ICAR
PUBLICATIONS
2. To submit (a separate note) giving highlights on Research Achievements that have taken place under the present scheme in 20 lines and also to make available a list of publications (including bulletins also). Also indicate whether any development objectives served, if so, the details may be given.

This may kindly be treated as Most Immediate.

Yours faithfully,

(K.V. Ramana)
Assistant Director General (PC)

Copy forwarded for information and necessary action to :-

1. The Senior Finance and Accounts Officer, Central Arid Zone Research Institute, Jodhpur-342 003(Rajasthan)
2. The Head, Regional Research Station, (Central Arid Zone Research Institute), Pali-Marwar-306 401, Rajasthan
3. Dr. P.K. Roy(P.I.), Scientist-Senior Scale(Plant Breeding), Regional Research Station(CAZRI), Pali-Marwar-306401, Rajasthan
4. The Project Coordinator (M&AP), National Research Centre for Medicinal and Aromatic Plants, Boriavi, Anand-387 310, (Gujarat), (along with copy of final report)
5. The ISO, ARIC, KAB-I, Pusa New Delhi –12. (along with copy of Final Report)
6. DDG(H), ICAR, KAB –II Pusa, New Delhi-12.
7. Under Secretary (Hort), Pusa New Delhi –12.
8. Technical Officer (PC), ICAR, KAB-II Pusa New Delhi-12.(along with copy of Final Report)
9. GA-II Section, ICAR, For settlement of accounts and release of final grants(if any) under the scheme.
10. Budget Section, ICAR.
11. Guard file/ Spare copies.

Asstt. Director General (PC)
Final Report
ICAR Ad hoc Scheme

Development of Agro-techniques for Henna
(Lawsonia inermis L.) Production

April 2001 to March 2004

P.K. Roy
S.S. Rao
and
P.L. Regar

Central Arid Zone Research Institute
Regional Research Station
Pali-Marwar 306401 Rajasthan
1. Project title: Development of Agro-techniques for Henna (Lawsonia inermis L.) Production

2. Sanction No.: 13(6)99-Hort I dated 24.01.2000 and 20.08.2004

3. Date of start: 01 April 2001

4. Date of termination: 31 March 2004

5. (a) Name of Institute: Central Arid Zone Research Institute
   (b) Division/Department/Section: Regional Research Station, Pali-Marwar
   (c) Location of work: Pali-Marwar (Rajasthan)

6. Technical Personnel employed:

<table>
<thead>
<tr>
<th>Name with Designation</th>
<th>Date of Joining</th>
<th>Date of Leaving</th>
<th>Total no. of man-months spent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sh. Manna Ram S/o</td>
<td>01 June 2001</td>
<td>31 March 2004</td>
<td>30</td>
</tr>
<tr>
<td>Shri Peera Ram, SRF</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Total Outlay: Rs. 7,67,920
8. Total amount spent: Rs. 5,96,430

9. Objectives and how far these have been achieved:
   To evolve high yielding genotypes; standardize nursery and cultivation practices including spacing, nutrition and water requirement; and undertake studies on quality and economics of henna cultivation.

   Work done in brief: Variability in henna germplasm accessions from the Sojat and Marwar region assessed and multi-location trial on some promising accessions started; crop spacing and FYM application studied under rainfed condition; trial on micro-irrigation for determination of water requirement initiated; procedure for colorimetric estimation of lawsone dye in henna leaves studied (work on quality improvement, diseases/pests and economics was affected due to transfer/study leave of designated scientists)

10. Approved Technical Programme:
    Germplasm collection/evaluation and improvement; development of improved cultural practices (nursery techniques/planting geometry and plant density/fertilizer use/irrigation and moisture conservation); quality improvement (foliar application, post-harvest drying); diseases and pests; economics

   (a) Remarks of Scientific Panel on earlier Annual Report
   (None received)
11. Detailed Report

Henna (*Lawsonia inermis* L.), the common garden hedge and ornamental species, is cultivated as a commercial dye crop in India, Pakistan, Sudan, Iran, Yemen, Morocco, Niger, Egypt, etc. Its leaves popularly called *mehndi* possess natural dyeing properties and are used for hair dyeing and for staining of palm, feet and other body parts since times immemorial.

Large-scale cultivation of henna in India as dye crop, once spread over parts of Punjab, Haryana, Gujarat and Madhya Pradesh, is now mostly confined to Pali district of Rajasthan contributing over ninety percent of the henna production. Presently about 35,000 ha land is under henna crop in the district with about 70 per cent area in Sojat area and the leafy produce worth about Rs. 40 crore is consumed in the domestic market and also exported to other countries.

