Chapter III

MATERIALS AND METHODS

A field experiment on weed management in maize based intercropping system was conducted under All India Coordinated Project on Weed Control during rainy (Kharif) season of 2004 and 2005, at the research farm of Birsa Agricultural University, Kanke, Ranchi. The relevant details about materials used, methods adopted, and techniques employed during the course of investigation have been described in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was carried out in plot No. 10 of the Birsa Agricultural University farm, Kanke, Ranchi for two consecutive Kharif seasons of 2004 and 2005. The experimental plots had uniform topography with homogenous fertility and soil characteristics typical to suit upland maize cultivation. The fields were fairly levelled and had good drainage having limited irrigation facility.

3.2 CLIMATE

Birsa Agricultural University, Kanke is situated in the suburb of Ranchi city on a latitude of 23° 17' N and longitude 85° 19' E with an altitude of 625.22 metres above the mean sea level in the Chotanagpur plateau of newly formed Jharkhand state under agroclimatic subzone IV (central and north eastern plateau) falling under agroclimatic zone VII (Eastern plateau and hill region) of India.

The climatic condition of this region is somewhat distinct with respect to topographic features, soils, climate, flora and fauna. Kanke has a sub tropical climate characterized with hot and dry summer. Comparatively cool
rainy season followed by moderate winter. The average annual rainfall of this locality is around 1400 mm of which 80-85 per cent is received during four monsoon months, June to September. Late arrival and early cessation of monsoonal rains are common. Monsoon usually breaks in the third week of June and ends in mid October.

Premonsoon showers along with some amount of post monsoonal rains are also experienced. Variation in temperature is seen from third week of September to December, whereas rapid decrease in temperature with occasional frost is observed during late December and January. The temperature starts rising from February and reached the maximum in the month of April and May. April and May are the hottest months while December and January are the coldest months. The temperature of this region varies from 2.2° C in winter to 42.4° C in summer.

The mean relative humidity (R.H) rises upto 93 per cent in July-August and goes down to 37 per cent in April-May. Sunshine hours also vary from 1.6 hours day⁻¹ in July to 8.8 hours day⁻¹ in April.

The weekly meteorological data on weather condition, prevailing during the crop growth period of both years of experimentations i.e. from June 2004 to October 2004 and June 2005 to October 2005, have been presented in Appendix – I and depicted in Figure 1.

3.3 WEATHER CONDITION

It is evident from the weather data that the weather condition prevailing during the periods of experimentation was, by and large, close to the normal.

The total rainfall (received from July to October) were 889.3 and 934.9 mm in 2004 and 2005 respectively.
The uniform distribution of rainfall during crop growth period favoured better yield of the crop during the year 2005 as compared to the year 2004. The number of rainy days during crop period (from July 2004 to October 2004) was 55 while it was 46 in the year 2005 during the corresponding period.

The maximum and minimum temperature correspondingly ranged from 25.6 to 33.7°C and 9.8 to 24.0°C in 2004 and from 25.2 to 31.9°C and 9.8 to 23.3°C, respectively in 2005. The relative humidity (R.H) during the crop season in both the years remained around 90 per cent at 7.0 a.m. and 75 per cent at 2.00 p.m. which was more or less close to the normal.

3.4 SOIL CHARACTERISTICS

The experimental field represents upland having ultipale ustalf red loam type of soil which belongs to the "Red yellow-light-gray" category soil association group, representing the major soil group of Jharkhand state. The soils are well aggregated with high permeability and low water retention capacity due to the presence of hydrated oxides of iron and aluminium.

Random soil samples (before sowing of crops) taken from the experimental plots up to depth of 0-20 cm were mixed together to form a composite sample. Mechanical and chemical analysis of the soil were done to assess the physico-chemical properties of soil. The results of physical and chemical analysis and methods used have been presented in table 3.1.
Table 3.1  **Physical properties of soil**

