CHAPTER-III
MATERIALS AND METHODS

A field experiment was conducted to study response of wheat (*Triticum aestivum* L.) under drip fertigation system during winter season of 2017-18. The details of experimental material used, procedures followed and techniques adopted during the course of present 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°30'55.69" N latitude and 70°27'23.19" E longitude with an altitude of 60 meter above mean sea level on the western side of the foothills of Girnar (Plate 3.1).

3.1.2 Climate

The study area 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 years 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.
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 can be seen that the soil of the experimental plot is clay in texture and slightly alkaline in reaction. The soil had organic carbon content of 0.90 %, and it had 23.77 % field capacity and 2.5 g/cc specific gravity. It had dry bulk density of 1.37 g/cc.

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></td>
<td><strong>Physical properties</strong></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>Clay</td>
</tr>
<tr>
<td>5</td>
<td>Field Capacity (%)</td>
<td>23.77</td>
</tr>
<tr>
<td>6</td>
<td>Dry bulk density (g/cm$^3$)</td>
<td>1.37</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>Specific Gravity</td>
<td>2.50</td>
</tr>
<tr>
<td>10</td>
<td>Voids Ratio</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td><strong>Chemical Properties</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Organic carbon (%)</td>
<td>0.90</td>
</tr>
<tr>
<td>2</td>
<td>pH (1:2.5)</td>
<td>6.87</td>
</tr>
<tr>
<td>3</td>
<td>EC(1:2.5) (ds/m)</td>
<td>1.13</td>
</tr>
<tr>
<td>4</td>
<td>Nitrogen (kg/ha)</td>
<td>320</td>
</tr>
<tr>
<td>5</td>
<td>Phosphorous ($P_2O_5$) (kg/ha)</td>
<td>73.65</td>
</tr>
<tr>
<td>6</td>
<td>Potash (K$_2$O) (kg/ha)</td>
<td>262.08</td>
</tr>
<tr>
<td>7</td>
<td>TDS</td>
<td>723.20</td>
</tr>
<tr>
<td>8</td>
<td>Sulphur (S)</td>
<td>15.85</td>
</tr>
<tr>
<td>9</td>
<td>Calcium (Ca)</td>
<td>137.5</td>
</tr>
<tr>
<td>10</td>
<td>Magnesium (Mg)</td>
<td>145.00</td>
</tr>
<tr>
<td>11</td>
<td>Copper (Cu)</td>
<td>2.00</td>
</tr>
<tr>
<td>12</td>
<td>Iron (Fe)</td>
<td>8.80</td>
</tr>
<tr>
<td>13</td>
<td>Manganese (Mn)</td>
<td>13.74</td>
</tr>
<tr>
<td>14</td>
<td>Zinc (Zn)</td>
<td>0.84</td>
</tr>
<tr>
<td>15</td>
<td>Boron (B)</td>
<td>0.44</td>
</tr>
</tbody>
</table>
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 is shown in Table 3.2.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Constituents</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EC (ds/m)</td>
<td>1.13</td>
</tr>
<tr>
<td>2</td>
<td>pH</td>
<td>6.87</td>
</tr>
<tr>
<td>3</td>
<td>Total Dissolve Salts (TDS) (ppm)</td>
<td>723.20</td>
</tr>
<tr>
<td>4</td>
<td>Calcium (Ca) (ppm)</td>
<td>100.0</td>
</tr>
<tr>
<td>5</td>
<td>Magnesium (Mg) (ppm)</td>
<td>72</td>
</tr>
<tr>
<td>6</td>
<td>Sodium (Na) (ppm)</td>
<td>238.00</td>
</tr>
<tr>
<td>7</td>
<td>K(ppm)</td>
<td>0.4</td>
</tr>
<tr>
<td>8</td>
<td>Bicarbonate (HCO$_3$) (ppm)</td>
<td>610</td>
</tr>
<tr>
<td>9</td>
<td>Chlorine (Cl) (ppm)</td>
<td>248.50</td>
</tr>
<tr>
<td>10</td>
<td>Sulphate ion (SO$_4$) (ppm)</td>
<td>5.60</td>
</tr>
</tbody>
</table>

3.2 EXPERIMENTAL MATERIAL AND SYSTEM DETAILS

The resources, materials and system details required for conducting the experiment are shown Table 3.3.