The increasing trend of using herbals has contributed to increase in demand of henna all over the globe. Many Islamic countries in the Middle East and North Africa cannot meet their high requirement from domestic production. These and other non-producing countries buy substantial quantities of henna from other countries. During 1988-93 the average volume of world trade in henna leaves, either powdered or whole, was at least 9,000 tonnes per annum and India exported 4,500 to 7,600 ton henna per annum during the period (Green, 1995).

In view of the growing demand of henna as a safe cosmetic dye, the importance of cultivating and producing adequate quantity of henna leaves for future is evidently beyond doubt. And for maintaining India's dominance in the world henna market concerted efforts are required to further improve level and quality of henna leaf production. Cultivation of henna is profitable under low rainfall conditions and is an important source of rural income of farmers in the drought prone arid and semi-arid regions. At 2003-04 price level henna farmers earned a profit of Rs. 12,450 per hectare on an average. Other benefits associated with henna cultivation include drought proofing, improved land use through sustainable forestry (henna plantations have an average productive life of about 10-15 years and come under short rotation forestry practices) and economic use of marginal and gravelly lands or wastelands. It also helps reduce soil erosion in the arid regions in particular due to deep root system and perennial nature of henna plantations. Thus there are adequate benefits for promoting henna cultivation for the economic and ecological development of the hot dry tracts of the country.

Henna is cultivated in dense plantations as an annual ratoon crop. One to three leaf harvests are taken every year depending on growth. However, due to the extensive nature of cultivation and low use of inputs (more than 90 per cent of henna in Pali is rainfed and use of fertilizers is minimal) there is risk of losing productivity in the long term. There is need to develop scientific management techniques for achieving sustainable and higher yield level from our henna plantations.

As very little scientific work has been done on this economically important export-oriented crop this project was taken up with the support of AP Cess Fund from ICAR to develop improved agro-techniques for henna cultivation.
11.1 SOILS AND WEATHER AT PROJECT CENTRE

The soils at CAZRI Regional Research Station, Pali-Marwar, the project location, are shallow, about 30-45 cm deep, and medium textured of sandy clay loam nature. They are underlain by a calcareous hardpan that impedes rapid infiltration of water. The average fertility status indicates availability of nitrogen low, phosphorus low to medium and potassium medium to high. Soil organic matter is about 0.37 per cent.

The climate is arid transitional type. Summers are hot and dry with high wind speed. The winters are relatively mild. Average rainfall is 420 mm received mostly during the monsoon period from July-September.

During the year 2001 maximum temperature 46.2 °C was recorded on May 06 and minimum 2.3 °C on Feb 02 (Table 1). It was a normal year receiving about 23 per cent higher rainfall of 519.3 mm. However the rainfall distribution was heavily skewed that had an adverse effect on normal crop production.

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature °C</th>
<th>RH (%)</th>
<th>Evaporation (mm)</th>
<th>Rainfall (mm)</th>
<th>Sunshine (h day⁻¹)</th>
<th>Wind speed (km h⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
<td>(Av.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan</td>
<td>25.9</td>
<td>6.0</td>
<td>40.2</td>
<td>3.6</td>
<td>9.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Feb</td>
<td>30.5</td>
<td>10.2</td>
<td>33.5</td>
<td>5.4</td>
<td>9.3</td>
<td>0.0</td>
</tr>
<tr>
<td>March</td>
<td>34.6</td>
<td>16.5</td>
<td>27.6</td>
<td>7.8</td>
<td>8.3</td>
<td>0.0</td>
</tr>
<tr>
<td>April</td>
<td>38.5</td>
<td>21.7</td>
<td>32.0</td>
<td>9.9</td>
<td>9.2</td>
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<tr>
<td>May</td>
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<td>27.8</td>
<td>46.2</td>
<td>13.7</td>
<td>10.6</td>
<td>7.0</td>
</tr>
<tr>
<td>June</td>
<td>38.6</td>
<td>27.6</td>
<td>57.7</td>
<td>10.0</td>
<td>8.2</td>
<td>5.5</td>
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<tr>
<td>July</td>
<td>31.7</td>
<td>25.4</td>
<td>81.4</td>
<td>3.2</td>
<td>3.3</td>
<td>44.1</td>
</tr>
<tr>
<td>August</td>
<td>33.0</td>
<td>24.7</td>
<td>77.9</td>
<td>3.9</td>
<td>6.3</td>
<td>338.9</td>
</tr>
<tr>
<td>Sep.</td>
<td>36.8</td>
<td>22.7</td>
<td>59.4</td>
<td>5.7</td>
<td>8.6</td>
<td>93.0</td>
</tr>
<tr>
<td>Oct.</td>
<td>37.5</td>
<td>20.3</td>
<td>48.6</td>
<td>5.7</td>
<td>9.5</td>
<td>19.0</td>
</tr>
<tr>
<td>Nov.</td>
<td>33.2</td>
<td>12.9</td>
<td>45.0</td>
<td>4.4</td>
<td>9.8</td>
<td>11.8</td>
</tr>
<tr>
<td>Dec.</td>
<td>29.1</td>
<td>7.9</td>
<td>52.0</td>
<td>2.9</td>
<td>9.5</td>
<td>0.0</td>
</tr>
</tbody>
</table>

