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# Nutrient management for *Brassica juncea* L. Czernj. and Cosson in moong-maize mustard cropping system

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**A**BSTRACT : The available nitrogen, phosphorus and potassium were 203kg, 18kg and 283kg/ha, respectively. There were ten treatments *viz.*,$T_1$ (Control), $T_2$ (100% PK), $T_3$ (100% NPK), $T_4$ (150% NPK), $T_5$ (100% NPK + S), $T_6$ (100% NPK + Zn @ 25kg $ZnSO_4$ /ha), $T_7$ (100% NPK + B @ 1kg B/ha), $T_8$ (100% NPK + FYM @ 2.5 t/ha), $T_9$ (100% NP) and $T_{10}$ (100% NK) with the RDF of 120:40:20kg N, $P_2O_5$ and $K_2O$/ha, respectively. Plant height did not differ significantly at all the stages of crop growth. Maximum plant height at all the stages of crop growth was recorded under the application of 100% NPK + FYM @ 2.5 t/ha ($T_8$) treatment. However, minimum plant height at all stages of crop growth was recorded under control ($T_1$) treatment. Dry matter accumulations per plant in relation to different fertility levels were found to be significant during all the stages of crop growth, except at harvest. Maximum dry matter accumulation occurs under 100% NPK + FYM @ 2.5t/ha ($T_8$) treatment followed by 100% NPK + S ($T_5$) and minimum dry matter accumulation occurs under control (Ti) treatment, respectively. Significantly higher number of secondary branches recorded under 100% NPK + FYM @ 2.5t/ha ($T_8$) treatment at all the stages of crop growth and minimum number of secondary branches recorded under control (Ti) treatment, respectively. Higher number of all the yield attributes was found fewer than 100% NPK + FYM @ 2.5t/ha ($T_8$) treatment and minimum number of all the yield attributes was found under control ($T_1$) treatment. Higher values of seed yield, stover yield, biological yield and harvest index was recorded under the application of 100% NPK + FYM @ 2.5 t/ha ($T_8$) treatment and minimum value was recorded under the application of control ($T_1$) treatment. The maximum nutrient uptake by the crop was recorded under the 100% NPK + FYM @ 2.5t/ha ($T_8$) treatment and lowest nutrient uptake by the crop was recorded under the control (Ti) treatment. Maximum oil content was found under 100% NPK + S @ 40kg/ha ($T_5$) treatment but maximum oil yield was recorded under 100% NPK + FYM @ 2.5t/ha ($T_8$) treatment. However, lowest oil content and oil yield was recorded under control (Ti) treatment. Maximum protein content was found under 100% NPK + FYM @ 2.5t/ha ($T_8$) and 150% NPK ($T_4$) treatment but maximum protein yield was found under 100% NPK + FYM @ 2.5t/ha ($T_8$). However, lowest protein content and protein yield was recorded under control ($T_1$) treatment. The maximum gross return and net return was obtained under 100% NPK +FYM @ 2.5t/ha ($T_8$) but maximum B : C ratio was found under 100% NPK + B @ 1kg B/ha ($T_7$) treatment and lowest grass return, net return and B: C ratio was obtained under control treatment (Ti).

**K**EY **W**ORDS : NPK, FYM, Protein content, Oil content, Nutrient management

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In India, oilseeds are the second largest agricultural commodity after cereals, occupying about 13.5% of the gross cropped area in the country and accounting for 5% of GNP and 10% of the value of all agricultural products. India is the third largest producer of rapeseed-mustard in the world after China and Canada with 11.12% per cent of the world's total production. Among the seven edible oilseeds cultivated in India, rapeseed-mustard contributes 28.6% in the total oilseeds production and rank second after soybean sharing 27.8% in the India's oilseed economy. Out of the estimated 58 mt of oilseeds required by 2020, the share of Rapeseed-Mustard has been projected at 24.2mt. Indian mustard (*Brassica juncea*) is predominantly cultivated in the states of Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Gujarat, Punjab and Bihar. Its cultivation is also being extended to non-traditional areas of Southern States like Karnataka, Andhra Pradesh and Tamil Nadu. In India, rapeseed-mustard crops are grown under irrigated and rainfed conditions during *Rabi* season depending on availability of water and suitable cropping system. However being more responsive to fertilizers, it gives better returns under irrigated conditions. Only, 30-40% of nutrients applied through fertilizers are utilized by the crop and the remaining is lost through various pathways (Davari and Mirzakhani, 2009). Indian mustard is nutritionally rich and its oil content varies from 37-49%. The seed and oil are used as a condiment in preparation of pickles, flavouring, curries and vegetables as well as for cooking and frying purposes. Its oil is used in many industrial products, cake as cattle feed and manure and green leaves for vegetable and green fodder (Chauhan *et al.*, 2011). The state of Uttarakhand has a huge deficit in oilseeds production and the total area under rapeseed-mustard stands at 18,000 ha. There is a need to make the state self sufficient in oilseed *vis-a-vis* rapeseed and mustard production by fitting this crop in diversified cropping systems involving upland crops. Apart from oilseeds, the state is also having equivalent deficit in pulses. So, under upland condition it will be of great significance to include a summer pulse (moong) crop followed by maize in *Kharif* and mustard in *Rabi* season. This will not only improve cropping intensity but also enhance the production of pulses and oilseeds in the state. However, to have an intensive cropping system, involving a legume and a cereal (like an exhaustive crop maize), there is a need to optimize and integrate the nutrients and the management practices for mustard to realize higher productivity of the system and *vis-a-vis* increased nutrient use efficiency. With development of new cultivars of rapeseed-mustard under the changing climatic scenario, it becomes imperative to assess the potential of the cultivars under varying fertility levels. Among the various essential nutrients, nitrogen is important in mustard being an essential constitute of all the living matters like chlorophyll, protoplasm, nucleic acids and proteins. The nitrogen requirement of mustard depends on the soil type and organic matter content. Consequent upon the release of improved cultivars, a significant change has occurred in plant type and fertilizer requirement and use efficiency as compared to the traditional varieties. Improved varieties of Indian mustard have been reported to respond to nitrogen application upto 120kg/ha. Rate of nitrogen depends on the initial soil status, climate, topography, cropping system in practice and the crop. Phosphorus has been commonly lacking in most of the soils in recent times. Although abundant amount of phosphorus is absorbed and accumulated by rapeseed-mustard group of crops, the actual amount needed for metabolic reactions and structural components of cells are relatively small. It is an important component of many bio chemicals including nucleic acids, phospholipids, DNA and RNA. Adequate phosphorus helps the Indian mustard plant to partition greater proportion of the additional dry matter in to the seed. Indian mustard genotypes exhibited differential response to phosphorus application. Apart from genotype, soil type and fertility status, level of applied nitrogen, potassium and environment for optimum crop growth are the factors that affect response to phosphorus. Potassium plays an important role in essential physiological processes including photosynthesis, assimilates transmission into sink, cell turgor maintenance and enzyme activates. It is vital in water regulation of the plant and plays an important balancing role with nitrogen to ensure healthy, vigorous growth and natural resistance to diseases, pests and stresses. It also increases the uptake of other nutrients like nitrogen, phosphorus and sulphur. Potassium is also an important nutrient for mustard as it shows synergistic effects with other nutrients. Sulphur is the fourth important nutrient after nitrogen, phosphorus and potassium for Indian agriculture. The nutrient which plays a multiple role in providing nutrition to oilseed crops, particularly those belonging to cruciferae family is sulphur. Each unit of fertilizer sulphur generates 3-5 units of edible oil, a commodity needed by every family. It is a constituent of three amino acids and helps in the formation of chlorophyll and synthesis of oils. Sulphur deficiency leads to reduction in the sulphur containing amino acids which inhibits protein synthesis and also decreases the chlorophyll content. Sulphur requirement of crop plants is quite high and high yielding varieties require higher amounts of sulphur as compared to the traditional varieties of the crops. Sulphur application also has marked effect on soil properties and is used as soil amendment to improve the availability of other nutrients in soil like gypsum and pyrite. Sulphur deficiency has been found to occur in soils which are coarse textured and low in organic matter. About 42.3% of the Indian soils are deficient in sulphur. It is well accepted that sulphur deficiency in Indian soils is wide spread and major constraint in the way of increasing crop productivity, quality and farm income (Tandon, 2010). Zinc plays a vital role in carbohydrate and protein metabolism as well as it controls the plant growth hormone IAA. It is an essential component of dehydrogenase, proteinase and promotes starch formation, seed maturation and production. Zinc deficiency has increased from 44 to 48%, and is expected to further increase upto 63% by 2025. Most of the marginal soils are showing higher response to added zinc (Singh *et al.*, 2009). Continuous use of high analysis fertilizers under intensified cropping and neglect of organic manures manifested the occurrence of widespread micronutrient deficiencies, especially of Zn in Indian soil. Apart from major plant nutrients, boron plays an important role in the production phenology of mustard and this crop responds to applied boron (Karthikeyan and Shukla, 2008). Boron has its role in cell wall synthesis, root elongation, glucose metabolism, carbohydrate transport, nucleic acid synthesis, lignifications, tissue differentiation and development. Boron also plays an important role in the development and differentiation of sugar in plants and helps in root development, flower and pollen grain formation. The productivity of mustard has been decreasing continuously in the intensively cultivated areas due to use of high analysis chemical fertilizers, which has made the soils not only deficient in micronutrients but also deteriorated in terms of the other soil health parameters. Further, application of high analysis NPK fertilizers with a very limited use of organic manures has caused depletion of micronutrients in the soils. This results in a big gap between the requirement and production of mustard in India. Therefore, a specific nutrient management through soil- test recommendation should be adopted to improve upon the existing yield levels obtained at farmers field (Shekhawat *et al.*, 2012). Considering the above facts in view, an investigation entitled "Nutrient management for Indian *Brassica juncea* L. Czernj and Cosson in moong-maize-mustard cropping system" was taken up during 2015-2016 with the following objectives: (i) To study the growth, yield attributes, yield and quality of Indian mustard as influenced by fertility levels and integration of organics, secondary and micro nutrients in moong-maize-mustard cropping system, (ii) To evaluate nitrogen, phosphorus and potassium uptake by Indian mustard with integration of nutrients, (iii) To study economics of fertility management for Indian mustard in the cropping system.