<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 m$^3$/h 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/cm$^2$ range</td>
</tr>
<tr>
<td>8</td>
<td>Main line</td>
<td>PVC pipe of 75 mm × 4 kg/cm$^2$</td>
</tr>
<tr>
<td>9</td>
<td>Sub main line</td>
<td>PVC pipe of 63 mm × 4 kg/cm$^2$</td>
</tr>
<tr>
<td>10</td>
<td>Lateral</td>
<td>Emitting Pipe 16 mm x 60 cm x 4 lph</td>
</tr>
</tbody>
</table>
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Other materials used for experiment are PVC fittings and flush valve 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.

3.3 FIELD EXPERIMENTAL DETAIL

The details of experimental design adopted are described as below.

Treatments Details:

(a) **Main factor:** Fertigation levels (F)

(F₁) 40 per cent RDF-N
(F₂) 60 per cent RDF-N
(F₃) 80 per cent RDF-N
(F₄) 100 per cent RDF-N

(b) **Sub factor:** Irrigation by ETₑ (I) with three ratios

(I₁) irrigation with 0.6 ETₑ
(I₂) irrigation with 0.8 ETₑ
(I₃) irrigation with 1.0 ETₑ

(c) **Total treatment combination:** (3 × 4) = 12

Replication: 3

(d) **Statistical Design:** Large plot technique

(e) **Plot Size:** Gross plot: 2.7 m×15 m

Net plot: 1.8 m×4 m

(f) **Spacing:** Crop Spacing: 22.5 cm,

Lateral Spacing: 67.5 cm

3.3.1 **Crop details**

a. Crop: Wheat
b. Variety: GW-496
d. Fertilizer dose per hectare (N: P: K): 120: 60: 60 kg/ha (RDF).
The details of the treatments are depicted in Table 3.4 and experimental layout are presented in Fig. 3.1 & Fig. 3.2.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N- Fertigation level</th>
<th>Irrigation Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>F1 I1 40 per cent RDF-N</td>
<td>0.6 ETc</td>
</tr>
<tr>
<td>T2</td>
<td>F1 I2 40 per cent RDF-N</td>
<td>0.8 ETc</td>
</tr>
<tr>
<td>T3</td>
<td>F1 I3 40 per cent RDF-N</td>
<td>1.0 ETc</td>
</tr>
<tr>
<td>T4</td>
<td>F2 I1 60 per cent RDF-N</td>
<td>0.6 ETc</td>
</tr>
<tr>
<td>T5</td>
<td>F2 I2 60 per cent RDF-N</td>
<td>0.8 ETc</td>
</tr>
<tr>
<td>T6</td>
<td>F2 I3 60 per cent RDF-N</td>
<td>1.0 ETc</td>
</tr>
<tr>
<td>T7</td>
<td>F3 I1 80 per cent RDF-N</td>
<td>0.6 ETc</td>
</tr>
<tr>
<td>T8</td>
<td>F3 I2 80 per cent RDF-N</td>
<td>0.8 ETc</td>
</tr>
<tr>
<td>T9</td>
<td>F3 I3 80 per cent RDF-N</td>
<td>1.0 ETc</td>
</tr>
<tr>
<td>T10</td>
<td>F4 I1 100 per cent RDF-N</td>
<td>0.6 ETc</td>
</tr>
<tr>
<td>T11</td>
<td>F4 I2 100 per cent RDF-N</td>
<td>0.8 ETc</td>
</tr>
<tr>
<td>T12</td>
<td>F4 I3 100 per cent RDF-N</td>
<td>1.0 ETc</td>
</tr>
</tbody>
</table>
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Fig. 3.2 Layout showing treatment and crop detail
3.4 AGRONOMICAL PRACTICES

3.4.1 Preparation of field

Soil was brought to fine tilt by two ploughing with rotary tiller (rotavator). Stubbles of previous crops were collected and removed from the experiment field. Beds of 2.7 m x 15 m size were prepared before sowing of seeds. Irrigation channel were prepared to facilitate common irrigation to all treatments.

