CHAPTER 3

MATERIALS AND METHODS

The present investigation ‘Studies on Enhancing the Productivity and Profitability of Wheat and Mentha Intercropping under Different Methods of Crop Establishment’ was carried out under the Faculty of Agriculture and Forestry, Guru Nanak Dev University, Amritsar during the cropping seasons of 2006-07 and 2007-08. The experiments were conducted at village Dalla of Block Qadian on the farm of Punjab Naujwan Kisan Sanstha’s member adopted by Farm Advisory Service Scheme (FASS), Punjab Agricultural University, Gurdaspur.

3.1 CLIMATE

The ‘Dalla’ is an important agricultural village of Block Qadian in District Gurdaspur, which is situated at 31° 45’N latitude and 75° 20’ E longitude at an altitude of 252 meters above mean sea level. This tract experiences three distinct seasons in a year namely dry summer (March to June), hot and humid rainy season (July to October) and cold and relatively moist winter (November to February). In summer season, the temperature touches 44°C or even sometimes crosses it. Dust storm occurs during May and June while frosty spells are common during December and January. The annual precipitation of the area is 1113 mm and about 80 percent of it is received during summer monsoon period from July to September. Occurrence of few showers of rains is common during December-January.

3.2 WEATHER DURING CROP SEASON

The meteorological data recorded at Agro-meteorological observatory of Punjab Agricultural University, Regional Research Station, Gurdaspur for crop growing seasons 2006-07 and 2007-08 are presented in Appendix I and II and Fig. 1 and 2. The weekly meteorological data indicated that during crop growing season of 2006-07, the minimum temperature ranged between 0.82°C to 24.8°C (-0.9°C to 25.2°C on daily basis) for wheat and 7.2°C to 32.4°C (6.9°C to 35.1°C on daily basis) for mentha while maximum temperature ranged between 9.8°C to 34.4°C (9.1°C to 36.1°C on daily basis) for wheat and 15.3°C to 39.2°C (12.7°C to 40.9°C on daily basis) for mentha. Mean minimum and maximum temperature remained between 6.9°C to 29.6°C (6.1°C to 30.7°C on daily basis) for wheat and 11.2°C to 35.8°C (11.1°C to 37.7°C on daily basis) for mentha. The weekly data recorded during
Fig. 1: Weekly meteorological data during the crop growth season 2006-07
Fig. 2: Weekly meteorological data during the crop growth season 2007-08
wheat growing season in 2007-08 indicated that minimum temperature ranged between 1.2°C to 23.9°C (0.1°C to 24.6°C on daily basis) for wheat and 6.2°C to 30.4°C (4.0°C to 33.1°C on daily basis) for mentha while maximum temperature ranged between 10.9°C to 29.2°C (9.8°C to 31.1°C on daily basis) for wheat and 11.1°C to 38.8°C (11.1°C to 39.2°C on daily basis) for mentha. Mean minimum and maximum temperature remained between 6.0°C to 26.4°C (5.3°C to 27.8°C on daily basis) for wheat and (9.2°C to 37.5°C on daily basis) for mentha. During 2006-07, the total rainfall received during the crop growing season of wheat and mentha was 266.8 mm whereas it was 156.4 mm and 247.0 mm for wheat and mentha alone, respectively. Mentha after wheat harvest received 110.4 mm of rainfall. Crop growing season of wheat and mentha during 2007-08 received 466.3 mm rainfall while in wheat and mentha alone, it was 95.6 mm and 415.3 mm, respectively. Mentha after wheat harvest received 370.7 mm of rainfall. Pattern of rainfall was normal during 2006-07 and remained favorable for the growth and development of wheat and mentha. During 2007-08, rainfall received from 23rd to 28th standard week (120 DAP to harvest stage of mentha) was higher than the year 2006-07 and remained remarkably good for the development of mentha on beds but adversely affected mentha crop on flat situation. Effect of maximum, minimum and mean air temperature was favourable for the overall growth and development of both wheat and mentha during both the years.

