Chapter III

MATERIALS AND METHODS

The present investigation was undertaken to ascertain the “Effect of irrigation and phosphorus levels on seed production of garden pea (Pisum sativum L.)” during the rabi seasons of 2005-06 to 2007-08 at the Experimental Farm of the Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The details of experimental site, materials used and the methods employed have been presented in this chapter under the following heads:

3.1 General description of the experimental site

3.1.1 Experimental site

The experiment was conducted at the Experimental Farm of the Department of Vegetable Science and Floriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experimental site is situated between 32.6° N latitude and 76.3° E longitude and at an altitude of 1290m above mean sea level.

3.1.2 Climate and weather

Agroclimatically, the experimental site falls in the sub-temperate mid-hill zone which is endowed with mild summer and cool winters along with high rainfall during monsoons. The weekly meteorological data recorded at the Meteorological Observatory of the Department of Agronomy, during the field experimental period of the years 2005-06, 2006-07 and 2007-08 have been given in Appendix I, II and III and illustrated in Fig.3.1a, Fig.3.1b and Fig.3.1c, respectively.
3.1.3 **Soil characteristics**

Soil samples were drawn from 0-15cm depth. These representative soil samples from different locations of the experimental area were mixed, dried, sieved and composite sample was drawn for determining various physico-chemical properties. The results of various soil physico-chemical properties, before the start of experiment, and the methods employed are given in Table 3.1.

**Table 3.1  Physicochemical properties of soil of experimental site**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Method employed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Depth (cm)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-15</td>
<td>15-30</td>
<td>30-60</td>
</tr>
<tr>
<td><strong>Mechanical analysis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand (%)</td>
<td>22.2</td>
<td>-</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>43.2</td>
<td>-</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>32.7</td>
<td>-</td>
</tr>
<tr>
<td>Texture</td>
<td>Silty clay loam</td>
<td></td>
</tr>
<tr>
<td>Bulk density (g/cm$^3$)</td>
<td>1.06</td>
<td>1.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.22</td>
</tr>
<tr>
<td><strong>Chemical analysis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic carbon (%)</td>
<td>0.95</td>
<td>-</td>
</tr>
<tr>
<td>Soil pH</td>
<td>5.9</td>
<td>-</td>
</tr>
</tbody>
</table>

(Before pre-sowing irrigation)

xxvi
Available Nitrogen (kg/ha) 292.0 - - Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg/ha) 17.2 - - Olsen’s method (Olsen et al., 1956)
Available potassium (kg/ha) 263.2 - - Ammonium acetate method using flame photometer (Jackson, 1967)

The soil analysis data showed that the soil of the experimental field was silty clay loam in texture, acidic in reaction (pH 5.9) and medium in organic carbon, available nitrogen, phosphorus and potassium (ranges given in Appendix IV).

3.1.4 Cropping history

Before start of the experiment in *rabi* 2005-06 field was under brinjal crop. Details during the experimental period are given below:

<table>
<thead>
<tr>
<th>Season</th>
<th>Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Rabi</em> 2005-06</td>
<td>Garden pea seed crop</td>
</tr>
<tr>
<td><em>Kharif</em> 2006</td>
<td>Okra</td>
</tr>
<tr>
<td><em>Rabi</em> 2006-07</td>
<td>Garden pea seed crop</td>
</tr>
<tr>
<td><em>Kharif</em> 2006</td>
<td>Fallow</td>
</tr>
<tr>
<td><em>Rabi</em> 2007-08</td>
<td>Garden pea seed crop</td>
</tr>
</tbody>
</table>

3.2 Experimental details

3.2.1 Field preparation and layout

The experimental field was prepared with the help of tractor driven disc plough, cultivation and harrow at the time of start of experiment. The experimental plots were prepared manually. During the subsequent seasons the experimental field was ploughed...
with tractor driven cultivator ensuring minimum displacement of soil and thereafter the experimental plots were prepared manually. The layout has been shown in Figure 3.2.