During 2002, historic and severe drought conditions prevailed. There was not a single effective rainfall during the growing season. A total of 65.5mm rainfall (16.0 per cent of long-term average) was received barring usual monsoon period and spread over 08 rainy days. The highest maximum temperature of 47.2°C was recorded on May 06 while January 22 recorded the lowest minimum temperature of 0.8°C (Table 2).

During the year 2003, normal monsoon prevailed. A total of 396.3 mm rainfall was received during usual monsoon period (Table 3). A drought spell of 26 days was observed during August. Monsoon ceased on 29 August. The highest maximum temperature of 44.8°C was recorded on 17 May, while 17 December recorded the lowest minimum temperature of 3.6°C.
Table 2. Weather parameters at Pali-Marwar during 2002

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature (°C)</th>
<th>R.H. % (Av.)</th>
<th>Evaporation (mm)</th>
<th>Rainfall (mm)</th>
<th>Sunshine (h day⁻¹)</th>
<th>Wind speed (km h⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
<td>(Av.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan</td>
<td>25.7</td>
<td>6.4</td>
<td>51.75</td>
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<td>8.6</td>
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<tr>
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<td>28.2</td>
<td>8.7</td>
<td>47.25</td>
<td>4.1</td>
<td>0.0</td>
<td>8.6</td>
</tr>
<tr>
<td>Mar</td>
<td>35.1</td>
<td>10.2</td>
<td>43.0</td>
<td>6.5</td>
<td>0.0</td>
<td>8.5</td>
</tr>
<tr>
<td>Apr</td>
<td>40.7</td>
<td>23.2</td>
<td>37.35</td>
<td>10.1</td>
<td>10.5</td>
<td>9.1</td>
</tr>
<tr>
<td>May</td>
<td>42.8</td>
<td>28.1</td>
<td>42.5</td>
<td>14.3</td>
<td>0.0</td>
<td>9.7</td>
</tr>
<tr>
<td>Jun</td>
<td>40.7</td>
<td>28.4</td>
<td>54.8</td>
<td>10.5</td>
<td>28.5</td>
<td>8.1</td>
</tr>
<tr>
<td>Jul</td>
<td>36.8</td>
<td>27.1</td>
<td>58.7</td>
<td>9.6</td>
<td>0.0</td>
<td>7.6</td>
</tr>
<tr>
<td>Aug</td>
<td>35.6</td>
<td>26.5</td>
<td>61.8</td>
<td>7.2</td>
<td>0.0</td>
<td>5.8</td>
</tr>
<tr>
<td>Sep</td>
<td>37.5</td>
<td>24.9</td>
<td>53.6</td>
<td>8.1</td>
<td>17.5</td>
<td>9.0</td>
</tr>
<tr>
<td>Oct</td>
<td>38.8</td>
<td>21.3</td>
<td>30.55</td>
<td>7.8</td>
<td>0.0</td>
<td>9.2</td>
</tr>
<tr>
<td>Nov</td>
<td>32.9</td>
<td>15.0</td>
<td>35.25</td>
<td>4.9</td>
<td>0.0</td>
<td>8.1</td>
</tr>
<tr>
<td>Dec</td>
<td>29.4</td>
<td>10.7</td>
<td>42.6</td>
<td>3.5</td>
<td>10.0</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Table 3. Weather parameters at Pali-Marwar during 2003