## Research Procedure

**Details of treatments:**

Number of treatment 10. (i) $T_1$- Control, (ii) $T_2$-100% PK, (iii) $T_3$-100% NPK (RDF)*, (iv) $T_4$-150% NPK, (v) $T_5$-100% NPK + S @ 40kg/ha, (vi) $T_6$-100% NPK+ Zn @ 25kg $ZnSO_4$/ha, (vii) $T_7$-100% NPK + B @ 1kg B/ha, (viii) $T_8$-100% NPK + FYM @ 2.5t/ha, (ix) $T_9$-100% NP, (x) $T_{10}$- 100% NK. * RDF = 120: 40: 20 kg N, $P_2O_5$ and $K_2O$/ha, respectively.

**Application of fertilizers:**

*Source of fertilizers and rate of application:*

The mustard crop was fertilized with the help of nitrogen, phosphorus, potassium, sulphur, zinc and boron. Urea, SSP, muriate of potash, gypsum, zinc sulphate and boric acid were used as the source of nitrogen, phosphorus, potassium, sulphur, zinc and boron, respectively. Urea, SSP, muriate of potash, gypsum, zinc sulphate and boric acid were applied to the individual plots as per the treatment with different rates.

*Time and method of fertilization:*

One-third dose of nitrogen along with full doses of phosphorus, potassium, sulphur, zinc and boron were applied as basal dressing. Remaining one-third dose of nitrogen was applied through top dressing after 30 DAS and remaining one-third dose was applied at before flowering.

*Seed and sowing:*

The required quantity of fertilizers for each plot was applied in the furrows opened at a distance 30cm with the help of kudal and mixed in the soil. Seeds were sown into the rows using seed rate @ 5kg/ha.

*Thinning :*

In order to maintain optimum plant population per unit area, thinning was done manually at seedling stage *i.e.* 20-25 days after sowing and maintained plant spacing 10 cm apart.

*Intercultural operations:*

One manual hand hoeing was done at 45 days after sowing.

*Irrigation:*

Two irrigations were given to the mustard crop. First irrigation was at 30 days after sowing and the second irrigation was at 75 days after sowing of the crop.

*Plant protection measures:*

To check the infestation of aphid spray of Monocrotophos 36% SL @ 0.5kg ai/ha was given. To control alternaria blight spray of Dithane M-45 75% WP @ 0.2% in 800 liters water/ha at 50DAS.

*Harvesting:*

The mustard crop was harvested as soon as 75% siliqua turned yellowish brown and the moisture content in seed was around 30-40%. The border rows were harvested first and kept aside, thereafter; net plots were harvested especially in the morning hours when siliquae are slightly damage with night dew to reduce shattering of the siliqua.

*Threshing, winnowing and bagging:*

The bundles of harvested plants were sun dried and finally brought to threshing floor. The produce of net plot was weight individually and recorded before threshing. Threshing was done by wooden sticks and the seed weight from the net plots was recorded carefully. Seed weight was subtracted from the total produce as to know the stover yield of each net plot.

**Observations recorded:**

*Growth and development studies:*

The various plant growth studies were carried out at 45, 60, 90DAS and finally at harvest, as per procedure given below:

*Plant height (cm):*

Five plants selected randomly, were tagged from each plot from selected rows and plant height was measured in cm with the help of meter scale from the base of the plant to apex of the plant and mean have been presented.

*Dry matter accumulation (g/plant) :*

Five plants from each plot were selected at random and uprooted every 30 days interval at 45, 60, 90DAS and at harvest and after sundried, materials were kept in an oven at 65°C till the constant weight. The average was recorded as dry matter g/plant.

*Number of branches/plant:*

Number of primary and secondary branches were counted from five randomly selected tagged plant at 45, 60, 90DAS and at harvest and the mean value was taken.

**Phenological studies:**

*Days taken at 50% flowering:*

The data on which 50% plants of four central rows had at least one flower, was considered for recording the day taken for 50% flowering.

*Days taken to 80% maturity:*

Number of days taken to maturity was recorded from the date of sowing to the time when 80% siliquae attained yellow colour.

**Yield and yield attributes:**

*Number of siliquae/plant:*

The total siliquae separated from five randomly selected tagged plants were counted and averaged was recorded as to assess the effect on the number of siliquae/ plant.

*Number of seeds/siliqua:*

Number of seeds in ten silique taken out from the five randomly selected tagged plants of each plot was counted and their average was worked out to find out the seeds/ siliqua.

*Length of siliqua (cm):*

Length of ten siliquae, taken out from the randomly selected tagged plants of each plot was measured with the help of thread and meter scale. Then the average was worked out and expressed as length of siliqua in cm.

*1000-seed weight (g):*

One thousand healthy seeds were counted from the representative sample of each plot and weighted as to record 1000-seeds weight in gram.

*Seed yield (kg/ha):*

From the individual plot, the net plot area was harvested separately and the produce was sun dried. After sundried, the crop were threshed and the produce was cleaned. The final weight was recorded in kg/plot and finally converted into kg/ha by using conversion factor.

*Stover yield (kg/ha):*

Stover yield was computed by deducting the seed yield from the total biological yield recorded/plot and expressed in kg/ha by multiplying with conversion factor.