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Value in per cent</th>
<th>Methods employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mechanical analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Sand</td>
<td>55.5</td>
<td>Hydrometer method (Bouyoucos, 1962)</td>
</tr>
<tr>
<td>ii. Silt</td>
<td>30.0</td>
<td>-do-</td>
</tr>
<tr>
<td>iii. Clay</td>
<td>15.0</td>
<td>-do-</td>
</tr>
<tr>
<td>2. Textural class</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandy loam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Water retention at</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. field capacity at 1/3 bar</td>
<td>17.54</td>
<td>Thermo-gravimetric and pressure membrane apparatus (Richard, 1941)</td>
</tr>
<tr>
<td>b. Permanent wilting point at 15 bar</td>
<td>7.52</td>
<td>-do-</td>
</tr>
<tr>
<td>4. Available soil moisture (cm/m soil depth)</td>
<td>15.30</td>
<td>Pressure plate apparatus (Richard, 1941)</td>
</tr>
</tbody>
</table>

**Table 3.2: Chemical properties of soil**

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Value in per cent</th>
<th>Methods employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Chemical analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Soil (pH (1:2.5))</td>
<td>5.9</td>
<td>Glass electrode pH meter (Jackson, 1973)</td>
</tr>
<tr>
<td>ii. Organic carbon (%)</td>
<td>0.52</td>
<td>Walkley and Black’s rapid titration method (Jackson, 1973)</td>
</tr>
<tr>
<td>iii. Available N (Kg ha⁻¹)</td>
<td>261.6</td>
<td>Kjeldahl’s method (Jackson, 1973)</td>
</tr>
<tr>
<td>iv. Available P₂O₅ (Kg ha⁻¹)</td>
<td>21.5</td>
<td>Colorimetric (Bray’s P₁) method (Jackson, 1973)</td>
</tr>
<tr>
<td>v. Available K₂O (kg ha⁻¹)</td>
<td>195.0</td>
<td>Flame photometer (Jackson, 1973)</td>
</tr>
</tbody>
</table>

The soil test values recorded indicated that the experimental plots had medium textured soil categorised as sandy loam with soil reaction falling in the acidic range. Fertility status of the experimental plots as envisaged through organic carbon, available nitrogen and phosphorus was low with medium in water retention capacity.
3.4.1 Cropping history of the experimental plot

The cropping history of the experimental plot for the last three years is given in table 3.3.

Table 3.3: Cropping history of the experimental plot

<table>
<thead>
<tr>
<th>Year</th>
<th>Cropping season</th>
<th>Kharif</th>
<th>Rabi</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001-2002</td>
<td>Maize + Cowpea</td>
<td>Maize + Cowpea</td>
<td>Fallow</td>
</tr>
<tr>
<td>2002-2003</td>
<td>Maize + Soybean</td>
<td>Maize + Soybean</td>
<td>Fallow</td>
</tr>
<tr>
<td>2003-2004</td>
<td>Maize + Groundnut</td>
<td>Maize + Groundnut</td>
<td>Fallow</td>
</tr>
</tbody>
</table>

3.5 DETAILS OF THE EXPERIMENT

3.5.1 Experimental design and lay out

The experiment was laid out in split plot design, comprising five cropping system as main plot treatment and five weed management practices as sub plot treatments with three replications. Thus, in each replication there were twenty-five treatment combinations and in all there were seventy-five sub-plots. The treatment details are presented as below and lay out plant of the experiment is depicted in figure 2.

3.5.2 Treatment details

Main plot: cropping system

C1 - Sole maize at 75 cm apart
C2 - Sole soybean at 30 cm apart
C3 - Sole ground nut at 30 cm apart
C4 - Maize + soybean (2 lines of soybean in between 2 lines of maize)
C5 - Maize + Groundnut (2 lines of groundnut in between 2 lines of maize)
Sub-plot: weed management

W1 - Weedy check (control)
W2 - Weeding thrice at 15, 30 and 45 days after sowing
W3 - Oxyfluorfen @ 0.2 kg a.i. ha$^{-1}$, pre-emergence
W4 - Alachlor @ 2.0 kg a.i. ha$^{-1}$, pre-emergence
W5 - Butachlor @ 1.5 kg a.i. ha$^{-1}$, pre-emergence + Quizalofop-ethyl @ 100 ml ha$^{-1}$, post emergence

Treatment combinations = 25
Total treatment combinations = 75
Design = split plot
Replication = 3 (three)

Plot size

Main plot = 4.5m x 20 m = 90 m$^2$
Sub-plot = 4.5m x 4.0 m = 18 m$^2$
Space between two main plot = 0.5 m
Space between two sub-plot = 0.5 m
Space between two replication = 1 m
Number of maize rows = 6
Number of soybean rows = 15
Number of groundnut rows = 15
Number of maize + soybean rows = 6 + 10
Number of maize + groundnut rows = 6 + 10
Total area = 75.5 m x 22.0 m (Gross)
= 67.5 m x 20.0 m (Net)
3.6  CROPS AND CULTIVARS

3.6.1 Main crop

a. *Maize (cv. Suwan composite)*

It is a composite variety of maize improvement upon by population improved programme at Birsa Agricultural University.