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature (°C)</th>
<th>R.H. % (Av.)</th>
<th>Evaporation (mm)</th>
<th>Rainfall (mm)</th>
<th>Sunshine (h day⁻¹)</th>
<th>Wind speed (km h⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
<td>(Av.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan</td>
<td>26.3</td>
<td>8.8</td>
<td>43.5</td>
<td>4.4</td>
<td>0.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Feb</td>
<td>27.7</td>
<td>12.4</td>
<td>48.7</td>
<td>4.6</td>
<td>23.4</td>
<td>8.6</td>
</tr>
<tr>
<td>Mar</td>
<td>33.9</td>
<td>16.9</td>
<td>35.7</td>
<td>7.5</td>
<td>0.0</td>
<td>8.7</td>
</tr>
<tr>
<td>Apr</td>
<td>39.7</td>
<td>24.1</td>
<td>34.2</td>
<td>10.7</td>
<td>0.0</td>
<td>9.9</td>
</tr>
<tr>
<td>May</td>
<td>41.6</td>
<td>26.8</td>
<td>35.2</td>
<td>15.5</td>
<td>0.0</td>
<td>10.2</td>
</tr>
<tr>
<td>Jun</td>
<td>39.5</td>
<td>28.1</td>
<td>56.1</td>
<td>12.4</td>
<td>85.0</td>
<td>10.4</td>
</tr>
<tr>
<td>Jul</td>
<td>33.9</td>
<td>26.3</td>
<td>79.1</td>
<td>4.9</td>
<td>183.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Aug</td>
<td>33.4</td>
<td>25.6</td>
<td>77.0</td>
<td>4.2</td>
<td>125.0</td>
<td>5.9</td>
</tr>
<tr>
<td>Sep</td>
<td>34.0</td>
<td>24.2</td>
<td>71.7</td>
<td>4.9</td>
<td>3.0</td>
<td>8.3</td>
</tr>
<tr>
<td>Oct</td>
<td>36.5</td>
<td>16.9</td>
<td>46.3</td>
<td>5.6</td>
<td>0.0</td>
<td>9.9</td>
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<tr>
<td>Nov</td>
<td>31.9</td>
<td>12.6</td>
<td>48.3</td>
<td>4.3</td>
<td>0.0</td>
<td>9.5</td>
</tr>
<tr>
<td>Dec</td>
<td>27.3</td>
<td>7.8</td>
<td>55.3</td>
<td>3.2</td>
<td>0.0</td>
<td>9.3</td>
</tr>
</tbody>
</table>
11.2 EXPERIMENTAL RESULTS

11.2.1 Henna Improvement

Assessment of germplasm collections

Performance of 34 accessions originating from the Sojat and adjoining areas of Pali district, considered to be an important centre of genetic diversity owing to the existence of vast cultivated areas of henna since over about 50 years, was studied during the 2001 growing season (Jun-Nov). Data on dry leaf yield/plant and five important morphological attributes and leaf dye content were recorded on 30 seedling-derived populations (accessions) in the ex situ germplasm repository and subjected to variance analysis along with the previous data on same traits recorded during 1998 to 2000 following field establishment in 1997 at 30cm X 30cm planting density. Being a perennial crop, year was considered as replicate. The variance analysis revealed significant differences among the populations for mean plant height, primary branches/plant, secondary branches/plant, dry leaf yield/plant, leaf: stem (L:S) ratio and 100-leaf (dry) weight but not for leaf dye content. The populations of designated desi accessions (26) showed greater variability for secondary branches/plant, L:S ratio and 100-leaf dry weight compared to the designated muraliya populations (4).

Comparison of mean performance of the desi and muraliya accessions is given in Table 4. The muraliya populations recorded smaller leaf size (30 per cent lower 100-leaf weight) and more woody plant habit (38 per cent lower L:S ratio). Further, the muraliya accessions recorded about 30 per cent greater dry leaf yield/plant under the extreme drought conditions of 2002 season compared to the desi accessions. This indicated the higher drought tolerance nature of the muraliya accessions.

Table 4. Performance of henna populations over four years after establishment

<table>
<thead>
<tr>
<th>Character</th>
<th>Desi type</th>
<th>Muraliya type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>Plant height (cm)</td>
<td>85.13 - 117.08</td>
<td>98.31 ± 4.43</td>
</tr>
<tr>
<td>Primary branch plant(^1)</td>
<td>3.73 - 6.33</td>
<td>4.76 ± 0.43</td>
</tr>
<tr>
<td>Secondary branch plant(^1)</td>
<td>71.65 - 147.48</td>
<td>110.20 ± 10.71</td>
</tr>
<tr>
<td>Dry leaf yield plant(^1) (g)</td>
<td>12.68 - 35.48</td>
<td>20.81 ± 2.23</td>
</tr>
<tr>
<td>Leaf: stem ratio(^@) (on dry weight)</td>
<td>0.537 - 0.853</td>
<td>0.689 ± 0.065</td>
</tr>
<tr>
<td>100-leaf dry weight (g)(^@)</td>
<td>2.91 - 3.30</td>
<td>2.57 ± 0.34</td>
</tr>
<tr>
<td>Lawsone dye content (mg g(^{-1}))(^@)</td>
<td>12.40 - 22.13</td>
<td>16.07 ± 1.99</td>
</tr>
</tbody>
</table>