### TABLE 1

CROPPING HISTORY OF EXPERIMENTAL FIELD

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop season</th>
<th>Kharif</th>
<th>Rabi</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment I</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004-05</td>
<td></td>
<td>Rice</td>
<td>Wheat</td>
</tr>
<tr>
<td>2005-06</td>
<td></td>
<td>Rice</td>
<td>Wheat</td>
</tr>
<tr>
<td>2006-07 (Experiment)</td>
<td></td>
<td>Rice</td>
<td>Wheat + mentha</td>
</tr>
<tr>
<td>2007-08 (Experiment)</td>
<td></td>
<td>Fallow</td>
<td>Wheat + mentha</td>
</tr>
<tr>
<td><strong>Experiment II</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004-05</td>
<td></td>
<td>Rice</td>
<td>Wheat</td>
</tr>
<tr>
<td>2005-06</td>
<td></td>
<td>Rice</td>
<td>Wheat</td>
</tr>
<tr>
<td>2006-07 (Experiment)</td>
<td></td>
<td>Rice</td>
<td>Wheat + mentha</td>
</tr>
<tr>
<td>2007-08 (Experiment)</td>
<td></td>
<td>Fallow</td>
<td>Wheat + mentha</td>
</tr>
</tbody>
</table>
3.3 COLLECTION OF SOIL SAMPLES

The soil samples were taken with posthole augur from 0-15 and 15-30 cm depth from five places each in experimental site I and experimental site II. The soil samples of respective depths were mixed separately to get a composite sample for each site and representative samples were analyzed for soil physical and chemical properties.

3.3.1 Mechanical analysis of soil

Mechanical analysis (Table 2) of soil was done by using International Pipette Method and the results have shown that the soil of the both experimental fields was silty clay loam in texture.

3.3.2 Chemical analysis

Chemical analysis of the experimental soils in Experiment I and Experiment II (Table 2) indicated that the soil was normal in reaction and non-saline, high in organic carbon, low in available nitrogen, high in available phosphorous and potassium at 0-15 cm

<table>
<thead>
<tr>
<th>Soil Property</th>
<th>Soil Depth (cm)</th>
<th>Method Used</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-15</td>
<td>15-30</td>
</tr>
<tr>
<td>Mechanical analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand (%)</td>
<td>40.5</td>
<td>40.9</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>32.7</td>
<td>31.7</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>26.8</td>
<td>27.4</td>
</tr>
<tr>
<td>Textural class</td>
<td>Silty clay loam</td>
<td>Silty clay loam</td>
</tr>
<tr>
<td>pH</td>
<td>7.9</td>
<td>8.0</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>0.40</td>
<td>0.30</td>
</tr>
<tr>
<td>(d s m⁻¹) at 20°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic carbon (%)</td>
<td>0.88</td>
<td>0.50</td>
</tr>
<tr>
<td>Available N (kg ha⁻¹)</td>
<td>241.9</td>
<td>224.0</td>
</tr>
<tr>
<td>Available P (kg ha⁻¹)</td>
<td>31.8</td>
<td>16.5</td>
</tr>
<tr>
<td>Available K (kg ha⁻¹)</td>
<td>340</td>
<td>309</td>
</tr>
</tbody>
</table>
depth whereas it was medium in organic carbon, low in available nitrogen, medium in available phosphorus and potassium at 15-30 cm depth.

3.4 EXPERIMENTAL DETAILS

The details of the treatments in Experiment I and II are given below and have been diagrammatically presented in fig. 5-9.

3.4.1 Experiment I

Effect of intercropping and planting methods on the productivity of wheat and mentha

