removed a mean quantity of 16.8 kg N, 4.0 kg P and 11.4 kg K/ha in the 0 X fertility gradient at 60 days after sowing. This was less than the mean of 21.0 kg N, 5.1 kg P and 12.8 kg K/ha in the 1 X fertility gradient. Similarly, at 75 days the crop removed more quantity of 24.6, 5.9 and 14.4 kg NPK/ha in the 1 X fertility than the mean of 23.1, 3.9 and 12.9 kg NPK/ha in the 0 X fertility gradient. Mean maximum quantity of 23.1, 5.3 and 13.7 kg NPK/ha was removed through the siliquae in the 2 X fertility gradient at 60 days after sowing. Similarly at 75 days after sowing, the crop removed large quantity of 25.9, 5.3 and 13.6 kg NPK/ha than in the lower fertility gradient. The application of 40 kg N/ha in the 0 X fertility gradient enabled the crop to remove large quantity of 17.8, 4.5 and 12.4 kg NPK/ha compared to 9.4,

2.6 and 7.8 kg NPK/ha in the control at 60 days after sowing. This trend was also reflected at 75 days after sowing. The application of 40 or 80 kg N/ha in the 1 X and 2 X fertility gradient recorded least deviation in the NPK content removed by the siliquae compared to those without the application of nitrogen to the crop. The application of 20 kg  $P_2O_5$  / ha to mustard in 0 X fertility gradient benefitted the crop to remove large quantity of 18.4 kg N, 3.9 kg P and 11.7 kg K/ha compared to the low quantity of 11.9, 2.8 and 8.8 kg NPK/ha removed by the siliquae of mustard at 60 days age of the crop and grown without the application of phosphorus. This trend was in consonance even at 75 days after sowing. Such a remarkable influence of the application of phosphorus @ 20, 40 and 60 kg  $P_2O_5$ /ha in the 1 X and 2 X fertility gradients was not evident either at 60 or 75 days after sowing.

The role of potassium was also similar to phosphorus. The application of 20 kg  $K_2O$ /ha enabled the crop to remove 16.9 kg N, 4.2 kg P and 11.8 kg K/ha compared to 11.2, 2.8 and 8.1 kg/ha of the respective nutrients removed through the siliquae of the crop receiving no potassium at 60 days after sowing. This trend was also recorded at 75 days after sowing. The siliquae removed 16.9, 1.7 and 8.8 kg NPK/ha without the application of potassium. Their removal increased to 23.0, 5.6 and 14.1 kg NPK/ha

consequent to the application of 20 kg  $K_2O$ /ha. But such differentiating trends due to the fertilization of potassium were not distinct in the 1 X and 2 X fertility gradients.

#### **4.2.1.12 Nutrient removal by seed**

The data on NPK removed by mustard seed in response to different levels of fertilizers under the different soil fertility gradients is presented in table 16. Mustard grown in 1 X fertility gradient without the application of nitrogen removed more quantity of 10.0, 2.83 and 6.0 kg NPK/ha through the seed compared to low quantity of 6.8, 2.0 and 3.7 kg NPK/ha in the O X fertility gradient. It removed still larger quantity of 14.0, 3.1 and 6.7 kg/ha NPK in the 2 X fertility gradient. Withholding the application of phosphorus in the 1 X fertility gradient also enhanced the removal of these nutrients to the extent of 18.6, 3.2 and 8.9 kg NPK/ha in contrast to the low quantity of 11.0, 2.5 and 5.2 kg NPK/ha through the seed by growing the crop in the O X fertility gradient. Seed removed relatively low quantity of these nutrients in the 2 X than in 1 X fertility gradient.

Maximum quantity of 16.1 kg N, 3.0 kg P and 7.8 kg K/ha was removed by the seed of mustard grown without the application of potassium in the 2 X fertility gradient compared to those in the 1 X and OX fertility gradients.

Increasing the level of nitrogen upto 120 kg/ha increased the NPK removal by seed of mustard grown in the three fertility gradients. Maximum quantity 31.9, 3.8 and 16.3 kg NPK/ha was removed by the application of 120 kg N/ha in the 2 X fertility gradient.

The increasing level of phosphorus at increments of 20 up to 60 kg  $P_2O_5$ /ha increased the removal of NPK through the seed of mustard grown in each of the three fertility gradients. The response was more prominent in the 1 X than 0 X fertility gradient. The crop required high level of 60 kg  $K_2O$ /ha to extract maximum quantity of 29.1, 4.3 and 15.4 kg NPK/ha when it was grown in 0 X fertility gradient. But it removed 31.1, 4.3 and 15.9 kg NPK/ha in response to the application of a low dose of 20 kg  $K_2O$ /ha in the 1 X fertility gradient.

#### **4.2.1.13 Nutrient removal by mustard**

The data on NPK removed by the crop in response to the graded levels of the three nutrients in the three fertility gradients is furnished in table 17. The crop removed a mean of 43.3 kg N, 4.4 kg P and 9.5 kg K/ha in the 0 X fertility gradient. The removal of this nutrient increased to 56.0 kg N, 5.1 P kg and 11.8 kg K /ha in the 1 X fertility gradient. There was no further improvement in the nutrient uptake by the crop grown in 2 X fertility gradient.

The application of NPK through the fertilizers in the 0 X, 1 X and 2 X fertility gradients substantially improved the removal of these nutrients by the crop. The crop removed 17.5 kg N, 2.2 kg P and 4.5 K/ha in the 0 X fertility gradient without the application of nitrogen. Large quantity of 62.2 kg N, 6.9 kg P and 13.8 kg K/ha was removed by the application of 120 kg N/ha. In the 1 X fertility gradient, the crop removed a still high quantity of 74.6 kg N, 5.6 kg P and 13.8 kg /ha at this level of fertilization compared to the low quantity of 29.9, 2.7 and 6.7 kg NPK/ha without the application of nitrogen. Similarly, the crop removed more nutrients by the application of 120 kg N/ha in the 2 X fertility gradient.

The crop responded to remove substantially large quantity of 60.7, 5.9 and 12.8 NPK/ha by the application of 60 kg P<sub>2</sub>O<sub>5</sub>/ha in the 0 X fertility gradient compared to the removal of 24.6, 2.5 and 6.0 kg NPK/ha in the control. Such a positive response to the application of 60 kg P<sub>2</sub>O<sub>5</sub>/ha was also recorded in the 1 X and 2 X fertility gradients. The necessity of application of potassium was also recognized by the increasing level of NPK removed by the crop in the three fertility gradients. Mustard grown in 0 X fertility gradient without the application of potassium removed 21.0, 2.1 and 5.5 kg NPK/ha. Consequent to the application of 60 kg K<sub>2</sub>O/ha a larger quantity of 63.2, 7.1 and 11.6 kg NPK/ha were recovered by the crop. A low dose of 20 kg K<sub>2</sub>O/ha was adequate

to maximize the removal of NPK to the extent of 70.5, 7.1 and 18.9 kg/ha in the 1 X fertility gradient

#### **4.2.1.14 Seed and stover yield**

The data on seed and stover yield of mustard in response to the graded levels of fertilizer application under different fertility gradients in the soil is presented in Table 18. The response of mustard was superior to produce more mean seed yield of 4.7 and 4.9 q/ha with mean production of 15.9 and 14.5 q/ha stover yield in the 1 X and 2 X than the seed yield of 3.9 and stover yield of 12.9 q/ha in the 0 X fertility gradient

The crop fertilized with NPK recorded a promising response to produce more seed and stover yield irrespective of the fertility gradient. It yielded 1.3 q seed and 4.7 q stover/ha without the application of nitrogen in the 0 X fertility gradient. The seed yield increased to 1.9 q in the 1 X and 2.6 q/ha in the 2 X fertility gradient with a corresponding stover yield of 8.4 and 9.3 q/ha. Similarly, the cultivation of mustard in the 1 X and 2 X fertility gradients recorded more seed and stover yield than in 0 X without the application of phosphorus and potassium. The crop required 80 to 120 kg N/ha to produce more seed and stover yield in the three fertility gradients. Maximum seed yield of 6.3 q/ha and high

stover yield of 18.7 q/ha was reaped by the application of 80 kg N/ha to mustard grown in 1 X fertility gradient.

Increasing level of phosphorus application to mustard increased the production of seed and stover yield in the three fertility gradients. Both seed and stover yield were more in the 1 X and 2 X fertility gradients under any level of phosphate fertilization. Maximum seed yield of 6.5 q/ha and stover yield of 18 q/ha was realized by the application of 60 kg P<sub>2</sub>O<sub>5</sub> / ha in the 2 X fertility gradient. Application of potassium also benefitted the crop to produce more in the three fertility gradients. Maximum seed yield of 5.7 q/ha was obtained by the application of 60 kg K<sub>2</sub>O/ha in the 2 X fertility gradient in contrast to a low yield of 3.9q/ha with the same level of fertilization to mustard grown in the 0 X fertility gradient.

#### **4.2.1.15 Response surfaces and contour plots**

The data on response surface through a three dimensional display and contour plots for similar yield with different levels of N and P fertilizer is furnished in fig 3. The response was best described by the regression function

$$Y = 1.93 + 0.0894 N - 0.0003 N^2 + 0.0000 N^3 + 0.0958 P - 0.0021 P^2 - 0.0000 P^3 - 0.0028 NP + 0.0000 N P^2 + 0.0000 N^2 K + 0.0000 N^2 P^2$$

The responses were quadratic both for N and P fertilizer. The estimated yield for any given level of N to be combined with the required level of phosphorus is exhibited in the graph showing these values for seed yield ranging from 3.0 to 5.5. q / ha.

Response surfaces and contour plot for seed yield in relation to the combined application of N and K fertilizer are shown in fig. 4. The response surfaces regression best describing the combine influence of N and K was

$$Y = 1.93 + 0.0226 N + 0.0004 N^2 + 0.0000 N^3 + 0.0650 K - 0.0012 K^2 - 0.00001 K^3 + 0.0013 NK - 0.00001 N K^2 - 0.0002 N^2 K + 0.0000 N^2 K^2.$$

The figure illustrated that the response to nitrogen was linear while, phosphorus recorded a curvilinear response. Contour lines indicating the level of given yield response for seed yield of mustard to the level of N and K fertilizer to be applied are also displayed.

#### **4.2.1.16 Oil content (%) and oil yield (q/ha)**

The data on oil percentage in the seed of mustard and oil yield per hectare in response to graded levels of NPK fertilizers and different fertility gradients of soil is presented in table 19. The results revealed that the mean oil content reduced with enriching

soil fertility from 40.7 per cent in 0 X to 38.7 per cent in 1 X and to 37.1 per cent in the 2 X fertility gradient. On the other hand, oil yield was 1.8 q/ha in 0 X fertility gradient. It increased to 2.0q/ha in 1 X and further to 2.2q/ha in the 2 X fertility gradient.

Mustard grown with or without the application of nitrogen in general, had more oil content in the 0 X fertility gradient of the soil. It was low in the 1 X and 2 X fertility gradients. Maximum oil content of 45.7 per cent was recorded by the application of 40 kg N/ha in the 0 X fertility gradient in contrast to no addition of this fertilizer in the same fertility gradient in which the mustard seed had a low oil content of 40.1 per cent. But, maximum oil yield of 2.8 q/ha was recorded by fertilizing the crop with 80 kg N/ha in the 2 X fertility gradient.

The application of phosphorus reduced the oil content with increase in the dose of its application at increments of 20 upto 60 kg P<sub>2</sub>O<sub>5</sub> /ha in the 0 X fertility gradient. On the other hand, the oil content of mustard seed was low with the application of phosphorus in the 1 X or 2 X fertility gradients. Maximum oil content of 42.6 per cent was recorded by the application of 20 kg P<sub>2</sub>O<sub>5</sub> / ha to mustard grown in 1 X fertility gradient of the soil. Maximum oil yield of 3.4 q/ha was obtained by the application 60 kg P<sub>2</sub>O<sub>5</sub> /ha in the 2 X fertility gradient.

The oil content of mustard seed did not show consistent trend in response to the increasing level of potassium from 0 to 60 kg K<sub>2</sub>O/ha in any of the three fertility gradients. The oil yield was invariably low without the application of potassium to mustard in the three fertility gradients. Maximum oil yield of 2.8 q/ha was registered by fertilizing the crop with 60 kg K<sub>2</sub>O/ha and growing it in the 2 X fertility gradient in contrast to a considerably low oil yield of 2.3 q/ha at the same level of fertilizer application in the 0 X fertility gradient.

#### **4.2.1.17 Soil available nutrients (kg/ha) after the harvest of mustard**

The results on soil available nutrients after the harvest of mustard grown with different levels of fertilizers under different fertility gradients of soil is presented in table 20. The available alkaline permanganate nitrogen was 197.6 kg/ha by growing the crop without the application of nitrogen in the 0 X fertility gradient. This was slightly more than the available 181.6 kg N/ha in the 0 X fertility gradient before sowing of the crop. In the 1 X treatment, the soil had 238.3 kg available N/ha after the harvest of exhaust crop and 242.2 kg N/ha after the harvest of mustard. But, the soil available nitrogen reduced drastically from 401.4 kg N/ha before sowing of mustard to 249.1 kg N/ha in the 2 X fertility gradient.

The application of nitrogen through the fertilizer increased the soil available N content in this fertility gradient. The soil had a large quantity of 304.5 kg N/ha in the 0 X fertility gradient due to the application 120 kg N/ha. This level of fertilization also resulted in increased availability of 304.7 kg N/ha in the 1 X fertility gradient compared to its availability with the low level of nitrogen application to the crop. In the 2 X fertility gradient, the available nitrogen was 303.8 kg/ha.

The soil had 47.0, 52.0 and 56.8 kg available  $P_2O_5$ /ha in 0 X, 1 X and 2 X fertility gradients before the sowing of mustard. But, the level of availability of this nutrient was more in the respective fertility gradients even without the application of nitrogen to the crop. These values raised consistently with increase in the level of nitrogen. The soil had 76.5, 78.7 and 80.1 kg available  $P_2O_5$  / ha in 0 X, 1 X and 2 X fertility gradient supplied with 120 kg N/ha.

The soil had 250.3, 372.2 and 391.2 kg available  $K_2O$  /ha in the 0 X, 1 X and 2 X fertility gradient before sowing of mustard. The availability of this nutrient increased to 384.5 and 399.3 kg/ha in the 0 X and 1 X gradient respectively without the application of nitrogen. But, it reduced slightly to 366.3 kg /ha in the 2 X fertility

gradient compared to its initial level and continued to be less even after the application of different levels of nitrogen.

