CHAPTER-III
MATERIALS AND METHODS

A field experiment was conducted to study the irrigation scheduling of fennel
The details of experimental site, experimental materials used, and procedures followed
and techniques adopted for attaining the objectives of the investigation are presented in
this chapter.

3.1 STUDY AREA

3.1.1 Location

The experiment was conducted at Instructional farm, College of Agricultural
Engineering and Technology, Junagadh, located at 21.5 °N latitude and 70.1 °E
Longitude with an altitude of 60 meter above mean sea level on the western side of the
foot hills of Girnar (Plate 3.1). The area is situated in South Saurashtra Agro climatic
Zone of Gujarat State.

3.1.2 Climate

The study area is having typically subtropical and semi-arid climate,
characterized by fairly cold and dry winter, hot and dry summer and warm and
moderately humid during monsoon. Partial failure of monsoon once in three to four
years is common in this region. Winter sets in the month of November and continues
till the end of February. January is the coldest month of winter. Summer commences in
the second fortnight of February and ends in the middle of June. April and May are the
hottest months of summer. The last 35 year weather data recorded at the JAU
observatory located near to the experimental site showed that the variation in the weekly
mean of daily maximum temperature, minimum temperature, relative humidity, wind
speed, bright sun shine hours and pan evaporation were from 29.5 °C to 39.4 °C, 10 °C
to 26.7 °C, 51 % to 81 %, 10.1 km/hr, 4.2 to 13.4 hours and 3.6 to 10.7 mm, respectively.
The average annual rainfall and evaporation is 852.4 mm and 2482 mm, respectively.
Materials And Methods

Plate 3.1 Location map of study area

3.1.3 Physiochemical Properties of the Soil

The experimental field has an even topography with a gentle slope and good drainage. The data presented in Table 3.1, show physiochemical properties of the soil of experimental field. From table it is seen that the soil of the experimental plot was clayey in texture and slightly alkaline in reaction. The soil had organic carbon content of 0.55 %, and was medium in available nitrogen and phosphorous and rich in available potash. It had 23.77 % field capacity and 2.5 g/cc specific gravity. It had dry bulk density of 1.51 g/cc.

3.1.4 Source of Irrigation

The source of water for the experiment was ground water. The diameter and depth of the bore well were 15 cm and 75 m respectively. The analysed quality of the irrigation water was as depicted in Table 3.2 and quality of water was found good for irrigation.
Table 3.1 Physiochemical properties of the soil of experimental field

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Particular</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Physical properties</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Sand (%)</td>
<td>31.88</td>
</tr>
<tr>
<td>2</td>
<td>Silt (%)</td>
<td>26.92</td>
</tr>
<tr>
<td>3</td>
<td>Clay (%)</td>
<td>41.19</td>
</tr>
<tr>
<td>4</td>
<td>Textural class</td>
<td>Clayey</td>
</tr>
<tr>
<td>5</td>
<td>Field Capacity (%)</td>
<td>23.77</td>
</tr>
<tr>
<td>6</td>
<td>Dry bulk density (g/cm³)</td>
<td>1.51</td>
</tr>
<tr>
<td>7</td>
<td>Infiltration rate (cm/h)</td>
<td>1.00</td>
</tr>
<tr>
<td>8</td>
<td>Porosity (%)</td>
<td>42.00</td>
</tr>
<tr>
<td>9</td>
<td>Voids Ratio</td>
<td>0.73</td>
</tr>
<tr>
<td>B</td>
<td>Chemical Properties</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Organic carbon (%)</td>
<td>0.55</td>
</tr>
<tr>
<td>2</td>
<td>pH (1:2.5)</td>
<td>8.09</td>
</tr>
<tr>
<td>3</td>
<td>EC(1:2.5) (dS/m)</td>
<td>0.30</td>
</tr>
<tr>
<td>4</td>
<td>Nitrogen (kg/ha)</td>
<td>256.0</td>
</tr>
<tr>
<td>5</td>
<td>Phosphorous (P₂O₅) (kg/ha)</td>
<td>30.0</td>
</tr>
<tr>
<td>6</td>
<td>Potash (K₂O) (kg/ha)</td>
<td>290.0</td>
</tr>
</tbody>
</table>

