The materials and methods followed during the course of the investigation are described below.

3.1 Experimental site:

The field experiment was conducted at the Instructional Farm of the Cooch Behar Krishi Vigyan Kendra, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India-736 165 for the consecutive two years during rabi of 2007-08 and 2008-09. The farm is situated at 26°19'86" N latitude and 89°23'53" E longitude and at an altitude of 43 meter above mean sea level.

3.2 Experimental soil:

The investigation was carried out in a medium land having good drainage facilities. The soil of the experimental plot was sandy loam in texture as it represents the real soil characteristics of the terai region of West Bengal. Composite soil sample from all the parts of the experimental plots were collected and analyzed before lay out of the experiment. The physico-chemical properties of experimental soil have been given in the table 3.1.

Table 3.1 : Physico-chemical properties of soil.

<table>
<thead>
<tr>
<th>A. Mechanical and physical composition of soil</th>
<th>Soil profile depth (in cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-15</td>
</tr>
<tr>
<td>Sand (%)</td>
<td>59.76</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>22.03</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>18.21</td>
</tr>
<tr>
<td>Bulk density (g/cc)</td>
<td>1.46</td>
</tr>
</tbody>
</table>
B. Chemical properties of experimental soil:

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.14</td>
</tr>
<tr>
<td>Organic Carbon (%)</td>
<td>0.77</td>
</tr>
<tr>
<td>EC (me/100g)</td>
<td>0.20</td>
</tr>
<tr>
<td>Available Nitrogen (N Kg ha⁻¹)</td>
<td>216.38</td>
</tr>
<tr>
<td>Available Phosphorus (P₂O₅ Kg ha⁻¹)</td>
<td>46.52</td>
</tr>
<tr>
<td>Available Potassium (K₂O Kg ha⁻¹)</td>
<td>147.45</td>
</tr>
<tr>
<td>Available Sulphur (SO₄ Kg ha⁻¹)</td>
<td>35.20</td>
</tr>
</tbody>
</table>

3.3 Cropping history of the experimental plot:

Cropping history of the experimental plot during the period from 2003-04 to 2007-08 are furnished in table 3.2.

Table 3.2: Cropping history of the experimental plot

<table>
<thead>
<tr>
<th>Year</th>
<th>Summer</th>
<th>Kharif</th>
<th>Rabi</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>Fallow</td>
<td>Fallow</td>
<td>Fallow</td>
</tr>
<tr>
<td>2004</td>
<td>Fallow</td>
<td>Paddy (Short duration)</td>
<td>Fallow</td>
</tr>
<tr>
<td>2005</td>
<td>Fallow</td>
<td>Paddy (Short duration)</td>
<td>Wheat</td>
</tr>
<tr>
<td>2006</td>
<td>Fallow</td>
<td>Paddy (Short duration)</td>
<td>Wheat</td>
</tr>
<tr>
<td>2007</td>
<td>Fallow</td>
<td>Paddy (Short duration)</td>
<td>Yellow sarson</td>
</tr>
</tbody>
</table>

3.4 Agro-Climatic condition of the experimental site:

The climate of the terai zone is sub-tropical in nature and distinctively characterized by high rainfall, high humidity and prolonged winter. A long rainy season and an extended winter or rabi are the two distinctive seasons of this region. The rainy season is characterized by hot
and humid weather, heavy precipitation by south-west monsoon with fewer bright sunshine hours and cloudy overcast days.

3.4.1 Rainfall

Occasional pre monsoon shower is one of the characteristic features of this region under the study. Generally monsoon starts in the middle of June and continues up to the second week of October. During winter months, the region usually receives a scanty or sometimes no rainfall. The rainfall data presented in the fig. 2 and table 3.3 was indicative of comparatively dry winter months where the crop received a slight rainfall at the siliqua development stage, during the second year of experimentation only.

3.4.2 Temperature

The average maximum and minimum temperatures were measured by maximum and minimum thermometer during the crop period. It has been observed that the maximum and minimum temperatures varied from 23.5 to 31.1°C and 11.9 to 20.8°C in 2007-08, 24.8 to 34.5°C and 7.8 to 19.5°C in 2008-09 respectively. The month-wise distribution of maximum and minimum temperature presented in fig.3 and table 3.3.