The available soil nitrogen was also more than the initial soil test value in the 0 X and 1 X fertility gradients without the application of phosphorus to the crop. The availability increased with the addition of this nutrient to the crop. But the soil available nitrogen was severely reduced in the 2 X gradient with or without the application of phosphorus compared to the initial value. The application of phosphorus through fertilizers increased the soil available phosphorus in each of the three fertility gradients. The soil available potassium increased substantially to 333.8 kg K<sub>2</sub>O/ha in 0 X fertility gradient without the application of phosphorus compared to initial soil test value of 250.3 kg K<sub>2</sub>O/ha. The application of phosphorus to the crop enhanced the availability of this nutrient. The soil had a similar quantity of 373.8 kg K<sub>2</sub>O/ha in the 1 X fertility gradient by growing the crop without the addition of phosphorus as the initial soil test value of 372.3 kg K<sub>2</sub>O/ha. The application of phosphorus improved the availability of this nutrient. In the 2 X fertility gradient, the soil available K<sub>2</sub>O reduced sharply with no regard to the level of phosphorus fertilization compared to the initial level.

The soil had an available balance of 216.4 kg N/ha in the 0 X fertility gradient without the application of potassium. The

availability of this nutrient increased by the application of potassium. The available nitrogen in the soil was relatively low in 1 X strip without the application of potassium to the crop compared to its initial level. However, more quantity of nitrogen was available by the application of potassium to the crop. In the 2 X gradient, the availability of nitrogen was severely reduced to 230.3 kg N/ha by growing the crop without the application of potassium. The availability of this nutrient increased by the application of potassium and yet remained far low than the initial nitrogen content of 401.1 kg N/ha.

The available phosphorus was more in the 1 X and 2 X fertility gradient than in the 0 X gradient with or without the application of potassium. The soil available potassium was more than the initial soil test value in the 0 X fertility gradient. The soil had 374 kg available  $K_2O$ /ha in the 1 X fertility gradient without the application of potassium to the crop. This was almost equal to the initial level of 372.3 kg  $K_2O$ /ha. Application of potassium to the crop increased the availability of this nutrient in the 0 X and 1 X fertility gradient. But, in the 2 X fertility gradient without the application of potassium the soil had a low quantity of 380.2 kg  $K_2O$ /ha compared to the initial level of 391.2 kg  $K_2O$ /ha. Consequent to the application of graded doses of potassium, the soil available  $K_2O$  reduced further in this gradient.

#### **4.2.1. 18 Correlation coefficients between nutrients and yield**

The data on the association of N, P and K added through the fertilizers recorded highly significant association with seed yield in the 0 X and 2 X fertility gradients (Table 21). This was true for nitrogen and phosphorus fertilizers, while potassium had a significant association at 95 % probability in the 1 X fertility gradient.

The relationship between the amount of nitrogen removed by the crop and seed yield was highly significant in the three fertility gradients. The correlation coefficients due to the removal of phosphorus by the crop did not show a significant association with the seed yield in any of the three fertility gradients. The removal of potassium had a significant correlation with the seed yield in the 0 X and 2 X fertility gradients but the positive correlation of potassium with seed yield in the 1 X fertility gradient was not significant.

The soil available nitrogen had a positive and highly significant association with the seed yield in the 0 X fertility gradient. But, it recorded a significant and positive association in the 1 X fertility gradient. The soil available phosphorus was positively and significantly correlated with the seed yield of

mustard in the three fertility gradients. The association of potassium with seed yield of mustard was not significant.

### **4.3 MULTIPLE REGRESSION**

#### **4.3.1 Soil available nutrients versus seed yield**

The empirical relationship between soil available NPK and seed yield of mustard per hectare established through multiple regression equation of the quadratic term was as follows.

$$Y = 95.51 + 1.665 SN - 0.0025 SN^2 + 6.322 SP + 0.0674 SP^2 - 31.65 SK + 0.0000169 SK^2 \dots\dots R^2 = 0.95$$

The linear first order and quadratic second order term of soil available nitrogen indicated a positive response to increase the yield in plots with relatively low level of available nitrogen followed by a reduction in the rate of improvement in yield in plots with low level of available nitrogen. The available phosphorus and potassium on the other hand, recorded a negative response in yield in plots with high level of these nutrients followed by a positive trend in plots with relatively more availability of these nutrients.

### 4.3.2 Relationship between nutrients supplied through fertilizers and soil versus yield

The empirical relationship best fitting the nutrient response to yield was

$$Y = 703.00 + 10.8180 FN - 0.0343 FN^2 - 0.6990 SN + 0.0004 SN^2 - 0.0070 FNSN - 11.5750 FP - 0.0267 FP^2 + 2.7210 SP + 0.0610 SP^2 + 0.1760 FPSP + 10.0180 FK - 0.0907 FK^2 - 4.7030 SK - 0.0047 SK^2 - 0.0071 FKSK \dots R^2 = 0.49$$

The estimated equation showed that there was a + - - response for the linear, quadratic and interaction terms for N and K and the coefficient of determination was 0.49.

### 4.3.3 Targeted yield equation

The data on the basic parameters and ready reckoner of fertilizers doses for attaining different targeted yield of mustard is presented in table 22.

The crop required an estimated amount of 5.20 kg N, 1.74 kg P<sub>2</sub>O<sub>5</sub> and 3.42 kg K<sub>2</sub>O/ha for the production of 1 q grain yield/ha. The nutrient supplying efficiency of the soil was 2.2% N, 3.3% P<sub>2</sub>O<sub>5</sub> and 1.1 % K<sub>2</sub>O. The efficiency of fertilizers to supply the nutrients was 19.0% N, 17.0% P<sub>2</sub>O<sub>5</sub> and 38.0% K<sub>2</sub>O. From

these basic parameters, the targeted yield equations developed were

$$FN = 27.50 T - 0.12 SN$$

$$FP_2O_5 = 10.25 T - 0.19 SP$$

$$FK_2O = 9.02 T - 0.03 SK$$

For desired or targeted yield goals in soils of different levels of nutrient availability, the fertilizer requirement can be worked out from these equations. A ready reckoner of fertilizer doses for obtaining estimated targeted yield of 6 and 10 q/ha for a wide range of soil available nutrients is presented in table 22. It may be verified that the level of fertilizer was more for 10 q than the targeted yield of 6 q / ha for any soil test value of available N, P and K. The fertilizer schedule decreased consistently with increase in the levels of soil available NPK.

The data on fertilizer doses required for attaining maximum yield, maximum profit and desired rate of return with the existing cost of fertilizers and mustard seed during different years is presented in table 23. It provides a ready reckoner for prescription of NPK to be applied through fertilizers in soils with varying level of nitrogen and potassium in the available form. The data clearly indicated that the fertilizer requirement decreased with the

increase in level of availability of these nutrients in the soil. The most profitable level of nutrients realized for each of these level of nutrient prescription was less than those to maximize the yield. The data also furnished the quantity of nutrients to be fertilized for maximum profit with the desired rate of return by considering the existing price of fertilizers and seed yield for three years. A ready reckoner is also presented in table 23, for desired rate of returns with twice the ratio for the cost of fertilizer nutrients with every kg production of seed for different years.

#### **4.3.4 Balance sheet**

The data on balance sheet of nutrients after the harvest of mustard crop is presented in table 24. The soil had 181.6 kg N in the 0 X, 238.8 kg N in 1 X and 401.4 kg N in 2 X fertility gradient before the sowing of mustard crop. The crop removed a mean of 40.5, 53.7 and 54.7 kg N/ha from these respective gradients. The expected balance was 201.1 kg N/ha in contrast to the higher value of 267.8 kg N in the available form in the 0 X strips. There was a net gain of 66.6 kg N/ha. But in the 1 X strip the actual balance was 264.4 kg N/ha against the computed balance of 244.6 kg N/ha in the 1 X strip. The available nitrogen was 20 kg in excess of computed balance. In the 2 X fertility gradient the soil was expected to have a balance of 406.8 kg N/ha but the actual

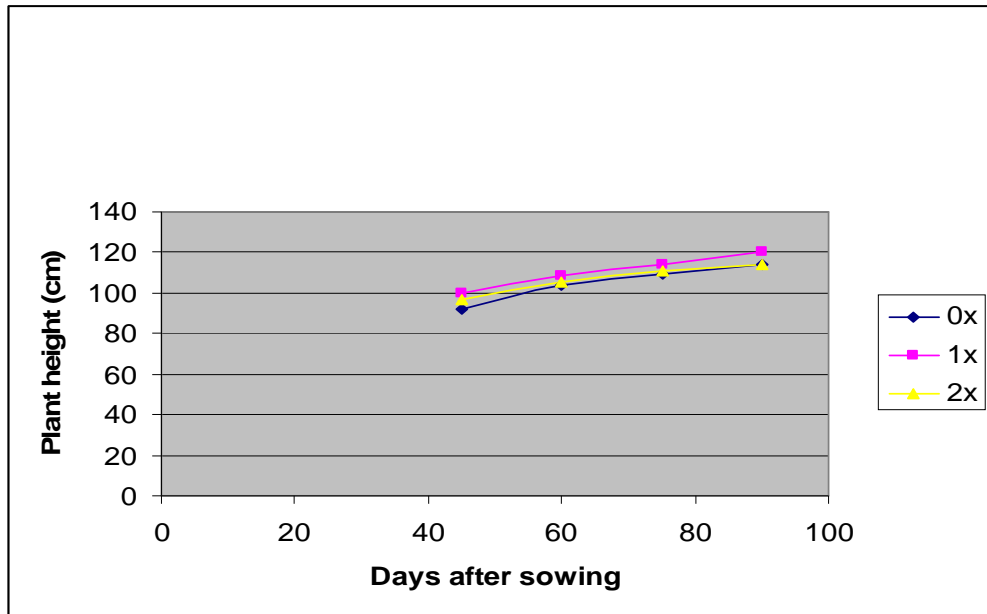
was depleted to as low as 289.2 kg/ha leaving behind a net loss of 117.8 kg N/ha.

The computed as well as actual balance of nitrogen increased with increase the level of fertilizer up to 120 kg N/ha in 1 X fertility gradient. The net gain reduced progressively with increase in the level of nitrogen application. The actual balance of this nutrient was less than the computed balance under each level of nitrogen applied in the 2 X gradient. Therefore, there was a net loss of nitrogen in all the treatments.

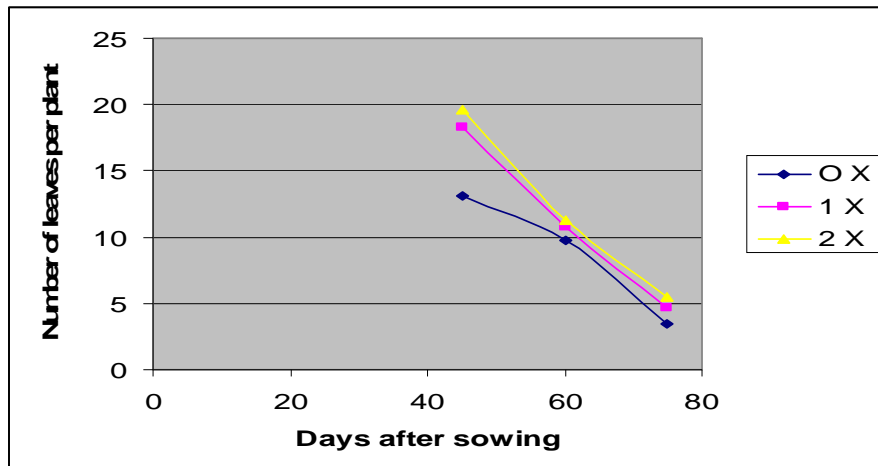
Initially the soil had 20.7, 22.9 and 25.0 kg P/ha before the sowing of mustard crop (Table 23a). It removed more quantity of phosphorus by the application of this nutrient through the graded doses than in the control. The computed balance was also expected to increase with the increasing level of phosphorus applied. But, the actual balance was less than the computed balance by the application of 40 or 60 kg  $P_2O_5$ /ha in the 0 X, 1 X and 2 X fertility gradients. This resulted in a net loss of available P balance. But the actual balance was in excess of the computed balance by the application of 20 kg  $P_2O_5$ /ha.

The initial soil test value of potassium was 207.7, 309.0 and 324.7 kg available K/ha in the 0 X, 1 X and 2 X fertility gradients (Table 23b). The crop responded to remove more K with increase

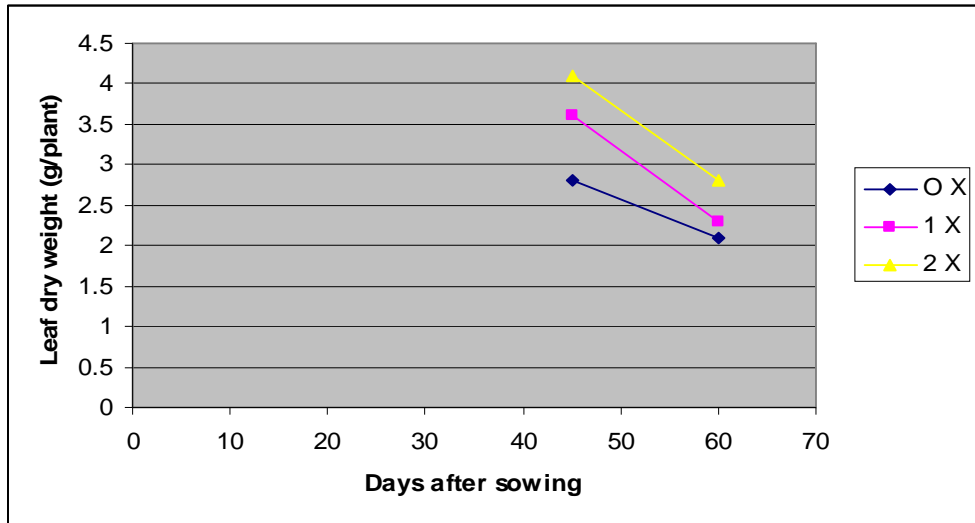
in the level of potassium applied up to 60 kg/ha in the three gradients. The computed balance was also more with the increasing level of this nutrient. The actual balance exceeded the computed balance in each of the fertilizer treatments in the 0 X gradient. There was a maximum net gain of 122.8 kg/ha by the application of 20 kg  $K_2O$ /ha. In the 1 X fertility gradient, the actual balance of 358.0 kg K/ha was more than the computed balance of 311 kg K/ha by the application of 20 kg  $K_2O$ /ha. But at high dose of 40 and 60 kg  $K_2O$  applied to the soil the actual balance was less than the computed balance. In the 2 X fertility gradient there was a net loss of available K owing to the actual soil test values which were less than computed balance irrespective of the level of K applied.