Table 3.2 Quality analysis of irrigation water

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Constituents</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carbonate (meq/L)</td>
<td>1.52</td>
</tr>
<tr>
<td>2</td>
<td>Bicarbonate (meq/L)</td>
<td>9.44</td>
</tr>
<tr>
<td>3</td>
<td>Calcium (meq/L)</td>
<td>2.92</td>
</tr>
<tr>
<td>4</td>
<td>Chlorine(meq/L)</td>
<td>5.88</td>
</tr>
<tr>
<td>5</td>
<td>Sodium (meq/L)</td>
<td>7.6</td>
</tr>
<tr>
<td>6</td>
<td>EC (dS/m)</td>
<td>1.35</td>
</tr>
<tr>
<td>7</td>
<td>pH</td>
<td>7.40</td>
</tr>
<tr>
<td>8</td>
<td>Magnesium</td>
<td>3.92</td>
</tr>
<tr>
<td>9</td>
<td>Sodium absorption ratio (SAR)</td>
<td>3.61</td>
</tr>
<tr>
<td>10</td>
<td>Salts (g/L)</td>
<td>0.864</td>
</tr>
</tbody>
</table>

3.2 EXPERIMENTAL MATERIAL AND SYSTEM DETAILS

The recourses, materials and system details required for conducting the experiment are shown Table 3.3. Other materials used for experiment are PVC fittings and flush for main/sub main line. Plain lateral of 16mm diameter, joiner, grommet, take off end plug etc., were used for 16mm diameter lateral along with other material for experimental setup.
Table 3.3 Resource materials and systems used

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Particulars</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water source</td>
<td>The tube well of 150 mm dia. having depth of 75 m</td>
</tr>
<tr>
<td>2</td>
<td>Pumping system</td>
<td>Electric submersible motor of 7.5 HP × 3-phase</td>
</tr>
<tr>
<td>3</td>
<td>By pass assembly</td>
<td>63 mm</td>
</tr>
<tr>
<td>4</td>
<td>Screen filter</td>
<td>25 m³/h capacity</td>
</tr>
<tr>
<td>5</td>
<td>Ventury injector</td>
<td>3/4 inch inlet capacity</td>
</tr>
<tr>
<td>6</td>
<td>Control valve</td>
<td>75 mm and 63 mm</td>
</tr>
<tr>
<td>7</td>
<td>Pressure gauge</td>
<td>0-4 kg/cm² range</td>
</tr>
<tr>
<td>8</td>
<td>Main line</td>
<td>PVC pipe of 75 mm × 4 kg/cm²</td>
</tr>
<tr>
<td>9</td>
<td>Sub main line</td>
<td>PVC pipe of 63 mm × 3.2 kg/cm²</td>
</tr>
<tr>
<td>10</td>
<td>Lateral</td>
<td>Emitting Pipe 16 mm x 0.60 m x 4 lph</td>
</tr>
<tr>
<td>11</td>
<td>Lateral cock</td>
<td>16 mm diameter</td>
</tr>
<tr>
<td>12</td>
<td>Operating pressure</td>
<td>1.5 kg/cm²</td>
</tr>
<tr>
<td>13</td>
<td>Irrigation frequency</td>
<td>As per treatment</td>
</tr>
</tbody>
</table>

3.3 FIED EXPERIMENTAL DETAIL

The experiment was undertaken to evaluate the conjunctive impact of four irrigation level; 1.0 IW/ETC, 0.8 IW/ETC, 0.6 IW/ETC, 0.4 IW/ETC and Irrigation interval mainly 2 day, 3 day, and 5 day adopted in this study. The details of experimental design adopted were as described below.

Treatments Details:

(a) Main factor: Irrigation frequency (F)
   (F₁) 2 day irrigation interval.
   (F₂) 3 day irrigation interval.
   (F₃) 5 day irrigation interval.

(b) Sub factor: Irrigation level by IW/ETC (I)
   (I₁) irrigation with 0.4 IW/ETC.
   (I₂) irrigation with 0.6 IW/ETC.
   (I₃) irrigation with 0.8 IW/ETC.
   (I₄) irrigation with 1.0 IW/ETC.