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_1$ : Flat planting with two rows of</td>
<td>FP-W+M (2:2) 67.5 cm</td>
</tr>
<tr>
<td>wheat and two rows of mentha on 67.5 cm</td>
<td></td>
</tr>
<tr>
<td>width</td>
<td></td>
</tr>
<tr>
<td>$T_2$ : Flat planting with three rows of</td>
<td>FP-W+M (3:2) 135 cm</td>
</tr>
<tr>
<td>wheat and two rows of mentha on 135 cm</td>
<td></td>
</tr>
<tr>
<td>width</td>
<td></td>
</tr>
<tr>
<td>$T_3$ : Flat planting with four rows of</td>
<td>FP-W+M (4:2) 135 cm</td>
</tr>
<tr>
<td>wheat and two rows of mentha on 135 cm</td>
<td></td>
</tr>
<tr>
<td>width</td>
<td></td>
</tr>
<tr>
<td>$T_4$ : Flat planted wheat sole crop at</td>
<td>FP-Sole-W</td>
</tr>
<tr>
<td>22.5 cm spacing</td>
<td></td>
</tr>
<tr>
<td>$T_5$ : Flat planted mentha sole crop at</td>
<td>FP-Sole-M</td>
</tr>
<tr>
<td>60 cm spacing</td>
<td></td>
</tr>
<tr>
<td>$T_6$ : Bed planting with two rows of</td>
<td>BP-W+M (2:2) 67.5 cm</td>
</tr>
<tr>
<td>wheat and two rows of mentha on 67.5 cm</td>
<td></td>
</tr>
<tr>
<td>width (37.5 cm bed top and 30 cm furrow)</td>
<td></td>
</tr>
<tr>
<td>$T_7$ : Broad Bed planting with three</td>
<td>BBP-W+M (3:2) 135 cm</td>
</tr>
<tr>
<td>rows of wheat and two rows of mentha on</td>
<td></td>
</tr>
<tr>
<td>135 cm width (105 cm bed top and 30 cm</td>
<td></td>
</tr>
<tr>
<td>furrow)</td>
<td></td>
</tr>
<tr>
<td>$T_8$ : Broad Bed planting with four</td>
<td>BBP-W+M (4:2) 135 cm</td>
</tr>
<tr>
<td>rows of wheat and two rows of mentha on</td>
<td></td>
</tr>
<tr>
<td>135 cm width (105 cm bed top and 30 cm</td>
<td></td>
</tr>
<tr>
<td>furrow)</td>
<td></td>
</tr>
<tr>
<td>$T_9$ : Bed planted wheat sole crop at 20</td>
<td>BP-Sole-W</td>
</tr>
<tr>
<td>cm spacing (37.5 cm bed top and 30 cm</td>
<td></td>
</tr>
<tr>
<td>furrow)</td>
<td></td>
</tr>
<tr>
<td>$T_{10}$ : Bed planted mentha sole crop</td>
<td>BP-Sole-M</td>
</tr>
<tr>
<td>at 60 cm spacing on 120 cm bed (90 cm</td>
<td></td>
</tr>
<tr>
<td>bed top and 30 cm furrow)</td>
<td></td>
</tr>
</tbody>
</table>
Materials and Methods

Design: Randomized Complete Block Design
Number of treatments: Ten
Number of replications: Three
Total number of plots: Thirty
Gross plot size: 5.40 m x 8 m = 43.2 m²
Net plot size for wheat in all the treatments: 2.70 m x 6 m = 16.2 m²
Net plot size for mentha in all the treatments except sole mentha: 2.70 m x 6 m = 16.2 m²
Net plot size for sole mentha: 3.0 m x 6 m = 18.0 m²

3.4.2 Experiment II
Effect of crop establishment methods on yield of wheat and mentha intercropping under varied levels of nitrogen

Treatments

(A) Planting Methods
   i) Flat planting with two rows of wheat and two rows of mentha on 67.5 cm width
   ii) Bed planting with two rows of wheat and two rows of mentha on 67.5 cm width (37.5 cm bed top and 30 cm furrow)

(B) Nitrogen Levels
   (i) 0 kg N ha⁻¹ applied to wheat and 0 kg N ha⁻¹ applied to mentha
   (ii) 90 kg N ha⁻¹ applied to wheat and 75 kg N ha⁻¹ applied to mentha
   (iii) 120 kg N ha⁻¹ applied to wheat and 75 kg N ha⁻¹ applied to mentha
   (iv) 150 kg N ha⁻¹ applied to wheat and 75 kg N ha⁻¹ applied to mentha
   (v) 180 kg N ha⁻¹ applied to wheat and 75 kg N ha⁻¹ applied to mentha

Design: Randomized Complete Block Design
Number of treatments: Ten
Number of replications: Three
Total number of plots: Thirty
Gross plot size: 5.40 m x 8 m = 43.2 m²
Net plot size: 2.70 m x 6 m = 16.2 m²
FIG. 3: LAYOUT PLAN OF EXPERIMENT I
FIG. 4: LAYOUT PLAN OF EXPERIMENT II
Fig. 5 Diagrammatic presentation of treatments $T_1$ and $T_2$ in Experiment I
Fig. 6 Diagrammatic presentation of treatments $T_3$ and $T_4$ in Experiment I
**Materials and Methods**

