CHAPTER-III

MATERIALS AND METHODS
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To find out the suitable doses of Farm Yard Manure (FYM), Nitrogen and Zinc for optimum production of Rajmash in Chhattisgarh plains, field experiments were conducted for two consecutive years. Details of the materials used and methods adopted during the course of investigation are described here.

3.1 Experimental site

Field experiments were carried out during winter (rabi season) 2004-05 and 2005-06 at Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh.

3.2 Geographical situation

Raipur comes under the Chhattisgarh plains Agro-climatic zone and located at 21°4'N latitude and 81°39'E longitude with an altitude of 298 m above the mean sea level.
3.3 Climate

The experimental site comes under the seventh Agro-climatic region of the country i.e. Eastern plateau and hills and it termed as sub-humid with hot summer and cold winter. The average annual rainfall of the region is 1326 mm (80 year’s mean) with a coefficient of variation of 23.4 per cent. More than 85 per cent of rains are received in between June to September with few showers during winter and occasionally in summer season too. The temperature varies from 45°C in summer (May-June) to 6°C in winter (December-January). Relative humidity varies in between 70 to 90 per cent from mid June to March end.

3.4 Weather condition during crop period

Weekly average meteorological data during the span of experimentation as recorded at meteorological observatory, I.G.K.V. Raipur are presented in Appendix-I and Fig. 3.1 for 2004-05 and in Appendix-II and Fig. 3.2 for 2005-06. Weather data recorded during crop period revealed that in rabi 2004-05, the rainfall was 135.4 mm whereas, 2.8 mm rainfall was received during rabi 2005-06. During the first year winter season, the maximum temperature was 22.0 to 33.4°C and minimum temperature was 9.6 to 16.6°C while, during second year winter season, the temperatures were 25.8 to 35.9°C and 7.7 to 18.2°C, respectively. The average maximum temperature for different months varied from 27.0 to 31.7°C during 2004-05
Fig. 3.1: Weekly meteorological data during crop growth period (5.11.2004 to 26.2.2005)
Fig. 3.2: Weekly meteorological data during crop growth period (10.11.2005 to 4.3.2006)
and 26.7 to 33.5°C during 2005-06, while, monthly average minimum temperature ranged between 10.9 to 16.0°C during 2004-05 and 10.2 to 14.9°C during 2005-06. Relative humidity throughout the crop season varied between 24 to 96 per cent during 2004-05 and 19 to 92 per cent during 2005-06. The average maximum relative humidity for different months varied from 85 to 90 per cent and 79 to 91 per cent, while, monthly average minimum relative humidity varied between 32 to 42 per cent and 24 to 32 per cent during 2004-05 and 2005-06, respectively. The open pan evaporation average values ranged from 2.8 to 4.2 mm day\(^{-1}\) and 2.9 to 4.8 mm day\(^{-1}\), whereas, average sunshine values varied from 6.1 to 9.2 hr day\(^{-1}\) and 6.6 to 9.2 hr day\(^{-1}\) during 2004-05 and 2005-06, respectively.

3.5 Physico-chemical characteristics of the soil

In order to analyze the nutrient status of the soil, ten samples were taken randomly from the experimental field up to 30 cm depth with the help of the soil auger and a composite sample was made for mechanical and chemical analysis.

The physico-chemical properties of the experimental soil are presented in Table 3.1. The soil of the experimental field was clayey in nature (Vertisols) locally known as ‘Kanhar’ soil. The soil was neutral in reaction. It had low nitrogen, medium phosphorus and high potassium content.
Table 3.1: Initial physico-chemical properties of the soil