Plants are about 180 cm tall and cobs are located at about mid height of the plant. It has 1.2 cobs per plant. It usually takes about 60 days to silk and 95-100 days to mature in Kharif season. Plants are thick stalk, dark green leaves, free from diseases, well filled ear, bold, pinkish yellow and flint type kernels. It is tolerant to lodging and hot climatic conditions and is recommended for cultivation in Kharif in Chotanagpur and Santhalparganas. Its grain yield potential in Kharif season is 45-50 q ha\(^{-1}\).

3.6.2 Inter Crop

a. *Soybean (cv. Bragg)*

Soybean variety 'Bragg' was used in the experiment. This variety is an introduction from USA. The seeds are bold in size and are yellow, shiny and with black hilum. The plants have determinate habit of growth with green stem. Leaves and pods are covered with brown hairs. Flowers are white in colour born in racemose at the leaf axis. Average plant height is 90-100 cm. The variety is resistant to the bacterial postule but susceptible to yellow mosaic and rots. Its protein and oil content is 40 per cent and 21 per cent, respectively. Its 100 seed weight is 14-15 gm and crop matures in about 105-110 days and having the yield potential of 30-35 q ha\(^{-1}\).

b. *Groundnut (Cv. AK 12-24)*

It is a selection from Spanish variety from Akola (Maharashtra) having chromosomes number 2n = 40. Plant type is erect (upright bunch) and belongs to Spanish bunch group. Its average height is 60-90 cm. Flowering
and pegging is synchronous, consequently majority of pods are well developed and uniform, it has predominantly two seeded pods.

Its oil content is 48-49 per cent and especially suited for dryland zones of the country with average yield of 18-25 q ha\(^{-1}\) in the plateau region of Jharkhand. It matures in about 100-105 days. It is best suited for double and intercropping system.

### 3.7 FIELD PREPARATION AND CROP MANAGEMENT

#### 3.7.1 Field Preparation

The field was ploughed once with tractor drawn cultivator followed by two ploughing with desi plough. Each ploughing was followed by planking. The experiment was laid out as per plan (Fig. 2) and plots were levelled. The precaution against any possible attack of soil borne pests, chlorpyriphos at the rate of 2 liters per hectare dissolved in 800 litres of water was applied in the soil during the course of land preparation. After allocation of treatment, furrows were opened as per row spacing of different crops under experiment and seeds were sown at optimum depth.

The fertilizer dose recommended for the component crops were applied before sowing. In case of maize nitrogenous fertilizers were applied in three split applications. The same lay out and plots were utilized for the sowing of the experiment in subsequent year (2005) also.

#### 3.7.2 Application of nutrients

All the crops under experimentation were fertilized as per the recommended dose of fertilizers (Table 3.4).
Table 3.4:  Recommended nutrient doses (100% for crops)

<table>
<thead>
<tr>
<th>Crops</th>
<th>Nutrients doses (Kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Sole maize</td>
<td>100</td>
</tr>
<tr>
<td>Sole soybean</td>
<td>30</td>
</tr>
<tr>
<td>Sole groundnut</td>
<td>30</td>
</tr>
<tr>
<td>Maize + soybean</td>
<td>100 + 30</td>
</tr>
<tr>
<td>Maize + groundnut</td>
<td>100 + 30</td>
</tr>
</tbody>
</table>

In sole and intercropping system of maize one third dose of N and full dose of P\(_2\)O\(_5\) and K\(_2\)O was applied as basal at the time of sowing. The remaining N was applied in two split application at Knee high and tasseling stages.

In soybean and groundnut either in sole or intercropping system the full doses of recommended N, P\(_2\)O\(_5\) and K\(_2\)O was applied as basal at the time of sowing. The N, P\(_2\)O\(_5\) and K\(_2\)O were applied in the form of urea, SSP and muriate of potash, respectively.