3.4.2 Sowing of wheat

Sowing of wheat seed at 22.5 cm row to row spacing was done on 17\textsuperscript{th} November, 2017 by tractor mounted seed cum fertilizer drill as shown in plate 3.2

![Plate 3.2 Sowing of wheat](image)

3.4.3 Drip irrigation 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 functioning of the system. Therefore, bypass assembly of 75 mm was fitted on main line after the conveyance pipe connection with the main line.
Irrigation water filtering was done to sustain the life of the drip irrigation system and to alleviate from clogging effect. Screen filter with filtering capacity 25 m$^3$/hr was adopted in present system. Pressure gauge of 0-4 kg/cm$^2$ was used for measuring the operating pressure in the main line. PVC pipe of 75 mm × 4 kg/cm$^2$ was used as main line and 63 mm × 4 kg/cm$^2$ was used as a sub main line. Heavy duty black coloured LLDPE emitters line of 16 mm × 60 cm × 4 lph was used to irrigate the crop. The
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emitting pipe was spaced at 0.67 m. Lateral cock of 16 mm at the starting of lateral line was adopted to control the irrigation water application.

Plate 3.5 View of experimental field

Plate 3.6 Field visit by committee members
3.5 IRRIGATION SCHEDULING

3.5.1 Calculation of Reference Evapotranspiration, ET₀

Water is a scarce natural resource. A clear understanding of various terms on compass in the water balance is essential for exploring water saving measures. However, one of the most important aspects of water balance is evapotranspiration (ET); unfortunately, this is also one of the most difficult parameter to measure in the field. The most frequently used in this sense is the FAO-24 concept (Doorenbos and Pruitt, 1977), which is updated by Allen, 1998. In FAO-24 four levels have been recommended, but many other levels have been developed and tested. Researches have revealed weaknesses in the FAO-24 and have proven a global validity of Penman–Monteith level for predicting the reference ET. Results of Jensen et al. (1990) indicated that Penman–Monteith showed excellent performance in both arid and humid climates, while the FAO Penman level overestimated in both the climatic conditions. The FAO-24 radiation level estimated quite well in the arid locations but tended to overestimate in the humid locations. All the temperature levels, with the possible exception of the FAO Blaney – Criddle required local calibration. FAO Pan Evaporation levels underestimated by 5% in humid and overestimated by 5 % in arid locations. Allen et al. (1998) showed that the Penman–Monteith equation has provided best estimates of the daily and monthly average reference ET and was the most consistent across all locations, followed by the Kimberley Penman, 1982 and Penman, 1963 equations. The FAO Penman estimated about 15–20 % higher than lysimeters measurement.

One of the method used to estimate ETₖ is the crop coefficient (Kₖ) algorithm. In this approach, adjusted FAO Kₖ was determined for different growth stages and multiplied by evapotranspiration from reference vegetation (ET₀) to compute ETₖ, or

\[ \text{ETₖ} = Kₖ \times \text{ET₀} \]  

...(3.1)

Where, \text{ETₖ} = \text{Crop evapotranspiration}

\[ Kₖ = \text{Crop factor}, \]

\[ \text{ET₀} = \text{Reference evapotranspiration}. \]

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.
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\[ ET_0 = \frac{0.408 \Delta (R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \]  

...(3.2)

Where, \( ET_0 \) is reference evapotranspiration [mm day\(^{-1}\)].

- \( R_n \) 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 [m s\(^{-1}\)],
- \( e_s \) is saturation vapour pressure [kPa],
- \( e_a \) is actual vapour pressure [kPa],
- \( e_s - e_a \) is saturation vapour pressure deficit [kPa],
- \( \Delta \) is slope vapour pressure curve [kPa °C\(^{-1}\)],
- \( \gamma \) is psychrometric constant [kJ Pa °C\(^{-1}\)].

3.5.2 Determination of crop coefficient (\( K_C \)) 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 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 growing 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.
3.5.3 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:

$$K_{C_{ini}} = f_w \times K_{C_{ini \ (tab \ fig)}} \quad \ldots(3.3)$$

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. 3.3), 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 (FAO 56):

$$I_w = \frac{I}{f_w} \quad \ldots(3.4)$$

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. 3.3 Average $K_{C_{ini}}$ as related to the level of $ET_0$ and the interval between irrigations and/or significant rain during the initial growth stage for all soil types when wetting events are

Fig. 3.4 Average $K_{C_{ini}}$ as related to the level of $ET_0$ and the interval between irrigations greater than or equal to 40 mm per wetting event, during the
light to medium (3-10 mm per event) 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. 3.3 and Fig. 3.4.

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

… (3.5)

Where, $K_{C_{ini}}$ (Fig.3.3) is value for $K_{C_{ini}}$ from Fig.3.3; $K_{C_{ini}}$ (Fig.3.4) is value for $K_{C_{ini}}$ from Fig. 3.4 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. 3.3 and Fig. 3.4 are based.