(c) Total treatment combination: (3 × 4) = 12
   Replication: 3
   Total no. of plots: 3 × 12 = 36

(d) Statistical Design: Split Plot

(e) Plot Size:
   a. Plot size of treatment : 2.7 m × 8 m
b. Plot size of replication: 9 m × 32 m

c. Plot size of experiment: 27 m × 32 m

(f) Spacing:
   a. 45 cm row to row
   b. 20 cm plant to plant

(g) Crop details
   a. Crop: Fennel
   b. Variety: Volina
   c. Date of sowing: Second fortnight of November
   d. Fertilizer dose per hectare (N: P: K): 90: 30: 00 kg/ha (RDF).

The details of the treatment depicted in Table 3.4 and the layout of experimental layout is presented in Fig. 3.1

Table 3.4: Detail of treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Irrigation Regimes (IW/ETc)</th>
<th>Irrigation Frequencies (day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>I₁F₁</td>
<td>0.4</td>
</tr>
<tr>
<td>T2</td>
<td>I₂F₁</td>
<td>0.6</td>
</tr>
<tr>
<td>T3</td>
<td>I₃F₁</td>
<td>0.8</td>
</tr>
<tr>
<td>T4</td>
<td>I₄F¹</td>
<td>1.0</td>
</tr>
<tr>
<td>T5</td>
<td>I₁F₂</td>
<td>0.4</td>
</tr>
<tr>
<td>T6</td>
<td>I₂F₂</td>
<td>0.6</td>
</tr>
<tr>
<td>T7</td>
<td>I₃F₂</td>
<td>0.8</td>
</tr>
<tr>
<td>T8</td>
<td>I₄F₂</td>
<td>1.0</td>
</tr>
<tr>
<td>T9</td>
<td>I₁F₃</td>
<td>0.4</td>
</tr>
<tr>
<td>T10</td>
<td>I₂F₃</td>
<td>0.6</td>
</tr>
<tr>
<td>T11</td>
<td>I₃F₃</td>
<td>0.8</td>
</tr>
<tr>
<td>T12</td>
<td>I₄F₃</td>
<td>1.0</td>
</tr>
</tbody>
</table>
3.4 AGRONOMICAL PRACTICES

3.4.1 Preparation of field

Soil was prepared for sowing by two time cultivation with rotary tiller (rotavator). Stubbles of previous crops were collected and removed from the experiment field. Beds of 2.0 m x 9.0 m size were prepared before sowing of seeds. Irrigation channel were prepared to facilitate common irrigation to all treatments shown in Plate 3.2.

![Plate 3.2 Preparation of experimental field](image)

3.4.2 Drip system specifications and installation

Drip irrigation system was installed as shown in Plate 3.3. The delivery line is 75 mm in diameter. Regulation of operating pressure in drip irrigation system is one of the prime requirements for proper running of system. Therefore bypass assembly of 75 mm was fitted on main line after the conveyance pipe connection with the main line.

![Plate 3.3 Drip system installation](image)

Irrigation water filtering was done to sustain the life of the drip irrigation system and alleviate clogging effect. Screen filter with filtering capacity 40 m³/hr was adopted in present system. Ventury injection of 63 mm was used for application of water soluble
fertilizer through drip irrigation. Pressure gauge of 0-4 kg/cm² was used for measuring the operating pressure in the main line. PVC pipe of 75 mm × 4 kg/cm² was used as main line and 63 mm × 4 kg/cm² was used as a sub main line. Heavy duty black colored LLDPE lateral line of 16 mm × 2.5 kg/cm² was used. An emitter discharge of 4 lph with spacing of 0.6 m was adopted in the present study. Lateral coke of 16 mm at the starting of lateral line was adopted to control the irrigation water application.

### 3.4.3 Sowing of Fennel

Sowing was done on 2nd December 2016. Fennel seed (Volina variety) was treated with thiram @ 3.0 gm per kg at time of sowing. Fennel seeds were sown at 3-5 cm depth manually at 20 cm × 20 cm distance as shown in Plate 3.6. Gap filling was done after germination of plants.

![Plate 3.4 Sowing of fennel](image)

### 3.4.4 Fertilizer application

The recommended package of agronomical practices was adopted. Recommended dose of fertilizer (90: 30: 00 kg/ha) was applied. Fifty percent N and P fertilizer was given as basal dose. The remaining dozes of fertilizers were given during vegetative, flowering, and seed development stages as per recommendation. Fertigation was done by using ventury which depicted in Plate 3.5.
3.4.5 Pest, Disease and Weed Control

To protect the Fennel crop from attack of pest, insect and fungus disease careful actions were taken during crop season. Spraying of thiometoxam @ 5 g/15 liter water and DDVP @10 ml / 15 liter water was done to control the insect. The crop was kept free from weeds for proper growth and development of plants. Spraying of pesticide was done as per requirements. Three hand weeding were done to remove weeds. (Plate 3.6).
3.4.6 **Crop harvesting**

Manually harvesting was carried out after 160 days of sowing.