Table 3.4.1:  Calculated quantity of urea, S.S.P and M.P applied per plot

<table>
<thead>
<tr>
<th>Crops</th>
<th>Quantity of fertilizers applied (gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urea</td>
</tr>
<tr>
<td>Sole Maize</td>
<td>391</td>
</tr>
<tr>
<td></td>
<td>(130.0 + 131.0 + 130.0)</td>
</tr>
<tr>
<td>Sole Soybean</td>
<td>117</td>
</tr>
<tr>
<td>Sole Groundnut</td>
<td>117</td>
</tr>
<tr>
<td>Maize + Soybean</td>
<td>485</td>
</tr>
<tr>
<td></td>
<td>(391 + 94)</td>
</tr>
<tr>
<td>Maize + Groundnut</td>
<td>485</td>
</tr>
<tr>
<td></td>
<td>(391 + 94)</td>
</tr>
</tbody>
</table>
3.7.3 Seed rate and sowing

Among the different component crops, maize was selected as base crop and soybean and groundnut were sown as intercrops. Details presented in Table 3.5.

Table 3.5: Row spacing, seed rate, dates of sowing and harvesting of component crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Row to row spacing (cm)</th>
<th>Seed rate (kg ha(^{-1}))</th>
<th>Date of sowing 2004</th>
<th>Date of sowing 2005</th>
<th>Date of harvesting 2004</th>
<th>Date of harvesting 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>75</td>
<td>20</td>
<td>11.07.04</td>
<td>04.07.05</td>
<td>20.10.04</td>
<td>15.10.05</td>
</tr>
<tr>
<td>Soybean</td>
<td>30</td>
<td>100</td>
<td>11.07.04</td>
<td>04.07.05</td>
<td>28.10.04</td>
<td>26.10.05</td>
</tr>
<tr>
<td>Groundnut</td>
<td>30</td>
<td>80</td>
<td>11.07.04</td>
<td>04.07.05</td>
<td>30.10.04</td>
<td>28.10.05</td>
</tr>
</tbody>
</table>

Seeds of the sole crops were sown in lines at the depth of 3-4 cm and two lines of soybean and groundnut were sown in between two lines of maize. The quantity of seeds of component crops to be used in intercropping system was calculated separately on the basis of the number of rows of each crop in different treatments.

Table 3.5.1: Number of crop rows in sole and intercropping

<table>
<thead>
<tr>
<th>Crop</th>
<th>Number of rows per plot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sole Maize</td>
<td>6</td>
</tr>
<tr>
<td>Sole Soybean</td>
<td>15</td>
</tr>
<tr>
<td>Sole Groundnut</td>
<td>15</td>
</tr>
<tr>
<td>Maize + Soybean</td>
<td>6 + 10</td>
</tr>
<tr>
<td>Maize + groundnut</td>
<td>6 + 10</td>
</tr>
</tbody>
</table>
3.7.4 Herbicides

a. Oxyfluorfen (Goal)

2 – Chloro – 1 - (3 ethoxy – 4 - nitrophenoxy) - 4 - (trifluoromethyl benzene. The structural formula is given below:

Oxyfluorfen, a diphenyl ether compound is a strong, systemic herbicide, showing also some contact activities and mostly used as pre emergence. At low doses of 0.1-0.25 kg a.i. ha⁻¹, its pre emergence application is found effective in certain pulses and vegetables. In the transplanted crops, it should be applied within 2-3 days of transplanting.

b. Alachlor (Lasso)

2 Chloro -2'6' diethyl-N-methoxymethyl acetanilide). The structural formula is given below:

It is very effective as pre-emergence herbicide for controlling annual weeds particularly grasses and nut sedges in maize and soybean. This chemical has also shown acceptable selectivity to cowpea, sunflower, rapeseed, linseed, beans, sugarcanes, peas and potato. Alachlor resist leaching in soils so it is more effective on medium texture soil than on heavy
soils. Its half life is 6 to 10 weeks. Its trade name is lasso and manufactured by Monsanto.

**c. Butachlor**

N – (butoxy methyl) – 2 – chloro – 2' 6' – diethyl acetanilide. The structural formula is given hereunder.

It is a selective and translocated herbicide observed to be effective in controlling weeds as pre-emergence application. It is manufactured by Monsanto chemicals of India Ltd., Mumbai with trade name "Machate" 50 E.C. Calculated quantity of herbicide dissolved in water was sprayed one day after sowing.