### 3.2.2 Details of treatments

**A. Irrigation levels (Main-plot)**

- **I<sub>1</sub>** Water seeding (0.43cm) viz., irrigation within the rows before sowing.
- **I<sub>2</sub>** I<sub>1</sub> + irrigation (1cm) during vegetative stage.
- **I<sub>3</sub>** I<sub>2</sub> + irrigation (1cm) at 75% flowering.
- **I<sub>4</sub>** I<sub>3</sub> + irrigation (1cm) at 75% podding.
- **I<sub>5</sub>** Recommended irrigation schedule (5cm depth) pre-sowing + vegetative + 75% flowering + 75% podding stage.

**B. Phosphorus levels (Sub-plot)**

- **P<sub>1</sub>** 40kg P<sub>2</sub>O<sub>5</sub>/ha
- **P<sub>2</sub>** 60kg P<sub>2</sub>O<sub>5</sub>/ha
- **P<sub>3</sub>** 80kg P<sub>2</sub>O<sub>5</sub>/ha

<table>
<thead>
<tr>
<th>Treatment combinations</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replications</td>
<td>3</td>
</tr>
<tr>
<td>Total number of plots</td>
<td>45</td>
</tr>
<tr>
<td>Spacing</td>
<td>45 X 10cm</td>
</tr>
<tr>
<td>Plot size</td>
<td>3.15m X 2.0m = 6.3m&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Design : Split-Plot

Variety : Palam Priya.

3.2.3 Application of manures and fertilizers

The entire recommended dose of nitrogen (50kg/ha), potassium (60kg/ha), FYM (20t/ha) and phosphorus fertilizer as per sub-plot treatments were applied and mixed with in furrows before water seeding. The fertilizers used were composite (12:32:16 NPK), urea (46% N) and muriate of potash (60% $K_2O$).

3.2.4 Sowing

Palam Priya variety of garden pea was procured from Vegetable Farm, CSKHPKV, Palampur. Seeds were soaked in bavistin (0.1%) solution for 24 hours before sowing. Seed sowing was done manually by placing 30 seeds/row at equidistance. Chlorpyriphos @ 2.5ml/litre of water was sprayed with in the rows before covering the seeds with soil to protect seed from soil born insects.

3.3 Crop management

3.3.1 Intercultural operations and plant protection

The recommended package of practices was followed to raise the crop. Thinning was carried out to maintain the required plant population of 140 plants/plot with in 35 DAS. Hoeing and weeding operations were carried out from time to time in each plot of the experiment. No prominent disease/insect-pest was observed in pea seed crop. However, bavistin (0.1%) sprays (one in each crop season) were given as a prophylactic measure. Besides, one spray of rogor (0.1%) insecticide was done during 2006-07 only to control leaf miner. More details are given in Appendix V.
3.3.2 Harvesting/Threshing

The seed crop was harvested treatment and replication wise manually at maturity. The harvested produce was sun dried for about a week. Threshing was carried out by enclosing the sun-dried produce within a threshing sheet followed by light beating with the help of a wooden stick at the threshing floor.

3.4 Observations recorded

Observations recorded on various traits in garden pea are described as follows:

3.4.1 Growth and development

3.4.1.1 Days to 50 per cent emergence

The experimental plots were visited every day. Days to 50 per cent germination were recorded treatment wise as the number of days taken from the date of sowing to the day when 50 per cent of the seedlings had emerged.

3.4.1.2 Days to 50 per cent flowering

Days to 50 per cent flowering were recorded treatment wise as the number of days taken from the date of sowing to the day when 50 per cent of the plants had flowered.

3.4.1.3 Plant height (cm)
Ten plants were taken at random in each treatment. The height of these plants were measured from the soil surface to the apex and averaged as mean plant height (cm).