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Value 2004-05</th>
<th>Value 2005-06</th>
<th>Rating</th>
<th>Method used</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Physical properties</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Mechanical Coarse sand (%)</td>
<td>5.50</td>
<td>5.42</td>
<td></td>
<td>International pipette method (Black, 1965)</td>
</tr>
<tr>
<td></td>
<td>15.94</td>
<td>15.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Fine Sand (%)</td>
<td>35.50</td>
<td>35.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Silt (%)</td>
<td>43.06</td>
<td>43.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Clay (%)</td>
<td></td>
<td></td>
<td>Clayey (Vertisols)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Field capacity (%)</td>
<td>33.63</td>
<td>33.65</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Permanent wilting point</td>
<td>17.52</td>
<td>17.59</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water holding capacity (%)</td>
<td>37.86</td>
<td>37.31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bulk density (mg m⁻³)</td>
<td>1.35</td>
<td>1.39</td>
<td></td>
</tr>
<tr>
<td>B. Chemical properties</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Available N (kg ha⁻¹)</td>
<td>219.0</td>
<td>224.0</td>
<td>Low</td>
<td>Alkaline permanganate method (Subbiah and Asija, 1956)</td>
</tr>
<tr>
<td>2 Available P (kg ha⁻¹)</td>
<td>14.70</td>
<td>16.8</td>
<td>Medium</td>
<td>Olsen's method (Olsen, 1954)</td>
</tr>
<tr>
<td>3 Available K (kg ha⁻¹)</td>
<td>366.4</td>
<td>352.7</td>
<td>High</td>
<td>Flame photometric method (Jackson, 1967)</td>
</tr>
<tr>
<td>4 pH (1:2.5 soil:water suspension)</td>
<td>7.21</td>
<td>7.30</td>
<td>Neutral</td>
<td>Glass electrode pH meter (Piper, 1967)</td>
</tr>
<tr>
<td>5 EC (dsm⁻¹ at 25°C)</td>
<td>0.46</td>
<td>0.44</td>
<td>Normal</td>
<td>Solubridge method (Black, 1965)</td>
</tr>
</tbody>
</table>

3.6 Cropping history of the experimental site

The cropping history of the experimental field for the past five years and during the year of experimentations is given in Table 3.2.

It is obvious from the data that rice was taken as main crop in kharif season followed by pulses in the rabi. The crops were grown with uniform doses of fertilizers in the past years. Thus, it could be said that the
fertility status of the experimental field was homogenous during the present investigation.

Table 3.2: Cropping history of the experimental field

<table>
<thead>
<tr>
<th>Year</th>
<th>Kharif</th>
<th></th>
<th></th>
<th>Rabi</th>
<th></th>
<th></th>
<th>Zaid</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crop</td>
<td>Fertilizer (kg ha⁻¹) NPK</td>
<td>Crop</td>
<td>Fertilizer (kg ha⁻¹) NPK</td>
<td>Crop</td>
<td>Fertilizer (kg ha⁻¹) NPK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999-00</td>
<td>Rice</td>
<td>100:60:40</td>
<td>Lentil</td>
<td>20:50:20</td>
<td>Fallow</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000-01</td>
<td>Rice</td>
<td>100:60:40</td>
<td>Chickpea</td>
<td>20:50:20</td>
<td>Fallow</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001-02</td>
<td>Rice</td>
<td>100:60:40</td>
<td>Lentil</td>
<td>20:50:20</td>
<td>Fallow</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002-03</td>
<td>Rice</td>
<td>100:60:40</td>
<td>Fieldpea</td>
<td>20:50:20</td>
<td>Fallow</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003-04</td>
<td>Rice</td>
<td>100:60:40</td>
<td></td>
<td></td>
<td></td>
<td>---</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.7 Field preparation

The preparation of the field was done when the soil reached to the working condition. The ploughing was done with tractor drawn cultivator followed by harrowing and then the experiment was laid out.

3.8 Experimental details

The treatments consisted of two FYM levels i.e. 0 and 5 t ha⁻¹, three nitrogen levels i.e. 0, 60 and 120 kg N ha⁻¹ and two zinc levels i.e. 0 and 20 kg ZnSO₄ ha⁻¹. The experiment was laid out in a randomized block design (factorial) and replicated thrice. The layout plan and other details of the experiment are depicted in Fig. 3.3.
Treatment details

A. FYM

- $F_0$ - 0 t ha$^{-1}$
- $F_5$ - 5 t ha$^{-1}$

B. N-levels

- $N_0$ - 0 kg ha$^{-1}$
- $N_{60}$ - 60 kg ha$^{-1}$
- $N_{120}$ - 120 kg ha$^{-1}$

C. Zn-levels

- $Zn_0$ - 0 kg ha$^{-1}$
- $Zn_{20}$ - 20 kg ha$^{-1}$

Design: RBD (Factorial)

Replications: Three

Spacing between

- Replication: 1.0 m
- Plot to plot: 0.5 m
- Row to row: 30 cm
- Plant to plant: 10 cm