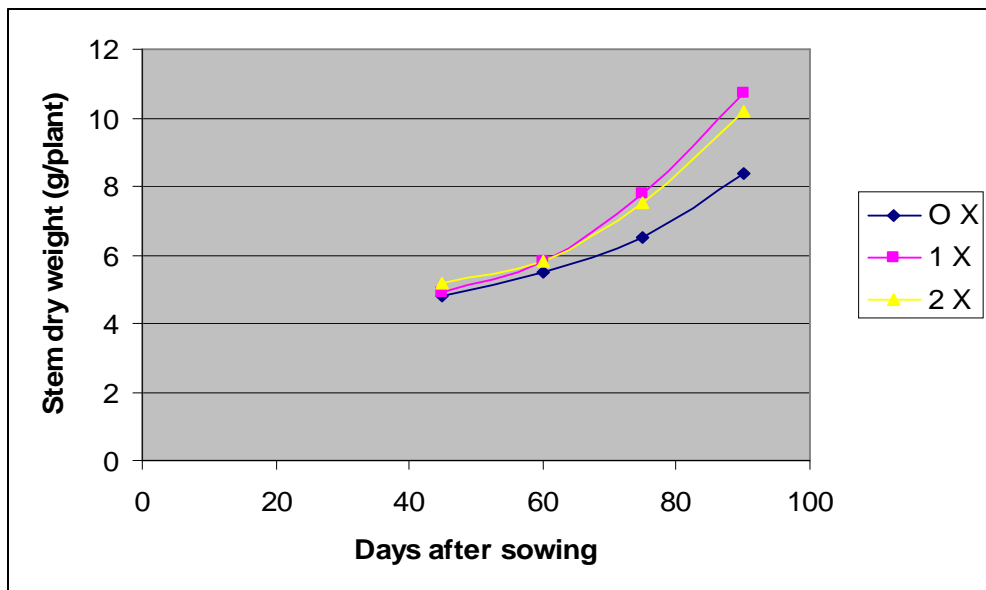
**Fig: 5 Influence of fertility gradient on mean plant height of mustard during crop growth**



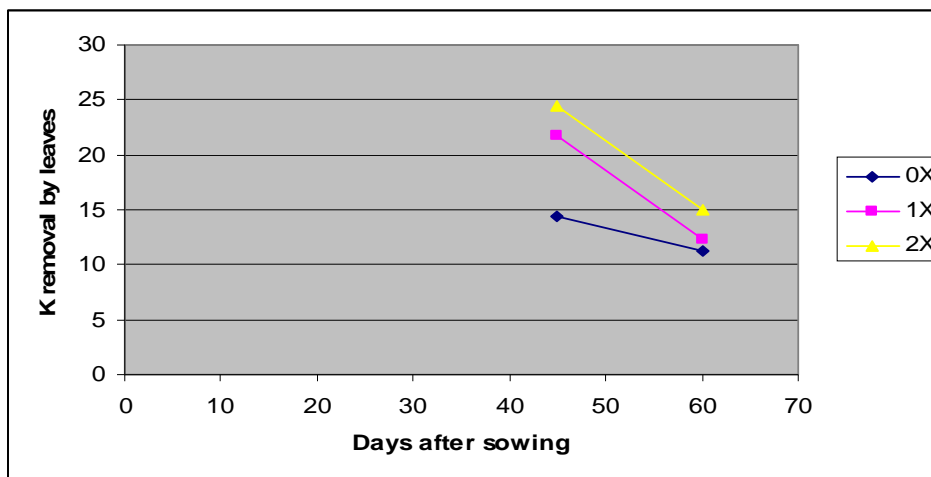
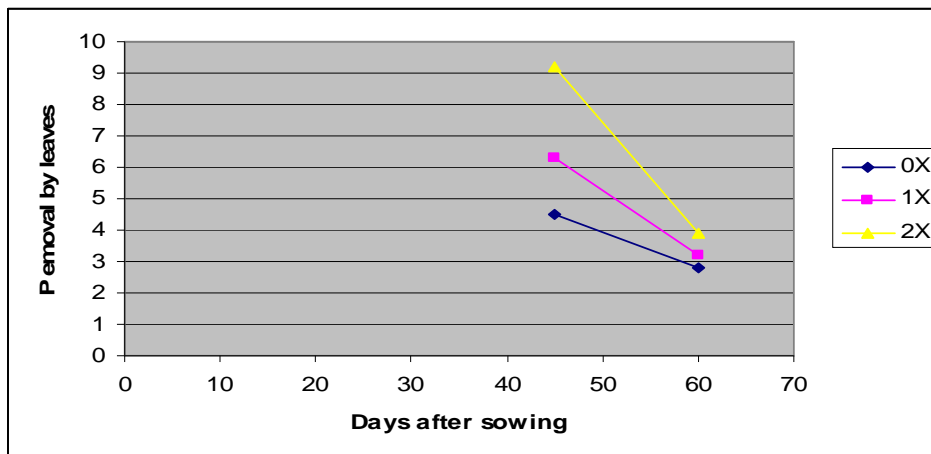
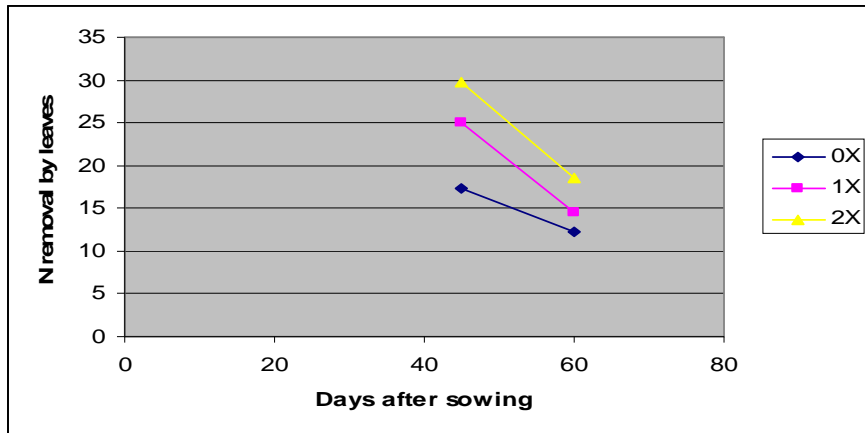
**Fig: 6 Influence of fertility gradient on mean number of leaves per plant of mustard during crop growth**



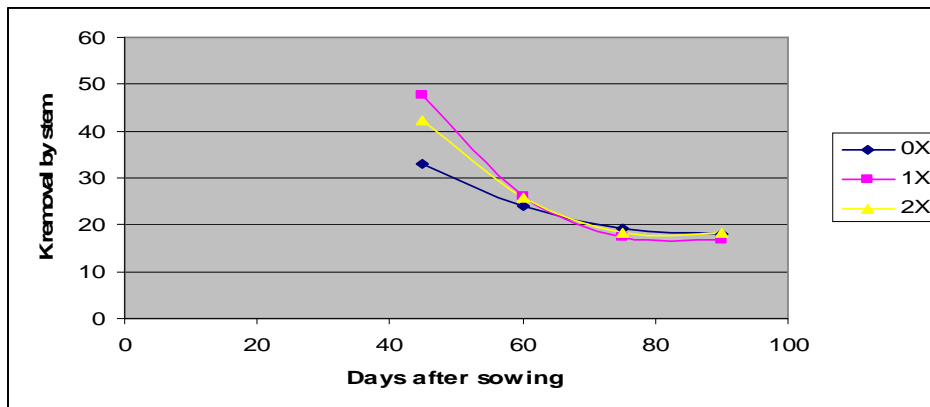
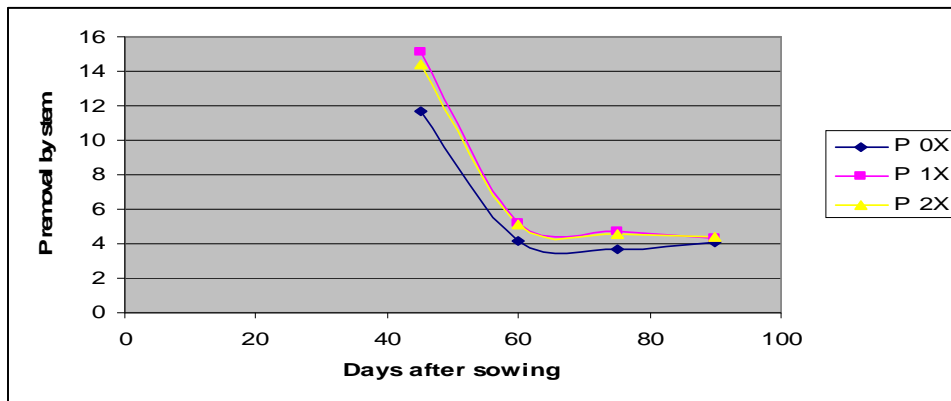
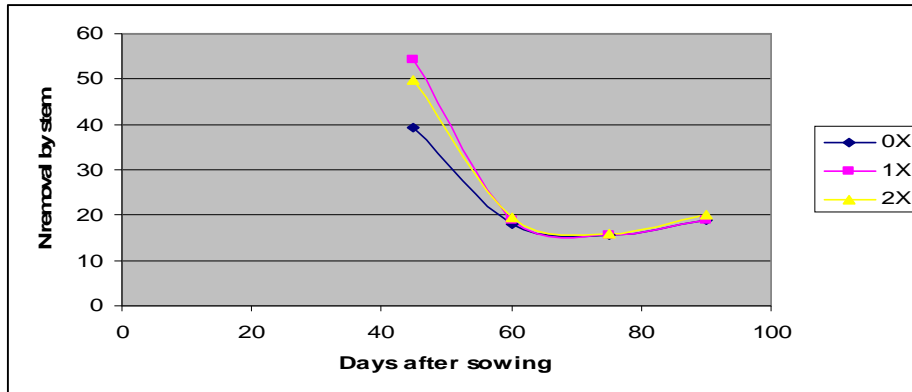
**Fig: 7 Influence of fertility gradient on mean leaf dry weight (g) per plant of mustard during crop growth**



**Fig: 8 Influence of fertility gradient on mean stem dry weight per plant of mustard during crop growth**



**Fig. 9 Removal of NPK (kg/ha) by leaves of mustard as influenced by different levels of fertilizers**



**Fig. 10 Removal of NPK (kg/ha) by stem of mustard as influenced by different levels of fertilizers**

**Table 1 : Physico-chemical properties of the experimental site**

<b>Particulars</b>	<b>Results</b>	<b>Method adopted</b>
<b>1. Physical properties</b>		
<b>Mechanical analysis</b>		
<b>Soil fraction</b>	<b>% composition</b>	
<b>Sand</b>	<b>65.3</b>	<b>International Pipette method (Page et al., 1982)</b>
<b>Silt</b>	<b>23.1</b>	
<b>Clay</b>	<b>14.9</b>	
<b>Textural classe</b>	<b>Sandy loam</b>	
<b>2. Chemical properties</b>		
<b>Soil reaction (pH)</b>	<b>7.1</b>	<b>Glass electrode pH meter Jackson, 1967</b>
<b>Electrical conductivity (dS/m)</b>	<b>0.138</b>	<b>Digital ECe meter (Jackson , 1967)</b>
<b>Available nitrogen (kg/ha)</b>	<b>213.25</b>	<b>Modified alkaline permanganate method (Kjeltec Auto 1030 Analyser)</b>
<b>Available phosphorus (P<sub>2</sub>O<sub>5</sub> kg/ha)</b>	<b>70</b>	<b>Olsen's method (olsen et al.,1954)</b>
<b>Available potassium (K<sub>2</sub>O kg/ha)</b>	<b>299</b>	<b>Flame photometer method (Jackson, 1973)</b>

Table 3: Calendar of operations

Operation	Date
<b>Ploughing</b>	<b>16.11.05</b>
Cultivator	18.11.05
Cultivator	19.11.05
Land leveling and layout	20.11.05
Soil sample collection	23.11.05
Fertilizer application	24.11.05
Sowing	25.11.05
1 <sup>st</sup> Irrigation	25.11.05
Herbicide spraying	29.11.05
Hand weeding	06.12.05
Hand weeding	10.12.05
Hand weeding	12.12.05
Thinning	14.12.05
2 <sup>nd</sup> irrigation	20.12.05
Split application of urea	30.12.05
3 <sup>rd</sup> irrigation	04.01.06
Hand weeding	12.01.06
Hand weeding	18.01.06
4 <sup>th</sup> irrigation	19.01.06
Insecticide spraying	24.01.06
5 <sup>th</sup> irrigation	03.02.06
6 <sup>th</sup> irrigation	18.02.06
Harvesting	13.03.06
Threshing and cleaning	16.03.06

**Table 4a : Soil chemical properties before and after harvest of the crop**

Gradients	Available nutrients (kg/ha)			pH	ECe (dS/m)
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O		
	Before sowing				
	213	70	299	7.10	0.138
After harvest					
OX	181	47	250	7.56	0.05
1X	238	52	372	7.26	0.04
2X	401	57	391	7.18	0.04

**Table 4b : Grain and fodder yield of sorghum (q/ha) in different gradients**

<b>Gradient</b>	<b>Grain</b>	<b>Fodder</b>
<b>OX</b>	1.51	31.83
<b>1X</b>	6.19	84.21
<b>2X</b>	9.14	82.78

Treatment	Alkaline permanganate N			Olsen's P			Ammonium acetate K		
	0 X	1 X	2 X	0 X	1 X	2 X	0 X	1 X	2 X
<b>N 0</b>	197.6	242.2	249.1	50.0	57.6	65.5	384.5	399.3	366.3
<b>N 40</b>	292.5	250.3	312.8	56.7	56.5	63.0	413.5	371.6	312.0
<b>N 80</b>	276.5	261.2	291.1	68.5	72.8	74.7	403.3	366.6	334.7
<b>N 120</b>	304.5	304.7	303.8	78.5	78.7	80.1	376.7	425.7	364.9
<b>P 0</b>	217.2	246.7	242.8	51.4	59.8	68.0	333.8	373.8	376.8
<b>P 20</b>	264.1	253.4	293.0	67.2	68.0	73.6	435.1	386.1	346.0
<b>P 40</b>	292.5	270.7	314.4	67.1	71.0	72.0	397.1	408.2	317.1
<b>P 60</b>	293.2	298.6	282.8	73.1	74.7	77.5	395.3	370.9	374.0
<b>K 0</b>	216.4	220.3	230.3	51.5	59.0	68.2	376.8	374.0	380.2
<b>K 20</b>	298.6	273.8	316.8	70.3	71.7	74.8	405.7	431.3	320.8
<b>K 40</b>	271.9	262.7	283.9	66.3	70.3	72.4	379.7	381.5	340.8
<b>K 60</b>	294.3	322.9	325.1	70.9	73.1	74.8	423.3	353.4	361.5
<b>Mean</b>	272.9	271.5	288.4	66.3	69.9	73.6	392.2	387.2	351.7
<b>SD</b>	49.4	51.0	51.7	11.2	10.7	8.3	61.4	78.4	56.2
<b>CV %</b>	18.0	19.0	17.7	17.0	15.4	11.4	15.6	20.1	16.3