*Biological yield (kg/ha):*

All above the ground plant parts of the net plot were dried and weighted in kg per plot to represent the biological yield.

**Chemical studies:**

*Chemical studies of soil samples:*

Initial soil samples were collected from the 0-15cm deep layer of the soil at 10 random points with the help of spade and khurpi, pooled together and processed for determination of initial physio-chemical properties of soil of the experimental site. Chemical analysis of soil was done after harvesting of crop.

*Chemical analysis of plant samples:*

The uniform and representative plant samples were collected randomly from every plot at harvest. These samples were used for following chemical studies:

**Nutrient content and uptake by plants:**

*Nitrogen content and uptake by seed, stover and plant:*

Total nitrogen content in seed and stover of each plot at harvest stage was estimated separately by modified micro-kjeldahl method (Jackson, 1973). The samples were grounded upto 2 mm mesh size and 0.2g of this sample were taken and digested. The aliquot was used for analysis of the per cent total N in crop at harvest. The nitrogen uptake was calculated by multiplying the concentration of N in seed and stover with respective dry matter production in one hectare, N uptake by plant was worked out by adding N uptake in seed and stover and expressed as kg/ha.

*Phosphorus content and uptake by seed, stover and plant:*

Total phosphorus content in seed and stover of each plot at harvest stage was estimated separately by vanado-molybdo-phosphoric acid yellow method (Jackson, 1973). The phosphorus uptake was calculated by multiplying the concentration of P in seed and stover with respective dry matter production in one hectare, P uptake by plant was worked out by adding P uptake in seed and stover and expressed as kg/ha.

*Potassium content and uptake by seed, stover and plant:*

Total potassium content in seed and stover of each plot at harvest stage was estimated separately by flame photometry method (Jackson, 1973). The potassium uptake was calculated by multiplying the concentration of K in seed and stover with respective dry matter production in one hectare, K uptake by plant was worked out by adding K uptake in seed and stover and expressed as kg/ha.

**Quality studies:**

*Oil content (%) and oil yield (kg/ha):*

Oil content was estimated by the conventional Soxhlet method. It was used for estimation of oil. In this method seed samples were kept in the oven at 70°C for removal of moisture. After removal of moisture the seeds were crushed in a pestle- mortar for extraction of oil. The oil content was reported on per cent basis. Oil yield was computed by multiplying the oil content value with the seed yield as per the treatments and presented in kg/ha.

*Protein content (%) and protein yield (kg/ha):*

Seed samples were analyzed for nitrogen content (%) and by multiplying the values of nitrogen content with a factor of 6.25, protein content was computed in percent. Protein yield was computed by multiplying the protein content value with the seed yield as per the treatments and presented in kg/ha.

**Economics:**

*Cost of cultivations:*

During experimentation, an added cost due to different treatments were calculated considering price of seed, fertilizer, herbicides, weeding etc. Total man days required were worked out considering 8 hours' work of one man equivalent to one man per day. The actual man days required for spraying and weeding were recorded at the time of treatments. Labour charges were calculated @ during crop growth duration. Net return under different treatments were calculated considering added cost due to herbicide, fertilizers, seeds of crop and other inputs and uniform cost of other cultural. Net return was considered as the difference between the gross return and the total cost of cultivation (cost of cultural operations + inputs + cost of treatments). Benefit: Cost ratios per rupee invested under different treatments were calculated by dividing net return by total cost of cultivation.

## RESEARCH ANALYSIS AND REASONING

The result of the experiment entitled "Nutrient management for *Brassica juncea* L. Czernj. and Cosson in moong-maize mustard cropping system" have been presented in this chapter. The observations recorded with respect to plant growth, yield and yield contributing characters, quality, nutrient content, uptake and economics have been presented in respective tables and illustrated graphically wherever found necessary and analyses of variances are given in appendixes, respectively. For information the yield of *Moong* and maize was 1036 and 4077 kg/ha, respectively. The results obtained have been logically interpreted with cause and effect relationship in this chapter.

### Growth and development studies on mustard crop:

*Plant height:*

The data pertaining to plant height recorded at various stages of crop growth have been presented in Table 1. In general, the plant height increased with the advancement in age of the crop and reached maximum at maturity. Plant height did not differ significantly at all the stages of crop growth. Maximum plant height at 45, 60, 90 DAS and at harvest was recorded under the application of 100% NPK + FYM @ 2.5t/ha treatment with height's measuring 88.3, 124.1, 156.2 and 164cm, respectively. However, minimum plant height of 70.7, 99.7, 121.0 and 129.5cm was recorded in control treatment at all stages of crop growth *i.e.* 45, 60, 90DAS and at harvest. The plant height was influenced with the application of different nutrients levels and their combinations. Favorable effect on plant growth with integration of 100% NPK and FYM over control may be attributed to better nutritional environment for plant growth at active vegetative stages as a result of number of metabolic processes taking place in the plant body like enhancement in cell multiplications, cell elongation and cell expression, which in turn are affected by a variety of inherent and environmental factors to which plant is exposed.

### Dry matter accumulation of mustard (g/plant):

The data pertaining to dry matter accumulation at various stages of crop growth have been presented in Table 2. The data revealed that dry matter accumulation in general increased as the crop advanced in age and reached maximum at maturity. The accumulation rate of dry matter in plant was found minimum at 45 DAS and there after a rapid increase was seen upto maturity stage. The data revealed that mustard crop accumulate the dry matter very rapidly between 45 and 90 DAS of crop

**Table 1 : Plant height of mustard at various stages of crop growth as influenced by different treatments**

| Treatments | | Plant height (cm) | | | |
|---|---|---|---|---|---|
| Symbols used | Combinations applied | 45DAS | 60DAS | 90DAS | At harvest |
| $T_1$ | Control | 70.7 | 99.7 | 121.0 | 129.5 |
| $T_2$ | 100% PK | 76.4 | 115.2 | 145.8 | 153.2 |
| $T_3$ | 100% NPK | 80.1 | 120.5 | 150.1 | 158.7 |
| $T_4$ | 150% NPK | 79.2 | 119.9 | 149.1 | 157.1 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 86.3 | 123.2 | 154.0 | 162.3 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 84.4 | 122.3 | 152.6 | 161.3 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 82.5 | 121.1 | 151.0 | 160.9 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 88.0 | 124.1 | 156.2 | 164.0 |
| $T_9$ | 100% NP | 78.6 | 117.2 | 147.8 | 155.3 |
| $T_{10}$ | 100% NK | 78.0 | 116.2 | 146.1 | 154.2 |
| S.E. $\pm$ | | 5.6 | 7.2 | 8.6 | 9.2 |
| C.D. (P=0.05) | | NS | NS | NS | NS |

NS=Non-significant

growth. At 45DAS highest dry matter accumulation was recorded under the 100% NPK + FYM @ 2.5t/ha treatment which was statistically at par with 100% NPK + S @ 40kg/ha 100% NPK + Zn @ 25kg $ZnSO_4$ /ha and 100% NPK + B @ 1kg B/ha treatment. The lowest dry matter accumulation was recorded in control treatment which was statistically at par with 100% PK 100% NP and 100% NK fertility levels but was significantly lower than other treatments.

