CHAPTER III

MATERIALS AND METHODS
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The present study entitled "Nitrogen, phosphorus and water requirement of soybean (Glycine max (L) Merr.) crop in black soil under rainfed condition" was carried out at the Research Farm of Indira Gandhi Krishi Vishwa Vidyalaya, Raipur, during the rainy seasons of 1987 and 1988.

The weather conditions, soil type of the experimental field, materials used and techniques adopted during the study period are described briefly in this chapter.

3.1. Location

Raipur, is situated in the South-eastern part of Madhya Pradesh at 21°16' N latitude and 81°36' E longitude and at an elevation of 298.5 m above mean sea level. Research Farm of Indira Gandhi Krishi Vishwa Vidyalaya, the place of present investigations, is located about 8 km east of Raipur city on the National Highway No.6.

3.2. Climate

The average climatic conditions prevailing and meteorological data recorded during the period of study are presented in Table 3.1 and illustrated through figure 3.1 and 3.2.
Table 3.1: Meteorological data during 1987 and 1988

<table>
<thead>
<tr>
<th>Week</th>
<th>Rainfall (mm)</th>
<th>Temperature (°C)</th>
<th>Bright Sunshine (hours)</th>
<th>Open pan evaporation (mm)</th>
<th>Wind speed (km/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26 25-1 July</td>
<td>12.6</td>
<td>129.2</td>
<td>40.6</td>
<td>31.8</td>
<td>27.0</td>
</tr>
<tr>
<td>27 02-8</td>
<td>51.4</td>
<td>37.4</td>
<td>32.6</td>
<td>30.9</td>
<td>24.6</td>
</tr>
<tr>
<td>28 09-15</td>
<td>85.8</td>
<td>16.4</td>
<td>31.0</td>
<td>31.1</td>
<td>23.0</td>
</tr>
<tr>
<td>29 16-22</td>
<td>112.6</td>
<td>24.3</td>
<td>32.2</td>
<td>31.9</td>
<td>24.2</td>
</tr>
<tr>
<td>30 23-29</td>
<td>67.0</td>
<td>5.5</td>
<td>30.0</td>
<td>30.0</td>
<td>22.9</td>
</tr>
<tr>
<td>31 30-5 Aug.</td>
<td>9.2</td>
<td>88.5</td>
<td>32.2</td>
<td>30.1</td>
<td>24.3</td>
</tr>
<tr>
<td>32 06-12</td>
<td>13.4</td>
<td>25.5</td>
<td>32.0</td>
<td>31.0</td>
<td>24.0</td>
</tr>
<tr>
<td>33 13-19</td>
<td>42.5</td>
<td>22.7</td>
<td>32.7</td>
<td>31.9</td>
<td>24.7</td>
</tr>
<tr>
<td>34 20-26</td>
<td>11.4</td>
<td>25.7</td>
<td>30.7</td>
<td>31.3</td>
<td>23.5</td>
</tr>
<tr>
<td>35 27-2 Sept.</td>
<td>89.0</td>
<td>41.3</td>
<td>27.6</td>
<td>32.3</td>
<td>22.4</td>
</tr>
<tr>
<td>36 03-9</td>
<td>57.8</td>
<td>54.1</td>
<td>29.9</td>
<td>31.6</td>
<td>23.3</td>
</tr>
<tr>
<td>37 10-16</td>
<td>19.2</td>
<td>19.4</td>
<td>30.6</td>
<td>33.0</td>
<td>23.1</td>
</tr>
<tr>
<td>38 17-23</td>
<td>28.0</td>
<td>45.8</td>
<td>32.9</td>
<td>30.5</td>
<td>23.8</td>
</tr>
<tr>
<td>39 24-30</td>
<td>1.8</td>
<td>38.8</td>
<td>33.6</td>
<td>32.0</td>
<td>23.2</td>
</tr>
<tr>
<td>40 01-7 Oct.</td>
<td>45.6</td>
<td>0.6</td>
<td>32.1</td>
<td>31.4</td>
<td>22.6</td>
</tr>
<tr>
<td>41 08-14</td>
<td>26.6</td>
<td>0.0</td>
<td>31.4</td>
<td>30.7</td>
<td>22.0</td>
</tr>
<tr>
<td>42 15-21</td>
<td>27.6</td>
<td>0.0</td>
<td>30.7</td>
<td>32.4</td>
<td>22.1</td>
</tr>
<tr>
<td>43 22-28</td>
<td>0.0</td>
<td>0.0</td>
<td>29.4</td>
<td>32.2</td>
<td>16.9</td>
</tr>
</tbody>
</table>