Crop: Rajmash

Variety: HUR-137

Seed rate: 120 kg ha$^{-1}$

Date of sowing: 05/11/04 & 10.11.05

Date of harvesting: 23-26/2/05 & 2-4.3.06

Fig. 3.3: Plan of Layout
3.9 Test crop

The crop rajmash (frenchbean)- *Phaseolus vulgaris* L. cultivar 'HUR-137' was taken as test crop. It is developed by Banaras Hindu University, Varanasi and released in 1991. It is also known as 'Malviya Rajmash 137'. The weight of 100 seeds is 33g and it matures in 110-115 days having yielding ability up to 20-25 q ha⁻¹ and on an average yields 10-12 q ha⁻¹. The seeds are bigger in size and reddish brown in colour.

3.10 Seed rate and spacing

On account of larger seed size (30-35 g 100 seed⁻¹) of rajmash, its seed rate was 120 kg ha⁻¹. The spacing for the crop was 30 cm x 10 cm between and within the rows.

3.11 Seed treatment and sowing

Seeds were treated with Bavistin @ 2.5 g, *Rhizobium* and PSB culture @10 g kg⁻¹ seed before sowing and seeds were sown in rows immediately.

3.12 Fertilizer application

The fertilizers were applied as per the treatments. FYM was applied as per treatment before sowing in furrows and very well mixed with the soil. Nitrogen doses were applied in two equal split i.e. 50% N as basal + 50% at branching stage as per the treatment. Basal application of 50 kg
P₂O₅, 20 kg K₂O and 20 kg S were applied through single super phosphate, muriate of potash and gypsum, respectively. Zinc was also applied through zinc sulphate as per the treatment.

### 3.13 Water management

Rajmash is the irrigation responsive legume due to its shallow root system and high nutrient requirement. Four irrigations i.e. just after sowing, 30, 60 and 90 DAS were applied through sprinkler system.

### 3.14 Weed management

Pre-emergence application of Pendimethalin @ 1.0 kg a.i. ha⁻¹ followed by 1 hand weeding at 30 DAS was quite effective in controlling weeds in rajmash.

### 3.15 Plant protection measures

Seeds were treated with Bavistin @ 2.5 g kg⁻¹ of seed at the time of sowing. The crop was not infested with major insect pests, however, as prophylactic measure one spray of Metasystox 25EC @ 750 ml ha⁻¹ in 600 litre of water was done at pod formation stage of crop.

### 3.16 Harvesting and Threshing

A net area of 15.96 m² was harvested in between 23rd to 26th February, 2005 and 2nd to 4th March, 2006 with the help of sickles by manual
labours. Harvesting of crop was done when the pod becomes yellowish brown and when the leaves turned reddish brown and start shedding. The crop was left in the field for sun drying. Four days after the harvesting, the produce from individual net plot was tied into bundles, weighed and threshed manually and seed yield was recorded.

3.17 Cultural schedule

The details of the cultural operations adopted in the experimental plots from preparatory tillage to harvesting are given in Table 3.3.

Table 3.3: Cultural schedule

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Cultural operation</th>
<th>Implement/ methods used</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2004-05</td>
</tr>
<tr>
<td>1.</td>
<td>Tilling and harrowing</td>
<td>Tractor drawn cultivator and disc harrow</td>
<td>5.11.04</td>
</tr>
<tr>
<td>2.</td>
<td>Layout and field channel preparation</td>
<td>Steel tape and manual</td>
<td>6.11.04</td>
</tr>
<tr>
<td>3.</td>
<td>Soil sampling</td>
<td>Soil auger</td>
<td>6.11.04</td>
</tr>
<tr>
<td>4.</td>
<td>Sowing and fertilizer application, seed treatment with Bavistin @ 2.5 g kg(^{-1}) of seed and Rhizobium and PSB cultures @ 10 g kg(^{-1}) of seed</td>
<td>Desi plough</td>
<td>7.11.04</td>
</tr>
<tr>
<td>5.</td>
<td>Weeding - Pendimethalin @ 1.0 kg ha(^{-1}), 1 HW at 30 DAS</td>
<td>Manual</td>
<td>8.11.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8.12.04</td>
</tr>
<tr>
<td>6.</td>
<td>Irrigation just after sowing, 30, 60 and 90 DAS</td>
<td>Sprinkler system</td>
<td>8.11.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8.12.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8.01.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8.02.05</td>
</tr>
<tr>
<td>7.</td>
<td>Plant protection (Metasystox 25 EC @ 750 ml ha(^{-1}))</td>
<td>Sprayer</td>
<td>9.01.05</td>
</tr>
<tr>
<td>8.</td>
<td>Harvesting</td>
<td>Manual</td>
<td>23-26.02.05</td>
</tr>
<tr>
<td>9.</td>
<td>Threshing</td>
<td>Manual</td>
<td>28.02.05</td>
</tr>
</tbody>
</table>
3.18 Studies on Rajmash