Highest amount of dry matter accumulation was recorded at 60DAS under the 100% NPK + FYM @ 2.5t/ha treatment, which was statistically at par with NPK level of 120:40:20 *i.e.* 100% NPK, 150% NPK, 100% NPK + S @ 40kg/ha, 100% NPK + Zn @ 25kg $ZnSO_4$ /ha and 100% NPK + B @ 1kg B/ha treatments but significantly superior than other treatments. However lowest amount of dry matter accumulation was recorded in control treatment which was statistically at par with 100% PK and 100% NK treatments but was significantly lower than remaining treatments. Dry matter accumulation as affected by different treatment at 90DAS was found significant. The highest amount of dry matter accumulation was recorded under the treatment 100% NPK + FYM @ 2.5t/ha which was statistically at par with all the treatments except control. The lower dry matter accumulation was recorded in control which was significantly lower than other treatments. At harvest stage dry matter accumulation was found to be non significant. Higher dry matter accumulation was recorded under 100% NPK + FYM @ 2.5t/ha treatment and however, lowest amount of dry matter accumulation was recorded under control. Dry matter accumulation per plant is an ultimate result of all the metabolic processes occurring inside the plant. The higher value of total dry matter per plant might be due to higher values of more number of leaves, primary, secondary and total branches and also higher uptake of nutrients by the crop, more photosynthesis which ultimately result higher dry matter accumulation. Adequate supply of readily available nitrogen and other essential nutrients through integration of fertilizer with FYM favor gradually mineralization and availability of nutrients along with increased moisture holding capacity of soil which creates favorable conditions to produced taller plants. Taller plants produced more dry matter because of more opportunity to production and accumulation of photosynthates.

**Number of primary branches/plant:**

The data pertaining to number of primary branches at various stages of crop growth have been presented in Table 3. In general the number of primary branches increased with advancement of crop age. Different treatments showed significant effect on number of primary branches at 45, 60, 90DAS and at harvest. Maximum number of primary branches was observed under 100% NPK + FYM @ 2.5t/ha treatments *i.e.* 2.0, 3.5, 5 and 6.4 at 45, 60, 90DAS and at harvest, respectively. The minimum values for primary branches were 1, 2.4, 3.4 and 4.4 at 45, 60, 90DAS and at harvest, respectively in case of control. Among the different treatments at harvest stage number of primary branches was found maximum under 100% NPK + FYM @ 2.5 t/ha treatment which was at par with 100% NPK + S @ 40kg/ha, 100% NPK + Zn @ 25 kg $ZnSO_4$ /ha, 100% NPK + B @ 1kg B/ha and 100% NPK treatment but was significantly higher over rest of the fertility levels.

**Table 2 : Dry matter accumulation of mustard (g/plant) at various stages of crop growth as influenced by different treatments**

| Treatments | | Dry matter accumulation/plant (g) | | | |
|---|---|---|---|---|---|
| Symbols used | Combinations applied | 45DAS | 60DAS | 90DAS | At harvest |
| $T_1$ | Control | 17.5 | 40.2 | 56.1 | 85.4 |
| $T_2$ | 100% PK | 19.9 | 46.0 | 76.8 | 91.4 |
| $T_3$ | 100% NPK | 23.1 | 51.1 | 81.8 | 97.2 |
| $T_4$ | 150% NPK | 22.2 | 50.8 | 81.3 | 96.2 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 27.5 | 55.7 | 85.4 | 101.0 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 26.7 | 54.3 | 84.5 | 100.4 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 25.5 | 53.6 | 83.9 | 99.1 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 28.6 | 56.2 | 86.2 | 102.7 |
| $T_9$ | 100% NP | 20.9 | 48.5 | 79.2 | 94.9 |
| $T_{10}$ | 100% NK | 20.4 | 47.9 | 78.2 | 93.4 |
| S.E. ± | | 1.4 | 2.6 | 4.4 | 6.0 |
| C.D. (P=0.05) | | 4.2 | 7.8 | 13.3 | NS |

NS=Non-significant

However, at harvest stage, lowest number of primary branches was found in control treatment which was at par with 100% PK, 100% NK, 100% NP and 150% NPK treatments but significantly lower than remaining treatments. Number of primary branches increased with increased nutrient levels and increased vigour of the plant during the vegetative phase, thus contributing towards the higher growth and vigour of the plants and production of branches per plant.

**Number of secondary branches/plant:**

The data pertaining to number of secondary branches at various stages of crop growth have been presented in Table 4. In general, the number of secondary branches increased with advancement of crop age. Higher number of secondary branches at 45DAS recorded with the application of 100% NPK + FYM @ 2.5t/ha treatment which was statistically at par with all the treatments except control, 100% PK, 100% NK and 100% NP treatments. However, the lowest number of secondary branches was recorded in control treatment which was statistically at par with 100% PK, 100% NK and 100% NP treatment but significantly.

Significant effect on number of secondary branches was also observed at 60DAS. Higher number of secondary branches was recorded under 100% NPK + FYM @ 2.5 t/ha treatment which was statistically at par with all the treatments except control, 100% PK, 100% NK and 100% NP treatments. Lowest number of secondary branches was recorded in control treatment which was not statistically at par with any treatments. At 90 DAS different treatments revealed significant number of secondary branches. Higher number of secondary branches was recorded with the application of 100% NPK + FYM @ 2.5t/ha treatment, which was at par with 100% NPK + S @ 40kg/ha, 100% NPK + Zn @ 25kg $ZnSO_4$ /ha, 100% NPK + B @ 1kg B/ha, 150% NPK, 100% NPK, 100% NK and 100% NP treatments.

**Table 3 : Number of primary branches at various stages of crop growth as influenced by different treatments**

| Treatments | | Number of primary branches/plant | | | |
|---|---|---|---|---|---|
| Symbols used | Combinations applied | 45DAS | 60DAS | 90DAS | At harvest |
| $T_1$ | Control | 1.0 | 2.4 | 3.4 | 4.4 |
| $T_2$ | 100% PK | 1.4 | 2.8 | 3.8 | 4.8 |
| $T_3$ | 100% NPK | 1.7 | 3.2 | 4.3 | 5.5 |
| $T_4$ | 150% NPK | 1.6 | 3.1 | 4.2 | 5.3 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 1.9 | 3.4 | 4.5 | 6.2 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 1.8 | 3.3 | 4.4 | 6.1 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 1.8 | 3.3 | 4.4 | 6.0 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 2.0 | 3.5 | 5.0 | 6.4 |
| $T_9$ | 100% NP | 1.5 | 2.9 | 4.1 | 5.1 |
| $T_{10}$ | 100% NK | 1.5 | 2.9 | 4.0 | 5.0 |
| S.E. $\pm$ | | 0.1 | 0.2 | 0.2 | 0.3 |
| C.D. (P=0.05) | | 0.3 | 0.6 | 0.7 | 1.0 |

**Table 4 : Number of secondary branches at various stages of crop growth as influenced by different treatments**

| Treatments | | Number of secondary branches/plant | | | |
|---|---|---|---|---|---|
| Symbols used | Combinations applied | 45DAS | 60DAS | 90DAS | At harvest |
| $T_1$ | Control | 1.1 | 2.7 | 5.4 | 8.0 |
| $T_2$ | 100% PK | 1.3 | 3.7 | 7.3 | 9.3 |
| $T_3$ | 100% NPK | 1.5 | 4.9 | 8.1 | 10.7 |
| $T_4$ | 150% NPK | 1.5 | 4.7 | 8.0 | 10.4 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 1.7 | 5.2 | 8.6 | 11.3 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 1.6 | 5.1 | 8.4 | 11.2 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 1.6 | 5.0 | 8.3 | 11.1 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 1.8 | 5.4 | 8.8 | 11.5 |
| $T_9$ | 100% NP | 1.4 | 4.1 | 7.8 | 9.9 |
| $T_{10}$ | 100% NK | 1.4 | 4.0 | 7.6 | 9.6 |
| S.E. $\pm$ | | 0.1 | 0.3 | 0.4 | 0.6 |
| C.D. (P=0.05) | | 0.3 | 0.9 | 1.4 | 1.8 |

However, the lowest number of secondary branches was recorded in control treatment which was significantly lower than all treatments. Significantly higher numbers of secondary branches was recorded under 100% NPK + FYM @ 2.5 t/ha treatment at harvest stage which was at par with 100% NPK + S @ 40kg/ha, 100% NPK + Zn @ 25kg $ZnSO_4$ /ha, 100% NPK + B @ 1kg B/ha, 150% NPK, 100% NPK and 100% NP treatments. However, the significantly lowest number of secondary branches was recorded in control treatment which was at par with 100% PK and 100% NK treatments. The increased number of secondary branches was probably due to better nutritional environment which facilitates more activities of meristematic tissue of the pant. The increased vigour of the plant during vegetative stage, thus contributed towards the higher production of secondary branches at different growth stages.