3.4.3 Relative humidity

High relative humidity is the characteristic feature of this region. The maximum relative humidity varied from 89 to 94% and from 95 to 100% in 2007-08 and 2008-09 respectively during the period of experimentation i.e. October to February. The minimum relative humidity varied from 53 to 71% and from 42 to 66% in 2007-08 and 2008-09 respectively during the crop period. The month-wise distribution of relative humidity presented in the fig.4 and table 3.3.
3.4.4 Bright Sunshine hours

The bright sunshine hours recorded through sunshine recorder during cropping period (October to February) were averaged on monthly basis and presented in fig.5 and table 3.3. The sunshine hours varied from 4.31 (January, 2008) to 8.91 hrs day\(^{-1}\) (November, 2007) in 2007-08 and 4.44 (January, 2009) to 8.84 hrs day\(^{-1}\) (November, 2008) in 2008-09.

3.5 Experimental details:

The experiment was carried out during rabi, 2007-08 and 2008-09 with different treatment combination tested on yellow sarson (*Brassica rapa* var. glauca). The treatments comprised of the combination of different fertility levels based on integrated nutrient management practices and different seed soaking levels with water and agro-chemicals before sowing. In this experiment, the use of locally available organic manures like Farm Yard Manure(FYM), vermicompost, free living non symbiotic nitrogen fixing bacteria (*Azotobacter*) and Phosphate Solubilizing Bacteria (P.S.B) have been included in the treatments after 25% curtailment of chemical fertilizer as of recommended dose. In treatment combination under study, the organic manure were applied along with chemical fertilizers and bio-fertilizers, based on blanket application in lieu of nutrient content as the nutrient content in organic manure varies widely with location, raw materials and production process. Use of secondary nutrient like S, has also been included in the treatment combination considering the higher requirement of S by yellow sarson. Side by side these fertility treatments were subjected to various soaking chemicals (Na\(_2\)HPO\(_4\) and KH\(_2\)PO\(_4\)) including water and the performances were assessed accordingly.
3.5.1 Experimental design:

The experiment was laid out in factorial randomized block design with twenty four treatment combinations in plot size of 4m x 3m and replicated thrice. Various fertility levels and pre-sowing seed soaking were considered as Factor-I and Factor-II respectively. Adequate numbers of irrigation channels were constructed to provide irrigation to each plot.

3.5.2 Treatment details:

Factor I (Fertility level):

\[ F_1 = \text{Recommended Dose (60:30:30 Kg N-P}_2\text{O}_5 -\text{K}_2\text{O ha}^{-1}) \]
\[ F_2 = 100\% \text{ Recommended Dose} + \text{ Sulphur (20 kg ha}^{-1}) \]
\[ F_3 = 75\% \text{ Recommended Dose} + 5t \text{ ha}^{-1} \text{ FYM} \]
\[ F_4 = 75\% \text{ Recommended Dose} + 5t \text{ ha}^{-1} \text{ vermicompost} \]
\[ F_5 = 75\% \text{ Recommended Dose} + 5t \text{ ha}^{-1} \text{ FYM} + \text{ Bio-fertilizer (Azotobacter)} \]
\[ F_6 = 75\% \text{ Recommended Dose} + 5t \text{ ha}^{-1} \text{ FYM} + \text{ Bio-fertilizer (P.S.B)} \]
\[ F_7 = 75\% \text{ Recommended Dose} +5t \text{ ha}^{-1} \text{ FYM}+ \text{ Azotobacter} + \text{ P.S.B} \]
\[ F_8 = 75\% \text{ Recommended Dose} + 5t \text{ ha}^{-1} \text{ FYM} + \text{ Sulphur (20 kg ha}^{-1}) \]

Factor II (Pre-sowing seed Soaking):

\[ P_0 = \text{Control (water soaking)} \]
\[ P_1 = \text{pre-sowing seed soaking in 0.01\% Na}_2\text{HPO}_4/100\text{ppm} \]
\[ P_2 = \text{pre-sowing seed soaking in 0.01\% KH}_2\text{PO}_4/100\text{ppm} \]
### Treatment combinations:

| $T_1$  | $T_2$  | $T_3$  | $T_4$  | $T_5$  | $T_6$  | $T_7$  | $T_8$  | $T_9$  | $T_{10}$ | $T_{11}$ | $T_{12}$ | $T_{13}$ | $T_{14}$ | $T_{15}$ | $T_{16}$ | $T_{17}$ | $T_{18}$ | $T_{19}$ | $T_{20}$ | $T_{21}$ | $T_{22}$ | $T_{23}$ | $T_{24}$ |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| $F_1P_0$ | $F_1P_1$ | $F_1P_2$ | $F_2P_0$ | $F_2P_1$ | $F_2P_2$ | $F_3P_0$ | $F_3P_1$ | $F_3P_2$ | $F_4P_0$ | $F_4P_1$ | $F_4P_2$ | $F_5P_0$ | $F_5P_1$ | $F_5P_2$ | $F_6P_0$ | $F_6P_1$ | $F_6P_2$ | $F_7P_0$ | $F_7P_1$ | $F_7P_2$ | $F_8P_0$ | $F_8P_1$ | $F_8P_2$ |

### 3.5.3 Layout of the experiment:

The plan of layout has been given in the Fig. 6.

### 3.5.4 Sources of nutrients used in the study:

Di-Ammonium Phosphate (18% Nitrogen and 46% Phosphate), Urea (46% Nitrogen), Muriate of Potash (60% Potash), elemental sulphur (91%), well decomposed farm yard manure (FYM) and vermicompost.

### 3.5.5 Agro-chemicals and bio-fertilizers used in the study:

#### 3.5.5.1 Di-sodium hydrogen phosphate ($\text{Na}_2\text{HPO}_4$):

Disodium hydrogen phosphate ($\text{Na}_2\text{HPO}_4$) is a sodium salt of phosphoric acid. It is a white powder that is highly hygroscopic in nature with high water solubility. It is therefore used commercially as an anti-caking
additive in powdered products. It is also known as disodium hydrogen orthophosphate, sodium hydrogen phosphate or sodium phosphate dibasic. It is commercially available in both the hydrated and anhydrous forms.

\[
\text{HO}^-\text{P}^-\text{O}^=\text{Na}^+ \quad \text{O}^-\text{Na}^+
\]

3.5.5.2 Potassium di-hydrogen phosphate (KH}_2\text{PO}_4\):

The buffering agent, monopotassium phosphate (also potassium di-hydrogen phosphate, KDP, or monobasic potassium phosphate, MKP), KH}_2\text{PO}_4\, is a soluble salt which is used as a fertilizer, a food additive and a fungicide. It is a source of phosphorus and potassium. When used in fertilizer mixtures with urea and ammonium phosphates, it minimizes escape of ammonia by keeping the pH at a relatively low level. It is one of the components of Gatorade (used as both an emulsifier and pH buffer) and is used as an additive in cigarettes. At 400 °C it decomposes, by loss of water, to potassium metaphosphate.

\[
\text{K}^+\text{O}^-\text{P}^-\text{OH} \quad \text{O}^-\text{P}^-\text{OH}
\]

Ramalal et al. (1993) reported that soaking of maize seeds in KH}_2\text{PO}_4\, solution significantly increased the germination, speed of germination, mean daily germination, shoot length, root length, seedling vigour index and seedling dry weight of untreated control. Nguyen Hun Hung (2006) reported that sunflower seeds could be invigourated with 2% KH}_2\text{PO}_4\, for six hours for getting the better plant establishment, growth characters, yield components and resultant seed quality.
3.5.5.3 *Azobacter chroococcum*:

*Azobacter*, a free-living, heterotrophic nitrogen fixing bacteria not only provides the nitrogen but produce a variety of growth promoting substances. Some of these growth promoting substances are indole acetic acid, gibberellins, B vitamins and anti-fungal substances (Rao, 1986). Another important characteristic of *Azobacter* association with crop improvement is excretion of ammonia in the rhizosphere in the presence of root exudates which helps in modification of nutrient uptake by the plant (Narula and Gupta, 1986). The genus *Azobacter* is highly versatile in utilizing carbon sources; therefore, application of organic carbon containing sources to the soil improves asymbiotic nitrogen fixation capacity of diazotroph (Rao, 1978). Solubilization of different inorganic phosphates by *Azobacter chroococcum* was also reported (Tilak and Singh, 1994).

The mechanisms by which the plants inoculated with *Azobacter* derive positive benefits in terms of increased grain yield, nitrogen uptake and plant biomass yield are attributed to small increase in nitrogen input from biological nitrogen fixation, branching of roots, development of roots, production of plant growth hormones, uptake of NO$_3$, NH$_4$, H$_2$PO$_4$, K, Rb and Fe, improved water status of plants, increased nitrate reductase activity and antifungal compounds (Wani et al., 1988).