In order to get representative sample, competitive five plants were selected randomly from each plot and labeled for recording observations on various growth and yield attributes.

3.19 Pre-harvest studies

3.19.1 Plant population

Plant population per square metre row length was counted separately from five places. Observations were taken at 20 days after sowing (DAS) and at harvest and then average plant population was calculated.

3.19.2 Plant height (cm)

Height of five plants was recorded at 30, 60, 90 DAS and at harvest. Plant height was measured in cm from ground level to the apex of the shoot and average plant height was worked out.

3.19.3 Number of branches plant$^1$

Number of branches of five selected plants were recorded at 30, 60, 90 DAS and at harvest. The average branch number was worked out by dividing the summation with five.
3.19.4 **Dry matter accumulation plant**

Five plants from each plot were selected randomly and uprooted carefully at 30, 60, 90 DAS and at harvest. After removing roots, the samples were sun dried followed by drying in an oven at 65°C for 24-48 hours till the constant weight was obtained. The samples were weighed on an electrical balance and then averaged to get dry matter accumulation plant\(^1\).

3.19.5 **Phenological studies**

(i) **Flower initiation:** Number of days taken from date of sowing to initiation of first flower in each plot was recorded.

(ii) **Day to 50% flowering:** Flowering was noted in terms of days from sowing to appearance of first flower on approximately 50% plants in each plot.

(iii) **Maturity:** Maturity was recorded in days from date of sowing to at least 80% pods had physiological maturity.

3.19.6 **Dry matter accumulation in pod**

Pods of five randomly selected plants were taken at 90 DAS and at harvest. The samples were dried in oven at 60°C for 24 hours and weighed on an electrical balance and then averaged to get dry matter accumulation in pods plant\(^1\).
3.20 Post-harvest studies

3.20.1 Number of pods plant$^{-1}$

Total number of pods on individual five plants were counted and averaged to get average number of pods plant$^{-1}$.

3.20.2 Number of seeds pod$^{-1}$

Ten pods from each five plants were randomly taken and total number of seeds were counted and averaged.

3.20.3 Number of seeds plant$^{-1}$

Total number of seeds from the five plants plot$^1$ were counted at the time of harvesting and then averaged.

3.20.4 Pod and seed weight plant$^{-1}$

Weight of sun-dried pods from five plants was recorded in gram before threshing and thereafter weight of seeds was also recorded in gram and then average pod and seed weight was calculated.

3.20.5 100-seed weight (g)

Randomly well developed dried 100-seeds were counted from the produce of each plot and then dried in oven till the weight became constant. After this, weight was recorded on an electronic balance.
3.20.6 Seed yield (kg ha\(^{-1}\))

The weight of clean seeds recorded from each net plot was converted into kg ha\(^{-1}\) by multiplying with the conversion factor of 626. Seed weight of sample plants was also added with plot yield before converting into yield ha\(^{-1}\).

3.20.7 Stover yield (kg ha\(^{-1}\))

The stover yield of each net plot including the stover weight of five sample plants was also converted kg ha\(^{-1}\) by multiplying with the factor used as in the case of seed yield.

3.21 Computation

3.21.1 Leaf area index (LAI)

To calculate the Leaf Area Index (LAI), length (L) and width (W) of three leaves from each of the five plants selected for observations were recorded in centimeter. To get the average leaf size, one leaf from lower, middle and upper portion of the plant was taken and measured. Average length and width of leaf was worked out. Observations were taken to 30, 60 and 90 DAS and at harvest. LAI was estimated using the following formula given by Bhatt and Chanda (2003) as under:

\[
\text{LAI} = 0.88 (L + W)
\]

Where, 0.88 is the correction factor

- L = Average length of leaf
- W = Average width of leaf
3.21.2 Crop growth rate (CGR)

The mean crop growth rate was calculated for the period 30-60 DAS, 60-90 DAS and 90 DAS to at harvest with the help of following formula:

\[
\text{Crop growth rate} = \frac{W_2 - W_1}{t_2 - t_1} \text{ (g day}^{-1}\text{ plant}^{-1})
\]

Where, \(W_2\) and \(W_1\) are the total dry weight of plant at the time of \(t_2\) and \(t_1\), (time interval) respectively.