\(^@\) based on 3 year data
Besides these, it was observed that the *muraliya* populations failed to flower (except for rare miniscule inflorescence in some year) since establishment in 1997 till 2004 whereas the *desi* accessions flowered every year after establishment with varying intensity. This indicated that the *desi* accessions had shorter juvenile period compared to the *muraliya* accessions and further that the two types of accessions were reproductively isolated from each other. Morphological differences were also noted between the two types of henna with respect to colour of foliage (leaves) and bark of stem, and plant habit. Ash green foliage colour, ash brown bark colour, and more erect plant habit with open (lax) canopy were characteristic of the *muraliya* plants whereas the *desi* type plants showed more green foliage colour, brown to dark brown bark colour and semi-erect to bushy plant habit with more compact canopy.

The phenotypic divergence and the difference in expression of flowering between the *desi* and *muraliya* accessions suggested that they are representative of different ecotypes of henna.

**Selection of promising henna accessions**

Based on the mean performance of different henna accessions in the field repository during 1998 to 2001 period the accessions Sojat 22, Sojat 8, Sojat 7 and Sojat 21, with high leaf yield potential ranging between 27.4 and 35.5 g dry leaves/plant at 30cm X 30cm planting density, were found to be promising for further varietal development work (Table 5).

**Table 5. Promising henna accessions for high leaf yield potential**

<table>
<thead>
<tr>
<th>Accession No.</th>
<th>Plant Height (cm)</th>
<th>Primary branch plant⁻¹</th>
<th>Secondary branch plant⁻¹</th>
<th>Dry leaf yield plant⁻¹ (g)</th>
<th>Leaf: stem ratio</th>
<th>100-Leaf dry weight (g)</th>
<th>Leaf dye content (mg g⁻¹DW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sojat 22</td>
<td>96.2</td>
<td>6.20</td>
<td>131.1</td>
<td>35.5</td>
<td>0.85</td>
<td>3.30</td>
<td>12.4</td>
</tr>
<tr>
<td>Sojat 7</td>
<td>89.9</td>
<td>6.33</td>
<td>119.9</td>
<td>32.2</td>
<td>0.84</td>
<td>3.01</td>
<td>14.7</td>
</tr>
<tr>
<td>Sojat 8</td>
<td>117.1</td>
<td>5.13</td>
<td>120.4</td>
<td>26.4</td>
<td>0.67</td>
<td>2.72</td>
<td>15.2</td>
</tr>
<tr>
<td>Sojat 21</td>
<td>107.4</td>
<td>4.78</td>
<td>124.0</td>
<td>27.4</td>
<td>0.59</td>
<td>2.73</td>
<td>16.5</td>
</tr>
<tr>
<td>CD 5%</td>
<td>13.8</td>
<td>1.19</td>
<td>31.9</td>
<td>6.6</td>
<td>0.18</td>
<td>0.90</td>
<td>NS</td>
</tr>
</tbody>
</table>

**Development of descriptors for henna**

To aid proper characterization of henna (*Lawsonia inermis* L.) plant material a minimal set of plant descriptors were identified comprising 22 traits of henna plant. These are to be recorded for vegetative, morphological and reproductive characters and dye content of main crop taken after monsoon season. Plant height, tillers/plant, 100-leaf fresh weight, 100-leaf dry weight, and leaf yield/plant are the quantitative descriptors and growth habit, leaf shape, thorns, bark colour and leaf colour are the qualitative descriptors for describing the vegetative growth of henna plant material. For the reproductive performance the descriptors are days to flower, flower colour, inflorescence size, immature fruit colour, mature fruit colour, average fruit weight, seeds/fruit, per cent large polymorphic seed and
1000-seed weight. The quality descriptors are lawsone content (of leaves), oil content in flower and biotic stress susceptibility. (This work was done in association with Dr. N.K. Dwivedi at NBFRG Regional Station, Jodhpur)

**Variability studies**

A replicated field trial was initiated in 2001 kharif 2001 involving ten random single plant progenies obtained from the germplasm repository to assess the variability parameters for different traits. Data were collected at the end of 2003 growing season on leaf yield and its main attributes. Maximum PCV and GCV were found for dry leaf weight/plant (35.4% and 20.5%) followed by dry stem weight/plant (32.9% and 15.6%) and plant height (13.7% and 6.6%). The $h^2_{bs}$ estimates for these traits were low and varied from 0.224 to 0.333 indicating the major effect of environment on the expression of these traits.