Total 702.5 575.2 - - - - 86.4 89.4 77.0 64.5 - -
Mean 39.0 21.9 31.8 31.4 23.2 22.4 4.8 4.9 4.3 3.6 8.6 7.6
SD 32.6 33.3 2.6 0.8 1.9 2.7 3.0 3.0 1.9 0.5 4.1 3.4
FIG 3.1: METEOROLOGICAL DATA DURING CROP SEASON 1987

Rainfall (mm)

0 10 20 30 40 50 60 70 80 90 100 110 120

Temp. °C, Open pan evaporation (mm), Sunshine (hrs), Wind speed (km/hr)

Standard meteorological weeks

Rainfall

EVAPORATION

SUNSHINE

WIND SPEED

T.MIN

T.MAX
FIG 3.2: METEOROLOGICAL DATA DURING CROP SEASON 1988
The climate of Raipur is classified as moist subhumid according to Thornthwaite's (moisture regime based) climatic classification (Subrahmanyam, 1956). This place receives an average annual rainfall of about 1400 mm. About 80 per cent of this annual rainfall is received during monsoon months i.e. June to September.

In 1987, (a national drought year) a total of 702.5 mm rainfall was received during the crop season. The average of weekly total during 1987 was $39.0 \pm 32.6$ mm per week. In the year 1988, (the worst drought year of the century for Raipur) only a total rainfall of 575.2 mm was received during the crop season with average weekly total of $31.9 \pm 33.3$ mm per week.

In 1987, the average daily maximum temperature was $31.8 \pm 2.6^\circ$ C during the crop season, with the lowest of $27.6^\circ$ C during last week of August and highest value of $40.6^\circ$ C during last week of June. In 1988 crop season the average daily maximum temperature was $31.4 \pm 0.8^\circ$ C ranging between 30.1 to 33.0$^\circ$ C.

Similarly the mean daily minimum temperature varied between 16.9 to 27.0$^\circ$ C during the crop season of 1987 with an average value of $23.2 \pm 1.9^\circ$ C. It ranged between 15.7 to 24.4$^\circ$ C with mean value of $22.4 \pm 2.7^\circ$ C in 1988 crop season.

During the entire crop season of 1988, the crop received longer hours of bright sunshine (625.8 hrs) as compared to 1987 (604.8 hrs). Thus the average sunshine hours per day were $4.9 \pm 3.0$ during 1988. It was $4.8 \pm 3.0$ hours per day in 1987.
The weekly mean of daily open pan evaporation values were higher during 1987 as compared to 1988 crop season. They were 4.3 ± 1.9 mm and 3.6 ± 0.5 mm per day during 1987 and 1988 respectively.

On an average the wind speed was higher in 1987 as compared to 1988 crop season, with values of 8.8 ± 4.1 and 7.6 ± 3.4 km/hr respectively.

3.3. Soil

The soil of the experimental site was clayey in texture with light black color locally known as "Kanhar" belonging to the "Vertisol" group.

Prior to sowing the seeds in the experimental plot, random soil samples, up to a depth of 30 cm, were collected from different places and a composite soil sample was drawn for physico-chemical analysis. The results of mechanical and chemical analysis are given in Table 3.2.