3.5.5.4 Phosphate Solubilizing Bacteria (PSB); *Bacillus polymyxa*:

Phosphorus is the second important nutrient after nitrogen for plants and micro-organism. The efficiency of utilization of phosphatic fertilizers is very low, only 20-25%, due to fixation in the soil. Native phosphorus is also unavailable to crops because of its low solubility. Some heterotrophic bacteria like PSB are known to have the ability to solubilize inorganic phosphorus from insoluble sources. *Bacillus polymyxa* is one of
them. This micro-organism can grow on insoluble phosphatic sources and convert them into soluble form. A variety of mechanisms are ascribed in the solubilization and mineralization of insoluble and organic phosphorus sources such as production of aliphatics, aromatic acids, phytases, phospholipases etc. Beneficial effect of phosphorus bio-fertilizers in increasing grain yield and phosphorus uptake was reported by many workers (Sharma and Singh, 1970; Kundu and Gaur, 1984).

3.5.6 Test crop:

Rapeseed (Brassica rapa var. glauca) belongs to the family cruciferae (Brassicaceae). Also known as mustard family. It is popularly known as sarson or yellow sarson. The name crucifer comes from the shape of flowers, with four diagonally opposite petals in the form of a cross. Brassica rapa has green foliage, leaves glabrous or slightly hispid when young, and the upper leaves partially clasping the stem. The stems are well branched, although the degree of branching depends on biotype / variety and environmental conditions.

The exact time and place of domestication are unknown, but Indian Sanskrit writings of 2000 to 1500 BC refer directly to oilseed rape and mustard, as do Greek, Roman and Chinese writings of 500 to 200 BC.

Brassica rapa is a cool-season crop. It is widely adapted, and performs well in a range of soil conditions, provided that moisture and fertility levels are adequate. Air and soil temperatures influence plant growth and productivity. The optimum temperature for maximal growth and development is just over 20°C, and it is best grown between 12°C and well below 30°C. After emergence, seedlings prefer relatively cool temperatures up to flowering; high temperatures at flowering will hasten the plant’s development, reducing the time from flowering to maturity.
3.5.7 Variety used in the study:

The variety chosen for the experiment was NC-1, popularly known as Jhumka, released from Pulses and Oilseeds Research Station, Government of West Bengal, Berhampore, West Bengal, India-742 101. It takes about 95-100 days to mature, seed colour is yellow, 1000 seed weight varies between 3.00 to 4.00. Seed yield potential is 16-18 q ha$^{-1}$.

3.6 Agronomic practices:

3.6.1 Land preparation:

The land was prepared with two ploughings by tractor mounted cultivator followed by once running of rotary plough. Weeds and stubbles of the previous crop were removed. Then the leveling was done with the help of ladder and rake and the layout of the experiment along with irrigation and drainage channels have been prepared with the help of measuring tape and spade.

3.6.2 Application of chemical fertilizers:

Fertilizers were applied in the plots as per treatments just after laying out of the experiment. Nitrogen and potash were applied as basal and top dressing. Nitrogen was applied in two splits (½ as basal and rest ½ as top dressing), while ¾ potassium was applied during final land preparation with ¼ as top dressing. Entire phosphatic fertilizers were applied as basal. The sources of P was DAP, while the same fertilizer and urea along with MOP were served as the sources of N and K respectively.
3.6.3 Application of Sulphur and Boron:

Sulphur was applied in the form of elemental sulphur just after the application of chemical fertilizers as per the treatment schedule and mixed thoroughly with soil. Boron was applied in each plot equally in the form of Borax @10 kg ha$^{-1}$.

3.6.4 Application of FYM:

Well decomposed FYM was applied as per treatments and mixed thoroughly with the soil sixth and fifth days of application of chemical fertilizers and sulphur in the year 2007-08 and 2008-09 respectively.

3.6.5 Application of vermicompost:

Vermicompost was applied as per treatments and mixed thoroughly with the soil after sixth and fifth days of application of chemical fertilizer and sulphur in the year 2007-08 and 2008-09 respectively.

3.6.6 Application of bio-fertilizers:

*Azotobacter* and PSB were applied as per treatments and mixed thoroughly with the soil after sixth and fifth days of application of chemical fertilizer and sulphur in the year 2007-08 and 2008-09 respectively.