Treatment	Initial K (kg/ha)	Total K applied (kg/ha)	K removed by the crop (kg/ha)	Computed balance K (kg/ha)	Actual balance K (kg/ha)	Net gain/loss (kg/ha)
<b>0 X</b>						
<b>K 0</b>	207.7	0.0	3.8	203.9	312.8	108.9
<b>K 20</b>	207.7	16.6	10.4	214.0	336.7	122.9
<b>K 40</b>	207.7	33.2	11.2	226.0	315.2	89.1
<b>K 60</b>	207.7	49.8	11.6	246.0	351.4	105.4
<b>Mean</b>	-	-	9.3	222.5	329.0	106.6
<b>1 X</b>						
<b>K 0</b>	309.0	0.0	7.4	301.5	310.5	46.4
<b>K 20</b>	309.0	16.6	13.9	311.6	358.0	-10.0
<b>K 40</b>	309.0	33.2	11.9	326.6	316.6	-50.4
<b>K 60</b>	309.0	49.8	15.0	343.7	293.3	-1.3
<b>Mean</b>	-	-	12.1	320.9	319.6	-3.8
<b>2 X</b>						
<b>K 0</b>	324.7	0.0	8.3	316.4	315.5	-0.9
<b>K 20</b>	324.7	16.6	11.6	329.8	266.3	-63.5
<b>K 40</b>	324.7	33.2	12.7	341.5	282.8	-58.7
<b>K 60</b>	324.7	49.8	13.2	361.4	300.0	-61.4
<b>Mean</b>	-	-	11.4	337.3	291.2	-46.1
<b>SD</b>	-	-	3.0	54.5	26.1	71.7
<b>CV %</b>	-	-	26.1	16.2	9.0	-155.5

**Table 23 : Ready Reckoner of fertilizer doses (kg/ha) for attaining maximum yield, maximum profit and desired rate of return**

SN	SK	Maximum Yield		Maximum Profit						Desired rate of return					
				1998		2002		2006		1998		2002		2006	
		FN	FK <sub>2</sub> O	FN	FK <sub>2</sub> O	FN	FK <sub>2</sub> O	FN	FK <sub>2</sub> O	FN	FK <sub>2</sub> O	FN	FK <sub>2</sub> O	FN	FK <sub>2</sub> O
100	100	147	51	139	49	138	49	140	49	130	47	128	47	132	47
150	150	142	49	134	47	132	47	134	47	125	45	123	45	126	45
200	200	137	47	129	45	127	45	129	45	120	43	117	43	121	43
250	250	132	45	123	43	122	43	124	43	115	41	112	41	116	41
300	300	127	43	118	41	117	41	119	41	110	39	107	39	111	39
350	350	122	42	113	39	112	39	114	39	105	37	102	37	106	37
400	400	117	40	108	37	107	37	109	37	100	35	97	35	101	35
450	450	112	38	103	35	102	35	104	35	94	33	92	33	96	33
500	500	106	36	98	33	97	33	99	33	89	31	87	31	91	31
550	550	101	34	93	31	91	31	93	32	84	29	82	29	85	29
600	600	96	32	88	29	86	29	88	30	79	27	76	27	80	27
650	650	91	30	82	27	81	27	83	28	74	25	71	25	75	25
700	700	86	28	77	25	76	25	78	26	69	23	66	23	70	24

**Fertilizer adjustment equations**

FN = 157.70 - 0.1025 SN - 14.58 R

FP<sub>2</sub>O<sub>5</sub> (- - + response type)

FK<sub>2</sub>O 55.23 - 0.0392 SK - 5.52 R

**Cost of fertilizer (Rs/kg)**

	1998	2002	2006
N	8.83	12.17	10.90
P <sub>2</sub> O <sub>5</sub>	19.37	17.75	23.12
K <sub>2</sub> O	6.34	7.70	7.72

**Selling price of mustard seed (Rs/kg)**

	1998	2002	2006
	15	18	20

## CHAPTER – V

### DISCUSSION

An earnest effort is made in this chapter to scan the probable cause and effect relationship of fertility management practices on crop production. The results are discussed for their probable implication in growing mustard crop by adopting balanced level of NPK through fertilizers depending upon their available status in the soil and expected yield goals.

#### 5.1 Fertility gradient experiment

The exhaust crop of fodder sorghum SSG 59-3 created a wide fertility gradient. This was ideal for conducting the Soil Test Crop Response experiment intended on mustard. Initially the soil had 213.3 kg N/ha in the 0 X fertility. It was brought to 181.6 kg N/ha. In the 1 X strip, it raised to 238.3 kg /ha and 401.4 kg /ha in the 2 X strip. Similarly, there was a variation in the available soil phosphorus. It was 47.0, 52.0 and 56.8 kg P<sub>2</sub>O<sub>5</sub>/ ha in the 0 X, 1 X and 2 X fertility gradient. The fodder sorghum thus exhausted this nutrient heavily from the initial level of 70 kg P<sub>2</sub>O<sub>5</sub>/ha. A wide variability in the available potassium was also recorded. It reduced from the initial soil test value of 299 kg/ha to 250.3 kg/ha

in 0 X gradient. But, it increased to 372.2 and 391.2 kg/ha in the 1 X and 2 X fertility gradients.

This variable trend in the fertility was reflected in the production of grain and fodder yield of sorghum. An extremely low grain yield of 1.51 q/ha and 31.83 q/ha fodder was realized from the unfertilized 0 X gradient. In the 1 X fertility gradient, a high yield of 6.19 q grain and 84.21q /ha fodder yield was realized. Maximum quantity of 9.14 q/ha grain and 82.78 q/ha fodder yield was realized in the 2 X fertility gradient. This trend was ideal for the conduct of Soil Test Crop Response experiment. The attainment of this wide variability in the soil available NPK creating distinct fertility gradients satisfied the pre-condition for the Soil Test Crop Response experiment as suggested by Ramamoorthy *et al.* (1967). Hence, mustard was tested for its response to different levels of fertilizers and their interaction with the soil available nutrients vis-à-vis the microbial activity *per-se*.

## **5.2 Soil Test Crop Response (STCR) correlation studies on mustard**

### **5.2.1 Effect on vegetative growth of crop**

The results established that mustard is highly responsive to the level of NPK nutrients available in the soil at the time of sowing. The data obtained on the relative vigour of mustard in

terms of plant height, number of branches, number of leaves and their dry matter per plant depicted that the contribution of soil available nutrients played an important role in imparting a high vigour. The exhaust crop of sorghum depleted the soil of nutrients leaving behind a low quantity of 181.6 kg N, 47.01 kg P<sub>2</sub>O<sub>5</sub> and 250.3 kg K<sub>2</sub>O / ha in 0 X fertility gradient. The respective nutrients were available in a relatively larger quantity of 238.4 kg N, 52.0 kg P<sub>2</sub>O<sub>5</sub> and 372.3 kg K<sub>2</sub>O/ ha in the 1 X fertility gradient created by the exhaust crop of sorghum. The mean performance of mustard recorded substantial variability due to the difference in the amount of nutrients available in the 2 X strip. The curves for mean plant height, number of leaves per plant, dry weight of leaves per plant, and dry matter of stem per plant projected in fig. 5, 6, 7 & 8 are overlaid in the 1 X over the 0 X fertility gradient. This indicated that these nutrients were not available in sufficient quantities for the crop to attain vigorous vegetative growth in the 0 X than in the 1 X fertility gradient. The soil available nutrients were 401.4 kg N, 58.8 kg P<sub>2</sub>O<sub>5</sub> and 391.2 kg K<sub>2</sub>O/ ha in the 2 X fertility gradient. The improvement in these vegetative parameters owing to higher level of available nutrients was relatively less compared to the wider response in 1 X than 0 X fertility gradient. This beneficial effect of improved vegetative growth of the crop could possibly be ascribed to the relatively larger quantity of NPK

removed by mustard through the leaves and stem in the nutrient rich 1 X and 2 X than in 0 X fertility gradient at 45 days after sowing (Fig. 9 & 10). A dip in the nutrient absorption curve by the leaves beyond 60 days age of the crop in the three fertility gradients owes mainly to the senescence of leaves.

Similarly, the relatively mean low NPK content in the stem past 45 days age of the crop until maturity was probably due to their translocation into the reproductive sinks. Working on the crop growth and nutrient absorption pattern of mustard Bishnoi and Singh (1981 and 1982) also reported that the crop removed large quantities of nitrogen with increasing level of its application up to 90 kg N/ha. Singh and Singh (1998) reported that the crop removed large quantities of N and P with increase in the level of fertilizer application up to 80 kg N/ha. But, Bhati and Rathor (1982) observed that the application of 60 kg N/ha was adequate for the crop to remove large quantities of N through the seed and stover. Patel and Thakur (1998) observed that the application of 60 kg N and 40 kg P<sub>2</sub>O<sub>5</sub> /ha enhanced the removal of this nutrient. Further increase in the level of application of fertilizers reduced the quantity of their removal.

The graded levels of NPK added to mustard in the present investigation enhanced the amount of nutrients removed through the leaves as well as stem and thereby promoted the vegetative

crop growth in the three fertility gradients. The crop responded to grow tall in response to the application of 80 kg N/ha in the 0 X fertility gradient. It required 40 kg N/ha in the 1 X and 2 X fertility gradients to manifest maximum improvement in this trait. However, the crop needed 120 kg N/ha in the three fertility gradients to produce more leaves per plant than the lower level of fertilization.

The dry matter production of leaves and stem also increased substantially by the liberal dose of fertilization up to 80 kg N/ha. This effect was incident mainly due to a substantial increase in the quantity of NPK removed by the crop through the leaves and the stem which increased progressively with increase in the level of nitrogen applied to the crop. The application of phosphorus at 20 kg P<sub>2</sub>O<sub>5</sub> /ha also increased the plant height and number of branches per plant. It produced more number of leaves per plant by the application of 40 kg P<sub>2</sub>O<sub>5</sub> / ha and increased the dry matter of leaves and stem per plant as it helped the crop to remove more quantity of NPK through the leaves and stem. The response was more prominent in 1 X and 2 X than in the 0 X fertility gradient.

The application of potassium also improved the crop growth. It recorded a positive response to increasing level of this nutrient up to 60 kg K<sub>2</sub>O / ha. But, 20 kg K<sub>2</sub>O/ ha was adequate to

increase the dry matter in the leaves and stem. The stem removed progressively more quantity of NPK with increase in the level of fertilization up to 60 kg K<sub>2</sub>O/ ha. But this was surplus since substantial improvement in the leaves and stem dry matter was limited to 20 kg K<sub>2</sub>O/ha. This result ascertained that the mustard grows vigorous by the application of 80 kg N, 40 kg P<sub>2</sub>O<sub>5</sub> and 20 kg K<sub>2</sub>O/ ha to attain high dry matter production in the leaves and stem.

The necessity for the external input of NPK through fertilizers for vigorous vegetative growth of mustard in soils with varying levels of nutrients has also been conformed in several other investigations. But results on the quantity of nutrients required for vigorous growth of the crop are highly inconsistent. Mudholkar and Ahlawat (1979) and Sonali *et al.*, (1999) recorded significant improvement in the vegetative crop growth characteristics of mustard by the application of 40 kg N/ha. But Bhati and Rathor (1982), Chauhan *et al.* (1995) and Kumar *et al.*, (2001) observed that the crop needed 60 kg N/ha to manifest a vigorous growth of the crop. A still high level of 75-80 kg N/ha was detected to improve the crop growth by Chaniara and Damor (1982), Sharma (1994) and Singh and Singh (1998). A still high level of 90 kg N/ha was reported to have promoted the crop growth in field experiment conducted by Bishnoi and Singh (1991)

and Mishra and Verma (1994). However, a high dose of 120 kg N/ha was found to be highly responsive to induce profuse vegetative crop growth characteristics by Singh and Dixit (1989), Kachroo and Kumar (1997) and Singh and Singh (2002). The interactive influence of nitrogen and phosphorus application also varied in different investigations. Khafi *et al.* (1997) recorded a grand improvement in crop growth by the combined application of 80 kg N and 30 kg P<sub>2</sub>O<sub>5</sub> /ha. Bhadoria and Chauhan (1994) and Gurjar and Chauhan (1997) recorded similar results by the application of 75 kg N/ ha with 45-50 kg P<sub>2</sub>O<sub>5</sub> / ha. While, Tomar *et al.* (1997) observed that the growth characteristics of mustard were highly vigorous by the combined application of 180 kg N and 80 kg P<sub>2</sub>O<sub>5</sub> / ha.

Investigations on the NPK requirement were also highly variable. Chauhan *et al.* (1995) observed that the crop required low level of fertilization at the rate of 10:30:20 kg / ha NPK. Sharma *et al.* (1999) ascertained that the crop required 40:80:20 kg NPK / ha to improve the crop growth. While, Daniel and Nepalia (2003) observed that the crop responded positively and accumulated more dry matter per plant consequent to substantial improvement in plant height and canopy development by the application of 60:20:40 kg NPK / ha. Singh *et al.* (2002) observed that the crop required 75, 50 and 25 kg NPK/ha. While Singh *et*

*al.* (1994) recorded a need to apply 90:90:60 kg NPK/ha. These investigations thereby confirmed that the mustard required 60 to 90 kg N and 40 kg P<sub>2</sub>O<sub>5</sub>/ha in different soil and agro ecological regions. This variation may be due to the varying genotype and environmental interactions.

### **5.2.2 Yield attributes and yield**

The soil available NPK content had a definite relationship with the yield attributes, seed and stover yield of mustard. The crop recorded low mean number of seeds per siliqua and seed yield per plant when grown in the 0 X fertility gradient of soil having low level of available NPK than in 1 X and 2 X gradient.

The importance of fertilizer application and available soil nutrients was best recognized by the number of siliquae and their dry weight, number of seeds per siliqua and eventually the seed yield/plant. The number of siliquae and their dry weight per plant were more in the 1 X than 0 X fertility gradient since the commencement of their formation at 45 days after sowing until maturity. The higher fertility status of the soil in the 2 X fertility gradient was outstanding. The plants produced more number of siliquae with more dry matter content at every stage of sampling in 1 X than 0 X fertility gradient. An increase in the number of siliquae and their dry matter at different stages of crop growth and

number of seeds per siliqua at maturity due to the influence of fertilizer application was the result of the removal of more NPK through leaves and stem and better translocation of photosynthates in the seeds than in the relatively low fertility gradient. The positive influence of fertilizer addition, available nutrients in the soil and their removal by the crop underline the importance of enriching the soil with these nutrients to improve the yield components and reap better dividends. The mean test weight also recorded little improvement. Literature abounds on the influence of fertilizer application in improving the yield attributes of mustard. Rana and Singh (1992), Chauhan *et al.* (1995), Yadav *et al.*, (1995), Khafi *et al.* (1997), Porwal *et al.*(1997) Mudholkar and Ahlawat (1997),Patel and Shelke (1998), Patel and Thakur (1998), Sharma *et al.* (1999), Kumar *et al.*,(2001), Singh and Singh (2002), Shukla *et al.* (2002),Daniel and Nepalia (2003) Abraham and Lal (2003) and Varshney and Larya (2004) recorded substantial improvement in the yield attributes.

Seed yield is the economic end product to justify the need for fertilizer application to the crop for enhanced productivity. The mean seed yield of mustard was 3.9 q/ha in the 0 X fertility gradient having low quantity of available NPK. It was 4.7 q/ha in 1 X and 4.9 q/ha in 2 X fertility gradient. This difference in

production level was due to the influence of residual fertility gradient created by the exhaust crop on the vegetative growth of mustard, which in turn improved the yield attributes and thereby the seed and stover yield / ha.