*Fig. 7 Diagrammatic presentation of treatments T₅ and T₆ in Experiment I*

**T₅:** FP-Sole-M

- 60 cm

**T₆:** BP-W+M (2:2) 67.5 cm

- 67.5 cm
- 1.25 cm
- 20 cm
- 15 cm
- 37.5 cm
Materials and Methods

Fig. 8 Diagrammatic presentation of treatments $T_7$ and $T_8$ in Experiment I

$T_7$: BP-W+M (3:2) 135 cm

$T_8$: BP-W+M (4:2) 135 cm
Fig. 9 Diagrammatic presentation of treatments $T_9$ and $T_{10}$ in Experiment I
3.5 **BED PREPARATION AND SIZE**

The land was prepared conventionally and with the help of Bed Planter, the raised beds of 67.5 and 135 cm were prepared by keeping 37.5 and 105 cm as the top of the bed, respectively, with furrows of 30 cm. In the centre of bed top, two, three or four rows of wheat were sown as per treatment keeping 20 cm row to row spacing. Irrigation water was applied in the furrows in between the beds. Water was not allowed to reach to the top of the bed, by applying 5 cm irrigation.

3.6 **CULTURAL OPERATIONS**

3.6.1 **Preparatory tillage**

After application of pre-sowing irrigation (*rauni*), when the field attained proper soil moisture condition, it was ploughed twice with cultivator followed by planking and again tilled once with tractor drawn cultivator and planked.

3.6.2 **Sowing/planting**

3.6.2.1 **Wheat**

In both the experiments, variety PBW 502 was sown on November 3 and 5 during 2006-07 and 2007-08, respectively. The seeding was done in solid drill rows on the ‘Flat’ and with the help of bed maker-cum-planter seed drill on the ‘Beds’. In the experiment I, seeding was done at row spacing of 20 cm using 75 kg seed ha$^{-1}$ in all the treatments except T$_4$ where it was sown at a row spacing of 22.5 cm (Flat) using 100 kg seed ha$^{-1}$. Among intercropping systems, all the ‘Bed’ sown row arrangements were exactly similar as followed in the ‘Flat’ situation. In Experiment II, seed rate of 75 kg ha$^{-1}$ was used both in ‘Flat’ and ‘Bed’ planted treatments. The layout plan with treatment allocation has been given in Fig. 3 and Fig.4.

3.6.2.2 **Mentha**

Planting of mentha variety ‘Kosi’ was accomplished on February, 7 and 10 during 2006-07 and 2007-08, respectively. In T$_6$, T$_7$ and T$_8$, two rows of mentha suckers were planted on the outer sides of the wheat rows on the bed top leaving 7.5 cm from the edge of the bed. Similar method of sowing was followed in T$_1$, T$_2$ and T$_3$ under flat situation. For sole mentha in ‘Flat’ (T$_5$) and ‘Bed’ (T$_{10}$) 60 cm row spacing was maintained. A seed rate of 375 kg ha$^{-1}$ was used for sole mentha crop on flat (T$_5$) and bed planting (T$_{10}$). On
67.5 cm flat and bed sown treatments (T₁ and T₆), mentha was planted by using a seed rate of 665 kg ha⁻¹, while, a seed rate of 333 kg ha⁻¹ was used in T₂ and T₃ (135 cm flat) and T₇ and T₈ (broad bed of 135 cm).

3.6.3 Fertilizer application

In the experiment I, recommended dose of 123.5 kg N and 61.8 kg P₂O₅ ha⁻¹ was applied to the wheat crop and 75 kg N ha⁻¹ to the intercropped mentha. In wheat, one-half of N and whole P were broadcast just before sowing of wheat and the remaining one-half of N was applied as top dressing after first irrigation. In mentha crop, out of the total N (75 kg ha⁻¹), one-half N was applied along the mentha rows at the time of planting. The remaining one-half of N was top dressed to mentha after the harvest of wheat crop. Under flat planting, the top dressing of fertilizer N was done through uniform broadcasting to both the crops, but in bed treatments it was applied on the bed top only.

In the Experiment II, nitrogen fertilizer was applied to wheat and mentha as per the treatment using the same method as detailed in the Experiment I. Phosphorus was applied only to the wheat crop as in the Experiment I. Source of N and P were urea and diammonium phosphate (DAP), respectively.

3.6.4 Irrigation

During both the years, first irrigation was applied 25 days after sowing of wheat. Second, third and fourth irrigations were given at boot, jointing and milk stages, respectively. One additional irrigation was also given in the second year a fortnight before harvesting of wheat. In case of bed, irrigation water was applied in the furrows and it was not allowed to reach to the top of the bed, by applying 5 cm irrigation on plot area basis.