3.6.7 Solution preparation for pre-sowing seed soaking:

The solution was prepared by dissolving 0.1 g of Na$_2$HPO$_4$ and KH$_2$PO$_4$ in distilled water and volume was made upto 1000 ml. Keeping the seed rate of *yellow sarson* as 6.0 kg ha$^{-1}$, the seed rate for the each experimental plot sized 12 sq.m was calculated and that quantity of seeds were placed in different containers used for different plots and treatments accordingly. After that the seeds were soaked with water, Na$_2$HPO$_4$ and
KH₂PO₄ as per the treatment schedule and allowed to absorb moisture up to 35 per cent of their weight and kept in imbibed condition for 6 hrs and the seeds were then spread out in a thin layer for drying under shade before sowing.

3.6.8 Sowing:

The sowing was done on November 03 and October 31 in the first and second year of experimentation respectively. Seeds were sown in lines in both the years with the help of duck foot tyne by opening a shallow furrow at uniform depth (2.5 to 3.0 cm), keeping the rows 30 cm apart. The seeds were covered immediately after sowing. The North-South sowing direction was followed on both the years.

3.6.9 Thinning:

For maintaining appropriate plant to plant distance, thinning was done. In both the years, thinning was performed once. In the first year (2007-08) thinning has been done at 14 DAS and in the second year (2008-09) it was performed at 16 DAS.

3.6.10 Weeding and hoeing:

One hand weeding along with hoeing in all the plots was done on both the years, at 34 DAS in the first year (2007-08) and at 35 DAS in the second year (2008-09).

3.6.11 Irrigation:

One light irrigation (2-3cm) was given to the yellow sarson crop at 37 and 39 DAS in the year 2007-08 and 2008-09 respectively.
3.6.12 Plant protection measures:

Infestation of Aphid (*Lipaphis erysimi*) was noticed in both the years at later stage of growth. Dimethoate @ 2 ml liter⁻¹ of water, was applied once in both the years for controlling aphids.

3.6.13 Harvesting:

The crop was harvested plot wise on February 16, 2008 for the first year of experiment and on February 15, 2009 for the second year of experiment. After making plot wise bundles, the produce was brought to the threshing floor and subsequently threshed after sun drying. Then the seeds were properly processed and sun dried before recording the productivity from each plot.

Table 3.4: Calendar of operations:

<table>
<thead>
<tr>
<th>Operations</th>
<th>Year 2007-08</th>
<th>Year 2008-09</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Pre-sowing seed soaking</td>
<td>03.11.2007</td>
<td>30.10.2008</td>
</tr>
<tr>
<td>9. Sowing of seeds</td>
<td>03.11.2007</td>
<td>31.10.2008</td>
</tr>
<tr>
<td>10. Thinning</td>
<td>17.11.2007</td>
<td>15.11.2008</td>
</tr>
</tbody>
</table>
3.7 Methods of recording observations:

3.7.1 Sampling procedure:

Each plot was divided into almost equal halves. One half was kept undisturbed for determining yield and remaining half was used for recording biometrical observations including destructive samples.

3.7.2 Emergence (%):

Keeping the seed rate @ 6 kg ha\(^{-1}\), the seed rate was calculated for each plot. Then the number of seeds per square meter were calculated by taking 1000-seed weight under consideration. Thereafter counting the emerged plant out of total number of seeds sowed in one m\(^2\) area, the emergence percentage was calculated.

3.7.3 Growth attributes:

3.7.3.1 Plant height:

Ten plants were selected randomly from each plot and plant heights were measured with a meter scale from ground level to tip of the main stem at 30 DAS, 45 DAS, 60 DAS, 75 DAS, 90 DAS. Finally the mean heights were expressed in centimetre (cm).

3.7.3.2 Number of primary branches per plant:

At harvest, number of primary branches plant\(^{-1}\) was recorded simply by counting total number of primary branches from randomly selected ten plants of each plot and numbers were finally averaged to obtain mean number of primary branches plant\(^{-1}\).
3.7.3.3 Leaf area index (LAI):

The representative green leaf laminas were taken from each treatment at 30, 45, 60, 75 and 90 days after sowing and leaf area was determined by leaf area meter. The leaves were then dried in a hot air oven at $70^\circ$C for 72 hours or till constant weight were obtained. The ratio of leaf area/weight of those leaves was used to measure the leaf area indices (Kemp, 1960). The leaf area index was obtained by using area-weight relationship where leaf areas of dried leaf samples were worked out.