The chemical analysis of the soil of experimental field showed that the organic carbon content in soil was low. The soil reaction (pH 7.4) was near normal. The available nitrogen, phosphorus and potash in soil were low, low and high respectively.
Table 3.2: Physico-chemical analysis of the soil of experimental plot

<table>
<thead>
<tr>
<th>Particular</th>
<th>Value</th>
<th>Classification</th>
<th>Methods adopted</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Mechanical analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand %</td>
<td>23.5</td>
<td>Clayey</td>
<td>International Pipette Methods of Piper (1966)</td>
</tr>
<tr>
<td>Silt %</td>
<td>27.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay %</td>
<td>48.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Chemical analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. pH</td>
<td>7.4</td>
<td>Normal</td>
<td>1:2.5 soil water suspension</td>
</tr>
<tr>
<td>2. Organic carbon (%)</td>
<td>0.58</td>
<td>Low</td>
<td>Walkely and Black (1934)</td>
</tr>
<tr>
<td>3. Available N kg/ha</td>
<td>172.3</td>
<td>Low</td>
<td>Subbiah and Asija (1956)</td>
</tr>
<tr>
<td>4. Available P kg/ha</td>
<td>9.5</td>
<td>Low</td>
<td>Olsen (1954)</td>
</tr>
<tr>
<td>5. Available K kg/ha</td>
<td>318.3</td>
<td>High</td>
<td>Neutral normal ammonium acetate method (Muhr et al., 1965)</td>
</tr>
</tbody>
</table>

3.4. Cropping history

Prior to the start of present experiment, the field was cropped with black gram (*Vigna mungo* L. Hepper) during "kharif" and Linseed (*Linum usitatissimum* L.) during "rabi" in the preceding two years.

3.5. Test Variety

The soybean (*Glycine max* (L) Merr.) variety "Gaurav" (JS 72-44), developed at Jawaharlal Nehru Krishi Vishwa Vidyalaya
Jabalpur in 1980, was taken as test variety in both the years of study. The variety was evolved by crossing D60-9647 and EC 7034. Plants of the variety are erect and have medium, bushy growth habit with purple stem in early stages. The leaves and pods are covered with brownish hairs. Flowers are purple and pods are predominantly two seeded. Seeds are yellow, medium, round with 12-14 g/100 seed weight. It matures in about 105-110 days. The variety is resistant to bacterial pustules and tolerant to caterpiller and green semilooper.

3.6. Experiments

To study the "Nitrogen, phosphorus and water requirement of Soybean (Glycine max (L) Merr.) crop in black soil under rainfed condition", two sets of experiments were carried out separately during "kharif" seasons in both the years. In the first experiment the effects of different levels of nitrogen and phosphorus on soybean crop were studied (section A). The water requirement of soybean was studied in a separate field adjoining to the first experimental plot with identical soil type and field conditions, where two sets of gravimetric lysimeters were installed. The details of lysimetric studies are described in section B.
A. Effect of nitrogen and phosphorus levels on Soybean (Glycine max (L.) Merr.) crop.

3.7. Experimental technique

In this study attempts were made to find out the optimum requirements of nitrogen and phosphorus of soybean crop in black soils under of Chhattisgarh region under ranifed conditions. The experimental layout and techniques adopted for these studies are described below:

3.7.1. Field Layout

The experiment was laid out in randomized block design with four replications. The treatments consisting of four levels each of nitrogen and phosphorus were randomised as per the layout plan depicted in Figure 3.3.

3.7.2. Treatments

<table>
<thead>
<tr>
<th>Levels of nitrogen</th>
<th>Levels of Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO - No nitrogen (control)</td>
<td>PO - No phosphorus (control)</td>
</tr>
<tr>
<td>N15 - 15 kg N/ha</td>
<td>P30 - 30 kg P205/ha</td>
</tr>
<tr>
<td>N30 - 30 kg N/ha</td>
<td>P60 - 60 kg P205/ha</td>
</tr>
<tr>
<td>N45 - 45 kg N/ha</td>
<td>P90 - 90 kg P205/ha</td>
</tr>
</tbody>
</table>

Treatment combinations:

T1 - NO PO  T5 - N15 PO  T9 - N30 PO  T13 - N45 PO
T2 - NO P30  T6 - N15 P30  T10 - N30 P30  T14 - N45 P30
T3 - NO P60  T7 - N15 P60  T11 - N30 P60  T15 - N45 P60
T4 - NO P90  T8 - N15 P90  T12 - N30 P90  T16 - N45 P90
FIG 3.3 : LAYOUT PLAN OF EXPERIMENTAL FIELD
3.7.3. Layout details

1. Gross plot size - 6.00x5.00 m = 30.00 sq m
2. Net plot size - 4.80x4.00 m = 19.20 sq m
3. Block border - 1.0 m
4. Plot border - 0.5 m
5. Total no. of plots - 64
6. Total experimental area - 52.0x44.0 = 2288.00 sq m

Table 3.3: Schedule of field operations and crop management

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Particulars</th>
<th>1987</th>
<th>1988</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Field preparation</td>
<td>Jun' 26&amp;27</td>
<td>Jun' 27&amp;28</td>
</tr>
<tr>
<td>2.</td>
<td>Sowing</td>
<td>Jun' 30</td>
<td>Jun' 29</td>
</tr>
<tr>
<td>3.</td>
<td>Fertilizer application</td>
<td>Jun' 30</td>
<td>Jun' 29</td>
</tr>
<tr>
<td>4.</td>
<td>Thinning and/or gap filling</td>
<td>Jul' 8</td>
<td>Jul' 6</td>
</tr>
<tr>
<td>5.</td>
<td>Weeding</td>
<td>Jul' 24</td>
<td>Jul' 25</td>
</tr>
<tr>
<td>7.</td>
<td>Harvesting</td>
<td>Oct' 19</td>
<td>Oct' 19</td>
</tr>
</tbody>
</table>

3.8. Field preparation

The experimental field was prepared by giving cross ploughing twice after the first showers of monsoon. After ploughing, the field was planked with "Pata". The residues were removed from the field before sowing to get weed and stubble free seed bed.
3.9. Sowing

Seeds were drilled in rows by hand with 30 cm row to row and 5-8 cm plant to plant spacings. Before sowing the seeds were treated with 'Bavistin' at the rate of 2g/kg of seed to protect the crop from soil born diseases.

3.10. Fertilizer application

Nitrogen and phosphorus fertilizers were drilled as per the treatments mentioned earlier at the time of sowing. A uniform basal dose of 30 kg K2O per hectare was applied at the time of field preparation. Full quantity of N and P2O5 were applied as basal dose.

3.11. Thinning and gap filling

In order to get uniform plant population, thinning and/or gap filling was done within 8-10 days after sowing in all the experimental plots.

3.12. Weed control

In the experimental plot, Barnyard grass (Echinochloa colonum), wire grass (Eulisine indica), motha (Cyperus rotundus), doobgrass (Cynodon dactylon) and Dudhi (Euphorbia hirta) were predominantly observed. All weeds were effectively uprooted by hand weeding in all the experimental plots on the dates given in Table 3.3.
3.13. **Plant protection**

Endemic and sporadic attack of leaf roller and girdle beetle were observed. The insects were controlled by plant protection measures in both the years of study as given in Table 3.3.

3.14. **Harvesting**

The crop was harvested before shattering of pods, when the leaves turned yellow and the pods fully developed and turned yellow to brown. Before harvesting, two rows from each row sides and 50 cm from other sides were removed leaving a net plot of 4.80x4.00 m.

3.15. **Threshing and winnowing**

The harvested crop was sun dried for a couple of days and after taking total weight of produce from net plot, the crop was threshed by hand beating. After threshing, the seeds were cleaned. Plotwise seed weight was recorded after uniform drying of the produce.

3.16. **Observations**

3.16.1. **Growth characteristics**

In order to examine the effects of nitrogen and phosphorus levels on crop growth characteristics, observations were recorded at seedling, vegetative, flowering, pod formation, pod filling and maturity stages. The techniques adopted for taking the observations on different growth characteristics are described below:
3.16.1.1. **Plant height**

Ten plants in each plot were randomly selected and tagged for height measurement. The height at different stages of growth was measured from the ground level to the tip of the longest leaf including petiole and leaf blade and then average height was worked out.