Wheat received 4 irrigations during the year I and 5 during year II. Mentha which was planted in February shared 2 and 3 irrigations with wheat during the respective years. After the harvest of wheat, mentha received 9 and 6 irrigations during the year I and II, respectively. In total, wheat and mentha intercropping system received 13 (2+2+9) irrigations and 11 (2+3+6) irrigations during first and second years, respectively (Table 3).
TABLE 3

IRRIGATION APPLIED TO WHEAT-MENTHA INTERCROPPING SYSTEM

<table>
<thead>
<tr>
<th>Crops</th>
<th>2006-07</th>
<th>2007-08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat (Before mentha planting)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Wheat+Mentha (Upto harvesting of wheat)</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Mentha (After the harvest of wheat)</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Total irrigation to mentha</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Total irrigation to wheat+mentha combined</td>
<td>13</td>
<td>11</td>
</tr>
</tbody>
</table>

3.6.5 Weed control

For the control of *Phalaris minor* in wheat, the post-emergence herbicide ‘Topik’ (Clodinafop 15 WP) was applied at the rate of 400 g ha\(^{-1}\) at 35 days after sowing. For the control of weeds in mentha, one hand hoeing was given immediately after the harvest of wheat crop.

3.6.6 Plant protection

Two sprays of Thiodan 35 EC (Endosulfan) @ 2.5 litre ha\(^{-1}\) in 500 liters water were applied to control the foliage pests of mentha during year I and year II.

3.6.7 Harvesting

The wheat and mentha were harvested manually on April 13 and June 26 during 2006-07 and on April 19 and July 10 during 2007-08, respectively.

3.6.8 Threshing

Threshing of wheat was done with engine operated thresher. The grains were cleaned and weighed separately treatment wise.

The herbage of mentha was collected and dried for two days. Afterwards, it was taken to mentha oil distillation plant at Ramgarh (District Jalandhar) for distillation of oil during both the years of study.

3.7 OBSERVATIONS

3.7.1 Wheat

3.7.1.1 Emergence count

Number of seedlings emerged in one meter row length from two spots in each plot were counted at 15 days after sowing and then expressed as number of plants m\(^{-2}\).
3.7.1.2 **Plant height**

The height of ten randomly selected plants from each plot was measured at 60, 90, 120 days after sowing and at harvest stage. The height was measured from the ground level to the base of last fully opened leaf during early stages and to the base of the ear at harvest. The mean of ten observations was expressed in centimetres (cm).

3.7.1.3 **Dry matter accumulation**

In Experiment I, the plant samples were collected by harvesting the 50 cm row length having a width of 67.5 cm for $T_1$, $T_4$, $T_6$ and $T_9$ and 135 cm x 50 cm for $T_2$, $T_3$, $T_7$ and $T_8$ at 60, 90, 120 days after sowing and at harvest stage. The whole aboveground portion of the plant was taken and sun dried. The sun-dried samples were then oven dried at 60$\pm$2º C to constant weight and dry matter accumulation was expressed as q ha$^{-1}$. Similarly, in the Experiment II, the plant samples were collected from an area of 67.5 cm x 50 cm and after oven drying, expressed as q ha$^{-1}$.

3.7.1.4 **Total tillers**

In Experiment I, the total tillers were counted from two spots at 60, 90, 120 days after sowing and at harvest stage from 67.5 cm x 50 cm in $T_1$, $T_4$, $T_6$ and $T_9$ and from 135 cm x 50 cm in $T_2$, $T_3$, $T_7$ and $T_8$ and were converted to one square metre. In the Experiment II, the data was recorded from 67.5 cm x 50 cm area for all the treatments and converted to one square metre.

3.7.1.5 **Effective tillers**

For Experiment I, the tillers bearing ears termed as effective tillers were counted from two spots in the plots at harvest from 67.5 cm x 50 cm in $T_1$, $T_4$, $T_6$ and $T_9$ and from 135 cm x 50 cm in $T_2$, $T_3$, $T_7$ and $T_8$ and were converted to one square metre. For Experiment II, the data was recorded from 67.5 cm x 50 cm area and converted to one square metre.

3.7.1.6 **Ear length**

Ten spikes were selected at random from each plot and length was measured from the base to tip (excluding awns) before harvesting of the crop. The average of ten spikes was calculated and presented as ear length in centimetres (cm).