3.7.3.4 Leaf area duration (LAD):

Leaf area duration is a measure of the ability of the plant to produce leaf area on unit land area throughout its life. Leaf area duration is the integrated leaf area index over time. It can be calculated with the following formula.

$$LAD = \frac{L_2 - L_1}{\log_e L_2 - \log_e L_1} \times t \text{ (days)}$$

Where, $L_2$ and $L_1$ are the final and initial leaf area indices at respective time.

3.7.3.5 Dry matter accumulation:

To study the dry matter accumulation at different stages destructive plant sample from 0.5 m row from each plot was taken at 30 DAS, 45 DAS, 60 DAS, 75 DAS, 90 DAS and at the time of harvest. The sampled plants were separated into leaves, stem, root and reproductive parts. The samples were oven dried at $65^\circ$C to $70^\circ$C till constant weights were obtained. Those weights were then converted in to weight m$^2$ taking in to consideration the row spacing.
3.7.3.6 Crop Growth Rate (CGR):

CGR indicates at what rate the crop is growing, i.e., whether the crop is growing at a faster or slower rate than normal. Crop growth rate (CGR) between 30 and 45 DAS; 45 and 60 DAS; 60 and 75 DAS; 75 and 90 DAS were determined with the following formula.

\[
\text{CGR} = \frac{w_2 - w_1}{t_2 - t_1} \text{ (g m}^{-2} \text{ day}^{-1})
\]

Where, \(w_1\) and \(w_2\) were the initial and final dry weights of all the plant parts per unit area at times \(t_1\) and \(t_2\) respectively.

3.7.3.7 Net assimilation rate (NAR):

It indirectly indicates the rate of photosynthesis. Net assimilation rate is the dry weight increment, i.e., net gain of assimilate mostly photosynthetic, per unit leaf area per unit of time. It was calculated by the formula as described by Watson, 1952 and expressed as g m\(^{-2}\) day\(^{-1}\).

\[
\text{NAR} = \left(\frac{w_2 - w_1}{t_2 - t_1}\right) \times \left(\frac{\log_e L_2 - \log_e L_1}{L_2 - L_1}\right) \text{ (g m}^{-2} \text{ day}^{-1})
\]

Where, \(w_1\) and \(w_2\) were the initial and final dry weights of all the plant parts per unit area at times \(t_1\) and \(t_2\) respectively and \(L_2\) and \(L_1\) are the final and initial leaf area indices at respective time.

3.7.3.8 Leaf stomatal conductance:

Leaf stomatal conductance was calculated by the following equation after recording related data by hand held portable photosynthesis
system (model no.Cl-340) on the third available leaf from the top and expressed in micro mol m\(^{-2}\) s\(^{-1}\).

\[
C_{\text{leaf}} = \frac{W}{e_{\text{leaf}} - e_0} \times \frac{P - e_0}{e_0 - e_i} \times 1000 - R_b W
\]

Where, \(e_{\text{leaf}}\) is the saturated water vapour at leaf temperature (bar), \(W\) is the mass flow rate per leaf area, \(P\) is the atmospheric pressure (bar), \(e_0\) (\(e_i\)) : outlet (inlet) water vapour (bar) and \(R_b\) is the leaf boundary layer resistance \(\text{m}^2\text{s mol}^{-1}\) 0.3m\(^2\)s mol\(^{-1}\) is used.

### 3.7.3.9 Leaf internal carbon dioxide concentration:

Leaf internal CO\(_2\) concentration was calculated by the following equation after recording related data by hand held portable photosynthesis system (model no.Cl-340) on the third available leaf from the top and expressed in ppm.

\[
\text{Internal CO}_2 = C_i - 1.6 \times P_n (R_b + R_{\text{leaf}})
\]

Where, \(C_0\) (\(C_i\)) : outlet (inlet) CO\(_2\) concentration (ppm or micro mol mol\(^{-1}\)), \(P_n\) is the Net photosynthesis rate, \(R_b\) is the leaf boundary layer resistance \(\text{m}^2\text{s mol}^{-1}\) 0.3m\(^2\)s/mol is used and \(R_{\text{leaf}}\) is the Leaf stomatal resistance \(\text{m}^2\text{s mol}^{-1}\)