**Correlation and Path analysis**

Association among different characters was studied in the germplasm accessions (30 nos.). Dry leaf yield/plant was found positively correlated with plant height ($r = 0.403^*$), primary branches/plant ($r = 0.571^{**}$) and secondary branches/plant ($r = 0.510^{**}$) but not with 100-leaf dry weight, L: S ratio and leaf dye content (Table 6).

<table>
<thead>
<tr>
<th></th>
<th>Plant height</th>
<th>Primary branch plant$^1$</th>
<th>Secondary branch plant$^1$</th>
<th>Dry leaf yield plant$^1$</th>
<th>100-leaf dry weight</th>
<th>Leaf: stem ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary branch plant$^1$</td>
<td>0.119</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary branch plant$^1$</td>
<td>0.447*</td>
<td>0.555**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry leaf yield plant$^1$</td>
<td>0.403*</td>
<td>0.571**</td>
<td>0.510**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100-leaf dry weight</td>
<td>-0.203</td>
<td>0.088</td>
<td>-0.265</td>
<td>0.194</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaf: stem ratio</td>
<td>-0.458*</td>
<td>-0.168</td>
<td>-0.611**</td>
<td>0.095</td>
<td>0.589**</td>
<td></td>
</tr>
<tr>
<td>Lawsone dye content</td>
<td>0.001</td>
<td>0.002</td>
<td>0.186</td>
<td>-0.181</td>
<td>-0.223</td>
<td>-0.269</td>
</tr>
</tbody>
</table>

*, ** indicate significance at $P = 0.05$ and 0.01, respectively

Path analysis revealed strongest direct effect (0.47) of primary branches/plant on dry leaf yield suggesting the utility of this trait as selection criteria for leaf yield improvement (Table 7).
Table 7. Direct (bold diagonal) and indirect effects of significant yield components of henna

<table>
<thead>
<tr>
<th></th>
<th>Plant height</th>
<th>Primary branch plant(^1)</th>
<th>Secondary branch plant(^1)</th>
<th>Correlation with dry leaf yield plant(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height</td>
<td>0.294</td>
<td>0.056</td>
<td>0.053</td>
<td>0.403*</td>
</tr>
<tr>
<td>Primary branch plant(^1)</td>
<td>0.035</td>
<td>0.470</td>
<td>0.066</td>
<td>0.571**</td>
</tr>
<tr>
<td>Secondary branch plant(^1)</td>
<td>0.131</td>
<td>0.261</td>
<td>0.119</td>
<td>0.510**</td>
</tr>
</tbody>
</table>

\(^*, **\) indicate significance at \(P = 0.05\) and 0.01, respectively

Varietal evaluation

A replicated trial involving seedling-derived populations of 15 selected germplasm accessions, established earlier during 2000 \textit{kharif} season, was studied during 2002 but differences among the populations for plant height, primary branches/plant, dry stem weight/plant and dry leaf weight/plant under the severe drought conditions were all non-significant. The trial was abandoned due to high drought induced mortality of the experimental plants.

To carry forward varietal evaluation work, a new trial involving 10 promising accessions (\(r = 3\)) was established at two locations (Pali and Jadan) during 2003 \textit{kharif} using nursery-derived seedlings.

11.2.2 AGRONOMIC STUDIES

Crop spacing and nitrogen application

The crop spacing significantly influenced dry leaf production of henna (Table 8). The dry leaf yield increased significantly under a spacing of 45 cm \(\times\) 30 cm by 27.0, 99.3 and 12.7 per cent over 30 cm \(\times\) 30 cm spacing in the year 1999, 2000 and 2001, respectively. Pooled analysis show that maximum dry leaf production of 904.2 kg \(\text{ha}^{-1}\) was recorded under 45 cm \(\times\) 30 cm followed by 867.5 kg \(\text{ha}^{-1}\) under 60 cm \(\times\) 30 cm as compared to 682.2 kg \(\text{ha}^{-1}\) under 30 cm \(\times\) 30 cm spacing. A further analysis of data show that plant performances at 45 cm \(\times\) 15 cm or 60 cm \(\times\) 15 cm spacing (that was selected to accommodate high plant population) was worse even than 30 cm \(\times\) 30 cm spacing. A spacing of 60 cm \(\times\) 30 cm followed 45 cm \(\times\) 30 cm also caused high leaf: stem ratio during the year 1999 and 2000. That irrespective of the inter row spacing, the leaf: stem ratio was higher under intra row spacing of 30 cm as compared to 15 cm on pooled basis. It clearly show maximum dry leaf yield was obtained by reducing 50 per cent plant population (increasing intra row spacing from 15 cm to 30 cm) in 45 cm or 60 cm rows.