The crop coefficient of wheat crop as per FAO is 0.70, 1.15 and 0.25 for $K_{C_{ini}}$, $K_{C_{mid}}$ and $K_{C_{end}}$, respectively from FAO 56 for drip irrigated wheat 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.

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

… (3.6)

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

… (3.7)

Where, $K_{C_{mid}(tab)} = Value of K_{C_{mid}}$ taken from Table 12(FAO 56),

$K_{C_{end}(tab)} = Value of K_{C_{end}}$ taken from Table 12(FAO 56),

$u_2 = mean value of daily wind speed at 2 m height over grass during the mid-season growth stage (m/s), for 1 m/s \leq u_2 \leq 6 \text{ m/s};$

$RH_{min} = mean value of daily minimum relative humidity;$

$h = mean plant height during the mid-season.
3.5.4 Total irrigation water requirement

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

\[ IW = L \times ET_c \]  

...(3.8)

Where, \( IW = \) Depth of water to be applied (mm/day).

\( L = \) level of irrigation (L=1 i.e. 100% of crop water requirements).

\( ET_c = \) crop evapotranspiration (mm/day).

3.5.5 Water application rate

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

\[ \text{Irrigation Rate (mm/hr)} = \frac{\text{Dripper Discharge (lph)}}{\text{Lateral Spacing (m)} \times \text{Dripper Spacing (m)}} \]  

...(3.9)

3.5.6 Time of operation

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

\[ \text{Irrigation time (h)} = \frac{\text{Water requirement (mm/day)} \times \text{Interval (days)}}{\text{Irrigation rate (mm/h)}} \]  

...(3.10)

3.6 FERTILIZER APPLICATION

The recommended dose of phosphorus @ 60 kg P₂O₅ ha⁻¹ and potassium @ 60 kg K₂O ha⁻¹ were applied as basal dose in the form of single super phosphate and muriate of potash, respectively. Nitrogen (urea) was applied at weekly interval up to 64 days as per treatments. The weekly dose of nitrogen was applied as per following percentage during various growth stage.

Table 3.6: Nitrogen schedule for wheat crop

<table>
<thead>
<tr>
<th>DAS</th>
<th>Nitrogen (%)</th>
<th>Recommended dose of N-fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N kg/ha</td>
<td>40% RDF-N</td>
</tr>
<tr>
<td></td>
<td>Urea kg/ha</td>
<td>N kg/ha</td>
</tr>
<tr>
<td>Basal</td>
<td>10</td>
<td>4.8</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>7.2</td>
</tr>
<tr>
<td>16-22</td>
<td>15</td>
<td>7.2</td>
</tr>
<tr>
<td>23-29</td>
<td>15</td>
<td>7.2</td>
</tr>
<tr>
<td>30-36</td>
<td>15</td>
<td>7.2</td>
</tr>
<tr>
<td>37-43</td>
<td>10</td>
<td>4.8</td>
</tr>
<tr>
<td>44-50</td>
<td>10</td>
<td>4.8</td>
</tr>
<tr>
<td>51-57</td>
<td>5</td>
<td>2.4</td>
</tr>
<tr>
<td>58-64</td>
<td>5</td>
<td>2.4</td>
</tr>
<tr>
<td>100</td>
<td>48</td>
<td>104</td>
</tr>
</tbody>
</table>
3.6.1 Determination of available nitrogen

Available nitrogen in the soil was determined by Alkaline KMnO₄ methods which describe as below.

I. Weight 20 gm of soil and transfer it into a distillation flask. Add 200 ml water.

II. Add 100 ml 0.32% KMnO₄ solution in distillation flask; then put it on the distillation stand. Take 25 ml of 4% boric acid into a 250 ml beaker, add 2-3 drops of mixed indicator and put it under the condenser.

III. Add 100 ml 2.5% NaOH solution in distillation flask in such a way, so that it runs down from the neck to the bottom of the flask without mixing. Fix-up the head air tightly.

IV. Light the burner and collect the ammonia in boric acid solution to about 150 ml. Titrate it with 0.1 N H₂SO₄. Colour is changed from bluish to pinkish red and calculate the available nitrogen in percent, ppm and kg/ha.