### 3.7.3.10 Transpiration rate:

Transpiration rate (\(E\)) was calculated by the following equation after recording related data by hand held portable photosynthesis system (model no.Cl-340) on the third available leaf from the top and expressed in micro mol m\(^{-2}\) s\(^{-1}\).

\[
E = \frac{e_0 - e_i}{P - e_0} \times W \times 10^3
\]

\[
e_0 = hr_0 \times e_i 100^{-1} \quad e_i = hr_i \times e_i 100^{-1}
\]
Where, e0 (ei) : Outlet (inlet) water vapour (bar), es is the saturated water vapour at air temperature (bar), W is the mass flow rate per leaf area, Ta is the air temperature (°C), P is the Atmospheric pressure (bar), hr0 (hr1) is the outlet (inlet) relative humidity (%).

3.7.3.11 Net photosynthesis rate:

Net photosynthesis rate (Pn) was calculated by the following equation after recording related data by hand held portable photosynthesis system (model no.CI-340) on the third available leaf from the top and expressed in micro mol m⁻² s⁻¹.

\[ P_n = -W \times (C_0 - C_i) = -2005.39 \times \frac{V \times P}{T_a \times A} \times (C_0 - C_i) \]

Where, C0 (Ci) : outlet (inlet) CO₂ concentration (ppm or micro mol mol⁻¹), W is the mass flow rate per leaf area, V is the leaf chamber volume, T₀ is the air temperature (°C), P is the atmospheric pressure (bar), A is the leaf area (cm²).

3.7.3.12 Root dry weight plant⁻¹:

To study the root dry weight at harvesting stage five plants were selected randomly from each plot. The roots were separated from sampled plants. The root samples were oven dried at 65°C to 70°C till constant weights were recorded. Finally mean weight was expressed in gram plant⁻¹.

3.7.3.13 Average root diameter:

To study the average root diameter at the harvesting stage five plants were selected randomly each plot. The roots were separated from sampled plants. Then with the help of Delta T Scan (splash cover) the average
root diameter were recorded. The mean of five plants was recorded as the average root diameter and expressed in millimeter.

3.7.3.14 Total root length:

Total root length was recorded at the harvesting stage from the five randomly selected plants of each plot. After separating the roots from each sampled plant total length of root from each plant were recorded by Delta T Scan (splash cover). The mean of five plants was recorded as the total root length and expressed in millimeter.

3.7.4 Yield attributes:

3.7.4.1 Number of siliqua plant$^{-1}$:

From the same plants that were taken for counting the number of branches, all the siliqua were stripped off and then counted and the mean was recorded as the number of siliqua produced per plant.

3.7.4.2 Length of siliqua:

For this purpose twenty five siliqua were randomly selected and their length was measured and expressed in centimetre.

3.7.4.3 Number of seeds siliqua$^{-1}$:

Twenty five siliqua were randomly selected from the previously stripped ones, threshed and the seeds were counted to determine the number of seed siliqua$^{-1}$ from each plot.
3.7.4.4 1000-seed weight (Test weight):

The weight of 1000 seeds was recorded after threshing, properly drying and counting of seeds from the seed samples drawn from the produce obtained from each plot expressed in gram.

3.7.5 Crop productivity and efficiency:

3.7.5.1 Seed yield:

At maturity all plants from net plot of earmarked halves that were kept undisturbed, were harvested. The bundles from each plot were sun dried and subsequently threshed. Seeds were separated, properly dried, cleaned and weighed and yield from the area was then converted in to kilogram hectare\(^{-1}\) basis.

3.7.5.2 Stick yield:

After threshing, the seeds were separated from harvested material of each plot. The weight of the rest portion of the harvested plant parts of each net plot was recorded and converted in to kilogram hectare\(^{-1}\) basis.