3.16.1.2. **Dry matter accumulation**

For this purpose five plants were randomly selected from each plot. These plants were uprooted, washed and their root portions were removed. The above ground parts were initially air dried and then was dried in hot air oven at 60°C till a constant weight was obtained. They were weighed to obtain per plant oven dry biomass.

3.16.1.3. **Number of leaves per plant**

The leaves were counted from all the plants, uprooted for dry biomass estimation and then average number of leaves per plant was calculated.

3.16.1.4. **Average Leaf area**

Leaf area was measured following method suggested by Singh and Saraf (1983). The leaves of five plants selected for dry matter estimation were also used for leaf area measurement. The leaves were divided into 3 groups according to their size i.e.
big, medium and small. Than 3 average sized leaves were picked from each group and the area of these representative leaves were measured with the help of planimeter. Finally the mean leaf area was calculated.

3.16.1.5. Leaf area index (LAI)

It is the relationship between the total leaf area with the total ground area in which the crop is grown. LAI was calculated using the following formula (Watson, 1947)

\[ \text{LAI} = \frac{\text{Total leaf area of the crop (sq cm)}}{\text{Total ground area under the crop (sq cm)}} \]

OR

\[ \text{LAI} = \frac{\text{Number of plant in m}^2 \text{ area} \times \text{Total leaf area/plant}}{\text{Total ground area (10,000 sq cm)}} \]

3.16.1.6. Crop growth rate (CGR)

It indicates overall growth rate of a crop plant and was measured after a fixed period of time irrespective of the previous growth rate. The value was calculated by using the following equation (Leopold and Kridemann, 1975)

\[ \text{CGR} = \frac{W_2 - W_1}{t_2 - t_1} = \text{(g/plant/day)} \]

where \( W_2 - W_1 \) = Difference in oven dry biomass at the time interval \( (t_2 - t_1) \)

\( t_2 - t_1 \) = time interval in days.
3.16.1.7. Relative growth rate (RGR)

Relative growth rate (g/g/day) indicates the increase in dry weight per unit of original dry weight over any specific time interval. The value was computed by using the formula (Leopold and Kriedemann, 1975)

\[
RGR = \frac{\ln W_2 - \ln W_1}{t_2 - t_1}
\]

where \( \ln \) = logarithm at base e (natural log)

\( W_2 - W_1 \) = difference in oven dry biomass at the time interval \( (t_2 - t_1) \)

\( t_2 - t_1 \) = time interval in days.

3.16.2. Yield attributing characters

Observations on yield attributing characters were taken at the time of harvesting or after harvest. The methods adopted for recording various observations are as follows:

3.16.2.1. Number of branches/plant

On harvest date, ten plants in each plot were selected randomly and the number of branches in each plant was counted from which the number of branches/plant was averaged out.

3.16.2.2. Number of pods/plant

The randomly selected plants used to determine the number of branches were also used to count the number of pods/plant. Total
number of pods in ten plants were counted and averaged to get the number of pods/plant.

3.16.2.3. Number of seeds/pod

The seeds from all these pods from the ten randomly selected plants were separated and counted from which the number of seeds/pod was worked out.

3.16.2.4. 100 seed weight

One hundred healthy seeds were counted from the bulk produce of each treatment and the 100 seed weight (test weight) was recorded by electronic balance.

3.16.2.5. Harvest index

Harvest index (%) is the ratio of economic (seed) yield and total biological yield. The value was computed by using the following formula:

\[
\text{Harvest index} = \frac{\text{Economic yield (seed yield)}}{\text{Total biological Yield}} \times 100
\]

3.16.3. Yields

Produce from the net plot for each treatment was weighed after uniform drying, for total dry matter production. The produce was threshed plotwise, seeds were cleaned and the seed weight per plot was recorded in kg. The weight of straw was
worked out by subtracting the seed weight from the weight of total produce. Finally the grain yield, straw yield and total yield from net plots were converted into q/ha by multiplying the net plot yield with the conversion factor i.e. 520.83.