**Calculation:**

\[
1 \text{ ml } 0.01 \text{ N H}_2\text{SO}_4 = 0.00014 \text{ g N}
\]

\[
\% \text{ Available N} = \frac{R \times 0.00014 \times 100}{\text{Weight of soil}}
\]

ppm available N = \% available N ×10000

Available N in kg/ha = ppm N×2.24

**Plate 3.7 Nitrogen analysis**
3.7 PEST, DISEASE AND WEED CONTROL

Spraying of pendimethalin 30 % EC Stomp after common surface irrigation to whole treatments to keep the weeds under check.

3.8 HARVESTING OF CROP

The crop period of wheat is about 110-120 days. The plant height was measured from each treatment before harvest. The harvesting of wheat crop was done manually with the help of sickle. Plants were harvested and tied with string for making bunch of plants. After harvesting all bunches of plants were kept in open field treatment for 4-5 days for drying. After that biological yield and grain yield were calculated with calibrations.

Plate 3.8 Experimental field view at harvesting time
3.9 OBSERVATIONS RECORDED

3.9.1. Plant height: Individual plant height was measured in centimetre (cm) from top to ground by measuring tape. The mean value of 5 plants were worked out for calculation by following formula.

\[ PH_{ij} = \frac{\sum ph_{ij}}{5} \]  

...(3.11)

Where, \( PH_{ij} \) = Average plant height under treatment-i and replication-j, (cm)

\[ \sum ph_{ij} = \text{Summation of 5 plants height uprooted from plot of treatment-i and replication-j, (cm)} \]

3.9.2 Ear length: Five ears were randomly selected from the sampled plants at harvest and length was measured from the base to the tip of the ear. Awns were not included in the ear length measurement. The mean was worked out and expressed in cm.

3.9.3 No. of grains per ear: The five ears selected randomly for measuring the ear length were used for recording the number of grains per ear. These ears were threshed separately and mean number of grains per ear was recorded.
3.9.4 No. of tillers per m$^2$: Number of tillers per m$^2$ was counted at maturity from 1 m$^2$ area in each treatment.

3.9.5 No. of ears per m$^2$: Number of ear per m$^2$ was counted at maturity from 1 m$^2$ area in each treatment.

3.9.6 Test weight: From the grain sample of each net plot, 1000 grains were selected at random and their weight was recorded in grams (g).

3.9.7 Grain yield: The yield of the crop was calculated based on the treatment plot data for each replication as below.

$$ Y_{gij} = \frac{W_{gij}}{A_{ij}} \times 10000 \quad \ldots (3.12) $$

Where, $Y_{gij}$ = Grain yield of wheat under treatment- i and replication-j, (kg/ha).

$W_{gij}$ = Weight of wheat grain produced from plot of treatment-i and replication-j, (kg).

$A_{ij}$ = Plot area of treatment-i and replication-j, (m$^2$).

3.9.8 Straw yield: The straw yield was calculated similar to grain yield as below.

$$ Y_{sij} = \frac{W_{sij}}{A_{ij}} \times 10000 \quad \ldots (3.13) $$

Where, $Y_{sij}$ = Straw yield of wheat under treatment-i and replication-j (kg/ha)

$W_{sij}$ = Weight of wheat straw produced from plot of treatment-i and replication-j (kg).

$A_{ij}$ = Plot area of treatment-i and replication-j (m$^2$).

3.9.9 Harvest Index: Harvest index was calculated from grain and biomass yield by using the following formula and expressed in percentage.

$$ \text{Harvest Index} (\%) = \frac{\text{Grain yield, kg/ha}}{\text{Biological yield, kg/ha}} \times 100 \quad \ldots (3.14) $$

3.9.10 Biological yield: The biological yield of the crop was calculated based on the treatment plot data for each replication as below.

$$ Y_{bij} = \frac{W_{bij}}{A_{ij}} \times 10000 \quad \ldots (3.15) $$

Where, $Y_{bij}$ = Biological yield of wheat under treatment-i and replication-j, (kg/ha).
Materials and methods

\[ \text{Wb}_{ij} = \text{Weight of wheat grain produced from plot of treatment-i and replication-j, (kg)}. \]

\[ \text{A}_{ij} = \text{Plot area of treatment-i and replication-j, (m}^2). \]

### 3.10 FERTILIZER USE EFFICIENCY

The fertilizer use efficiency (FUE) was computed as

\[ \text{FUE}_{ij} = \frac{\text{Yg}_{ij}}{\text{F}_{ij}} \quad \text{...(3.16)} \]

Where,

- \( \text{FUE}_{ij} \) = Fertilizer use efficiency of wheat seed under treatment- i and replication-j
- \( \text{Yg}_{ij} \) = Yield of wheat seed under treatment- i and replication-j, (kg/ha).
- \( \text{F}_{ij} \) = Total quantity of fertilizer applied in treatment- i and replication-j, (kg/ha).