3.4.1.4 Leaf area index (LAI)

In the active growth stage (peak podding stage) three plants per experimental plot were marked at random, uprooted and brought to the laboratory to measure the leaf area of entire plants with the area measurement system, MK-2 (Delta-T Dereces Ltd. Burrvell, Cambridge, England). These values were then converted to total leaf area per plant (cm$^2$). Leaf area index (LAI) was calculated as per formula given by Redford (1967):

$$LAI = \frac{\text{Leaf area}}{\text{Ground area}}$$

3.4.1.5 Leaf water potential (-kPa)

Leaf water potential was also recorded in the active growth stage using a portable pressure chamber apparatus (Waring and Cleary, 1967). A fully exposed compound leaf along with tendril, third from top of the plant, was taken for this purpose. Three such leaves from three plants in each treatment were used for determination of leaf water potential (in -bars). Values were averaged for each treatment and converted into -kPa by multiplying with 100.

3.4.1.6 Root nodules per plant

Root nodules were not visible at the time of seed maturity. Hence, the data on this trait could not be recorded.

3.4.2 Yield attributes and yield

3.4.2.1 Effective plant population
The effective plant population was recorded at the time of harvesting by counting number of plants in each plot of the experiment and compared with the plant population of 140/plot maintained after the thinning operation.

3.4.2.2 Days to seed maturity

The data on the days to seed maturity were recorded as the number of days from the date of sowing to the day when ≥75% of the pods on plants in an experimental plot had turned yellow in colour.

3.4.2.3 Biological yield (g/plot or q/ha)

The plants were harvested manually in each experimental plot above the ground level at maturity and weighed in g/plot with the help of a weighing balance. The biological yield was converted into q/ha by multiplying the net plot yield by the factor 0.01587.

3.4.2.4 Number of pods per plant

Ten plants were taken at random on the day of harvest, total pods were counted and average values were worked out.

3.4.2.5 Number of seeds/pod

Ten pods were taken at random from 3.4.2.4. The numbers of seed were counted after shelling and the average seeds/pod were recorded.

3.4.2.6 Seed yield (g/plot or q/ha)

The harvested plants from each experimental plot were sun-dried for about a week and threshed. The threshed seeds were cleaned and sun dried for a couple of days before weighing. The seed yield then converted into q/ha by multiplying the net plot seed yield (g/plot) by the factor 0.01587.

3.4.3 Seed quality parameters

3.4.3.1 100-seed weight (g)

A random sample of 100-seeds was drawn from each treatment and weighed on electronic balance.

3.4.3.2 Seed germination (%)

A random sample of 100-seeds per treatment was drawn and seeds were placed in between the germination papers (BP) and incubated at 25 ± 1°C. Data on
germination were recorded based on ISTA rules on the 8th day of incubation (Agrawal, 1986).

3.4.3.3 Seed vigour

Total length (root+shoot) of all the germinated seeds (3.4.3.2) were recorded and average length was calculated by dividing the total length of all the seedlings with the total number of the germinated seeds. The seed vigour index was calculated as per Abdul-Baki and Anderson (1973) as follows:

Seed vigour index = Seedling length x germination percentage.

3.4.3.4 Crude protein content (%)

Crude protein content in garden pea seed was estimated by multiplying the nitrogen content (%) by the factor 6.25.

3.4.4 Plant/soil Chemical studies

3.4.4.1 Preparation and analysis of plant samples

The sun dried seed and straw samples were powdered separately and kept in paper bags for further analysis. The detail of chemical analysis is given below:

3.4.4.2 Total nitrogen content

Powdered straw and seed samples were digested with concentrated H$_2$SO$_4$ using digestion mixture and total nitrogen was determined by micro-Kjeldhal’s method (Jackson, 1967).

3.4.4.3 Total phosphorus content

Straw and seed samples were digested with diacid mixture of HNO$_3$ and HClO$_4$ in the ratio of 9:4 and the extract was made to a definite volume. Total phosphorus was determined by Vanadomolybdate phosphoric acid yellow colour method at 470nm (Jackson, 1967).