3.16.4. Uptake studies

Under this study the nitrogen and phosphorus per cent content in seed, straw and their uptake were evaluated.

3.16.4.1. Nitrogen content of seed and straw

Oven dry samples of seed and straw were taken separately for the estimation of nitrogen. One gram of sample was taken in 300 ml kieldhal flask. 10 gm salt mixture (K2SO4 and CuSO4 in 9.5:0.5) and 20 ml conc. sulphuric acid were added to it and digested on flame till the appearance of green colour. Finally volume was made upto 100 ml using distilled water. This sample was subjected to distillation as per the procedure described by Chapman and Pratt (1961).

3.16.4.2. Phosphorus content of seed and straw

Oven dry samples of seed and straw were taken separately for determination of phosphorus. One gram sample was taken in 300 ml digestion flask and 20 ml triacid mixture (a mixture of conc. nitric acid, perchloric acid and sulphuric acid in 10:4:1 ratio) was added and digested on hot plate till colourless solution appears. Then volume was made upto 100 ml with distilled water.
out of which 10 ml aliquot was taken in 50 ml volumetric flask. 10 ml yellow reagent and 30 ml distilled water were added to make the volume upto 50 ml. Finally reading was taken by using colorimeter with blue filter and phosphorus content was calculated as described by Piper (1966).

3.16.4.3. **Nutrient uptake by seed and straw**

Nutrients uptake (N and P) in kg/ha by seed and straw were calculated by multiplying the per cent content of nitrogen and phosphorus in seed and straw with the respective biomass. The total nutrient uptake was computed by adding the nutrient uptake by seed and straw respectively.

3.16.4.4. **Nitrogen and phosphorus requirement**

Nitrogen and phosphorus requirement (kg N or P/q seed) was calculated using the formula given below:

1. **Nitrogen requirement**

\[
\text{Nitrogen requirement (kg N/q seed)} = \frac{\text{Total uptake of N (kg/ha)}}{\text{Seed yield (q/ha)}}
\]

2. **Phosphorus requirement**

\[
\text{Phosphorus requirement (kg P/q seed)} = \frac{\text{Total uptake of P (kg/ha)}}{\text{Seed yield (q/ha)}}
\]

3.16.5. **Seed quality (protein and oil)**

3.16.5.1. **Protein content and protein production**

Protein content (%) in seed was calculated by multiplying the per cent concentration of nitrogen in seed with a factor 6.25
following Ranganna (1979) and Singh (1985). Likewise the protein production (kg/ha) was computed by multiplying the per cent value of protein in seed with respective seed yield for each treatment.

3.16.5.2. Oil content and oil Yield

Oil content (%) in seed was determined by Soxhlet apparatus (Ranganna, 1979) and oil yield (kg/ha) was calculated by multiplying the oil content in seed with the seed yield for each treatment.

3.17. Statistical analysis

All the data were tabulated and analysed statistically as per the procedure suggested by Panse and Sukhatme (1967) and Chandel (1984). The 'F' test was used for judging the significance of the treatment mean at 5% level. Whenever 'F' test showed significant difference, the differences between treatment means were further tested by using critical difference (CD) value.

To compare different mean value of treatments, critical difference (CD) values were calculated as follows:

(i) \[
\text{SED} = \sqrt{\frac{2 \times \text{Ems}}{n}}
\]

Where

\[
\text{SED} = \text{Standard error of difference}
\]
\[
\text{Ems} = \text{Error mean square}
\]
\[
n = \text{number of observations on which the mean values is based}
\]
CD (5%) = $\text{SEdx't'}$ at 5% for Error df (2.02)

3.17.1. Relation between crop yield and yield attributes

The Person's correlation coefficients were worked out between yields and its different attributing characters like plant height, leaf area index, dry matter, number of branches/plant, number of seeds/pod, 100 seed weight, and harvest index. The significance of calculated correlation coefficient values were tested against the table values at 5% and at 1% probability levels at the corresponding degrees of freedom (n-2). For correlation analysis, observations of 16 treatments for two years (n=32 observation) were included.