**Number of days taken to 50% flowering and 80% maturity:**

The data pertaining to number of days taken to 50% flowering and 80% maturity have been presented in Table 5. Differences in days taken to 50% flowering and 80% maturity due to different treatments were found to be non-significant. 100% PK treatment took more number of days to 50% flowering than all other treatments. However, treatment control took minimum number of days to 50% flowering. Among the different treatments more numbers of days taken for 80% maturity was fewer than 100% PK and 100% NK treatments and minimum number of days for 80% maturity under control. Days taken to 50% flowering and 80% maturity were influenced due to nutrient combinations.

It revealed that better nutrition makes the crop 50% flowering synchronously than the poorly feed crop. Balance nutrition helps in distinct division of vegetative and reproductive growth which brings uniformity in flowering and synchronous maturity. The data also revealed that balanced and optimum nutrition helps in proper and timely maturity of Indian mustard.

**Yield attributing characters:**

The data pertaining to yield attributing characters of crop are presented in Table 6.

**Number of siliquae/plant:**

Highest numbers of siliquae/plant recorded under 100% NPK + FYM @ 2.5t/ha (274) treatment which was statistically at par with 100% NPK, 150% NPK, 100% NPK + S @ 40kg/ha, 100% NPK + Zn @ 25kg $ZnSO_4$ /ha and 100% NPK + B @ 1kg B/ha treatments, but was significantly higher than other treatments. Lowest number of siliquae/plant was found under control treatment which was significantly lower than all treatments. Increased number of siliquae/plant happens to be an index of higher seed yield/plant and also govern by the number of branches/plant. This increase may be attributed to more number of total branches/plant. The number of siliquae/plant is a function of number of primary and secondary branches. Increased number of siliqua at higher fertility levels may have been contributed by mostly the secondary branches which were result out effect of the better nutrition at higher fertility levels.

**Length of siliqua (cm):**

Different treatments showed significant effect on

**Table 5 : Number of days taken to 50% flowering and 80% maturity as influenced by different treatments**

| Treatments | | Number of days taken for | |
|---|---|---|---|
| Symbols used | Combinations applied | 50% flowering | 80% maturity |
| $T_1$ | Control | 43.3 | 128.0 |
| $T_2$ | 100% PK | 46.0 | 130.3 |
| $T_3$ | 100% NPK | 44.7 | 129.3 |
| $T_4$ | 150% NPK | 44.7 | 129.0 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 45.0 | 128.0 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 45.0 | 127.7 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 43.7 | 128.3 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 44.3 | 127.7 |
| $T_9$ | 100% NP | 45.3 | 130.0 |
| $T_{10}$ | 100% NK | 45.5 | 130.3 |
| S.E. $\pm$ | | 0.6 | 0.8 |
| C.D. (P=0.05) | | NS | NS |

NS=Non-significant

siliqua length of mustard crop. Higher siliqua length was found with the application of 100% NPK + FYM @ 2.5t/ha treatment, which was at par with 100% NPK + S @ 40kg/ha, 100% NPK + Zn @ 25kg $ZnSO_4$ /ha and 100% NPK + B @ 1kg B/ha treatments. However, the lowest siliqua length was recorded in control treatment which was at par with 100% PK, 100% NP and 100% NK treatments but significantly less than other treatments. Higher siliqua length at higher fertility revealed that proper translocation of food material from source to sink. This also revealed that adequate plant nutrition is required not only for vegetative growth of the crop but also for reproductive compartments in case of mustard crop.

**Number of seeds/siliqua:**

The number of seeds per siliqua could be influenced by the application of different nutrients none significantly. Application of 100% NPK + FYM @ 2.5t/ha treatment increased number of seeds per siliqua. The lowest number of seeds per siliqua reported in control. This increase in number of seeds per siliqua might be due to application of FYM with fertilizer might have resulted from optimum fertilization of flowers and increased pollen grain viability and thereby increased number of seeds per siliqua.

**1000-seed weight (g):**

The data pertaining to 1000 seed weight are presented in Table 6. Fertility levels had significant effect on 1000-seed weight. Application of 100% NPK + FYM @ 2.5 t/ha (3.8 g) recorded the highest 1000 seed weight which was statistically at par with 100% NPK, 150% NPK, 100% NPK + S @ 40kg/ha, 100% NPK + Zn @ 25 kg $ZnSO_4$ /ha, 100% NPK + B @ 1kg B/ha and 100% NP treatments but significantly higher over rest of the treatments. However, lowest 1000-seed weight was reported under control treatments which were statistically at par with 100% PK and 100% NK treatments, but was significantly lower than rest of the treatments. Test weight is an index of boldness of seed resulting from transfer of photosynthates from vegetative parts to reproductive parts.

**Yield studies:**

*Seed yield:*

The data pertaining to seed yield are presented in Table 7. The data revealed that the seed yield of Indian mustard was affected significantly due to different fertility levels. Higher seed yield was recorded in 100% NPK + FYM @ 2.5t/ha treatment. On an average there was 108.3% increase in the seed yield as compared to control. The lowest (1067 kg/ha) was recorded in control treatment which was at par with 100% PK treatment. The 100% NPK + FYM @ 2.5t/ha treatment produced significantly higher seed yield over all treatments. The results also revealed that the source of food materials for the seeds needs to be maintained for a longer duration as translocation of food material needs to be distributed to main shoot, primary and also to secondary branches, which all together added to be the yield attributes and yield of Indian mustard which is evidenced from integration of 100% NPK and FYM taking advantage of both fast and slow form of nutrient availability and thereby more yield. Seed yields obtained in 100% NP, 100% NK, 100% NPK + 1 kg B/ha, 100% NPK + Zn @ 25kg $ZnSO_4$ /ha and 100% NPK + S @ 40kg/ha, 100% and 150% NPK all resulted at par yields. The increase in seed yield

**Table 6 : Yield attributes of mustard crop as influenced by different treatments**

| Treatments | | Number of siliquae/ plant | Number of seeds/siliqua | Length of siliqua (cm) | 1000-seed weight (g) |
|---|---|---|---|---|---|
| Symbols used | Combinations applied | | | | |
| $T_1$ | Control | 140 | 10.4 | 2.8 | 2.7 |
| $T_2$ | 100% PK | 198 | 11.2 | 3.0 | 3.0 |
| $T_3$ | 100% NPK | 240 | 11.9 | 3.5 | 3.4 |
| $T_4$ | 150% NPK | 228 | 11.7 | 3.4 | 3.4 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 268 | 12.9 | 3.8 | 3.7 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 260 | 12.7 | 3.7 | 3.6 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 251 | 12.5 | 3.6 | 3.5 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 274 | 13.5 | 4.1 | 3.8 |
| $T_9$ | 100% NP | 219 | 11.5 | 3.3 | 3.3 |
| $T_{10}$ | 100% NK | 202 | 11.3 | 3.1 | 3.1 |
| S.E. ± | | 16.4 | 0.7 | 0.1 | 0.1 |
| C.D. (P=0.05) | | 49.2 | NS | 0.5 | 0.5 |

NS=Non-significant

under adequate nutrients supply might be ascribed mainly due to the combined effect of higher plant height, more primary and secondary branches/plant, number of siliqua/plant, more number of seeds/siliqua and higher 1000-seed weight, which was the result of better translocation of photosynthates from source to sink which ultimately increased seed yield.