3.21.3 Relative growth rate (RGR)

The mean relative growth rate was calculated for the period 30-60 DAS, 60-90 DAS and 90 DAS to at harvest with the help of the following formula.

\[
\text{Relative growth rate} = \frac{\ln W_2 - \ln W_1}{(g g}^{-1}\text{day}^{-1}\text{ plant}^{-1}) t_2 - t_1
\]

Where, \(\ln W_1\) and \(\ln W_2\) are the natural logarithm of total dry weight of plant at the time interval \(t_2\) and \(t_1\), respectively.

3.21.4 Chlorophyll content

The total chlorophyll content in leaf was determined at 55, 65 and 90 DAS from each plot with the help of Spade Chlorophyll meter.
3.21.5 Light interception (LI) and Light transmission ratio (LTR)

Light interception by rajmash crop canopy at 60 and 80 DAS was worked out by observing the light intensity by Lux meter. Light interception was computed by the following formula.

$$LI(\%) = \frac{\text{Light intensity at top} - \text{Average light intensity (mid+ground)}}{\text{Light intensity at the top of the plant}} \times 100$$

LTR is penetration of light in percent from canopy top to ground surface through foliage. It may be calculated by following equation:

$$LTR(\%) = \frac{L_1}{L_n} \times 100$$

Where, \(L_1\) is light intensity at ground, \(L_n\) is light intensity over the canopy.

3.21.6 Pod setting index

For this purpose three plants were selected randomly from each plot at flowering. Total of flowers appearing at different periods from the start of flowering were tagged. At the time of harvesting, the total number of pods developed from them were counted and pod setting index was calculated with the help of following formula:

$$\text{Pod setting index (\%)} = \frac{\text{Total number of developed pods}}{\text{Total number of flowers on individual plant}} \times 100$$
3.21.7 Seed setting index

Seed setting index was worked out by the following formula:

\[
\text{Seed setting index (\%) = \frac{\text{No. of pods plant}^{-1} \times \text{Av. No. of seeds pod}^{-1}}{\text{No. of seeds plant}^{-1}}} \times 100
\]

3.21.8 Pod growth rate

To work out the mean pod growth rate (PGR) dry matter accumulation in five pods was recorded at 10, 20, 30, 40 days after flowering (DAF) and at harvest. Then PGR was calculated with the help of the following formula:

\[
\text{Pod growth rate} = \frac{W_2 - W_1}{(g \text{ day}^{-1} \text{ pods plant}^{-1})} \frac{1}{t_2 - t_1}
\]

Where, \( W_2 \) and \( W_1 \) are the total dry weight of pods at the time \( t_2 \) and \( t_1 \), respectively.

3.21.9 Relative pod growth rate

The mean relative pod growth rate was worked out with the help of the following formula:

\[
\text{RPGR (g g}^{-1} \text{ day}^{-1} \text{ pods plant}^{-1}) = \frac{\text{Ln}W_2 - \text{Ln}W_1}{t_2 - t_1}
\]
Where, $\ln W_1$ and $\ln W_2$ are the natural logarithms of total dry weight of pods at the time interval of $t_1$ and $t_2$.

### 3.21.10 Harvest index

Harvest index was computed as the ratio of the economic yield to the total biological yield and expressed in percentage. It was calculated by the following formula:

\[
\text{Harvest index (\%) } = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100
\]

### 3.21.11 Productivity rating index (PRI)

The productivity of rajmash was determined in Verisols by using the following formula:

\[
\text{PRI (\%)} = \frac{\text{Average seed yield (kg ha}^{-1}) \text{ obtained in plots}}{\text{Standard yield of rajmash (kg ha}^{-1})} \times 100
\]

Standard yield of variety HUR 137 in Raipur condition was used as 12 q ha$^{-1}$ (Pandey et al., 2004).