The stover of mustard is also an important commodity after its harvest which coincides with the lean period of green fodder availability to the cattle. The stem, leaves and the pod covers are all very valuable roughage which can be mixed with a small quantity of legume to meet the hunger requirement of animals (Deeb and Solan 1975; Guillard *et al.*, 1995 and Vidyadhari 2004). The results indicated that the crop raised on 1 X and 2 X fertility gradients produced mean stover yield of 15.9 and 14.5 q/ha compared to 12.9 q/ha in the 0 X fertility gradient.

The graded levels of NPK recorded remarkable variations in yield. The crop required 120 kg N/ha in 0 X fertility gradient to produce maximum grain yield of 5.4 q/ha. The requirement of this fertilizer was reduced to 80 kg N/ha in the 1 X fertility gradient. Even with this reduction of 40 kg N/ha the crop produced additional seed yield of 90 kg /ha in the 1 X fertility gradient. This trend showed that the prescription of nitrogen through the fertilizers varies with the available nutrient status of the soil. This inference is further strengthened by the production trends varying wide for different levels of fertilizer application from the

investigations conducted elsewhere in different soils with different management practices and environmental variations Mudholkar and Ahlawat (1979) obtained significant yield response by the application of 40 kg N/ha in sandy loam soil. Bhati and Rathor (1982), Chauhan *et al.* (1995), Patel and Thakur (1998) and Sonali *et al.* (1999) reported that the seed yield of mustard increased with increase in the level of fertilization up to 60 kg N/ha. Bishnoi and Singh (1982), Sonali *et al.* (1994), Sharma (1994), Khafi *et al.* (1997) and Rana and Singh (1998) recorded a significant yield response to the application of 90 kg N/ha. While, Singh and Rathi (1984), Singh and Dixit (1989), Mishra and Verma (1994), Kachroo and Kumar (1997), Mankotia and Sharma (1998), Kumar *et al.* (2001) and Singh and Singh (2002) obtained still high yield response by the application of 120 kg N/ha. Tomar *et al.* (1997) reported significant yield response of mustard to a high level of fertilization at 180 kg N/ha.

The application of phosphorus increased the seed yield of mustard by increasing its application up to 60 kg P<sub>2</sub>O<sub>5</sub> / ha in the three fertility gradients. Nonetheless, the yield level increased remarkably in the 1 X than 0 X fertility gradient and was maximum in the 2 X fertility gradient, at any level of fertilizer application. The crop needed 60 kg P<sub>2</sub>O<sub>5</sub> /ha to get maximum grain yield. This level of fertilization in 1 X fertility gradient enabled the crop to

produce 140 kg additional seed yield in the 1 X fertility gradient. This level of fertilizer application in the 2 X fertility gradient enabled the crop to produce additional seed yield of 200 kg /ha than in 0 X fertility gradient.

Considerable variation in the prescribed dose of phosphorus to mustard in different soils can be best explained due to the variability in soil available nutrients in addition to several other factors like climatic, edaphic and management variables. Ram and Pareek (2000) obtained significant yield response to low level of fertilizer application at 30 kg P<sub>2</sub>O<sub>5</sub> / ha. Sharma *et al.* (2002) reported that the crop required 40 kg P<sub>2</sub>O<sub>5</sub> / ha to produce high yield. Rana and Singh (1992), Mankotia and Sharma (1998) and Patel and Shelke (1998) reported that 80-90 kg P<sub>2</sub>O<sub>5</sub>/ha was adequate for mustard to produce high yield.

The crop required a high dose of 60 kg K<sub>2</sub>O/ ha in the present investigation to produce maximum yield of 5.4 q/ha in the 0 X fertility gradient. But, it responded to produce 6.5 and 5.2 q /ha seed in the 1 X and 2 X fertility gradients with a low dose of only 20 kg K<sub>2</sub>O/ha and that the increasing level of 40 or 60 kg K<sub>2</sub>O/ha was of no practical advantage to increase the yield.

It could be deduced that the nutrient requirement of mustard ranged from 80 to 120 kg N, 20 to 60 kg P<sub>2</sub>O<sub>5</sub> and 20 to 60 kg K<sub>2</sub>O/ha based on the initial nutrient status in the sandy soil. Therefore, the soil nutrient analysis for available NPK paved the path to fertilizer recommendations for optimum production.

### **5.2.3 Response surfaces and contour plots**

The response surfaces for the combined application of N and P fertilizer recorded curvilinear trends while, the response due to N and K application revealed a linear trend for N and quadratic trend for K. contour lines for yield estimates of mustard for any given level of N with different proportion of P and K are furnished graphically.

### **5.2.4 Oil content (%) and Oil yield (kg/ha)**

The percentage of oil is the prominent criterion for the disposal value of this important oilseed. The mean oil percent was more in the O X than in the 1 X and 2 X fertility gradients. It was substantially low by nurturing the crop without the application of nitrogen compared to the response due to the application of 40 kg N/ha. This difference was of the order of 5.6 per cent in the O X fertility gradient, 5.4 per cent in the 1 X and 4.8 per cent in the 2 X fertility gradient. Conversely, the oil yield increased from 0.6 to 1.4 q / ha in the O X fertility gradient, 0.7 to 2.1 q / ha in the 1 X

fertility gradient and 2.0 q / ha in the 2 X fertility gradient. Further increase in the level of nitrogen up to 120 kg /ha reduced the oil content sharply. This inverse relationship with increasing level of nitrogen at high level of its application with the oil content was mainly due to its function in the formation of protein and reduction in oil per cent. This phenomenon has been ascribed in several oilseed crops by Zubriski and Zimmerman (1974), Mohammad and Rao (1981), Kumar *et al.* (1991), Singh *et al.* (1994), Tomar *et al.*,(1996), Sreemannarayana *et al.* (1998), Amruthavalli and Reddy (2000), Jat and Giri (2000) and Mandal and Giri (2002). The oil yield increased with increasing level of N up to 80 kg / ha. This positive response in oil yield despite lowering trend in oil per cent owes mainly to the larger responses in seed yield.

Oil per cent was also remarkably less without the application of phosphorus in the 1 X and 2 X fertility gradients compared to the response due to 20 kg P<sub>2</sub>O<sub>5</sub> / ha. Further increase in the level of phosphorus reduced the oil per cent but, increased the oil yield up to 60 kg P<sub>2</sub>O<sub>5</sub> / ha in the three fertility gradients. The importance of fertilizing mustard with 30-40 kg K<sub>2</sub>O / ha in increasing the oil content was reported by Rana and Singh (1992), Sharma *et al.* (2000) and Tomer *et al.* (1992). The mustard seed was substantially enriched with the oil content by the application of 40 kg K<sub>2</sub>O / ha in the 1 X and 2 X fertility

gradients. The oil yield also increased by its application compared to control.

The crop required 40 kg N, 20 kg P<sub>2</sub>O<sub>5</sub> and 20 kg K<sub>2</sub>O / ha in the 1 X and 2 X fertility gradients to realize  $\geq$  the oil yield obtained from the 0 X fertility gradient with the application of high level of 120 kg N, 60 kg P<sub>2</sub>O<sub>5</sub> and 60 kg K<sub>2</sub>O / ha. The result signifies the importance of restoring the soil fertility to minimize the use of chemical fertilizers.

### **5.3 Empirical relationship between nutrients and seed yield**

The application of NPK through the fertilizers had a positive and significant correlation with seed yield of mustard grown in soil depleted with nutrients in the 0 X gradient or the improved fertility of the soil in the 1 X or 2 X fertility gradient. Obviously, it indicates that the fertilizer application is essential to enhance the seed yield of the crop.

The removal of N by mustard in the three fertility gradients recorded a positive and highly significant association. Therefore it is imperative that the crop has to draw this nutrient in relatively larger quantity to produce more yield. However, the removal of phosphorus did not establish a significant correlation with seed yield of mustard. This trend may possibly be due to the significant quantity of available P<sub>2</sub>O<sub>5</sub> in the three fertility gradients.

Potassium on the other hand, had a positive and significant association in 0 X and 2 X fertility gradients.

The initial soil nitrogen recorded a positive and highly significant correlation only in the 0 X fertility gradient, while, the initial soil available phosphorus had a positive and strong association in the three fertility gradients. Working on Soil Test Crop Response studies in castor Ahmed *et al.* (2000) observed that the seed yield was positively and significantly correlated with fertilizer N but not with K. They also recorded positive and significant association of seed yield with the uptake of N, P and K. Reddy and Ahmed (1999) recorded positive and significant correlation with soil and fertilizer N and P but not K vs rice yield. However, the uptake of these three nutrients had a positive and highly significant association. Khadke and Ahmed (2000) observed that the soil potassium permanganate N, Olsen's P and ammonium acetate K had no significant association with the seed yield of castor grown in the alfisol. Fertilizers N, P and K also did not establish a significant association. Sreedevi *et al.* (2001) observed that the yield of sunflower had a positive and significant association with soil available NPK and their uptake. The yield was also significantly associated with fertilizer N and P but not K.

#### 5.4 The Multiple regression equation

The multiple regression equation of the quadratic term explained 49 per cent of the variability in the yield of mustard as shown by the  $R^2$  value of 0.49. The equation also satisfied the + - - response trend for N and K in relation to their linear, quadratic and interaction terms. The fertilizer dose for maximum yield, maximum profit and desired rate of return were worked out for fertilizer N and K. The response with phosphorus was of - - + type. This may be due to the initial high status of this nutrient and the variability created by the exhaust crop was also very narrow unlike in N and K.

The crop required 5.2 kg N, 1.74 kg  $P_2O_5$  and 3.42 kg  $K_2O$  for every quintal of seed production. Working on the prescription based fertilizer recommendation in silty clay loam soil at Palampur, Varma and Bhagat (1996) reported that mustard required 6.5 kg N, 2.5 kg  $P_2O_5$  and 3.0 kg  $K_2O$  per quintal of seed production. These estimates were in close proximity to those attained in our investigation. Sharma *et al.* (1999) reported that the nutrient requirement per quintal of seed production of mustard varied from 4.29 to 5.31 kg N, 1.58 to 2.12 kg  $P_2O_5$  and 4.73 to 6.12 kg  $K_2O$  for different varieties grown on typical ustrochrept at New Delhi. It was also reported that the variety PR-45 required lowest amount of 4.29 kg nitrogen, but highest amount of 6.16 kg

$K_2O$ . Pusa bold on the other hand, required lowest amount of 4.73 kg  $K_2O$  and highest amount of 5.13 kg N and 2.12 kg  $P_2O_5/q$  seed. The variety Pusa Jaikisan required the lowest amount of 1.58 kg  $P_2O_5/q$ . It was deduced that the nutrient requirement for a given crop variety does not change for a given set of soil - crop and agro climatic condition. The utilization efficiency of soil and fertilizer nutrients are also specific for a given set of soil – crop - agro climatic condition.

The fertilizers were more efficient to supply larger quantity of 19 per cent N, 17 per cent  $P_2O_5$  and 38 per cent  $K_2O$  than the low contribution of 2.2, 3.3 and 1.1 per cent of these nutrients contributed by the soil. The low contribution of 9.7 % soil nitrogen could possibly be due to the low rate of mineralization of this nutrient because of the low temperature prevailing during winter season.

The basic data were transformed into simple workable fertilizer adjustment equations for the calculation of fertilizer doses for any yield target based on initial soil available nutrients. A ready reckoner for prescription of NPK fertilizers based on their availability in the soil is furnished for targeted yield of 6 and 10 q of mustard grown on sandy loam soil for the agroecological Southern Telangana Zone of Andhra Pradesh (Table 22). A ready reckoner is also furnished for the fertilizer doses required to

obtain maximum seed yield, maximum profit and desired rate of return. These developed equations are to be verified for their suitability of fertilizer application rates in achieving the targeted yield with  $\pm 10\%$  variability. This experiment should be repeated for another 2-3 years in the research station and based on the consistency of the results verification trials can be conducted over a large number of farmers field for making candid recommendation to the Pusa Jaikisan variety of mustard in the sandy soil of this region.

### **5.5 Nutrient budget**

Majority of Indian soils are depleting fast in  $N > P > K$ . Restoration of the soil fertility is no less important than the objective of increased crop production to meet the food requirement of burgeoning population by the government, realize higher profit per unit of crop production by the progressive farmers and enhanced profit per rupee investment on variable cost of production by the small farmers, but also to safe guard the soil of its fertility for the future generation.

The soil had a larger balance of available nitrogen in the fertilized treatment plots after the harvest of mustard grown in the 0 X fertility gradient in which this nutrient was severely depleted by growing the exhaust crop without fertilizer application than the

1 X fertility gradient in which the exhaust crop was fertilized to sustain the soil available nitrogen. This trend is paradoxical. A critical analysis indicated that the nitrogen was removed by the crop in substantially larger quantity leading to higher productivity in this gradient than in the 0 X fertility gradient. In the high fertility gradient of 2 X strip, mustard removed almost similar quantity of nitrogen at a given level of graded dose of nitrogen applied through the fertilizer. Obviously, the computed balance was more as expected. But the actual balance was not proportionately higher than in the 1 X gradient.

This resulted in loss of nutrient indicating that the indiscriminately high rate of application of fertilizers to the previous crop lead to unwarranted wastage.

The application of 20 to 40 kg  $P_2O_5$ /ha to mustard in the 1 X fertility gradient enabled it to remove this element in larger quantities than its application in the 0 X fertility gradient. The actual balance of this nutrient was more than the initial soil test value.

The application of potassium @ 20 kg  $K_2O$ / ha in the 1 X fertility gradient also enhanced the nutrient uptake to more than that removed by the crop grown in 0 X fertility gradient at a higher level of 60 kg  $K_2O$ /ha and yet left behind a much higher actual

balance than the initial soil test value in the 1 X fertility gradient. These results established that the soil fertility should be restored by the application of fertilizers in accordance with the initial soil test values while harvesting optimum seed yield by adopting the fertilizers adjustment equations for targeted yields.

## CHAPTER – IV

### SUMMARY

A field experiment was conducted on soil test crop response correlation studies in Indian mustard variety Pusa Jai kisan on the Alfisol at students' farm of the Acharya N. G. Ranga Agricultural University Rajendranagar, Hyderabad, during 2005-06. A fertility gradient experiment was conducted by growing an exhaust crop of fodder sorghum (SSG 59 -3) during the *kharif* season on 30.06.05. It was raised in the three fertility gradients created by supplying 150 kg N, 75 kg P<sub>2</sub>O<sub>5</sub> / ha and 100 kg K<sub>2</sub>O/ ha. The phosphorus application was based on the pre tested critical value following Waugh and Fitts (1966). The dose of potassium was fixed on the basis to supply 150 kg exchangeable K<sub>2</sub>O/ ha in one strip designated as 1 X.