*Stover yield (kg/ha):*

The data on stover yield are presented in Table 7. The data revealed that stover yield was affected significantly due to different fertility levels. Among the different treatments higher stover yield was recorded with the application of 100% NPK + FYM @ 2.5t/ha treatment which was statistically at par with 100% NPK, 150% NPK, 100% NPK + S @ 40kg/ha, 100% NPK + Zn @ 25kg $ZnSO_4$ /ha and 100% NPK + B @ 1kg B/ha treatments. However, the lowest stover yield was recorded under control treatments which was statistically at par with 100% PK treatments but significantly lower than remaining treatments. This increase might be due to increased plant growth at different crop growth stages. Stover yield is the resultant effect of overall physiology of plant growth as explained earlier. The increase in stover yield under adequate nutrient supply might be ascribed, mainly due to the combined effect of macro nutrients with FYM.

*Biological yield (kg/ha) :*

The data pertaining to biological yield are presented in Table 7. Different treatments had significant effect on biological yield of mustard crop. Maximum biological yield was recorded in 100% NPK + FYM @ 2.5t/ha and was statistically at par with 100% NPK, 100% NPK + S @ 40 kg/ha, 100% NPK + Zn @ 25kg $ZnSO_4$ /ha and 100% NPK + B @ 1kg B/ha treatments. However, lowest biological yield per hectare was recorded under control treatment which was statistically at par with 100% PK treatments and significantly lower than rest of the treatments. The increase in biological yield per hectare could be attributed to increased seed and stover yields under these treatments and also the pattern of dry matter accumulation at different stages. Dry matter accumulation per plant in relation to different treatments were found to be significant during all stages of crop growth except, at harvest stage and maximum dry matter accumulation occurs under 100% NPK + FYM @ 2.5t/ha which is responsible for high biological yield in the same treatment.

*Harvest index:*

The data pertaining to harvest index are presented in Table 7. Higher value of harvest index was recorded with the application of 100% NP. However, lowest value of harvest index reported in control treatment. It is the real index for determining the economic yield from the total biological yield. The harvest index speaks the conversion efficiency of non-grain portion by turning up nutrient uptake as well as their utilization which happened with higher fertility levels resulting better growth and dry matter production and partitioning.

**Nutrient (N, P and K) content in crop:**

*Nutrient (N, P and K) content in seed and stover:*

**Table 7 : Seed yield, stover yield, biological yield and harvest index influenced by different treatments**

| Treatments | | Seed yield (kg/ha) | Stover yield (kg/ha) | Biological yield (kg/ha) | Harvest index (%) |
|---|---|---|---|---|---|
| Symbols used | Combinations applied | | | | |
| $T_1$ | Control | 1067 | 6554 | 7621 | 13.81 |
| $T_2$ | 100% PK | 1298 | 7973 | 9271 | 14.03 |
| $T_3$ | 100% NPK | 1859 | 11420 | 13279 | 14.20 |
| $T_4$ | 150% NPK | 1817 | 11162 | 12979 | 14.28 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 1945 | 11948 | 13893 | 14.11 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 1924 | 11819 | 13743 | 14.08 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 1913 | 11751 | 13664 | 14.15 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 2223 | 13656 | 15879 | 14.11 |
| $T_9$ | 100% NP | 1754 | 10775 | 12527 | 14.29 |
| $T_{10}$ | 100% NK | 1720 | 10566 | 12286 | 14.27 |
| S.E. $\pm$ | | 90 | 869 | 930 | 1.45 |
| C.D. (P=0.05) | | 271 | 2600.9 | 2783.8 | NS |

NS=Non-significant

The data pertaining to NPK content in seed and stover are presented in Table 8, 9 and 10. None of the nutrient levels showed significant difference in nutrient content *i.e.* nitrogen, phosphorus and potassium in the seed and stover. Nitrogen content in seed is higher under 100% NPK + FYM @ 2.5t/ha and 150% NPK treatment and lower nitrogen content in seed under control treatment. Nitrogen content in stover was higher under 100% NPK + FYM @ 2.5t/ha treatment. However, lowest under control treatments. Phosphorus content in seeds and stover was also higher under 100% NPK + FYM @ 2.5t/ha treatment. However, lowest Phosphorus content in seed and stover was recorded under control treatment. Seeds containing higher amount of potassium under 100% NPK + FYM @ 2.5t/ha treatments. However, lowest potassium content was recorded under control treatment. Among the all treatments potassium content was highest in stover under 100% NPK + FYM @ 2.5t/ha treatment. However, the lowest amount of potassium in stover was under control treatment.

**Nutrient (N, P and K) uptake kg/ha by crop:**

*Nitrogen uptake (kg/ha):*

The data pertaining to nitrogen uptake by seed, stover and crop presented in Table 11.

*Nitrogen uptake by seed (kg/ha):*

Higher amount of nitrogen uptake by seeds was recorded under 100% NPK + FYM @ 2.5t/ha treatment which was significantly higher than remaining treatments. However, the lowest amount of nitrogen uptake by seeds was recorded in control treatment which was statistically at par with 100% PK treatments, but was significantly lowest than remaining treatments.

*Nitrogen uptake by the stover (kg/ha):*

Among the different treatments highest amount of nitrogen uptake by stover was recorded under 100% NPK + FYM @ 2.5t/ha treatment which was statistically at par with 100% NPK + S @ 40kg/ha and 100% NPK + Zn @ 25kg $ZnSO_4$ /ha treatments significantly higher than rest of the treatments. However, lowest amount of nitrogen uptake by stover was recorded under control treatment which was statistically at par with 100% PK treatments, but significantly lower than rest of the treatments.

*Total nitrogen uptake by the crop (kg/ha):*

The effect of different fertility levels on N uptake by crop was found significant. 100% NPK + FYM @ 2.5t/ha treatment resulted higher nitrogen uptake by the crop which was significantly superior over rest of the treatments. However, lowest amount of nitrogen uptake by crop was recorded under control treatment which was at par with 100% PK but significantly lowest than remaining treatments. Higher fertility levels resulted higher total nitrogen uptake, through the N content was found to be non-significant. The more total N uptake at higher fertility levels revealed better N nutrition and it accumulated in seed and stover.

*Phosphorus uptake (kg/ha):*

The data on phosphorus uptake by seeds, stover and crop presented in Table 12.

**Table 8 : Nitrogen content (%) in seed and stover at harvest as influenced by different treatments**

| Treatments | | Nitrogen content (%) | |
|---|---|---|---|
| Symbols used | Combinations applied | Seed | Stover |
| $T_1$ | Control | 3.08 | 0.40 |
| $T_2$ | 100% PK | 3.10 | 0.43 |
| $T_3$ | 100% NPK | 3.14 | 0.45 |
| $T_4$ | 150% NPK | 3.18 | 0.47 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 3.17 | 0.47 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 3.16 | 0.46 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 3.15 | 0.46 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 3.18 | 0.48 |
| $T_9$ | 100% NP | 3.13 | 0.44 |
| $T_{10}$ | 100% NK | 3.12 | 0.44 |
| S.E. $\pm$ | | 0.05 | 0.01 |
| C.D. (P=0.05) | | NS | NS |

NS=Non-significant

*Phosphorus uptake by the seed (kg/ha):*

The different fertility levels showed significance effect on the uptake of phosphorus by seed of Indian mustard. Application of 100% NPK + FYM @ 2.5t/ha treatment which showed maximum value was significantly higher than remaining treatments. However, significantly lowest amount of phosphorus uptake by seeds was recorded under control treatment which was significantly lowest among all treatment.