### 3.21.12 Production efficiency (PE)

Production efficiency was calculated with the help of the following formula:
PE (kg ha\(^{-1}\) day\(^{-1}\)) = \frac{\text{Seed yield (kg ha}\(^{-1}\))}{\text{Duration of the crop (days)}}

3.21.13 Growing degree days (GDD)

Growing degree days at flower initiation, at 50% flowering and at maturity were calculated by simple arithmetic accumulation of daily mean temperatures above a base temperature i.e. 5°C considered as base temperature for winter crops (Nuttenson, 1955). Thus, GDD is represented as:

\[ \text{GDD (°days)} = \sum_{i=1}^{n} \left( \frac{T_{\text{max}} + T_{\text{min}}}{2} \right) - \text{base temperature} \]

Where, \( T \) is = Temperature °C.

3.21.14 Heat use efficiency (HUE)

Heat use efficiency is defined in terms of dry matter production as ratio of amount of above ground biomass produced plant\(^{-1}\) at maturity and accumulated heat units during crop season. It was calculated by using the following formula:

\[ \text{HUE (kg ha}\(^{-1}\) day\(^{-1}\)) = \frac{\text{Dry matter accumulation (g plant}\(^{-1}\))}{\text{Accumulated GDD (°days)}} \]
3.22 Chemical analysis

3.22.1 N, P and K contents in seed and stover

Rajmash seeds and stover samples collected from individual plots at harvest were separately analysed for estimation of nitrogen (Micro Kjeldahl method), phosphorus (Vando molybdo phosphoric yellow colour method) and potassium (Flame photometry) contents in seed and stover (Jackson, 1967).

3.22.2 Protein content (%) and protein yield (kg ha⁻¹)

Protein content of seed was computed by multiplying nitrogen content with a factor 6.25 for rajmash. The protein yield ha⁻¹ was calculated from the mean seed yield of the corresponding treatments.

3.22.3 N, P and K uptake (kg ha⁻¹)

N, P and K uptake by the rajmash crop was computed from their respective elemental concentrations.

Nutrient uptake (kg ha⁻¹) = Concentration (%) of nutrient x yield (kg ha⁻¹)

3.23 Energy studies in rajmash

Energy input was calculated from sowing to harvest pertaining to each treatment of experiment on rajmash. It was estimated in Mega Joule (MJ) ha⁻¹ with reference to the standard values prescribed by Mittal et al.
(1985). Energy values which were taken for energy estimation are given in Appendix III, IV and V. The standard energy output. Then, the energy output-input ratio was computed. Energy use efficiency and energy output-input ratio were calculated by using the following formula:

\[
\text{Energy use efficiency} = \frac{\text{Total produce (q)}}{\text{Energy input (MJ} \times 10^3)}
\]

\[
\text{Energy output-input ratio} = \frac{\text{Energy output (EO)}}{\text{Energy input (EI)}}
\]

\[
\text{Energy productivity} = \frac{\text{Mean grain yield, g}}{\text{Total energy input, MJ}}
\]

\[
\text{Energy intensiveness} = \frac{\text{Total energy output (MJ)}}{(\text{MJ Re}^{-1})} / \text{Total cost incurred (Rs)}
\]

3.24 Economic analysis (Rs ha\(^{-1}\))

The cost of cultivation of rajmash crop was calculated on the basis of prevailing prices for different inputs. The production of rajmash was converted into gross return (Rs ha\(^{-1}\)) on the basis of prevailing support prices for grain fixed by Government and local market prices for stover. Net return (Rs ha\(^{-1}\)) was calculated by deducting the cost of cultivation from the gross return. Benefit cost ratio (B:C) was computed by dividing net return with cost of cultivation. The values for calculation of cost of cultivation are presented in Appendix VI and VII.
3.25 Economic efficiency (EE)

Economic efficiency was calculated from the following formula.

\[
\text{Economic efficiency} = \frac{\text{Yield} \times \text{Rate}}{\text{Input} \times \text{Rate}}
\]

3.26 Statistical analysis

Data collected through various observations on rajmash were subjected to the "Analysis of variance" appropriate to the design (RBD factorial) as given by Gomez and Gomez (1984). Test of significance of the treatment differences was done on the basis of 'F' test. The significant differences between treatments were compared with the critical difference at 5 per cent level of probability.