![Plate 3.7 Harvesting of fennel](image)

3.5 **IRRIGATION SCHEDULING**

3.5.1 **Calculation of Reference Evapotranspiration, ET₀**

A popular method used to estimate ET₀ is the crop coefficient (Kᵢ) algorithm (e.g., in the UN’s Food and Agriculture Organization (FAO) artical-24 by Doorenbos and Pruitt 1977). In this approach, adjusted FAO Kᵢ was determined for different treatment and multiplied by evapotranspiration from reference vegetation (ET₀) to compute ETᵢ, or

\[ ETᵢ = Kᵢ \times ET₀ \]  \hspace{1cm} \text{... (3.1)}

Where,

- ETᵢ = Crop evapotranspiration
- Kᵢ = Crop factor,
- ET₀ = Reference evapotranspiration.

Allen *et al.*, (1998) defined and published the FAO paper no. 56 the Penman-Monteith ET₀, as the rate from a hypothetical reference crop with an assumed crop height (12 cm), a fixed surface resistance (70 sm⁻¹) and albedo (0.23), closely resembling the ET from an extensive surface of green grass cover with adequate water. Using daily or monthly data it can be simplified as follows.

\[ ET₀ = \frac{0.408 \Delta (Rₙ - G) + \gamma \frac{900}{T + 273} u_s (e_s - e_a)}{\Delta + \gamma (1 + 0.34 u_s)} \]  \hspace{1cm} \text{... (3.2)}

Where, ET₀ is reference evapotranspiration [mm day⁻¹], Rₙ is net radiation at the crop surface [MJ m⁻² day⁻¹], G is soil heat flux density [MJ m⁻² day⁻¹], T is mean daily air...
temperature at 2 m height \([°C]\), \(u_2\) is wind speed at 2 m height \([\text{m s}^{-1}]\), \(e_s\) is saturation vapour pressure \([\text{kPa}]\), \(e_a\) is actual vapour pressure \([\text{kPa}]\), \(e_s - e_a\) is saturation vapour pressure deficit \([\text{kPa}]\), \(\Delta\) is slope vapour pressure curve \([\text{kPa °C}^{-1}]\), \(\gamma\) is psychrometric constant \([\text{kPa °C}^{-1}]\).

### 3.5.2 Determination of Crop Coefficient (Kc) Values

Fundamentally, the crop coefficient is defined as the ratio of crop ET (ET\(_C\)) to some reference ET (ET\(_0\)) as defined by weather data. In FAO-56, values listed for K\(_C\) represent ET under growing conditions having a high level of management and with little or no water or other ET reading stress and thus represent what are referred to as potential levels for crop ET.

K\(_C\) curve is comprised of four straight line segments representing the initial period, the development period, the midseason period, and the late season period. These segments are defined by three primary K\(_C\) values; K\(_C\) during the initial period K\(_{C\ ini}\) K\(_C\) during midseason (full cover) period K\(_{C\ mid}\), and K\(_C\) at harvest (or at the end of late season) K\(_{C\ end}\). The K\(_{C\ ini}\) defines the horizontal portion of the K\(_C\) curve during the initial period until approximately 10 % of the ground is covered by vegetation. The K\(_{C\ mid}\) defines the value for K\(_C\) during the peak period for the crop, which is normally when the crop is at “effective full cover”. This period is described by a horizontal line extending through K\(_{C\ mid}\). The development period is defined by a sloping line that connects the initial and midseason period. The late season has a sloping line that connects the initial and midseason periods. The late season has a sloping line that connects the end of the midseason period with the harvest (end) date.