3.4.4.4 Total potassium content

It was determined by using flame-emission spectrophotometer from the extract obtained by digestion with diacid mixture (Chapman and Brown, 1950).

3.4.4.5 Nutrient uptake

The concentration of nitrogen, phosphorus and potassium were determined in straw and seed samples and uptake was calculated as follows:
Uptake (kg/ha) = % concentration of nutrient × sun dried straw/seed yield of crop (kg/ha)

Total uptake was calculated as follows:

Total uptake = uptake in straw + uptake in seed

3.4.4.6 Available phosphorus in soil

Plot wise soil samples were drawn from 0-15cm depth after harvest of crop during all the three seasons whereas plot wise soil samples before sowing were drawn only during 2006 and 2007. The available soil phosphorus in the soil was determined by using Olsen’s method (Olsen et al., 1956).

3.4.5 Water studies

3.4.5.1 Soil water content (%)

The changes in soil water content during the crop season at different profile depths (0-15, 15-30 and 30-60cm) were monitored at about 15 day’s interval by using gravimetric method. The soil water content was calculated by the following formula:

\[
W = \frac{M_s - M_d}{M_d} \times 100
\]

Where,

\(W\) : Soil water content (%)

\(M_s\) : Fresh mass of soil sample (g)

\(M_d\) : Oven dried mass of soil sample (g)
The volumetric moisture content ($\theta$) was worked out as follows:

$$\theta = W \times \rho$$

where, $\rho = \text{bulk density}$

### 3.4.5.2 Total water use

The total water use by the pea crop was computed from the effective rainfall (ER), seasonal moisture depletion from 60cm profile ($\Delta S_{60}$) and irrigation water applied (cm) as per treatment (I), all in centimeter unit by using the following equation:

$$\text{Total water use} = \text{ER} + \Delta S_{60} + I$$

### 3.4.5.3 Water use efficiency

The water use efficiency (WUE) was computed as:

$$\text{WUE (kg seed/ha/cm water used)} = \frac{\text{Seed yield (kg/ha)}}{\text{Total water use (cm)}}$$

### 3.5 Statistical analysis

The average data recorded treatment wise and replication wise on various parameters were subjected to statistical analysis using split-plot design as follows:

#### 3.5.1 Analysis of variance for split-plot design
The ANOVA table for Split-Plot Design as explained by Gomez and Gomez (1984) is given in Table 3.2.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degree of Freedom (df)</th>
<th>Sum of Squares (SS)</th>
<th>Mean Sum of Squares (MS)</th>
<th>Computed ‘F’</th>
<th>Tabulated ‘F’ (P=0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>(r-1)</td>
<td>R_{ss}</td>
<td>R_{ss}/(r-1) = R_{ms}</td>
<td>R_{ms}/E_{ams}</td>
<td>3.84 at 4 and 8 df</td>
</tr>
<tr>
<td>Main-plot factor (a)</td>
<td>(a-1)</td>
<td>M_{ss}</td>
<td>M_{ss}/(a-1) = M_{ms}</td>
<td>M_{ms}/E_{ams}</td>
<td>2.45 at 8 and 20 df</td>
</tr>
<tr>
<td>Error (a)</td>
<td>(r-1) (a-1)</td>
<td>E_{ass}</td>
<td>E_{ss}/(r-1)(a-1) = E_{ams}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-plot factor (b)</td>
<td>(b-1)</td>
<td>S_{ss}</td>
<td>S_{ss}/(b-1) = S_{ms}</td>
<td>S_{ms}/E_{bms}</td>
<td>3.49 at 2 and 20 df</td>
</tr>
<tr>
<td>axb</td>
<td>(a-1) (b-1)</td>
<td>I_{ss}</td>
<td>I_{ss}/(a-1)(b-1) = I_{ms}</td>
<td>I_{ms}/E_{bms}</td>
<td>2.45 at 8 and 20 df</td>
</tr>
<tr>
<td>Error (b)</td>
<td>a (r-1) (b-1)</td>
<td>E_{bss}</td>
<td>E_{bss}/a(r-1)(b-1) = E_{bms}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>rab-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where, a = main-plot factor; b = sub-plot factor; r = replication; E = error

In a split-plot design, with two variable factors and two error terms, there are four different types of comparisons. Each requires its own set of CD values. These comparisons are as follows:

1. Comparison between two main-plot treatment (irrigation levels) means averaged over all sub-plot treatments.
2. Comparison between two sub-plot treatment (phosphorus levels) means averaged over all main-plot treatments.