### 3.11 WATER USE EFFICIENCY

The water use efficiency is the yield of wheat seed produced per unit water application. Water use efficiency will be calculated as the quantity (kg) of wheat seed production per ha-mm of water.

\[ \text{WUE}_{ij} = \frac{\text{Yg}_{ij}}{\text{W}_{ij}} \quad \text{...(3.17)} \]

Where,

- \( \text{WUE}_{ij} \) = Water use efficiency of wheat seed under treatment- i and replication-j, (kg/ha-mm).
- \( \text{Yg}_{ij} \) = Yield of wheat seed under treatment- i and replication-j, (kg/ha).
- \( \text{W}_{ij} \) = Seasonal irrigation water applications in treatment- i and replication-j, (mm).

### 3.12 STATISTICAL ANALYSIS

Experimental was laid out as per large plot technique and data analysis was carried out as per Factorial Completely Randomized Design (FCRD) (Panse and Sukhatme, 1985).

### 3.13 ECONOMICS

The economics of Wheat cultivation included the total cost and total return per unit area.
3.13.1 Total Cost of cultivation

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

\[ TCC = CCC + VCC + CI \]  \hspace{1cm} (3.18)

Where, TCC = Total cost of wheat cultivation (₹/ha/season),

CCC = Common cost of wheat cultivation (₹/ha/ season),

VCC = Variable cost of cultivation (₹/ha/ season),

CI = Cost of irrigation (₹/ha/ season).

\[ CI = FCI + VCI \]  \hspace{1cm} (3.19)

Where, FCI = Fixed cost of irrigation (₹/ha/ season)

VCI = Variable cost of irrigation (₹/ha/ season)

3.13.2 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, fungicides, pesticides, insecticides etc.

3.13.3 Variable cost of cultivation

Variable cost of cultivation (VCC) includes cost of fertilizer.

3.13.4 Fixed Cost of Irrigation

The fixed cost of irrigation (FCI) for all drip irrigation treatments included the cost of pumping unit and drip irrigation system and its installation.

The FCI was calculated as below:

\[ FCI = SC_{ps} + SC_{is} \]  \hspace{1cm} (3.20)

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

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

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

\[ SC_{ps} = \frac{PVPS \times i \times (1+i)^m}{(A \times s) \left[(1+i)^m - 1\right]} \]  \hspace{1cm} (3.21)
Where, PVPS = Present value of the pumping unit (₹)

\[ m = \text{Life of the pumping system, 15 years} \]

\[ i = \text{Prevailing rate of interest (fraction), 0.10} \]

\[ A = \text{Total area commanded by the pumping unit in a season (ha)} \]

\[ s = \text{Number of season per year to which the pumping system can be used} \]

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

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

\[
\text{SC}_{is} = \frac{\text{PVIS} \times i \times (1+i)^n}{s \left[ (1+i)^n - 1 \right]} \quad \text{...(3.22)}
\]

Where, PVIS = Present value of the irrigation system (₹/ha),

\[ i = \text{Prevailing rate of interest (fraction), 0.10} \]

\[ n = \text{life of the irrigation system, 10 years} \]

\[ s = \text{Number of season for which the irrigation system be used.} \]

The PVIS included the purchase cost of all required drip irrigation systems’ items for one hectare. The seasonal cost of irrigation system (SC_{is}) included PVC main line, PVC sub-main line, PVC valves, grommet, take off, pressure gauge, lateral, emitters, filter etc.

### 3.13.5 Variable cost of irrigation

Variable cost of irrigation (VCI) was calculated by considering the application rate, depth and time of application. The variable cost of irrigation (VCI) includes operational cost towards the labour and electricity for pumping, conveyance and irrigation application and maintenance charges. The variable cost of irrigation was calculated by taking water charges as ₹33 at the rate of ₹5 per unit of electricity consumed.
3.13.6 Gross Income

The gross income in terms of ₹ per hectare was calculated from the wheat grain and straw yield at the prevailing market price. (₹17.50 per kg for grain yield and ₹1.50 per kg for straw).

3.13.7 Net Income

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

3.13.8 Benefit Cost Ratio

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