#### 3.5.2.1 Crop coefficient as per FAO 56

Crop coefficient for the initial stage (K\(_{C\ ini}\)) calculated using procedure suggested by FAO for a trickle irrigation system from the following figure given by FAO 56. FAO also suggested adjustment for partial wetting by irrigation, in which, the fraction of the surface wetted, \(f_w\) only 0.4 (Table 3.5). When only a fraction of the soil surface is wetted, the value for K\(_{C\ ini}\) obtained from Table 12 of FAO 56 should be multiplied by the fraction of the surface wetted to adjust for the partial wetting:

\[
K_{C\ ini} = f_w \times K_{C\ ini\ (tab\ fig)} \tag{3.3}
\]

Where, \(f_w\) the fraction of surface wetted by irrigation or rain (0-1); K\(_{C\ ini\ (tab\ fig)}\) the value for K\(_{C\ ini}\) from Table 12. In addition, in selecting which figure to use (i.e., Fig. 3.4), the average infiltration depth, expressed in millimetres over the entire field surface, should
be divided by \( f_w \) to represent the true infiltrated depth of water for the part of the surface that is wetted (Fig. 3.1, FAO 56):

\[
I_w = \frac{1}{f_w}
\]  
\[\text{... (3.4)}\]

Where \( I_w \) = irrigation depth for the part of the surface that is wetted (mm),

\( f_w \) = fraction of surface wetted by irrigation,

\( I \) = the irrigation depth for the field (mm)

---

**Fig. 3.2** Average \( K_{C_{ini}} \) as related to the level of \( ETo \) and the interval between irrigations and/or significant rain during the initial growth stage for all soil types when wetting events are light to medium (3-10 mm per event)

**Fig. 3.3** Average \( K_{C_{ini}} \) as related to the level of \( ETo \) and the interval between irrigations greater than or equal to 40 mm per wetting event, during the initial growth stage for medium and fine textured soils

**Table 3.5** Common values of fraction \( f_w \) of soil surface wetted by irrigation or precipitation

<table>
<thead>
<tr>
<th>Wetting event</th>
<th>( f_w )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>1.0</td>
</tr>
<tr>
<td>Sprinkler irrigation</td>
<td>1.0</td>
</tr>
<tr>
<td>Basin irrigation</td>
<td>1.0</td>
</tr>
<tr>
<td>Border irrigation</td>
<td>1.0</td>
</tr>
<tr>
<td>Furrow irrigation (every furrow), narrow bed</td>
<td>0.6 – 1.0</td>
</tr>
<tr>
<td>Furrow irrigation (every furrow), wide bed</td>
<td>0.4 – 0.6</td>
</tr>
<tr>
<td>Furrow irrigation (alternated furrow)</td>
<td>0.3 – 0.5</td>
</tr>
<tr>
<td>Trickle irrigation</td>
<td>0.3 – 0.4</td>
</tr>
</tbody>
</table>

In condition of average infiltration depth between 10 mm and 40 mm, the value for \( K_{C_{ini}} \) can be estimated from interpolation between Fig. 3.4 and Fig. 3.5.

\[
K_{C_{ini}} = K_{C_{ini}} (\text{Fig.3.5}) + \frac{(1-10)}{40-10} [K_{C_{ini}} (\text{Fig.3.4}) + K_{C_{ini}} (\text{Fig.3.5})] 
\]  
\[\text{... (3.5)}\]

Where, \( K_{C_{ini}} \) (Fig.3.4) is value for \( K_{C_{ini}} \) from Fig.3.4; \( K_{C_{ini}} \) (Fig.3.5) is value for \( K_{C_{ini}} \)
from Fig. 3.5 and I is average infiltration depth (mm). The values 10 to 40 in equation 3.5 are the average depth of infiltration (mm) upon which Fig. 3.4 and Fig. 3.5 are based.

The crop coefficient of fennel crop as per FAO is 0.70 (using equation 3.3), 1.05 and 0.90 for $K_{C_{ini}}$, $K_{C_{mid}}$ and $K_{C_{end}}$, respectively from FAO 56 for drip irrigated fennel crop. The above values were corrected for non-standard conditions using FAO 56 procedure. Now find the adjusted $K_{c_{mid}}$ and $K_{c_{end}}$ find from the following equations.

$$K_{c_{mid}} = K_{c_{mid (tab)}} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)](\frac{h}{3})^{0.3} \quad \ldots (3.6)$$

$$K_{c_{end}} = K_{c_{end (tab)}} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)](\frac{h}{3})^{0.3} \quad \ldots (3.7)$$

Where, $K_{c_{mid (tab)}} = \text{Value of } K_{c_{mid}} \text{ taken from Table 12}; u_2 = \text{mean value of daily wind speed at 2 m height over grass during the mid-season growth stage (m/s), for 1 m/s} \leq u_2 \leq 6 \text{ m/s}; RH_{min} = \text{mean value of daily minimum relative humidity}; h = \text{mean plant height during the mid-season.}$

### 3.5.3 Total irrigation water requirement

The total irrigation water requirement as per irrigation level was calculated as below:

$$IW = I \times ET_C \quad ... (3.8)$$

Where, $IW = \text{Depth of water to be applied (mm)}$. $I = \text{level of irrigation (I=1 i.e. 100% of crop water requirements)}$. $ET_C = \text{crop evapotranspiration (mm/day)}$.