Also, linear and multiple regression equations between seed yield and yield attributes with $R^2$ values and the contribution of each parameter to explain the yield variability were worked out.

B. Estimation of water requirement of soybean (Glycine max (L) Merr.) crop.

3.18. Lysimetric studies

For studying the water requirement of soybean, the crop was sown in a separate field where two gravimetric lysimeters were installed. Under this study the evapotranspiration (ET) losses, water use efficiency, water balance, and drought pattern for soybean crop were undertaken. The details of these studies are described below.
3.18.1. Crop management

In the lysimetric field, except for the fertilizer application, the cultivation practices adopted were similar to the first experiment. In this experiment a basal dose of 30 kg N, 60 kg P2O5 and 30 kg K2O were applied uniformly before sowing (/ha). The cultural details in lysimeters plots are given in Table 3.4.

Table 3.4 : Operational schedule in lysimeters experiment

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Operation</th>
<th>1987</th>
<th>1989</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Field preparation</td>
<td>Jul' 3&amp;4</td>
<td>Jun' 22&amp;23</td>
</tr>
<tr>
<td>2.</td>
<td>Sowing</td>
<td>Jul' 7</td>
<td>Jun' 25</td>
</tr>
<tr>
<td>3.</td>
<td>Fertilizer application</td>
<td>Jul' 7</td>
<td>Jun' 25</td>
</tr>
<tr>
<td>4.</td>
<td>Thinning and/or gap filling</td>
<td>Jul' 15</td>
<td>Jul' 3</td>
</tr>
<tr>
<td>5.</td>
<td>Weeding</td>
<td>Jul' 30</td>
<td>Jul' 20</td>
</tr>
<tr>
<td>6.</td>
<td>Plant protection</td>
<td>1. Aug' 9</td>
<td>Jul' 30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Sep' 19</td>
<td>Sep' 5</td>
</tr>
<tr>
<td>7.</td>
<td>Harvesting</td>
<td>Oct' 30</td>
<td>Oct' 15</td>
</tr>
</tbody>
</table>

3.18.2. Gravimetric Lysimeters

The gravimetric lysimeters which are also known as weighing type lysimeters are exclusively used to measure evapotranspiration (ET) rates in cropped fields (Except rice). A cross sectional diagram of the gravimetric lysimeters installed in the field is shown in Figure 3.4.

It contains an outer tank of dimensions 1.4x1.4 m in which a
FIG 3.4: SCHEMATIC DIAGRAM OF GRAVIMETRIC LYSIMETER

two ton capacity platform type balance is placed. On this balance another tank called inner tank is placed with a dimension of 1.2x1.2 m and with a depth of one m. At 60 cm depth a horizontal plate with holes is placed so that the excess water can drain-out from soil to the bottom.

The inner tank is filled with the soil dugout for installing the outer tank. Care is taken to see that the soil is placed exactly in the same way (layer-wise) as in the field. Also efforts were made to maintain the same compactness at each layer of the soil as was outside. To be more accurate, experiments were conducted after one year of installation so that near natural compaction of the soil is attained.

3.18.2.1. Evapotranspiration

The daily evapotranspiration (ET) rates of soybean crop from sowing to harvesting were measured with the help of two sets of gravimetric lysimeters installed centrally in the 60 x 60 m field. The purpose of such a big plot was to provide a good fetch for the soybean crop in the lysimeters.

Observations were recorded daily at 08.00 Hrs and 15.00 Hrs by measuring the tank weight. The difference of weight from previous observation gives the total water loss and it was later converted into depth of water units. Along with the evapotranspiration (ET) observations, the ambient weather data for the same period were also collected from near by agromet observatory.
Also the crop coefficients (ratio of evapotranspiration and open pan evaporation) were worked out both on weekly basis as well as on crop growth stages basis viz; seedling, vegetative, reproductive and maturity stages.