3.7.5.3 Harvest index:

The harvest index was obtained by using the following formula:

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

The economic yield indicates the seed yield, whereas biological yield represents the yield of above ground plant parts recorded in this experiment.
3.7.5.4 Oil content:

The percentage of oil in yellow sarson was estimated by SOCS plus instrument, manufactured by Pelican Instruments, Chennai adopting Soxhlet Ether Extraction Method (Anonymous, 1970). 5 g of seed sample was used for each treatment for that purpose.

\[
\text{Oil content (\%)} = \frac{\text{weight of oil}}{\text{weight of seed (\approx 5g)}} \times 100
\]

3.7.5.5 Oil yield:

Oil yield was calculated by using following formula.

\[
\text{Oil yield (kg ha}^{-1}\text{)} = \text{seed yield (kg ha}^{-1}\text{)} \times \text{oil content (\%)}
\]

3.7.6 Economics Analysis:

3.7.6.1 Economics:

The prevailing cost of various inputs like seeds, FYM, vermicompost, bio-fertilizers, sulphur, chemical fertilizers, labour, ploughing, irrigation etc. during the time of experimentation were considered for working out the cost of cultivation. Gross return was calculated from the market price of the produces that were prevailing at the time of the harvest of the crop.
3.7.6.2 Net return:

Net returns ha\(^{-1}\) were calculated for each treatment by deducting the cost of cultivation ha\(^{-1}\) from the gross income ha\(^{-1}\).

3.7.6.3 Return rupee \(^{-1}\) of investment hectare \(^{-1}\):

Return per rupee of investment per hectare was calculated by the following formula:

\[
\text{Return } \text{₹}^{-1} \text{ invested ha}^{-1} = \frac{\text{Gross return (₹ ha}^{-1})}{\text{Cost of cultivation (₹ ha}^{-1})}
\]

3.7.7 Methods of chemical analysis:

Methods were adopted for soil and plant analysis are given in table 3.5.

Table 3.5: Methods of Chemical Analysis

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Methods employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil analysis</td>
<td></td>
</tr>
<tr>
<td>Soil texture</td>
<td>Hydrometer method as described by Bouycous (1951)</td>
</tr>
<tr>
<td>Soil pH</td>
<td>Determined with the help of Backmen pH meter in 1:2.5 soil:water suspension as recommended by Soil Reaction Committee and described by Jackson (1973).</td>
</tr>
<tr>
<td>Particulars</td>
<td>Methods employed</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Electrical conductivity (me/100g)</td>
<td>1:2.5 soil:water suspension measured by conductivity bridge as described by Jackson (1973)</td>
</tr>
<tr>
<td>Organic Carbon (%)</td>
<td>Volumetric method (Walkley and Black, 1934) as described by Muhr et al (1956)</td>
</tr>
<tr>
<td>Available Nitrogen (N kg ha⁻¹)</td>
<td>Easily mineralizable form using alkaline KMnO₄ method as described by Subbiah and Asija (1954)</td>
</tr>
<tr>
<td>Available Phosphorus (P₂O₅ kg ha⁻¹)</td>
<td>Bray and Kurtz extraction method no.1 as described by Jackson (1973)</td>
</tr>
<tr>
<td>Available Potassium (K₂O kg ha⁻¹)</td>
<td>1N NH₄OAc (pH 7.00) extraction method as described by Jackson (1973)</td>
</tr>
<tr>
<td>Available Sulphur (SO₄ Kg ha⁻¹)</td>
<td>0.15% CaCl₂ method as described by Williams and Steinbergs (1969)</td>
</tr>
<tr>
<td><strong>Plant analysis</strong></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>Digestion with Conc. H₂SO₄ and distillation described by Jackson (1973)</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Tri-acid digestion described by Jackson (1973)</td>
</tr>
<tr>
<td>Potassium</td>
<td>Tri-acid digestion described by Jackson (1973)</td>
</tr>
<tr>
<td>Sulphur</td>
<td>Turbidimetry method using BaCl₂ crystal and gum acacia as described by Chesnin and Yien (1951)</td>
</tr>
</tbody>
</table>
3.7.8 Methods of statistical analysis:

The data collected from the experiment at different growth stages were subjected to statistical analysis as described by Gomez and Gomez (1984). The analysis of variance method (Cochran and Cox, 1977; Panse and Sukhatme, 1978) was followed for statistical analysis of the various data. The significance of different sources of variation was tested by Error Mean Square Method of Fisher-Snedecor's F-test at probability of 0.05 for approximate degree of freedom. In the summary tables of results, the standard error of means (S.Em.+), the value of critical difference (C.D) to compare the differences between treatment means and the co-efficient of variation (c.v) have been provided. For comparison of ‘F’ tables and for comparison of ‘CD’ Fisher and Yates table was consulted.