One of the strip was fertilized with twice the quantity of these nutrients and designated as 2 X and third strip was unfertilized. A fairly high nutrient gradient was created after the harvest of the crop. The initial soil test value was 213 kg N, 70 kg P<sub>2</sub>O<sub>5</sub> and 299 kg K<sub>2</sub>O / ha in the 0 X fertility gradient. The corresponding value changed to 181.6, 47.0 and 250.3 kg NPK / ha in the 0 X, 238.3, 52.0 and 372.2 in the 1 X and 401.4, 56.8 and 391.2kg/ha in the 2 X fertility gradient strip. The grain and

fodder yield of sorghum were in accordance with these nutrient levels. This satisfied the condition of high variability in the available soil nutrients for conducting the STCR experiment.

Mustard variety Pusa Jaikisan was grown during the subsequent *rabi* season on 25.11.2006. There were 21 fertilizer treatments involving a combination of N, P and K and three unfertilized treatments in each strip as advocated by the All India Co-coordinated Research Project on soil test crop response studies.

The results showed a wide variability in the performance of mustard in the three variable fertility gradients. The crop was more vigorous with better canopy development in 1 X and 2 X than 0 X fertility gradient. The mean plant height was invariably low with less number of leaves and their mean dry matter per plant at different stages of crop growth in the 0 X fertility gradient. The crop required 80 kg N / ha in the 0 X fertility gradient to maximize the plant height at different stages of crop growth. But a low dose of only 40 kg N / ha could suffice the crop to grow tall in the 1 X and 2 X fertility gradients. It required 80 kg N / ha to produce more number of branches per plant. It required a high dose of 120 kg N / ha for prolific canopy development. The numbers of leaves per plant were remarkably more in the 1 X and 2 X fertility gradient at the same level of nitrogen application than

in the 0 X fertility gradient. The leaves and stem accumulated more dry matter in response to the application of 80-120 kg N/ ha. But maximum dry matter accumulation in siliquae were recorded by the application of 40 kg N / ha in the 1 X and 2 X fertility gradients compared to the requirement of 120 kg N / ha in the 0 X fertility gradient. Yet, the dry weight of siliquae per plant with low dose of 40 kg N / ha had an edge in the medium and high fertility gradients than in the low fertility gradient supplemented with a high dose of 120 kg N / ha.

Application of phosphorus at 20 kg  $P_2O_5$ /ha remarkably increased the plant height and number of branches per plant over control. But a high dose of 40 - 60 kg  $P_2O_5$  / ha increased the number of leaves per plant. The dry matter in the leaves and stem as well as the siliquae in general increased by the application of 20 kg  $P_2O_5$  / ha over control.

The application of potassium @ 60 kg  $K_2O$  /ha exhibited substantial improvement in the plant height of mustard grown in 0 X fertility gradient at different stages of crop growth. But the crop required only 20 kg  $K_2O$ / ha in the 1 X and 2 X fertility gradients to exhibit similar response. The number of leaves per plant and their dry weight were more by the application of 20 kg  $K_2O$  / ha in the 0 X fertility gradient than the control. For the same level of 20 kg  $K_2O$  / ha in the 1 X and 2 X fertility gradients, the

crop produced more number of leaves with higher dry weight per plant. This trend was similar for the dry weight of stem and siliquae per plant.

The yield attributes of mustard also exhibited remarkable variability due to the residual fertility of the previous crop and the level of fertilizers applied in the current season. The mean number of siliquae and their dry matter per plant increased substantially at every stage of sampling by growing the crop in 1 X than 0 X fertility gradient. The mean values were higher in the 2 X fertility gradient. The number of siliquae per plant increased with increase in the level of nitrogen upto 120 kg N / ha in the 0 X fertility gradient. More number of siliquae and their dry weight was recorded at this level of fertilization in the 1 X and 2 X fertility gradients. The application of phosphorus or potassium at 20 kg  $P_2O_5$  and  $K_2O$  / ha also enhanced this parameter remarkably in the three fertility gradients. The number of seeds per siliqua, 1000 seed weight and seed yield per plant also increased by the application of 120 kg N /ha compared to control. The application of 40 kg  $P_2O_5$  and 40 kg  $K_2O$ / ha also recorded substantial increase in these yield components.

The leaves, stem and siliqua removed less NPK in the 0 X than in 1 X and 2 X fertility gradients at different stages of crop growth. The application of 120 kg N removed large quantities of

NPK through the leaves, stem, siliquae and seed. Similarly, at harvest the removal of these nutrients by the crop increased with increase in the level of nitrogen upto 120 kg / ha. The crop also responded to remove more NPK by the application 40 - 60 kg  $P_2O_5$  and  $K_2O$  / ha. This response was more prominent in the 1 X than in 2 X fertility gradient.

Mustard produced a mean seed yield of 3.9 q / ha in the 0 X fertility gradient starved of nutrients. The mean production increased to 4.7 q / ha in the 1 X fertility gradient and further to 4.9 q / ha in the 2 X fertility gradient. The crop grown without the addition of nitrogen produced low seed yield. This in turn showed a wide variability in seed production by the residual fertility of the exhaust crop. It produced seed yield of 1.3 q/ ha in 0 X fertility gradient. The yield increased to 1.9 q in 1 X and 2.6 q/ ha in 2 X fertility gradient.

The crop yielded 5.4, 5.5 and 6.2 q/ ha seed yield in the 0 X, 1 X and 2 X fertility gradients in response to the application of 120 kg N/ha. The application of 60 kg  $P_2O_5$ / ha to mustard in the 0 X fertility gradient enhanced the seed yield from 2.2 to 4.5 q/ ha in control. The corresponding yield increased from 4.1 to 5.9 q/ ha in the 1 X fertility gradient and from 2.8 to 6.5 q/ ha in the 2 X fertility gradient. The crop required only 20 kg  $P_2O_5$  / ha to be applied in the 1 X and 2 X fertility gradient to produce more seed

yield of 5.7q/ha than 4.5q/ha obtained by the application of 60 kg  $P_2O_5$ /ha in the 0 X fertility gradient.

Mustard grown without the application of potassium recorded 2.2, 2.3 and 3.5 q / ha seed yield in the 0 X, 1 X and 2 X fertility gradients. It produced 5.4 q/ ha seed yield by the application of 60 kg  $K_2O$  / ha in the 0 X fertility gradient but a high seed yield of 6.5 and 5.2 q/ha was recorded in the 1 X and 2 X fertility gradients by the application of a low dose of 20 kg  $K_2O$  / ha.

The stover yield increased with increasing level of nitrogen upto 120 kg N / ha and was maximum in 1 X fertility gradient. The stover yield also increased with the application of 60 kg  $P_2O_5$  and 60 kg  $K_2O$  / ha in the three strips. This positive response to increasing level of two nutrients was prominent in the 1 X than the 0 X fertility gradient.

Mustard seed obtained from the crop grown without the application of nitrogen had more oil content of 40.1 % in the 0 X than 37.3% in 1 X and 37.4% in the 2 X fertility gradients. Application of 40 kg N/ ha increased the oil content to 45.7% in the 0 X, 42.7% in the 1 X and 42.2% in the 2 X fertility gradient. Oil yield was more in the 1 X and 2 X than in the 0 X fertility gradient. The oil per cent decreased with further increase in the

level of nitrogen in the three fertility gradients while, the oil yield increased up to 80 kg N / ha.

Application of phosphorus in the 0 X fertility gradient did not improve the oil content but increased the oil yield. The crop grown in the 1 X and 2 X fertility gradients required 20 kg P<sub>2</sub>O<sub>5</sub>/ ha to substantially improve the oil per cent and oil yield over control. Application of potassium did not show a consistency in improving the oil content but, it improved the oil yield.

The correlation coefficients revealed that the fertilizer N, P and K were positively and significantly associated with the seed yield of mustard in the three fertility gradients. The removal of nitrogen by the crop also had a positive and highly significant correlation with the yield. The removal of P and K by the crop also established positive correlation with the yield. This association was strong in the 0 X and 2 X fertility gradients and feeble in the 1 X fertility gradient. Among the soil available nutrients phosphorus alone had a significant correlation with the yield in the three fertility gradients. The soil available nitrogen had a significant positive correlation with seed yield in the 0 X fertility gradient while, it was negative in the 1 X fertility gradient.

The multiple regression equation of the quadratic term indicating the contribution of soil available nutrients, their application through fertilizers and their interaction was as follows:

$$Y = 703.001 + 10.8180 FN - 0.0343 FN^2 - 0.6990 SN + 0.0004 SN^2 - 0.0070 FNSN - 11.575010 FP - 0.0267 FP^2 + 2.7210 SP + 0.0610 SP^2 + 0.1760 FPSP + 10.0180 FK - 0.0907 FK^2 - 4.7030 SK - 0.0047 SK^2 - 0.0071 FKSK \dots R^2 = 0.49$$

This equation established + - - response only with N and K fertilizers. Based on these responses, the estimated equations developed for fertilizer dose to obtain maximum and profitable yield and desired rate of return were as follows:

$$F N = 157.70 - 0.1025 SN \quad \text{Maximum yield}$$

$$F K_2O = 55.23 - 0.0392 SK \quad \text{Maximum yield}$$

$$F N = 157.70 - 0.1025 SN - 14.58 R \quad \text{Maximum profit}$$

$$F K_2O = 55.23 - 0.0392 SK - 5.52 R \quad \text{Maximum profit}$$

$$F N = 157.70 - 0.1025 SN - 14.58 R \times 2 \quad \text{Desired rate of return}$$

$$F K_2O = 55.23 - 0.0392 SK - 5.52 R \times 2 \quad \text{Desired rate of return}$$

A ready reckoner for fertilizer N and K to be applied in soils of varying fertility were prepared for maximum yield, profit and desired rate of returns. The targeted yield equations based on the

nutrient requirement and efficiency of the nutrients supplied by the soil and fertilizers were derived as

$$F N = 27.50 T - 0.12 SN$$

$$F P_2O_5 = 10.27 T - 0.19 SP$$

$$F K_2O = 9.02 T - 0.03 SK$$

Ready reckoners of fertilizer recommendations for different soil fertility levels for targeted yield of 6 and 10 q / ha are furnished.

The budgeting of nutrients showed that the application of 120 kg N / ha remarkably increased the balance available from the initial value of 181.6 kg N to 304.5 kg N / ha in O X and from 238.3 to 304.7 kg N / ha in the 1 X fertility gradient. But, in the 2 X fertility gradient the actual nitrogen balance was less than the initial value irrespective of the fertilizer treatment. The available balance of phosphorus was more than the initial value due to different levels of phosphorus compared to the initial value in the three fertility gradients. The application of different levels of potassium increased the actual balance of this nutrient after the harvest of the crop compared to initial value in the 0 X fertility gradient. In the 2 X fertility gradient the available balance reduced sharply with no regard to the level of this nutrient applied through the fertilizers.

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The pattern of 'Literature cited' presented above is in accordance with the 'Guidelines for thesis presentation for Acharya N G Ranga Agricultural University, Hyderabad.

\* Original not seen

### Appendix - B

Plant height (cm) of mustard as influenced by different levels of fertilizers at different stages of crop growth

N:P:K (Kg/ha)	0 X				1 X				2	
	Days after sowing									
	45	60	75	90	45	60	75	90	45	60
00:40:40	54.0	94.2	101.2	101.6	68.0	101.4	110	113.4	81.0	96.0
40:20:20	108.2	110.8	111.6	111.8	106.8	108.0	111.2	114.6	109.4	111.2
40:40:20	99.6	101.1	111.6	118.2	102.0	111.0	119.4	121.4	100.8	102.4
40:20:40	93.2	102.6	119.4	111.4	107.2	110.0	119.2	127.4	90.2	112.2
40:40:40	92.2	96.3	103.4	106.3	112.0	117.0	119.2	128.4	105.0	106.2
80:00:40	114.0	118.2	121.1	123.0	111.4	114	117.2	120.2	99.2	101.6
80:40:00	111.2	116.6	128.4	129.4	106.6	109.6	114.2	123.8	94.6	102.2
80:20:20	102.0	109.8	112.2	116.0	97.8	112.8	123.2	128.6	105.8	109.8
80:40:20	96.6	106.2	108.2	115.2	109.4	115.8	118.3	121.3	98.8	110.4
80:20:40	106.6	106.2	108.8	116.2	98.8	105.6	110.2	116.3	117.4	120.4
80:40:40	100.8	109.6	112.2	115.4	107.6	115.0	118.3	119.6	99.0	103.8
80:40:60	108.2	112.0	113.6	114.8	113.0	120.0	122.0	124.3	108	109
80:60:40	78.8	102.8	102.8	104.8	96.8	112.0	119.2	121.0	98.6	99.4
80:60:60	110.0	115.0	119.6	126.3	88.8	101.2	109.2	111.2	106.4	113.8
120:20:20	93.2	108.4	111.2	113.8	114.2	117.0	119.2	123.2	99.2	109.2
120:40:20	103.0	109.6	110.8	120.0	111.0	115.8	119.3	129.3	100.8	106.6
120:40:40	109.6	110.8	111.4	114.2	87.6	94.8	103.4	120.6	103.8	113.4
120:60:20	93.0	101.2	116.6	118.6	110.8	113.0	116.0	130.6	100.8	105.4
120:40:60	106.2	109.4	116.6	114.2	103.8	116.2	191.8	130.8	89.8	91.8
120:60:40	108.8	114.4	118.3	128.8	111.0	114.5	116.3	121.2	87.0	111.6
120:60:60	111.6	118.8	119.2	122.6	103.8	104.4	121.2	121.2	72.6	99.4
00:00:00	46.0	59.6	77.2	93.3	77.4	98.0	94.8	105.3	88.0	95.2
00:00:00	40.8	88.4	89.2	93.2	72.0	102.2	111.2	114.6	96.6	106.6
00:00:00	54.8	93.6	100.8	107.2	100.4	103.2	108.2	111.0	81.0	104.8

### Appendix - F

Number of siliquae per plant of mustard as influenced by different levels of fertilizers at different stages of crop growth

N:P:K (Kg/ha)	0X				1X				2X	
	45	60	75	90	45	60	75	90	45	60
00:40:40	5.8	31.8	35.8	49.8	10.4	11.0	39.8	68.8	46.0	52.3
40:20:20	31.6	47.4	48.4	85.6	58.0	46.6	75.2	101.8	43.2	45.6
40:40:20	31.6	37.4	46.2	82.4	36.2	38.6	56.6	105.0	18.4	53.0
40:20:40	22.2	32.8	48.6	74.4	37.8	39.8	41.4	96.2	29.3	50.2
40:40:40	18.6	31.8	41.2	67.2	30.2	39.1	41.6	104.4	39.6	45.3
80:00:40	35.6	45.2	47.6	81.4	31.4	36.4	40.6	106.2	31.0	54.2
80:40:00	44.4	53.2	67.8	96.2	37.0	42.3	65.3	117.6	28.0	35.6
80:20:20	24.4	41.6	40.0	79.6	47.8	58.8	68.2	115.2	45.5	73.4
80:40:20	12.3	47.0	67.2	106.8	14.4	32.6	57.6	82.0	35.8	59.2
80:20:40	28.2	42.8	75.3	100.6	31.2	42.1	57.0	94.6	38.0	51.4
80:40:40	23.8	45.2	65.2	115.2	15.8	29.6	36.4	115.0	46.8	52.1
80:40:60	19.8	44.0	59.6	106.2	34.4	41.1	44.0	141.4	39.6	48.5
80:60:40	22.6	22.8	37.4	91.6	17.2	27.3	37.0	88.6	18.8	41.6
80:60:60	35.4	36.6	39.4	84.0	35.4	38.1	42.8	92.2	26.4	42.8
120:20:20	28.8	44.0	40.2	97.4	11.4	38.7	51.8	113.6	32.2	65.2