The application of nitrogen had significant effect on henna. Dry leaf yield increased significantly at 90 kg \(\text{N} \text{ha}^{-1}\) during the year 2000 and 60 kg \(\text{N} \text{ha}^{-1}\) during the year 2001. The lack of response of applied N to henna during the year 1999 may be ascribed to under-utilization of applied N due to moisture stress. On pooled basis, the effect of 60 kg \(\text{N} \text{ha}^{-1}\) being at par with 90 kg \(\text{ha}^{-1}\), produced significantly higher dry leaf yield of 761.6 kg \(\text{ha}^{-1}\) as
compared to control that recorded 679.6 kg ha\(^{-1}\). The apparent increase in availability of N to plant roots caused higher photosynthetic rate leading to the production of more carbohydrate.

Table 8. Effect of crop spacing and nitrogen on dry leaf yield and leaf: stem ratio

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dry leaf yield (kg ha(^{-1}))</th>
<th>Total biomass (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crop geometry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 cm × 30 cm</td>
<td>401.2</td>
<td>403.1</td>
</tr>
<tr>
<td>45 cm × 15 cm</td>
<td>295.4</td>
<td>386.7</td>
</tr>
<tr>
<td>60 cm × 15 cm</td>
<td>338.9</td>
<td>376.2</td>
</tr>
<tr>
<td>45 cm × 30 cm</td>
<td>509.6</td>
<td>803.4</td>
</tr>
<tr>
<td>60 cm × 30 cm</td>
<td>426.2</td>
<td>778.1</td>
</tr>
<tr>
<td><strong>SEm±</strong></td>
<td>22.8</td>
<td>26.4</td>
</tr>
<tr>
<td><strong>CD ((P=0.05))</strong></td>
<td>74.2</td>
<td>86.2</td>
</tr>
<tr>
<td><strong>Nitrogen (kg ha(^{-1}))</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>382.2</td>
<td>510.9</td>
</tr>
<tr>
<td>30</td>
<td>395.8</td>
<td>543.7</td>
</tr>
<tr>
<td>60</td>
<td>390.4</td>
<td>567.9</td>
</tr>
<tr>
<td>90</td>
<td>408.6</td>
<td>575.6</td>
</tr>
<tr>
<td><strong>SEm±</strong></td>
<td>17.7</td>
<td>20.0</td>
</tr>
<tr>
<td><strong>CD ((P=0.05))</strong></td>
<td>NS</td>
<td>57.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>F-test</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>**</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>**</td>
</tr>
<tr>
<td>Year × Spacing</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>**</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>**</td>
</tr>
<tr>
<td>Year × Nitrogen</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>NS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>**</td>
</tr>
</tbody>
</table>

Leaf dye content varies significantly due to different crop spacing across the year (Table 9). Unlike leaf yield, maximum dye content of 30.9 mg g\(^{-1}\) was observed with the crop spacing of 60 cm × 15 cm followed by 30.0 mg g\(^{-1}\) under 45 cm × 15 cm and 27.6 mg g\(^{-1}\) under 30 cm × 30 cm during the year 2000. The corresponding dye content of above spacing was 27.8 mg g\(^{-1}\), 24.8 mg g\(^{-1}\) and 24.8 mg g\(^{-1}\) during the year 2001. The treatments that gave maximum dry leaf yield were low in dye content during both the years.
Application of nitrogen had significant effect on leaf dye content. The effect of N on leaf dye content was rational during the year 2000 but it was significant during the year 2001. On pooled basis, N application at 90 kg ha\(^{-1}\) significantly increased leaf dye content to 27.3 mg g\(^{-1}\) as compared to control that recorded 25.6 mg g\(^{-1}\). Further, N application has also increased N content of henna leaves linearly up to 90 kg ha\(^{-1}\).