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3. Comparison between two sub-plot treatment means (phosphorus levels) at the same main-plot treatments (irrigation levels).

4. Comparison between two main-plot treatment (irrigation levels) means at the same or different sub-plot treatments (phosphorus levels).

The Standard Error (SE) of Mean Difference for each of these types of pair comparisons are computed as follows:

<table>
<thead>
<tr>
<th>Type of pair comparison</th>
<th>SE$_{d}^{\pm}$</th>
<th>Tabulated 't' at P=0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Two main-plot means (averaged over all sub-plot treatments)</td>
<td>$(2E_{ams}/rb)^{1/2}$</td>
<td>$t_a$</td>
</tr>
<tr>
<td>2. Two sub-plot means (averaged over all main-plot treatments)</td>
<td>$(2E_{bms}/ra)^{1/2}$</td>
<td>$t_b$</td>
</tr>
<tr>
<td>3. Two sub-plot means at the same main-plot treatments.</td>
<td>$(2E_{bms}/r)^{1/2}$</td>
<td>$t_b$</td>
</tr>
<tr>
<td>4. Two main-plot means at the same or different sub-plot treatments</td>
<td>$[2((b-1) E_{bms} + E_{ams})/rb]^{1/2}$</td>
<td>$t_w$</td>
</tr>
</tbody>
</table>

These SE$_{d}$ values were then multiplied by tabular standard t-values for the calculation of CD values except for the comparison which involved more than one error term like type-4 comparison. For such comparison SE$_{d}$ was multiplied with weighted tabular t-value which was computed by the formula given below:

Weighted Tabular t-value ($t_w$) = $[(b-1) E_{bms}t_b + E_{ams}t_a]/ [(b-1)E_{bms} + E_{ams}]$

The critical difference (CD) also called as least significant difference were calculated as follows:

CD1 = SE$_{d1}$ x $t_a$

CD2 = SE$_{d2}$ x $t_b$

CD3 = SE$_{d3}$ x $t_b$
CD4 = SE_{d4} \times t_w

### 3.5.2 Analysis of variance for Randomized Block Design (RBD)

Water use efficiency (WUE) was analysed as per randomized block design since irrigation levels were in main plots. The ANOVA table for RBD is given in Table 3.3.

**Table 3.3 ANOVA table for Randomized Block Design**

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degree of Freedom</th>
<th>Sum of Squares (df)</th>
<th>Sum of Squares (SS)</th>
<th>Mean Sum of Squares (MS)</th>
<th>Computed ‘F’ (Rms/E_ms)</th>
<th>Tabulated ‘F’ (P=0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>(r-1)</td>
<td>R_{ss}</td>
<td>R_{ss}/(r-1) = R_{ms}</td>
<td>R_{ms}/E_{ms}</td>
<td>4.303 at 2 and 8 df</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>(t-1)</td>
<td>T_{ss}</td>
<td>T_{ss}/(t-1) = T_{ms}</td>
<td>T_{ms}/E_{ms}</td>
<td>2.776 at 2 and 8 df</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>(r-1) (t-1)</td>
<td>E_{ss}</td>
<td>E_{ss}/(r-1)(t-1) = E_{ms}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>(rt-1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where, r = replication; t = treatment; E = error.

For the treatment comparisons, the critical difference (CD) value was computed as follows:

\[ CD = SE_{d} \times t_{0.05} \]

Where \( SE_{d} = (2E_{ms}/r)^{1/2} \).