120:40:20	17.8	40.6	50.0	95.0	47.0	53.6	88.4	123.6	34.6	56.6
120:40:40	18.0	51.0	74.8	77.1	24.8	32.8	56.3	110.2	17.0	46.4
120:60:20	13.2	40.0	43.4	102.6	42.0	58.6	70.8	151.8	40.4	59.0
120:40:60	28.2	43.2	50.4	122.2	37.6	52.3	77.6	102.0	36.4	39.0
120:60:40	39.4	43.0	58.9	84.8	23.6	32.8	42.0	116.6	76.0	60.2
120:60:60	11.0	41.4	45.2	76.2	12.4	32.8	54.6	168.0	11.2	45.8
00:00:00	6.4	16.2	29.4	34.4	13.2	36.4	48.2	74.6	17.0	39.0
00:00:00	3.6	19.6	20.4	35.8	7.0	9.2	39.0	66.4	33.0	50.2
00:00:00	11.6	31.4	48.0	56.4	12.2	29.0	40.6	87.8	17.0	48.8

<b>X</b>	
<b>75</b>	<b>90</b>
108.6	111.4
111.8	114.6
109.0	113.8
114.2	120.0
109.4	108.8
104.4	105.4
102.4	111.4
118.8	125.6
112.2	115.2
124.6	125.2
109.0	112.2
114.2	116.2
104.2	110.0
115.8	129.6
111.6	118.2
103.8	113.2
111.2	112.2
114.2	116.4
101.6	102.8
116.6	118.6
109.6	112.2
98.6	100.2
108.2	110.2
112.4	115.2

**different**

<b>75</b>	<b>90</b>
62.2	86.8
55.3	94.2
59.1	145.8
81.9	225.6
57.2	82.2
59.3	113.8
55.8	88.4
94.2	201.8
86.9	108.0
75.4	124.0
60.8	105.6
89.8	111.4
61.1	112.4
56.8	99.6
75.2	84.4

89.3	153.0
78.8	146.6
81.4	128.2
61.3	97.6
88.3	176.2
78.6	110.6
42.6	59.0
65.8	115.0
57.2	72.6

**Appendix - C**

**Number of leaves/plant of mustard as influenced by different levels of fer stages of crop growth**

N:P:K (Kg/ha)	OX			1X		
	Days after sowing					
	45	60	75	45	60	75
00:40:40	8.2	9.4	3.7	11.0	7.6	6.0
40:20:20	12.4	10.2	4.3	23.6	12.8	6.0
40:40:20	16.6	9.0	0.0	16.0	8.8	2.5
40:20:40	12.0	9.6	0.0	14.6	9.8	3.3
40:40:40	13.0	7.6	4.0	16.8	9.6	4.5
80:00:40	17.0	12.0	5.0	21.8	12.6	6.0
80:40:00	22.0	11.0	3.7	21.6	15.4	4.7
80:20:20	12.6	9.6	4.0	27.6	8.8	4.6
80:40:20	19.0	10.4	4.0	12.8	10.0	6.3
80:20:40	13.8	11.0	3.0	20.4	10.6	5.5
80:40:40	10.6	10.0	0.0	17.0	9.6	5.0
80:40:60	17.6	12.0	3.5	24.0	17.6	8.0
80:60:40	12.2	8.2	5.0	15.8	8.8	4.0
80:60:60	14.2	11.0	4.0	19.4	11.8	5.8
120:20:20	13.0	9.8	3.8	16.8	12.4	3.5
120:40:20	17.2	13.6	2.7	29.2	10.2	7.0
120:40:40	18.6	17.0	4.0	16.4	12.8	6.0
120:60:20	12.6	10.4	0.0	28.2	13.8	3.5
120:40:60	18.8	13.8	3.5	23.4	11.6	6.0
120:60:40	17.2	10.4	3.5	20.4	10.8	3.5
120:60:60	12.8	9.4	4.6	21.0	15.0	7.8
00:00:00	7.0	11.6	4.5	12.2	7.6	5.0
00:00:00	6.6	9.4	4.7	10.4	9.2	4.7
00:00:00	8.2	9.8	4.7	12.8	10.2	4.0

**tilizers at different**

<b>2X</b>		
<b>45</b>	<b>60</b>	<b>75</b>
14.6	10.6	5.3
17.6	10.8	5.6
17.0	14.8	4.5
13.4	9.2	5.5
18.4	11.6	4.8
19.8	15.8	7.7
24.2	9.0	9.6
19.0	12.2	6.0
35.6	11.2	6.4
23.2	13.0	5.8
30.6	12.2	4.5
18.8	11.8	7.0
19.4	7.4	4.3
21.4	12.2	4.5
19.6	10.2	3.0
27.4	15.0	7.8
14.6	13.0	5.3
30.8	14.8	9.2
23.4	16.8	5.7
14.2	11.2	5.8
10.4	9.8	7.0
9.8	9.6	4.7
16.0	9.0	3.3
14.0	11.6	4.8

**Appendix - D**

**Nutrient concentration in siliquae of mustard as influenced by different levels of fertilizers at different stages of crop growth**

N:P:K (Kg/ha)	OX					
	Days after sowing					
	60			75		
	N	P	K	N	P	K
00:40:40	1.38	0.42	1.25	1.01	0.26	1.04
40:20:20	2.01	0.38	1.22	1.88	0.56	1.10
40:40:20	1.38	0.52	1.20	1.52	0.07	0.88
40:20:40	1.91	0.35	1.11	1.88	0.53	1.04
40:40:40	1.66	0.46	1.28	1.51	0.31	1.08
80:00:40	1.91	0.38	1.18	1.81	0.25	1.00
80:40:00	1.88	0.44	1.05	1.72	0.31	0.82
80:20:20	1.56	0.41	1.18	1.41	0.33	0.91
80:40:20	1.91	0.41	1.21	1.82	0.33	0.92
80:20:40	1.96	0.47	1.26	1.63	0.28	1.02
80:40:40	1.38	0.44	1.26	1.48	0.49	1.11
80:40:60	1.77	0.48	1.30	1.58	0.41	1.14
80:60:40	1.81	0.49	1.24	1.09	0.10	0.86
80:60:60	2.3	0.45	1.32	2.18	0.13	0.83
120:20:20	2.16	0.41	1.25	1.08	0.44	0.98
120:40:20	1.29	0.40	1.25	1.21	0.40	0.89
120:40:40	2.16	0.46	1.26	1.71	0.44	0.98
120:60:20	2.11	0.49	1.21	2.01	0.57	0.94
120:40:60	1.99	0.42	1.30	1.81	0.26	0.78
120:60:40	1.88	0.50	1.28	1.76	0.38	1.22
120:60:60	2.18	0.48	1.31	2.10	0.10	0.95
00:00:00	1.31	0.33	1.11	1.41	0.11	0.72
00:00:00	1.59	0.38	1.21	1.61	0.12	0.88
00:00:00	1.43	0.42	1.18	1.41	0.08	0.78
	1X					
00:40:40	1.71	0.44	1.28	1.33	0.17	1.14
40:20:20	2.81	0.41	1.21	1.89	0.35	1.15
40:40:20	1.9	0.46	1.17	1.24	0.37	1.02
40:20:40	2.02	0.34	1.08	1.76	0.82	1.03
40:40:40	2.01	0.51	1.31	1.91	0.46	1.14
80:00:40	1.88	0.41	1.31	1.76	0.29	1.08
80:40:00	1.91	0.58	1.38	1.81	0.31	1.17
80:20:20	1.88	0.40	1.22	1.88	0.74	1.03
80:40:20	2.16	0.40	1.24	1.98	0.19	0.98
80:20:40	2.18	0.46	1.23	1.83	0.89	1.13
80:40:40	1.89	0.42	1.20	1.71	0.29	1.11
80:40:60	2.19	0.59	1.33	1.69	0.28	1.11
80:60:40	2.11	0.56	1.21	1.48	0.95	1.04
80:60:60	2.23	0.48	1.41	1.98	0.24	1.17
120:20:20	2.08	0.46	1.28	2.01	0.46	1.01
120:40:20	1.92	0.43	1.34	1.41	0.90	0.96
120:40:40	2.21	0.53	1.25	2.10	0.45	1.11
120:60:20	2.13	0.54	1.28	2.11	0.48	1.02
120:40:60	2.16	0.48	1.34	1.91	0.51	1.01
120:60:40	1.91	0.56	1.19	1.81	0.37	1.13
120:60:60	2.81	0.53	1.48	2.11	0.41	1.10
00:00:00	1.88	0.58	1.21	1.79	0.38	0.98

00:00:00	2.16	0.67	1.23	1.93	0.54	1.04
00:00:00	1.96	0.57	1.20	1.81	0.40	1.01
	<b>2X</b>					
00:40:40	1.76	0.48	1.35	1.48	0.44	1.08
40:20:20	2.43	0.42	1.28	2.14	0.56	1.21
40:40:20	1.79	0.56	1.21	1.89	0.32	0.96
40:20:40	2.33	0.48	1.18	1.91	0.30	1.01
40:40:40	1.88	0.53	1.29	1.81	0.41	1.12
80:00:40	2.23	0.39	1.42	1.81	0.30	1.12
80:40:00	2.36	0.41	1.15	1.86	0.36	0.96
80:20:20	2.01	0.49	1.19	2.01	0.31	1.11
80:40:20	2.31	0.48	1.22	2.08	0.40	0.98
80:20:40	2.11	0.43	1.28	1.98	0.40	1.11
80:40:40	1.91	0.48	1.31	1.88	0.38	1.08
80:40:60	2.61	0.61	1.42	1.81	0.43	1.21
80:60:40	2.08	0.59	1.23	2.01	0.66	1.01
80:60:60	2.28	0.64	1.44	2.13	0.44	1.18
120:20:20	2.11	0.44	1.31	2.03	0.55	1.01
120:40:20	2.11	0.42	1.41	1.68	0.46	0.89
120:40:40	2.41	0.58	1.29	2.31	0.34	1.07
120:60:20	2.18	0.62	1.33	2.12	0.52	0.98
120:40:60	2.13	0.46	1.40	2.11	0.22	0.96
120:60:40	1.82	0.61	1.33	1.83	0.50	1.08
120:60:60	3.28	0.59	1.52	2.18	0.52	1.12
00:00:00	2.16	0.50	1.28	1.98	0.31	1.02
00:00:00	2.01	0.48	1.30	1.89	0.42	0.98
00:00:00	1.88	0.41	1.19	1.92	0.35	0.90

**Dry matter(g)/plant in siliquae of mustard as influenced by different levels of fertiliz  
at different stages of crop growth**

N:P:K (Kg/ha)	0X			1X			2X	
	Days after sowing							
	60	75	90	60	75	90	60	75
00:40:40	1.87	2.18	9.49	2.66	6.65	11.43	3.95	4.81
40:20:20	3.38	4.48	10.90	2.89	8.92	14.63	3.01	5.25
40:40:20	3.58	5.41	9.87	3.61	9.11	14.03	2.52	10.16
40:20:40	2.50	5.66	13.16	3.28	7.56	14.31	2.63	11.25
40:40:40	2.89	4.86	7.53	3.21	8.69	14.46	3.68	7.23
80:00:40	2.94	4.39	5.34	3.56	6.31	11.56	3.78	8.69
80:40:00	2.51	3.77	16.76	2.37	7.86	12.82	3.85	5.45
80:20:20	3.27	4.19	11.01	3.14	5.86	12.29	5.63	14.56
80:40:20	2.20	3.46	14.11	2.54	7.86	15.00	3.32	5.22
80:20:40	3.40	3.95	10.66	2.37	5.79	11.24	3.53	5.94
80:40:40	2.87	4.02	13.50	3.13	6.58	12.48	3.15	7.89
80:40:60	3.15	6.65	11.50	4.06	8.76	14.05	2.63	5.36
80:60:40	2.05	5.63	10.68	3.91	9.12	16.92	3.11	7.89
80:60:60	3.91	4.43	9.21	2.02	3.71	10.38	2.83	5.89
120:20:20	2.01	7.26	13.74	2.97	5.13	12.03	3.45	4.56
120:40:20	3.09	8.56	16.83	3.14	4.61	13.83	3.34	8.78
120:40:40	3.86	4.10	11.33	2.47	6.85	13.18	3.24	4.78
120:60:20	2.95	4.42	13.89	3.08	8.32	15.63	4.12	9.12
120:40:60	2.59	5.26	10.16	4.06	3.47	14.50	2.30	7.10
120:60:40	3.22	5.08	10.10	3.23	3.91	17.74	3.16	10.87
120:60:60	3.05	5.31	4.95	2.88	4.62	18.55	3.03	7.86
00:00:00	2.04	2.32	5.28	2.48	4.26	8.12	3.40	3.86
00:00:00	1.88	5.88	12.55	2.67	2.91	10.08	3.53	6.12
00:00:00	2.12	4.36	9.60	2.43	4.11	14.10	2.56	4.65

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<b>90</b>
10.02
10.06
17.49
19.01
10.95
15.08
9.52
28.97
12.79
13.64
13.99
11.01
10.74
11.04
8.87
14.62
11.37
15.46
10.43
18.88
13.36
7.90
10.69
9.99

**Appendix - F**

**Dry matter(g)/plant in stem of mustard as influenced by different levels of fertilizers at different stages of crop growth**