**d. Quizalofop-ethyl**

\[(R) – 2 – [4 – [(6 – chloro – 2- quinoxaliny) oxy]\]

Quizalofop-p-ethyl is formulated as an EC and sold under the trade name Assure-II. it provides control of emerged annual and perennial grass in number of crops, including canola, cotton, drybeans, dry and succulent peas, lentils, soybean and in non crop areas.
Because it is applied to emerged grass, soil has little effect on its efficiency. It is moderately absorbed on sandy loam soil and is strongly absorbed to silt loam soils. Quizolofope-ethyl is rapidly degraded by microbes under aerobic and anaerobic conditions. It has a moderate soil residual life but posses no problem to crops raised in sequence.

### 3.7.5 Cultural Operation and Care

Adequate plant protection measures were taken to save the crops from insect, pest and diseases for successful experimentation. Weeds were controlled by chemical herbicide and hand weeding as per treatments. Application of forate 10 G @ 5 kg ha⁻¹ was done in maize, while in case of soybean and groundnut, Dithan M-45; 2 kg dissolved in 800-1000 liters of water per hectare were done for the control of diseases.

### 3.7.6 Harvesting and Threshing

The crops were harvested according to maturity as per treatment from the net plot area of each plot with the help of sickle and digger. Border rows were harvested separately. The crops were sundried properly then threshed, shelled and winnowed manually. The grains and pods were cleaned and finally the yield of grain, pod and straw were recorded. The sample plants were harvested separately, labelled properly and brought to laboratory for post harvest studies.

### 3.8 BIOMETRIC OBSERVATIONS

#### 3.8.1 Pre-harvest studies

##### 3.8.1.1 Plant population

Number of plants per metre row length at 15 days after sowing were recorded for component crops separately.
3.8.1.2 Plant height (cm)

The height of five randomly selected plants in each plot were measured in centimeter with the help of a meter scale from the ground level to the growing tip of the plant at 30, 60 and 90 days after sowing. The average height of these plants were computed and mean values were reported.

3.8.1.3 Number of branches

Branches of soybean and groundnut were counted from five randomly selected plants in each plots at harvest and their mean values were recorded.

3.8.1.4 Number of nodules per plant

For the study of nodules, five plants of soybean and groundnut were excavated carefully from the soil after saturating the soil profile with water at 30 and 60 days after sowing. The roots were washed gently and thoroughly with water with the help of sieve to remove the soil. After careful washing the nodules were separated and counted.

3.8.1.5 Light interception

The total solar radiation and light interception was measured with the help of illuminometer (Model 5200; Kyoritsu-Electrical Instruments Works Ltd., Japan). The observation was recorded at 30, 60 and 90 days after sowing. All recorded values were averaged for different height of the crop canopy. The light interception was then computed by the formula given below.

\[
\text{Light interception (\%)} = \frac{I_o - I_c}{I_o} \times 100
\]

Where,

- \(I_o\) is the total incident radiant energy above the crop canopy and \(I_c\) is the incident radiation below the crop canopy.
3.8.2 POST HARVEST STUDIES

3.8.2.1 Yield attributes of component crops

3.8.2.1.1 Number of cobs per plant

Number of cobs per plant were counted from randomly selected five maize plants in each plot and their mean values were calculated and then reported.

3.8.2.1.2 Length of cob

At harvest five cobs of the five randomly selected tagged maize plants from each plots were taken out and length of cobs was measured with the help of meter scale and average values were calculated and recorded.

3.8.2.1.3 Girth of cob

Girth of the above mentioned cobs were measured at three places around the maize cobs, namely bottom, middle and top position with the help of measuring tape. These three values were averaged out to get girth of a single cob of maize.

3.8.2.1.4 Number of grain rows in a cob

Number of grain rows in five randomly selected maize cobs were counted and mean of these five was recorded.

3.8.2.1.5 Number of grains per row

Number of grains in each row in five randomly selected maize cobs were counted and their mean was recorded.

3.8.2.1.6 Number of pods per plant

Pods were collected from five selected plants of soybean and groundnut at harvest and average number of pods per plant were calculated for each crop and recorded accordingly.
3.8.2.1.7 Number of seeds per pod

Seeds were collected from five selected pods of soybean at harvest and average number of seeds per pod were calculated for each plot.