3.7.1.7 **Number of grains per spike**

The number of grains per spike was recorded from ten randomly selected ear heads from each plot. The seeds were counted and the average of the ten was calculated and presented as number of grains per spike.
3.7.1.8 Test weight

One thousand grains were counted from the randomly selected grains from each sample and then weighed to get 1000-grain weight in grams (test weight).

3.7.1.9 Grain yield

The harvested crop from the net plot size was threshed and expressed in quintals per hectare.

3.7.1.10 Straw yield

It was calculated by deducting the grain yield from the total above ground biological yield in kg per plot (bundle weight before threshing) from each treatment and expressed as quintals per hectare.

3.7.1.11 Biological yield

The total of grain and straw yield from each treatment was shown as biological yield in quintals per hectare.

3.7.1.12 Lodging score

At harvest stage, lodging score was calculated with the formula as given by Fischer and Stapper (1987).

\[
\text{Lodging score} = \frac{\left(\% \text{ plot area lodged} \times \text{angle of lodging from the vertical}\right)}{90}
\]

3.7.2 Mentha

3.7.2.1 Biometrical studies

3.7.2.1.1 Plant height

Five plants were selected at random from each experimental plot to record the periodic plant height at 60, 90, 120 days after planting and at harvest stage. Height was measured from ground level up to the base of the uppermost leaf on the main shoot.

3.7.2.1.2 Stools

For the Experiment I, the number of stools from two spots were counted from an area of 67.5 cm x 50 cm in T_1 and T_6, 135 cm x 50 cm area in T_2, T_3, T_7 and T_8 and 60 cm x 50 cm area in T_5 and T_10 at 60, 90, 120 days after sowing and at harvest stage. The recorded stools were presented as number of stools m^{-2}.

3.7.2.1.3 Dry matter accumulation

Dry matter accumulation was recorded from an area of 67.5 cm x 50 cm in T_1 and T_6 and from 135 cm x 50 cm area in T_2, T_3, T_7 and T_8 and from 60 cm x 50 cm area in T_5 and T_10 at 60, 90, 120 days after planting and at harvest stage. The whole aboveground
portion of the plant was taken and sun dried. The sun dried samples were then oven dried at 60±2°C to constant weight and expressed as q ha\(^{-1}\).

3.7.2.1.4 Leaf: Stem ratio

Leaves and stems of 200 g fresh herbage sample from each plot were separated and weighed after drying first under the sun and then in oven at 60±2°C to constant weight, at 90, 120 days after planting and at harvest.

\[
\text{Leaf: Stem ratio} = \frac{\text{Leaf weight}}{\text{Stem weight}}
\]

3.7.2.1.5 Fresh herbage yield

The crop was harvested at 5-6 cm above ground level from each plot. The weight of fresh herbage from the net plot area was recorded immediately after harvesting and expressed as q ha\(^{-1}\).

3.7.2.2 Laboratory studies

3.7.2.2.1 Essential oil content

The essential oil content was distilled at harvest stage using 500 g fresh herbage of each treatment with Clevenger’s distillation method (A.O.A.C., 1975) and expressed as percentage (v/w) on fresh weight basis.

3.7.2.2.2 Essential oil yield

Essential oil yield under different treatments was computed by multiplying herbage yield (q ha\(^{-1}\)) at harvest with essential oil content (%) and expressed in litres per hectare.

3.7.2.2.3 Physico-chemical properties of oil

Physico-chemical properties (specific gravity, optical rotation, refractive index and menthol content) of \textit{M. arvensis} oil were determined according to the methods given by Indian Standards Institution, IS 326-1928.

3.7.2.2.3.1 Specific gravity

The specific gravity of the mentha oil was determined at room temperature with the help of specific gravity bottle and converted to 30°C using the correction factor ±0.00076 for each degree centigrade change in temperature. For temperature higher than 30°C, correction factor was added and vice versa.

3.7.2.2.3.2 Refractive index

The refractive index of oil was determined at room temperature by using Abbe refractometer and corrected at 30°C using the correction factor of ±0.00040 for each
3.7.2.3.3 Optical rotation

The optical rotation of essential oil was determined with Polarimeter having ‘D’ line of sodium (double at 5890 Å) by using the Polarimeter tube of 100 mm length.

3.7.2.3.4 Menthol content

The menthol content was estimated with Gas Chromatography from the Quality Control and Quality Assurance Laboratory, IIIM (CSIR), Jammu.