### 3.5.4 Water application rate

Water application rate of emitter was calculated using the following formula:

$$\text{Irrigation Rate (mm/hr)} = \frac{\text{Dripper Discharge (lph)}}{\text{Lateral Spacing (m) } \times \text{ Dripper Spacing (m)}} \quad ... (3.9)$$

### 3.5.5 Time of operation

The time of operation (hr) of drip irrigation system for each treatment plot:

$$\text{Irrigation time (hr)} = \frac{\text{Water requirement (mm/day)}}{\text{Irrigation rate (mm/hr)}} \quad ... (3.10)$$

### 3.6 OBSERVATIONS RECORDED

#### 3.6.1 Crop Parameters

**Plant height**

Plant height was measured at every 15 day from base of the plant to top of the plant and expressed in cm from selected plants in each treatment.
Plate 3.8 Measurement of plant height

**Seed Yield**
Seed yield was recorded from sample collected from net plot area in each of the plot.

**Dry Matter**
Dry matter was recorded from sample collected from net plot area in each of the plot.

**No. of Umbel per Plant**
Number of Umbels was recorded from selected plant in each of the plot.

**No. of Umbellate per Umbel**
Number of Umbellate per umbel was counted from selected plant in each of the plot.

**No. of Seed per Umbel**
Number of seed per umbel was counted from each and every umbel of selected plant in each of the plot.

**1000 Seed Weight (Test weight)**
After drying of seed 1000 seed were counted and weighed on balance for test weight.

### 3.7 WATER USE EFFICIENCY (WUE)

The water use efficiency is the yield of fennel seed produced per unit water application. Water use efficiency was calculated by the quantity (kg) of fennel seed production per ha-mm of water.

\[ WUE_{ij} = \frac{Y_{gij}}{W_{ij}} \]  \hspace{1cm} (3.11)

Where,

- \( WUE_{ij} \) = Water use efficiency of fennel seed under treatment- i and replication-j, (kg/ha-mm),
- \( Y_{gij} \) = Yield of fennel seed under treatment- i and replication-j, (kg/ha),
Wij = Seasonal irrigation water applications in treatment- i and replication-j, (mm).

3.8 STATISTICAL ANALYSIS

The data of various parameters of growth, yield and yield attributes were collected from the net plot area of each treatment and action. The statistical analysis carried out according to Split Plot design as mentioned in section 3.3.

3.9 ECONOMICS

The economics of rabi fennel cultivation includes the total cost and total return per unit area.

3.9.1 Total Cost of Cultivation

The total cost of cultivation was computed using the following expression:

\[ TCC = CCC + FCI + VCI \] \hspace{1cm} (3.12)

Where, TCC is the total cost of fennel cultivation (₹/ha/season),

CCC is the common cost of cultivation (₹/ha/season),

FCI is the fixed cost of irrigation (₹/ha/season) and

VCI is the variable cost of irrigation (₹/ha/season)

3.9.2 Common Cost of Cultivation

Common cost of cultivation (CCC) included cost towards the common agronomic practices like ploughing, harrowing, sowing, top dressing, weeding, inter-cultivation, harvesting, plant protection measures and fertilizer application and common inputs like seeds, fertilizer, weedicides, etc.