3.18.2.2. Water use efficiency

The water use efficiency of soybean crop during the years 1987 and 1988 was worked out with the help of total evapotranspiration (ET) values obtained from lysimeters and the crop yield recorded from the lysimeter field. The crop yields in lysimeter field were recorded in 20 plots of one sq m each and averaged out. The evapotranspiration (ET) experiment required a large fetch for avoiding any disturbance from outside fields. Therefore, the lysimetric experiment was conducted in a large field of about 3,600 M and hence to evaluate the yields, 20 randomly selected plots of one sq m were taken.

The water use efficiency (WUE) was estimated as follows:

\[
WUE = \frac{\text{Total seed yield (kg/ha)}}{\text{Total evapotranspiration (ET) in mm}} = \frac{\text{kg/ha}}{\text{mm of ET}}
\]

3.18.2.3. Relation between evapotranspiration (ET) and weather parameters

An analysis of correlation and linear regression between evapotranspiration (ET) and weather parameters like maximum and minimum temperature, bright sunshine hours, wind speed, open pan evaporation and relative humidity was also worked out.
3.19. Water balance

The field water balance parameters like soil moisture variations, actual evapotranspiration (AE), and deficit and surplus of water were worked out with the help of Thornthwaite's climatic water balance book keeping model (Thornthwaite and Mather, 1955) with the help of tables given by Subrahmanyan (1982).

The daily values of potential evapotranspiration (PE) for water balance computation were worked out with the help of Penman's (1948) equation as given below:

\[ PE = \frac{\Delta H + \gamma E_a}{\Delta + \gamma} \quad \text{or} \quad \frac{\Delta H + E_a}{\gamma} \quad \text{or} \quad \frac{\Delta}{\gamma} + 1 \]

Where \( \Delta \) = Slope of the saturated vapour pressure curve at temperature T° C

\( \gamma \) = Psychrometric constant

\( H \) = Energy balance term

\[ H = RA \left( 1 - \alpha \right) \left( 0.18 + 0.55 \frac{n}{N} \right) - \]

\[ \sigma T_a^4 \left( 0.56 - 0.072 \sqrt{ed} \right) \left( 0.1 + 0.9 \frac{n}{N} \right) \]

Where RA = Extra terrestrial radiation (mm water)

\( \alpha \) = Albedo, which is assumed as 0.25

\( n \) = Actual hours of bright sunshine

\( N \) = Possible hours of bright sunshine

\( \sigma \) = Stephan-Boltzman constant

\( T_a \) = Mean air temperature (°C)

\( ed \) = Vapour pressure (mb)

\( E_a \) = Aerodynamic term
\[ U_2 = 0.35 \left( ea - ed \right) \left( 1 + \frac{U_2}{100} \right) \]

Where 

- \( ea = \) Saturated vapour pressure (mb)
- \( U_2 = 24 \) hours total wind run at 2 meters height in miles

The wind speed which is measured at 10 feet height was converted at 2 meter height using the logarithmic equation:

\[ Uh_1 \log h_1 = Uh_2 \log h_2 \]

\[ \frac{Uh_1 \log h_1}{Uh_2} = \frac{Uh_1 \log h_1}{\log h_2} \]

Where \( h = \) Wind run at height \( 'h' \). for computing the Penman's PE, the tables given by Krishnan and Sastri (1978) were used.

The data on soil moisture accumulation from the water balance studies were used to examine the soil moisture variability and corresponding stress period if any.

3.20. **Drought pattern**

The agricultural drought pattern of soybean crop was evaluated with the help of Index of moisture adequacy (IMA) as described by Patel et al. (1983).

\[ \frac{AE}{IMA} = \frac{100}{PE} \]

However, the actual stress period were worked out with the help of systems analysis approach as suggested by Krishnan and et al. (1981). In this approach the cumulative values of PE, PE/2 and AE were used for assessing the stress situation.