N:P:K (Kg/ha)	OX				1X				2X	
	Days after sowing									
	45	60	75	90	45	60	75	90	45	60
00:40:40	3.62	4.51	5.11	5.78	3.80	4.94	4.90	10.87	5.52	5.55
40:20:20	5.13	5.84	6.23	8.82	4.75	5.03	9.16	10.87	5.68	5.22
40:40:20	5.78	5.87	6.32	8.41	5.11	5.44	8.47	10.13	4.42	5.57
40:20:40	4.96	5.25	6.12	7.89	4.63	5.77	8.17	12.02	5.04	6.19
40:40:40	5.15	5.37	5.61	6.01	4.59	6.21	7.42	13.33	5.83	6.85
80:00:40	4.76	6.59	7.00	9.88	5.74	6.66	8.44	8.76	5.09	5.64
80:40:00	4.83	5.56	9.79	10.65	4.07	5.63	8.83	9.15	5.82	5.90
80:20:20	5.26	5.92	6.43	8.39	5.02	5.17	9.32	9.87	4.74	6.02
80:40:20	4.67	5.34	7.72	11.71	5.13	5.36	6.53	10.38	5.63	7.06
80:20:40	4.81	5.73	6.65	7.86	5.97	6.03	7.17	8.77	5.43	5.79
80:40:40	5.18	5.93	7.74	8.33	4.14	5.56	7.62	9.46	5.31	5.36
80:40:60	5.62	5.91	7.11	9.39	4.75	6.94	9.83	11.02	6.45	5.07
80:60:40	3.68	3.78	5.45	7.79	4.57	6.38	6.48	10.71	4.38	5.46
80:60:60	5.26	6.55	8.55	8.76	4.53	5.11	7.00	9.11	4.61	6.00
120:20:20	4.75	5.73	5.52	11.09	6.18	6.24	7.48	8.74	4.49	6.01
120:40:20	5.04	5.51	7.01	9.58	5.56	5.06	9.74	16.54	5.90	6.05
120:40:40	6.05	7.22	8.01	8.57	4.54	5.02	6.57	9.49	4.69	5.72
120:60:20	5.44	5.59	5.90	9.22	5.14	5.72	12.03	17.32	5.44	7.47
120:40:60	6.00	6.08	6.19	7.86	5.16	6.85	9.94	11.46	5.17	5.76
120:60:40	5.32	5.77	7.51	9.15	5.01	7.31	7.38	10.48	5.15	6.34
120:60:60	5.67	5.82	7.13	8.14	5.84	6.39	7.58	15.16	4.57	5.32
00:00:00	2.11	3.48	4.04	4.02	4.39	5.14	4.68	5.42	4.75	4.95
00:00:00	3.30	4.03	3.91	9.06	4.29	5.16	6.33	8.64	5.48	6.12
00:00:00	3.56	4.85	5.17	6.15	5.05	5.21	6.06	11.50	5.30	4.91

erent stages

<b>75</b>	<b>90</b>
8.56	8.66
6.38	7.94
7.89	12.33
7.13	13.15
7.91	9.33
8.25	9.91
7.09	7.37
8.01	16.37
8.14	11.06
10.35	12.31
9.82	10.53
9.00	15.39
6.77	9.09
8.36	11.67
6.25	9.27
9.12	9.63
8.70	12.79
9.73	9.33
7.08	9.94
5.95	12.14
5.58	8.81
4.88	5.99
7.75	11.54
5.39	5.42

**Appendix - E**

**Nutrient concentration (%) in seeds of mustard as influenced by different levels of fertilizers**

N:P:K (Kg/ha)	90 DAS								
	N	P	K	N	P	K	N	P	K
	0X			1X			2X		
00:40:40	3.05	0.35	0.54	2.91	0.53	0.71	2.93	0.51	0.72
40:20:20	2.08	0.1	0.54	2.41	0.46	0.69	2.33	0.19	0.67
40:40:20	2.14	0.1	0.49	2.38	0.56	0.89	2.65	0.12	0.58
40:20:40	2.11	0.23	0.56	2.71	0.1	0.49	2.97	0.142	0.61
40:40:40	2.47	0.17	0.68	2.28	0.18	0.48	2.69	0.08	0.65
80:00:40	2.77	0.24	0.53	2.33	0.14	0.54	3.25	0.51	0.81
80:40:00	2.19	0.16	0.47	2.86	0.13	0.53	2.88	0.13	0.48
80:20:20	2.18	0.19	0.55	2.81	0.18	0.38	3.44	0.16	0.59
80:40:20	2.44	0.17	0.55	3.19	0.23	0.58	2.18	0.12	0.55
80:20:40	2.95	0.48	0.62	2.91	0.48	0.59	3.06	0.15	0.58
80:40:40	2.78	0.14	0.55	2.52	0.14	0.4	2.83	0.14	0.35
80:40:60	2.78	0.28	0.47	2.59	0.61	0.83	2.66	0.53	0.69
80:60:40	2.83	0.34	0.57	3.18	0.18	0.62	3.11	0.14	0.68
80:60:60	3.01	0.18	0.45	2.75	0.14	0.52	2.77	0.106	0.62
120:20:20	2.86	0.47	0.75	3.18	0.13	0.48	3.02	0.42	0.52
120:40:20	3.14	0.18	0.57	3.21	0.24	0.54	2.83	0.12	0.59
120:40:40	2.66	0.52	0.71	3.1	0.46	0.74	3.12	0.18	0.58
120:60:20	2.81	0.13	0.7	2.86	0.43	0.66	2.92	0.14	0.6
120:40:60	2.51	0.2	0.44	2.58	0.16	0.56	3.46	0.16	0.59
120:60:40	2.66	0.16	0.58	3.37	0.12	0.43	2.91	0.12	0.55
120:60:60	3.12	0.56	0.69	3.17	0.15	0.59	2.64	0.14	0.54
00:00:00	2.41	0.19	0.15	2.8	0.2	0.73	2.73	0.18	0.56
00:00:00	3.11	0.16	0.21	2.83	0.18	0.39	3.11	0.24	0.68
00:00:00	2.85	0.14	0.54	3.17	0.16	0.7	2.95	0.15	0.76



## Appendix - H

### Yield attributes of mustard as influenced by different levels of fertilizers

N:P:K (Kg/ha)	No of seed/siliqua			1000 Seeds wt (g)			Seed yield/plant (g)		
	OX	1X	2X	OX	1X	2X	OX	1X	2X
00:40:40	10.4	11.6	11.6	4.7	5.4	5.9	4.2	6.0	5.3
40:20:20	11.8	14.0	13.0	6.1	5.9	5.5	5.6	7.4	6.5
40:40:20	11.6	14.2	11.6	1.3	5.2	6.1	5.2	8.0	9.7
40:20:40	11.0	12.8	13.8	5.1	5.3	6.1	4.5	7.6	9.2
40:40:40	8.8	14.2	12.6	5.0	5.2	7.2	4.0	8.5	6.0
80:00:40	13.6	13.4	13.2	6.9	6.6	7.1	7.5	6.4	8.2
80:40:00	6.4	13.8	11.8	6.6	5.9	5.6	2.1	6.8	5.2
80:20:20	11.8	11.6	15.4	4.3	5.4	6.6	5.4	6.3	16..3
80:40:20	15.6	13.8	12.6	5.8	5.1	7.4	7.9	8.5	7.2
80:20:40	12.2	13.2	9.6	5.5	5.9	5.8	5.7	5.8	4.6
80:40:40	13.2	11.6	13.4	5.7	6.9	6.6	7.6	5.2	7.0
80:40:60	13.8	13.6	11.6	6.1	6.8	5.3	6.4	7.4	5.9
80:60:40	13.4	15.0	11.8	5.7	5.9	6.7	5.7	9.4	5.3
80:60:60	7.6	7.8	11.6	5.4	5.7	5.2	2.2	5.9	5.5
120:20:20	14.4	9.8	8.2	6.3	5.2	7.1	8.5	5.3	4.0
120:40:20	14.0	13.8	13.4	6.4	6.2	5.7	7.6	7.7	7.4
120:40:40	13.6	12.2	11.6	5.9	5.2	5.2	6.3	7.5	5.4
120:60:20	13.6	12.2	13.8	6.7	4.5	5.7	6.1	9.3	8.1
120:40:60	16.2	13.2	12.4	6.6	6.4	5.7	11.2	7.4	6.1
120:60:40	12.0	12.6	15.8	6.0	4.5	7.3	4.5	9.5	10.8
120:60:60	11.0	17.6	12.4	5.9	6.5	5.7	4.6	11.7	6.4
00:00:00	7.6	8.8	10.2	4.7	6.4	5.7	2.5	4.2	4.3
00:00:00	11.6	11.2	11.0	4.9	4.9	5.1	5.8	4.6	5.3
00:00:00	11.0	11.8	10.6	5.1	5.0	5.0	5.5	8.5	5.3

### Appendix - O

Oil content (%) and oil yield (q/ha) of mustard as influenced by different levels of fertili:

N:P:K (Kg/ha)	Oil Content			Oil Yield		
	OX	1X	2X	OX	1X	2X
00:40:40	35.8	41.6	43.9	0.4	0.6	1.5
40:20:20	44.0	43.7	38.2	1.2	1.4	2.3
40:40:20	43.5	42.1	43.0	1.3	1.6	2.0
40:20:40	43.4	43.6	44.0	2.0	1.8	2.4
40:40:40	52.0	41.2	43.5	2.2	2.4	2.7
80:00:40	43.1	34.4	38.8	1.9	1.4	2.2
80:40:00	43.0	42.1	40.5	2.2	2.5	2.6
80:20:20	42.1	40.2	34.5	2.6	3.1	2.6
80:40:20	41.6	42.9	37.2	2.7	2.9	2.8
80:20:40	43.4	45.2	45.2	2.3	2.9	2.7
80:40:40	42.9	42.6	43.2	2.1	2.9	2.7
80:40:60	30.8	34.0	30.0	1.5	2.1	2.2
80:60:40	43.7	42.1	43.2	2.4	3.2	3.7
80:60:60	42.3	36.3	43.0	2.2	3.1	3.9
120:20:20	33.5	40.1	30.0	1.9	2.2	2.0
120:40:20	41.7	38.4	32.0	2.4	2.2	2.0
120:40:40	34.0	41.2	33.1	2.2	3.2	2.1
120:60:20	35.0	30.3	35.0	2.0	2.0	2.0
120:40:60	42.2	41.3	33.1	2.9	2.2	2.0
120:60:40	32.4	40.7	40.1	1.8	2.8	4.3
120:60:60	43.0	33.2	32.4	2.7	2.7	2.9
00:00:00	41.5	42.0	30.7	0.6	0.9	0.7
00:00:00	41.5	35.2	34.7	0.9	0.7	0.8
00:00:00	41.4	30.5	40.2	0.6	0.6	1.0

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### Appendix - M

Removal of N,P and K (kg/ha) by mustard at harvest as influenced by different levels of fertilizer

N:P:K (Kg/ha)	OX			1X			2X		
	N	P	K	N	P	K	N	P	K
00:40:40	32.5	3.7	5.8	20.8	3.8	5.1	46.8	8.2	11.5
40:20:20	30.4	1.5	7.9	51.1	9.8	14.6	45.6	3.7	13.1
40:40:20	23.5	1.6	5.4	33.7	7.9	12.6	51.1	2.3	11.2
40:20:40	25.8	2.8	6.8	36.4	1.3	6.6	58.2	2.8	12.0
40:40:40	28.7	2.0	7.9	59.6	4.7	12.5	40.8	1.2	10.3
80:00:40	61.0	5.3	11.7	92.8	5.6	21.5	56.1	8.8	14.0
80:40:00	46.6	3.4	10.0	44.0	2.0	8.2	74.1	3.3	12.4
80:20:20	36.8	3.2	9.3	76.0	4.9	10.3	84.1	3.9	14.4
80:40:20	53.2	3.7	12.0	87.0	6.3	15.8	37.3	2.1	9.4
80:20:40	84.0	13.7	17.7	66.8	11.0	13.5	70.7	3.5	13.4
80:40:40	57.2	2.9	11.3	56.2	3.1	8.9	62.0	3.1	7.7
80:40:60	59.5	6.0	10.1	64.8	15.3	20.8	55.6	11.1	14.4
80:60:40	45.0	5.4	9.1	91.5	5.2	17.8	40.9	5.3	8.9
80:60:60	53.3	3.2	8.0	41.6	2.1	7.9	60.1	2.3	13.5
120:20:20	33.8	5.5	8.9	88.6	3.6	13.4	56.4	7.8	9.7
120:40:20	70.8	4.1	12.9	87.5	6.5	14.7	58.9	2.5	12.3
120:40:40	65.9	12.9	17.6	49.9	7.4	11.9	76.5	4.4	14.2
120:60:20	65.4	3.0	16.3	69.9	10.5	16.1	52.6	2.5	10.8
120:40:60	59.7	4.8	10.5	64.9	4.0	14.1	59.0	2.7	10.1
120:60:40	59.4	3.6	13.0	68.5	2.4	8.7	121.6	5.0	23.0
120:60:60	80.2	14.4	17.7	93.0	4.4	17.3	71.9	3.8	14.7
00:00:00	4.0	1.8	4.3	20.1	3.0	11.1	32.1	2.1	6.6
00:00:00	10.6	1.4	3.6	22.4	1.8	3.1	24.3	2.6	7.5
00:00:00	22.8	1.7	4.3	28.4	2.1	7.4	26.6	1.4	6.8

### Appendix - L

Removal of N,P and K (kg/ha) by mustard seed as influenced by different levels of ferti

N:P:K (kg/ha)	OX			1X			2X		
	N	P	K	N	P	K	N	P	K
00:40:40	10.08	1.58	7.32	7.01	1.82	4.89	20.42	3.83	7.43
40:20:20	15.24	1.76	6.30	24.57	4.23	10.49	19.74	3.15	14.12
40:40:20	11.34	2.66	5.30	12.25	3.26	11.16	23.84	2.32	13.98
40:20:40	12.23	2.13	5.80	15.42	2.33	8.94	26.95	2.43	14.17
40:40:40	10.83	2.16	8.36	25.79	3.91	21.95	19.06	2.10	8.42
80:00:40	26.64	3.33	13.09	41.58	5.58	16.75	21.25	4.35	12.15
80:40:00	24.29	2.22	10.67	16.98	2.88	7.42	28.79	3.72	12.17
80:20:20	14.73	3.34	9.56	27.53	3.30	19.65	34.82	3.40	19.05
80:40:20	20.61	2.84	19.10	48.03	4.85	16.61	16.40	2.77	12.40
80:20:40	29.65	6.19	24.26	28.64	5.69	16.05	34.82	3.47	16.97
80:40:40	22.60	2.72	10.36	24.01	5.29	14.33	28.84	3.55	14.07
80:40:60	24.32	3.51	15.82	25.49	5.75	14.00	22.97	5.80	11.48
80:60:40	17.77	2.74	13.06	40.37	3.77	13.40	22.11	2.41	6.91
80:60:60	22.39	3.04	14.08	19.26	2.23	18.33	29.92	3.37	11.12
120:20:20	15.80	2.52	7.96	36.18	3.82	17.21	28.22	4.43	7.15
120:40:20	23.01	3.53	15.00	34.76	5.02	20.38	27.34	3.23	16.53
120:40:40	28.75	5.23	16.87	17.53	3.41	13.59	30.39	3.50	21.15
120:60:20	25.03	2.85	16.29	34.55	5.89	15.78	28.73	3.29	11.84
120:40:60	31.49	4.42	14.01	26.89	5.07	10.54	27.50	3.10	11.18

120:60:40	25.10	2.69	17.76	28.08	3.67	10.84	48.48	5.33	25.16
120:60:60	38.38	6.19	17.75	39.88	4.40	21.58	32.41	4.03	20.89
00:00:00	1.82	1.35	2.07	14.07	2.29	8.98	12.36	3.12	7.51
00:00:00	3.80	3.11	2.13	8.31	2.54	3.20	12.33	2.38	6.43
00:00:00	11.66	2.13	3.36	10.48	2.46	6.85	11.02	2.88	5.24

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