3.7.3 Nitrogen studies

3.7.3.1 Nitrogen content

Oven dried samples were ground in Willey’s mill to pass through 32 mesh sieve and analyzed for nitrogen content as per the method given by Subbiah and Asiza (1956).

Procedure

Nitrogen content in plant samples was determined by modified Micro Kjeldhal’s method given by Subbiah and Asiza (1956). For determination of nitrogen content, wet digestion method was used. Oven dried sample (0.5g) from each treatment was subjected to wet digestion using concentrated sulphuric acid, potassium sulphate, copper sulphate and selenium powder. Digested material was taken in 50 ml volumetric flask and volume was made to 50 ml with distilled water and filtered. Five ml of the filtrate was taken in a distillation tube of Micro Kjeldahl’s assembly and then 10 ml NaOH was poured into the tube. Flask containing 5 ml boric acid was kept under the condenser until the appearance of purple colour. Then distilled sample was titrated against the N/70 H$_2$SO$_4$ until the appearance of pink colour. Final volume of N/70 H$_2$SO$_4$ used, was taken for final calculation.

3.7.3.2 Nitrogen uptake

Nitrogen uptake by wheat grain and straw was computed by multiplying grain yield (q ha$^{-1}$) and straw yield (q ha$^{-1}$) with their respective per cent nitrogen content and expressed as kg ha$^{-1}$ whereas in mentha, it was computed by multiplying dry matter of mentha (q ha$^{-1}$) with per cent nitrogen content and expressed as kg ha$^{-1}$.
3.7.4 Growth analysis

3.7.4.1 Crop growth rate (CGR)

Crop growth rate of wheat and mentha was calculated at 60-90 DAS, 90-120 DAS and 120 DAS-harvest stages by using the following formula and it was expressed in kg ha\(^{-1}\) day\(^{-1}\).

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

where, \(W_1\) and \(W_2\) referred to dry matter weight of plants at time \(t_1\) and \(t_2\), respectively.

3.7.4.2 Relative growth rate (RGR)

Relative growth rate of wheat and mentha was calculated at 60-90 DAS, 90-120 DAS and 120 DAS-harvest stages by using the following formula and it was expressed in mg g\(^{-1}\) day\(^{-1}\).

\[
\text{RGR} = \frac{(\log W_2 - \log W_1)}{(t_2 - t_1)}
\]

where, \(W_1\) and \(W_2\) were dry matter weight of plants at time \(t_1\) and \(t_2\), respectively.

3.7.5 Assessment of yield advantage parameters in wheat-mentha intercropping system

No single index is capable of giving good comparison of different cropping systems. So, a number of indices are used together to assess the economic viability of the system. The wheat-mentha intercropping system was evaluated in terms of wheat grain equivalent yield, profitability, Land Equivalent Ratio (LER), Land Equivalent Coefficient (LEC), Area Time Equivalent Ratio (ATER), B:C ratio and Production Efficiency as given below:

3.7.5.1 Wheat grain equivalent yield of intercropping system

The wheat grain equivalent yield of intercropping system (q ha\(^{-1}\)) was calculated by the formula as given below:

\[
\text{Wheat grain equivalent yield} = \text{Wheat grain yield (q ha}\(^{-1}\)) + \frac{\text{Mentha essential oil yield (l ha}\(^{-1}\)) \times \text{Price (Rs l}\(^{-1}\))}{\text{Price of wheat (q ha}\(^{-1}\))}
\]

3.7.5.2 Profitability (Rs ha\(^{-1}\))

Profitability = Gross returns – cost of cultivation
3.7.5.3 Land equivalent ratio (LER)

The land equivalent ratio (LER) was calculated as described by Willey (1979). LER is often the indicator used in determining the efficacy of intercropping. LER higher than one ratio is indicative of the fact that intercropping is economical.

\[
\text{Land Equivalent Ratio} = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}
\]

where,

- \(Y_{ab}\) = Wheat grain yield in intercropping with mentha
- \(Y_{ba}\) = Mentha essential oil yield in intercropping with wheat
- \(Y_{aa}\) = Wheat grain yield as sole crop
- \(Y_{bb}\) = Mentha essential oil yield as sole crop