*Phosphorus uptake by the stover (kg/ha):*

The uptake of phosphorus by stover was found significant. Maximum phosphorus uptake by stover was found under 100% NPK + FYM @ 2.5t/ha treatment which was statistically at par with 100% NPK + S @ 40kg/ha, 100% NPK + Zn @ 25kg $ZnSO_4$ /ha and 100% NPK + B @ 1kg B/ha treatments. However, significantly lowest amount of phosphorus uptake by stover was recorded under control treatment which was statistically at par with 100% PK treatments.

*Total phosphorus uptake by crop (kg/ha):*

Among the different treatments significantly highest amount of phosphorus uptake by crop was recorded under 100% NPK + FYM @ 2.5t/ha treatment which were statistically at par with 100% NPK +S @ 40kg/ha and 100% NPK + Zn @ 25 kg $ZnSO_4$ /ha treatments but significantly higher over rest of the treatments. However, lowest amount of phosphorus uptake by crop was recorded under control treatment which was statistically at par with 100% PK treatment. The more total P uptake at higher fertility levels revealed better P nutrition and its

**Table 9 : Phosphorus content (%) in seed and stover at harvest as influenced by different treatments**

| Treatments | | Phosphorus content (%) | |
|---|---|---|---|
| Symbols used | Combinations applied | Seed | Stover |
| $T_1$ | Control | 0.68 | 0.31 |
| $T_2$ | 100% PK | 0.71 | 0.33 |
| $T_3$ | 100% NPK | 0.72 | 0.34 |
| $T_4$ | 150% NPK | 0.72 | 0.34 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 0.75 | 0.36 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 073 | 0.35 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 0.73 | 0.35 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 0.76 | 0.36 |
| $T_9$ | 100% NP | 0.71 | 0.33 |
| $T_{10}$ | 100% NK | 0.70 | 0.32 |
| S.E. $\pm$ | | 0.70 | 0.01 |
| C.D. (P=0.05) | | NS | NS |

NS=Non-significant

**Table 10 : Potassium content (%) in seed and stover at harvest as influenced by different treatments**

| Treatments | | Potassium content (%) | |
|---|---|---|---|
| Symbols used | Combinations applied | Seed | Stover |
| $T_1$ | Control | 0.76 | 1.94 |
| $T_2$ | 100% PK | 0.81 | 1.97 |
| $T_3$ | 100% NPK | 0.85 | 1.99 |
| $T_4$ | 150% NPK | 0.82 | 1.98 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 0.87 | 2.02 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 0.86 | 2.00 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 0.86 | 2.00 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 0.88 | 2.05 |
| $T_9$ | 100% NP | 0.79 | 1.96 |
| $T_{10}$ | 100% NK | 0.81 | 1.97 |
| S.E. $\pm$ | | 0.02 | 0.03 |
| C.D. (P=0.05) | | NS | NS |

NS=Non-significant

accumulation in seed and stover.

*Potassium uptake:*

The data on potassium uptake by seeds, stover and crop presented in Table.

*Potassium uptake by seeds (kg/ha):*

Significant difference in potassium uptake in seed was realized. Potassium uptake by seeds was found maximum in 100% NPK + FYM @ 2.5 t/ha treatment which was significantly higher than remaining treatments. Lowest amount of potassium uptake was observed in control treatment which was significantly lower than other treatments. Potassium uptake by seed was found maximum because high fertility levels result more seed yield.

*Potassium uptake by stover (kg/ha):*

Among the different treatments higher amount of Potassium uptake by stover was found under 100% NPK + FYM @ 2.5t/ha treatment which was significantly higher than other treatments. However, lowest amount of potassium uptake by stover was recorded under control treatment which was significantly lower than remaining treatments.

*Potassium uptake by crop (kg/ha) :*

Maximum potassium uptake by crop was found under 100% NPK + FYM @ 2.5t/ha treatment which was significantly higher over all treatments. Lowest amount of potassium uptake by crop was observed in control treatment which was significantly lower than other treatments. Nutrient uptake by crop varied significantly due to different fertility levels. All nutrients availability to

**Table 11 : Nitrogen uptake in seed, stover and total uptake by crop at harvest as influenced by different treatments**

| Treatments | | Nitrogen uptake (kg/ha) | | |
|---|---|---|---|---|
| Symbols used | Combinations applied | Seed | Stover | Total |
| $T_1$ | Control | 32.70 | 26.02 | 58.72 |
| $T_2$ | 100% PK | 40.07 | 33.90 | 73.97 |
| $T_3$ | 100% NPK | 58.46 | 51.14 | 109.60 |
| $T_4$ | 150% NPK | 57.87 | 52.66 | 110.54 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 61.65 | 56.29 | 117.94 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 60.67 | 54.58 | 115.25 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 60.25 | 53.61 | 113.86 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 70.78 | 65.38 | 136.16 |
| $T_9$ | 100% NP | 55.00 | 47.54 | 102.54 |
| $T_{10}$ | 100% NK | 53.73 | 46.42 | 100.15 |
| S.E. ± | | 3.19 | 3.76 | 5.10 |
| C.D. (P=0.05) | | 9.56 | 11.28 | 15.29 |

**Table 12 : Phosphorus uptake in seed, stover and total uptake by crop at harvest as influenced by different treatments**

| Treatments | | Phosphorus uptake (kg/ha) | | |
|---|---|---|---|---|
| Symbols used | Combinations applied | Seed | Stover | Total |
| $T_1$ | Control | 7.24 | 20.41 | 27.65 |
| $T_2$ | 100% PK | 9.17 | 26.41 | 35.58 |
| $T_3$ | 100% NPK | 13.41 | 38.73 | 52.14 |
| $T_4$ | 150% NPK | 13.09 | 38.10 | 51.19 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 14.54 | 43.08 | 57.62 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 14.02 | 41.58 | 55.60 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 13.90 | 40.86 | 54.76 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 16.86 | 48.94 | 65.80 |
| $T_9$ | 100% NP | 12.44 | 35.48 | 47.92 |
| $T_{10}$ | 100% NK | 12.03 | 33.74 | 45.77 |
| S.E. ± | | 0.62 | 3.26 | 3.47 |
| C.D. (P=0.05) | | 1.86 | 9.76 | 10.40 |

crop that has increased biomass production and thus uptake. Nutrient uptake by the crop depends on the type of crop, plant age, soil type, variety, present nutrients status of soil, moisture, temperature and season. Since nutrient uptake is a numerical product of nutrient content and dry matter accumulation which was low under control treatment than other treatments. Higher nutrient uptake might be attributed to more proliferation of root system and higher dry matter accumulation by individual plant which in turn yielded higher in comparison to other treatments. Nutrient per cent in various plant parts as well as total nutrient uptake by the crop remained higher under higher rates of nutrient application. The significant improvement in uptake of these nutrients coupled with increased seed and stover yields increased the total uptake of N, P and K substantially. The increase of nutrient concentration and uptake with application of FYM might be due to increased availability of nutrients to plants and improving the physical condition of the soil.

**Quality studies :**

*Oil content (%) in seed and oil yield kg/ha:*

Oil content in seeds:

None of the fertility levels was able to bring significance difference in oil content in seed. A critical examination of the data revealed that higher oil content was recorded under 100% NPK + S @ 40kg/ha treatments followed by 100% NPK + FYM @ 2.5t/ha as compared to rest of the treatments. Minimum oil content was recorded under control treatments. The increase in the oil content with sulphur fertilization may be attributed to its role in oil synthesis, as sulphur is a constituent of glutathione, a compound that plays a vital role in oil synthesis (Table 14).