3.8.2.1.8 Effective pods per plant (Filled pod and per cent filled pods/plant)

Average number of filled pods and total number of pods per plant of ground nut were recorded per plant and filled pod per cent (effective pod) was calculated as under:

\[
\text{Filled pod percentage} \% = \left( \frac{\text{Number of filled pod}}{\text{Number of total pod}} \right) \times 100
\]

3.8.2.1.9 Sound mature kernel (SMK) percentage

One hundred gram pod sample was drawn from the produce and shelled for the determination of total kernel weight. One hundred kernels were counted and weight was recorded. Similarly sound matured kernels weight and total kernel weight in 100 gm pod sample was recorded and sound mature kernel percentage was calculated by formula given below:

\[
\text{Sound matured kernel} \% = \left( \frac{\text{Sound matured kernel weight}}{\text{Total kernel weight}} \right) \times 100
\]

3.8.2.1.10 Shelling percentage (%)

It is the percentage of kernels obtained from a given sample of dry pods of ground nut and calculated as under:

\[
\text{Shelling percentage} \% = \left( \frac{\text{Weight of kernels}}{\text{Weight of pods}} \right) \times 100
\]
3.8.2.1.11 Grain / kernel weight (g)

Hundred grains / kernel of maize, soybean and groundnut were counted from the yield of each net plot and weighed to obtain 100 grain/kernel weight in gram.

3.8.2.2 Yield

3.8.2.2.1 Grain/ Pod yield

After threshing/shelling of plants of each net plot area, grains/pods were cleaned and sun dried for two days. Then the grain pods weight of each net plot was recorded and converted in kg ha\(^{-1}\).

3.8.2.2.2 Stover/ straw/ haulm yield

The straw yield obtained after threshing the plants of individual net plot was kept separately and the weight was recorded. Straw yield in kg per hectare (kg ha\(^{-1}\)) was later computed from straw yield obtained per net plot.

3.8.2.2.3 Maize equivalent yield

Maize equivalent yield was calculated by converting the grain yield of intercrops into maize yield, considering the market rates of both the grains (Rs kg\(^{-1}\)). This was calculated with the help of the following formula.

\[
\text{Maize equivalent} = \frac{\text{Grain yield of intercrop} \times \text{Market price of intercrops}}{\text{Market price of maize}} + \text{Yield of maize yield}
\]

3.8.2.2.4 Harvest index

The harvest index for each treatment was calculated by using the formula given below:

\[
\text{Harvest index} = \frac{\text{Economic (grain) yield}}{\text{Biological (grain + straw) yield}}
\]
3.8.3 Studies on weeds

The study on weeds in respect of their count and dry matter accumulation were made at 30, 60 and 90 days after sowing.

3.8.3.1 Weed count

The number of weeds were counted from an area of 0.25 m$^2$ randomly selected at two places in each plot and marked with pegs. The mean value was recorded and converted to per metre square at each observation. List of major weed flora (narrow leaf, broad leaf and sedge) was also prepared.

3.8.3.2 Dry matter accumulation

A 0.25 m$^2$ quadrant was placed randomly at two places in each plot, outside the net plot area but inside the border rows and the enclosed weeds were carefully uprooted, cleaned and kept in sun for initial drying. Thereafter, these weeds were dried in the oven at 60°C for 48 hours to reach constant weight. The dry weight of weeds so obtained at different days after sowing i.e., at 30, 60 and 90 DAS were accordingly converted into gram per square metre (gm$^{-2}$).

3.8.3.3 Weed control efficiency

Weed control efficiency was computed by the formula given below:

\[
\text{WCE} (%) = \frac{\text{WDC} - \text{WDT}}{\text{WDC}} \times 100
\]

Where,

\[
\begin{align*}
\text{WCE} &= \text{Weed control efficiency} \\
\text{WDC} &= \text{Dry matter accumulation by weeds in unweeded plot} \\
&\quad \text{(g m}^{-2}\text{)} \\
\text{WDT} &= \text{Dry matter accumulation by weeds in treated plots} \\
&\quad \text{(g m}^{-2}\text{)}
\end{align*}
\]
3.8.3.4 Weed index (%)

The weed index was calculated by using the following formula:

\[
\text{WI} (\%) = \frac{X - Y}{X} \times 100
\]

Where,

\( \text{WI} \) = Weed index

\( X \) = Grain yield from weed free plot (kg ha\(^{-1}\))

\( Y \) = Grain yield from treated plot (kg ha\(^{-1}\))

Since there is no weed free treatment in the experiment hence the maximum grain yield (maize equivalent yield) obtained under the treatment has been considered as weed free treatment.