3.7.5.4 Land equivalent coefficient (LEC)

According to Willey (1979), one of the criterions for assessing the yield advantage of cropping system is to realize full yield from base crop and to get some extra yield from the component crop. Any intercropping system involving two crops to become beneficial should have an LEC of more than 0.25 indicating that each component crop in the system should give at least 50 percent of their sole crop yield. The Land Equivalent Coefficient (LEC) was calculated as described by Adetiloye et al. (1983).

\[
\text{Land Equivalent Coefficient (LEC)} = \frac{LA \times LB}{LA + LB}
\]

Where, \(LA=\) LER of main crop (wheat) and \(LB=\) LER of intercrop (mentha)

3.7.5.5 Area time equivalent ratio (ATER)

It takes into account the duration of crops and permits an evaluation of crops on yield per day basis. It is a modification of LER. The time (duration) the field was dedicated to production is not considered in the calculation of LER. But area \(x\) time equivalent ratio (ATER) as proposed by Hiebsch and McCollum (1987) considers the land occupancy period of the crops also.

\[
\text{ATER} = \frac{(LA \times DA) + (LB \times DB)}{T}
\]

where,

- \(LA=\) LER of main crop wheat
- \(LB=\) LER of intercrop mentha
- \(DA=\) Duration of main crop wheat (days)
- \(DB=\) Duration of intercrop mentha (days)
- \(T=\) Duration of the intercropping system (days)
3.7.5.6 Production efficiency (PE)

\[
PE (\text{Rs ha}^{-1} \text{day}^{-1}) = \frac{\text{Total net returns of wheat-mentha intercropping system}}{\text{Total duration of intercropping system}}
\]

3.7.5.7 Benefit cost ratio (B: C Ratio)

\[
\text{B: C Ratio} = \frac{\text{Total net returns of wheat-mentha intercropping system}}{\text{Cost of cultivation of wheat-mentha intercropping system}}
\]

3.7.6 Optimum dose of nitrogen and nitrogen use efficiency in wheat-mentha intercropping system

3.7.6.1 Optimum dose of nitrogen

The polynomial response curve of wheat grain equivalent grain yield versus fertilizer N dose was used to calculate optimum fertilizer dose when wheat grain equivalent yield was maximum and dy/dx = 0. The polynomial response curve of wheat grain equivalent yield value versus fertilizer N dose was used to calculate economic maximum dose when the slope of polynomial response curve is equivalent to the slope of linear regression between fertilizer dose and cost of fertilizer.

3.7.6.2 Nitrogen use efficiency (NUE)

The nitrogen-use efficiency was computed as per expression given by Bock (1984) viz., Agronomic Efficiency, Physiological Efficiency and Apparent N Recovery.

3.7.6.2.1 Agronomic efficiency (kg grain kg$^{-1}$ applied N)

\[
\text{AE} = \frac{(Y_N-Y_0)}{F_N}
\]

where,

- $Y_N$ = Wheat grain equivalent yield of wheat-mentha intercropping system in nitrogen fertilized plot
- $Y_0$ = Wheat grain equivalent yield of wheat-mentha intercropping system in control plot
- $F_N$ = Fertilizer applied in wheat-mentha intercropping system

3.7.6.2.2 Physiological efficiency (kg grain kg$^{-1}$ N uptake)

\[
\text{PE} = \frac{(Y_N-Y_0)}{(U_N-U_0)}
\]
where,

\[ Y_N = \text{Wheat grain equivalent yield of wheat-mentha intercropping system in nitrogen fertilized plot} \]
\[ Y_0 = \text{Wheat grain equivalent yield of wheat-mentha intercropping system in control plot} \]
\[ U_N = \text{N uptake of wheat-mentha intercropping system in nitrogen fertilized plot} \]
\[ U_0 = \text{N uptake of wheat-mentha intercropping system in control plot} \]

3.7.6.2.3 Apparent N recovery; ANR (%)

\[ \text{ANR} = \left( \frac{U_N-U_0}{F_N} \right) \times 100 \]

where,

\[ U_N = \text{N uptake of wheat-mentha intercropping system in nitrogen fertilized plot} \]
\[ U_0 = \text{N uptake of wheat-mentha intercropping system in control plot} \]
\[ F_N = \text{Fertilizer applied in wheat-mentha intercropping system} \]

3.7.7 Statistical analysis

The data collected on various characters were statistically analyzed according to the procedure given by Cochran and Cox (1967). The comparison of treatments means was made at 5 percent level of significance.

**ANOVA for Experiment I**

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**ANOVA for Experiment II**

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