Oil yield kg/ha:

The effect of different nutrients on oil yield was found to be significant. The oil yield was found higher under the application of 100% NPK + FYM @ 2.5t/ha treatment which was significantly superior to other treatments. However, lowest amount of oil yield was obtained under control treatment which was statistically at par with 100% PK treatments but significantly lowest than other treatments. In case of control treatment low oil yield because of inadequate amount of nutrient available to the crop and also poor yield of crop. The highest oil yield was recorded under 100% NPK + FYM @ 2.5t/ha treatment because the balanced amount of NPK were applied to the crop with FYM which improves soil physical, chemical and biological properties of soil and provide adequate amount of nutrients to the plants and produced more yield attributing characters, ultimately more seed yield. Oil yield is the function of oil content in seeds multiplied by seed yield per hectare. Higher the seed yield, the higher was the oil yield.

*Protein content in seeds (%) and protein yield (kg/ ha):*

Protein content in seeds (%):

The data pertaining to protein content in seeds are presented in Table 15. The effect of different fertility levels was found to be non-significant. However, the maximum protein content was found under the application of 100% NPK + FYM @ 2.5 t/ha and 150% NPK treatments. The minimum protein content was recorded in control treatment. The increase might be due to higher

**Table 13 : Potassium uptake in seed, stover and total uptake by crop at harvest as influenced by different treatments**

| Treatments | | Potassium uptake (kg/ha) | | |
|---|---|---|---|---|
| Symbols used | Combinations applied | Seed | Stover | Total |
| $T_1$ | Control | 8.18 | 127.44 | 135.62 |
| $T_2$ | 100% PK | 10.58 | 156.75 | 167.33 |
| $T_3$ | 100% NPK | 15.84 | 226.93 | 242.77 |
| $T_4$ | 150% NPK | 14.84 | 221.03 | 235.87 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 16.84 | 241.46 | 258.30 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 16.61 | 236.60 | 253.21 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 16.44 | 235.68 | 252.12 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 19.55 | 280.12 | 299.67 |
| $T_9$ | 100% NP | 13.80 | 214.08 | 224.88 |
| $T_{10}$ | 100% NK | 13.96 | 207.90 | 221.86 |
| S.E. $\pm$ | | 0.62 | 3.26 | 3.47 |
| C.D. (P=0.05) | | 1.86 | 9.76 | 10.40 |

nitrogen content in seeds of these treatments as it is a mathematical value calculated from nitrogen content of seeds, as increasing nitrogen level increases the proteinious substances in seeds. Protein content was higher also due to higher concentration of P which increased the number of seeds.

Protein yield (kg/ha):

The data on protein yield is presented in Table 15. Among the different treatments higher protein yield was recorded with the application of 100% NPK + FYM @ 2.5t/ha treatment which was significantly superior over the rest treatments. However, the lowest protein yield was recorded under control which was at par with 100% PK treatments but significantly lower than remaining treatments. It is a function of protein content in seeds multiplied by seed yield per hectare.

**Economic studies:**

*Cost of cultivation:*

There was variation in cost of cultivation from treatments to treatments. The cost of cultivation was maximum with 100% NPK + FYM @ 2.5t/ha treatment and lowest with control treatment.

*Gross return:*

Among the different treatments maximum gross return was found in 100% NPK + FYM @ 2.5 t/ha treatment Minimum gross return was found under control treatment.

*Net return:*

The data on economic studies are presented in Table 16. The data on economic study revealed that the maximum net return was under 100% NPK + FYM @

**Table 14 : Oil content (%) in seed and oil yield (kg/ha) as influenced by different treatments**

| Treatments | | Oil content (%) | Oil yield (kg/ha) |
|---|---|---|---|
| Symbols used | Combinations applied | | |
| $T_1$ | Control | 40.3 | 427.3 |
| $T_2$ | 100% PK | 40.5 | 521.8 |
| $T_3$ | 100% NPK | 40.7 | 754.1 |
| $T_4$ | 150% NPK | 40.6 | 737.5 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 41.2 | 798.2 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 40.9 | 784.9 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 40.8 | 780.6 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 41.1 | 911.0 |
| $T_9$ | 100% NP | 40.6 | 712.9 |
| $T_{10}$ | 100% NK | 40.6 | 697.1 |
| S.E. $\pm$ | | 0.9 | 33.0 |
| C.D. (P=0.05) | | NS | 98.9 |

NS=Non-significant

**Table 15 : Protein content (%) in seed and protein yield (kg/ha) as influenced by different treatments**

| Treatments | | Protein content (%) | Protein yield (kg/ha) |
|---|---|---|---|
| Symbols used | Combinations applied | | |
| $T_1$ | Control | 19.25 | 204.4 |
| $T_2$ | 100% PK | 19.37 | 250.4 |
| $T_3$ | 100% NPK | 19.62 | 365.3 |
| $T_4$ | 150% NPK | 19.87 | 361.7 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 19.81 | 385.3 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 19.75 | 379.2 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 19.68 | 376.6 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 19.87 | 442.3 |
| $T_9$ | 100% NP | 19.56 | 343.7 |
| $T_{10}$ | 100% NK | 19.5 | 335.8 |
| S.E. $\pm$ | | 0.35 | 19.9 |
| C.D. (P=0.05) | | NS | 59.7 |

NS=Non-significant

**Table 16 : Cost of cultivation, gross return, net return and B: C ratio as influenced by different nutrients treatments**

| Treatments | | Cost of cultivation (Rs./ha) | Gross return (Rs./ha) | Net return (Rs./ha) | B: C ratio |
|---|---|---|---|---|---|
| Symbols used | Combinations applied | | | | |
| $T_1$ | Control | 19890 | 37700 | 17810 | 0.89 |
| $T_2$ | 100% PK | 22278 | 45875 | 23597 | 1.05 |
| $T_3$ | 100% NPK | 23783 | 65691 | 41908 | 1.76 |
| $T_4$ | 150% NPK | 25729 | 64207 | 38478 | 1.49 |
| $T_5$ | 100% NPK + S @ 40kg/ha | 24643 | 68731 | 44088 | 1.78 |
| $T_6$ | 100% NPK + Zn @ 25kg $ZnSO_4$ /ha | 25283 | 68000 | 42717 | 1.68 |
| $T_7$ | 100% NPK + B @ 1kg B/ha | 23091 | 67600 | 44509 | 1.92 |
| $T_8$ | 100% NPK + FYM @ 2.5 t/ha | 27533 | 78578 | 51045 | 1.85 |
| $T_9$ | 100% NP | 23159 | 61991 | 38832 | 1.67 |
| $T_{10}$ | 100% NK | 21827 | 60801 | 38974 | 1.78 |

2.5 t/ha treatment whereas, the minimum remained under the control treatment.

### Benefit: cost ratio:

Among the different treatments maximum B. C ratio was obtained under 100% NPK + B @ 1kg B/ha treatment followed by 100% NPK + FYM @ 2.5t/ha and 100% NPK + S @ 40kg/ha and 100% NK treatments. However lowest B: C ratio was obtained under control treatment followed by 100% PK treatment, respectively. The results of present investigation indicated appreciable variation in net return due to different nutrient levels. It might be due to fact that 100% NPK + FYM @ 2.5t/ha treatment got the maximum gross return *i.e.*, Rs. 78,578. In general, net return and B: C ratio is a function of total cost of cultivation and gross return per hectare. B: C ratio was maximum in 100% NPK + B @ 1kg B/ha.

### Conclusion :

Based on the findings of the present study, it can be inferred that the application of 100% NPK + FYM @ 2.5 t/ha ($T_8$) produced maximum growth *viz.*, plant height, primary and secondary branches, dry matter accumulation and resulted increased yield attributing characters *viz.*, number of siliqua/plant, length of siliqua, number of seeds/siliqua and 1000-seed weight. All these characters ultimately resulted in to more seed, stover, oil, protein yield and higher net returns of mustard crop during *Rabi* season with the mustard cultivar NDRE-4.

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