3.8.3.5 Weed seed rain of major weeds

Total number of weed seeds produced by weed species per square meter is known as weed seed rain.

Important weeds of experimental plots were selected and their seeds were collected at maturity. Number of seeds produced by each weeds were counted and total number of weed seeds per square metre was estimated.

3.9 Competition Studies

3.9.1 Land equivalent ratio

Land equivalent ratio was calculated by using the following formula given by Willey, 1979 as:

\[
\text{LER} = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}
\]

where,

\( \text{LER} \) = Land equivalent ratio

\( Y_{aa} \) = Pure stand yield of species ‘a’
3.9.2 Aggressivity (A)

This was proposed by Mc Gilchrist (1965). It gives a simple measure of how much the relative yield increase in component ‘a’ is greater than that for component ‘b’.

\[
A_{ab} = \frac{\text{Mixture yield of ‘a’}}{\text{Expected yield of ‘a’}} - \frac{\text{Mixture yield of ‘b’}}{\text{Expected yield of ‘b’}}
\]

Where,

- \( Y_{ab} \) = Mixture yield of component ‘a’ in combination with component ‘b’
- \( Y_{ab} \) = Pure stand yield of component ‘a’ (sole crop)
- \( Y_{ba} \) = Mixture yield of component ‘b’ in combination with component ‘a’
- \( Y_{bb} \) = Pure stand yield of component ‘b’ (Sole crop)
- \( Z_{ab} \) = Sown proportion of component ‘a’ in combination with ‘b’
- \( Z_{ba} \) = Sown proportion of component ‘b’ in combination with ‘a’

3.9.3 Competitive ratio (CR)

The competitive ratio of the crops grown in different intercropping combinations can be calculated by the formula given by Willey and Rao, 1980.

\[
CR_a = \frac{\text{LER}_a \times Z_{ba}}{\text{LER}_b \times Z_{ab}}
\]
Where,

\[ CR_a = \ \text{Competitive ratio} \]
\[ \text{LER}_a = \ \text{Land equivalent ratio of component ‘}a’ \]
\[ \text{LER}_b = \ \text{Land equivalent ratio of component ‘}b’ \]
\[ Z_{ab} = \ \text{Sown proportion of component ‘}a’ \text{ with component ‘}b’ \]
\[ Z_{ba} = \ \text{Sown proportion of component ‘}b’ \text{ with component ‘}a’ \]

### 3.9.4 Competition index (CI)

It is a measure of find out the yield of various crops when grown together as well as separately. It can be calculated by the formula given by Donald (1963).

\[
CI = \frac{(Y_{aa} - Y_{ab}) \times (Y_{bb} - Y_{ba})}{Y_{aa} \times Y_{ab}}
\]

Where,

\[ CI = \ \text{Competition index} \]
\[ Y_{aa} = \ \text{Yield in pure stand of component ‘}a’ \]
\[ Y_{bb} = \ \text{Yield in pure stand of component ‘}b’ \]
\[ Y_{ab} = \ \text{Mixture yield of component ‘}a’ \text{ grown with component ‘}b’ \]
\[ Y_{ba} = \ \text{Mixture yield of component ‘}b’ \text{ grown with component ‘}a’ \]

### 3.10 CHEMICAL STUDIES

#### 3.10.1 Weed and plant sample analysis

Weed samples collected at different growth stages i.e. at 30, 60 and 90 days after sowing were dried and whole parts were ground and then subjected to chemical analysis for N, P and K content and its uptake (kg ha\(^{-1}\)) by weeds.
At harvest N, P and K content of components crops were estimated by mixing grains and straw to form a composite sample representing grain and straw of component crops from each treatment. After the estimation of N, P and K content in the representative samples, uptake of N, P and K (kg ha\(^{-1}\)) were worked out by multiplying the dry weight of weeds and dry matter yield of component crops (kg ha\(^{-1}\)) by their respective N, P and K content (Jackson, 1973). The nitrogen content of weeds and plant samples were determined by the modified Kjeldahls method as outlined by Jackson, 1973. Whereas phosphorus and potash content for the same were determined spectrophotometrically and by flame photometer respectively.