3.9.3 Fixed Cost of Irrigation

The fixed cost of irrigation (FCI) in case of all treatments under drip irrigation included the cost of pumping unit and drip irrigation system and its installation. While in case of treatments under border irrigation included the cost of pumping unit, making of bunds and water conveyance channel. The FCI was calculated as below:

\[ FCI = SC_{ps} + SC_{is} + SC_{id} \] \hspace{1cm} (3.13)

Where, \( SC_{ps} \) is the seasonal cost of pumping system (₹/ha/season),

\( SC_{is} \) is the seasonal cost of irrigation system (₹/ha/season),

\( SC_{id} \) is the seasonal cost of installation of drip system (₹/ha/season)
The seasonal cost of pumping system was computed using the following expression:

$$SC_{ps} = \frac{PVPS \times i \times (1+i)^m}{(A \times s) \left[1 - \frac{(1+i)^{m}}{1+i} \right]}$$

... (3.14)

Where, PVPS is the present value of the pumping unit (₹)

- m is the life of the pumping system, taken as 15 years
- i is the prevailing rate of interest (fraction), taken as 0.10
- A is the total area commanded by the pumping unit in a season (ha) and
- s is the number of season per year to which the pumping system can be used

PVPS included the purchasing price of the pump, electric motor, suction and delivery pipes, all fittings, accessories, and cost of well construction.

The seasonal cost of drip irrigation system was computed using the following expression:

$$SC_{is} = \frac{PVIS \times i \times (1+i)^n}{s \left[1 - \frac{(1+i)^n}{1+i} \right]}$$

... (3.15)

Where, PVIS is the present value of the irrigation system (₹/ha),

- i is the interest rate (fraction), taken as 0.10
- n is the life of the irrigation system, taken as 10 years (Sagarka, 1998)
- s is the number of season for which the irrigation system be used.

The PVIS included the purchase cost of all required drip irrigation systems’ items. It was estimated considering the material quantity for 1 hectare square field under drip irrigation system. Rate of components, tax were considered as per price fixed by GGRC (Gujarat Green Revolution Company) Vadodara, Gujarat for the year 2016-17 (Appendix – C). The fixed cost of drip irrigation system was calculated considering the 10 years life of system and 10% rate of interest. The number of season (s) was taken as 1 seasons. The seasonal cost of irrigation system (SCid) included PVC main line, PVC sub-main line, PVC valves, grommet, take off, pressure gauge, lateral, emitters, filter etc. The SCid is taken as 1000 ₹ per ha per season.

### 3.9.4 Variable cost of cultivation

Variable cost of cultivation (VCC) was estimated considering cost of weeding
and harvesting. Cost of weeding and harvesting was calculated based on how many labor required during whole season.

3.9.5 Variable Cost of Irrigation

The variable cost of irrigation (VCI) included operational cost towards the labour and electricity for pumping, conveyance and irrigation applications and maintenance charges. The cost of applying the water per hour under drip irrigation was computed using the discharge capacity of pump, electricity charges and cost of labour for irrigation applications. The variable cost of irrigation was computed using the cost of unit depth of water and total seasonal depth of irrigation under the respective treatment.

3.9.6 Gross Income

The gross income in terms of total monetary return ₹ per hectare was calculated from the fennel grain yield at the prevailing market price of APMC mentioned in level norms papers.

3.9.7 Net Income

The net income was worked out by deducting the total cost of the cultivation (TCC) from the gross income per hectare for each treatment.

3.9.8 Benefit Cost Ratio

The benefit cost ratio of fennel cultivation was worked out for each treatment by dividing the gross income with total cost of cultivation.

3.10 Crop Water Production Function (CWPF)

The water productivity was worked out by dividing total income to depth of irrigation water applied in respective treatment. Water production functions the relationship between the quantity of applied water and the yield or production of crop. The quadratic polynomial function can be used for optimization. It has thee form:

\[ Y_a = b_0 + b_1 d + b_2 d^2 \] … (3.16)

Where,

\( Y_a \) = crop production or yield (kg/ha),
\( d \) = applied irrigation water (mm),
\( b_0, b_1 \) and \( b_2 \) = fitting coefficients.

Maximum applied water (\( d_{\text{max}} \)) is calculated by differentiating the CWPF and equating it to zero, then the maximum predicted yield (\( Y_{\text{max}} \)) can be calculated by substituting the \( d_{\text{opt}} \) in the following equation.
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\[ \frac{dy}{dx} = b_1 + 2b_2 X = 0 \quad \ldots (3.17) \]

\[ d_{\text{max}} = -\frac{b_1}{2b_2} \quad \ldots (3.18) \]

\[ Y_{\text{max}} = b_0 + b_1 d_{\text{max}} + b_2 d_{\text{max}}^2 \quad \ldots (3.19) \]

The same procedure was followed and equations were also used to optimize the depth of emission under trickle irrigation.