3.10.2 Soil

Soil sample collected form the each plot after harvest of crops were air dried ground and sieved from 20 mesh sieve. The samples were subjected to analysis for available N, P\(_2\)O\(_5\) and K\(_2\)O as per standard methods (Table 3.2) to determine the nutrient status of the soil after two years of experimentations.

3.10.3 Total nutrient uptake at harvest

The nutrient (N, P and K) uptake per unit area by crops at harvest was calculated by using the formula as follows:

\[
\text{Total nutrient uptake (kg ha}^{-1}\text{)} = \text{Nutrient uptake by sole crop (kg ha}^{-1}\text{)} + \text{Nutrient uptake by intrecrops (kg ha}^{-1}\text{)}
\]

3.11 STATISTICAL ANALYSIS

The experimental data for different characters were subjected to statistical analysis by adopting the methods appropriate to the design (Cochran and Cox, 1963). The results were interpreted on the basis of 'F' test (Fisher, 1935) and critical differences (CD) between treatments mean. Interaction effects were discussed only wherever they were found applicable i.e., significant. Whenever the variance ration (F value) was found significant. Critical differences (CD) values were computed for the comparisons among the
treatments means. The analysis of variance table for split plot design and formula for SEm ±, CD and CV are presented below:

### 3.11.1 Skeleton of ANOVA

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Degree of freedom</th>
<th>Sum of square</th>
<th>Mean of sum of square</th>
<th>F value</th>
<th>Remarks</th>
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</thead>
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<tr>
<td>Replication</td>
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<td></td>
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</tr>
<tr>
<td>Cropping system</td>
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<td></td>
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<tr>
<td>Error (a)</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Weed management</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Weed management X cropping system</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error (b)</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>74</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.11.2 Critical differences for split plot design

To test the significant difference among the treatments, the following formula were used for calculating the critical differences.

**SEm ± and CD for main plot treatments (cropping system)**

\[
\text{SEm ±} = \frac{\sqrt{\text{Ve(a)}}}{r \times w}
\]

Where,

- \(\text{Ve (a)}\) = Error (a) variance
- \(r\) = Number of replication
- \(w\) = Number of sub-plot treatments

\[
\text{CD (p = 0.05)} = \sqrt{2} \times \text{SEm ±} \times t\text{-value at 5% for Error (a) D.F}
\]

**SEm ± and CD for sub-plot treatments (weed-management)**

\[
\text{SEm ±} = \frac{\sqrt{\text{Ve(b)}}}{r \times c}
\]
Where,

\[ Ve (b) = \text{Error (b) variance} \]

\[ c = \text{Number of sub-plot treatment} \]

\[ CD (p = 0.05) = \sqrt{2 \times SEm \pm X t-\text{value at 5}\% \text{ for Error (b) D.F}} \]

\[ SEm \pm \text{ and CD for interaction (cropping system X weed management)} \]

\[ SEm \pm = \frac{\sqrt{Ve(b)}}{r} \]

\[ CD (p = 0.05) = \sqrt{2 \times SEm \pm X t-\text{value at 5}\% \text{ for Error (b) D.F}} \]

\[ CV (\%) = \frac{\sqrt{Ve(b)}}{GM} \times 100 \]

Where,

\[ GM = \text{General mean} \]

### 3.12 ECONOMICS

The cost of cultivation of maize based intercropping system under each treatment were calculated on the basis of inputs used and their existing cost. Simultaneously gross return was calculated on the basis of grain and straw yield and their existing price. These values were used to calculate net return (Rs ha\(^{-1}\)) and benefit : cost ratio for each treatments by using the following formula.

\[ \text{Gross return (Rs ha}^{-1}) = \text{Grain yield (kg ha}^{-1}) \times \text{Market price (Rs. kg}^{-1}) + \text{Straw yield (kg ha}^{-1}) \times \text{Market price (Rs.kgha}^{-1}) \]

\[ \text{Net return (Rs. ha}^{-1}) = \text{Gross return – Cost of cultivation (Rs. ha}^{-1}) \]

\[ \text{Benefit : Cost ratio} = \frac{\text{Gross return (Rs. ha}^{-1})}{\text{Cost of cultivation (Rs. ha}^{-1})} \]