Table 9. Effect of crop geometry and nitrogen on leaf dye content and dye yield

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Leaf dye content (mg g(^{-1}))</th>
<th>Dye yield (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000</td>
<td>2001</td>
</tr>
<tr>
<td><strong>Crop geometry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 cm x 30 cm</td>
<td>27.6</td>
<td>24.8</td>
</tr>
<tr>
<td>45 cm x 15 cm</td>
<td>30.0</td>
<td>24.8</td>
</tr>
<tr>
<td>60 cm x 15 cm</td>
<td>30.9</td>
<td>27.8</td>
</tr>
<tr>
<td>45 cm x 30 cm</td>
<td>25.9</td>
<td>22.3</td>
</tr>
<tr>
<td>60 cm x 30 cm</td>
<td>26.2</td>
<td>23.7</td>
</tr>
<tr>
<td><strong>SEm±</strong></td>
<td>0.60</td>
<td>0.92</td>
</tr>
<tr>
<td><strong>CD (P=0.05)</strong></td>
<td>1.97</td>
<td>3.01</td>
</tr>
<tr>
<td><strong>Nitrogen (kg ha(^{-1}))</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>27.2</td>
<td>23.3</td>
</tr>
<tr>
<td>30</td>
<td>28.4</td>
<td>23.7</td>
</tr>
<tr>
<td>60</td>
<td>28.4</td>
<td>25.6</td>
</tr>
<tr>
<td>90</td>
<td>28.5</td>
<td>26.2</td>
</tr>
<tr>
<td><strong>SEm±</strong></td>
<td>0.52</td>
<td>0.81</td>
</tr>
<tr>
<td><strong>CD (P=0.05)</strong></td>
<td>NS</td>
<td>2.34</td>
</tr>
<tr>
<td><strong>F- test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Year x Spacing</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Year x Nitrogen</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Effect of organic manure, fertilizer application and row spacing on dry leaf yield

A field experiment on integrated nutrient management of henna was started in 2001. The treatment involved FYM application, fertilizer levels and row spacing. Application of farmyard manure at 5 t ha\(^{-1}\) significantly increased dry leaf yield of henna by 13.2 per cent over no farmyard manure (Table 10). Dry leaf yield of henna enhanced significantly by 12.8 per cent due to fertilizer application up to 80 kg N and 40 kg P\(_2\)O\(_5\) ha\(^{-1}\) over control. Among the different spacing, rows at 45 cm gave highest dry leaf yield in this experiment also. There was a significant interaction between FYM and row spacing during 2003-04.
Table 10. Effect of organic manure, fertility levels and row spacing on henna 2003-04

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>Branches plant⁻¹</th>
<th>Dry leaf yield (kg/ha)</th>
<th>Dye content (mg/g⁻¹)</th>
<th>Dye yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organic manure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No farmyard manure</td>
<td>4.6</td>
<td>970.0</td>
<td>23.9</td>
<td>23.2</td>
</tr>
<tr>
<td>Farmyard manure 5t ha⁻¹</td>
<td>5.3</td>
<td>1098.5</td>
<td>24.1</td>
<td>26.5</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>0.3</td>
<td>83.6</td>
<td>NS</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>Fertility Level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N0P0</td>
<td>4.6</td>
<td>983.4</td>
<td>23.7</td>
<td>23.4</td>
</tr>
<tr>
<td>N40P20</td>
<td>5.1</td>
<td>1010.0</td>
<td>24.3</td>
<td>24.5</td>
</tr>
<tr>
<td>N80P40</td>
<td>5.2</td>
<td>1109.3</td>
<td>24.1</td>
<td>26.6</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>0.4</td>
<td>102.4</td>
<td>NS</td>
<td>2.7</td>
</tr>
<tr>
<td><strong>Row Spacing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 cm rows</td>
<td>4.6</td>
<td>985.0</td>
<td>24.3</td>
<td>23.8</td>
</tr>
<tr>
<td>45 cm rows</td>
<td>5.1</td>
<td>1085.0</td>
<td>23.7</td>
<td>25.8</td>
</tr>
<tr>
<td>60 cm rows</td>
<td>5.2</td>
<td>1032.7</td>
<td>24.0</td>
<td>24.8</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>0.4</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Growth and productivity of henna under fertigation through drip irrigation and planting configuration

The field experiment to study the effect of irrigation through drip irrigation, fertilizer application and planting configuration on henna was initiated during 2003. The drip irrigation system was procured and installed. The experimental crop is transplanted successfully in the field under both the square and paired-row planting configurations. Recording of observations is continuing.

11.2.3 QUALITY STUDIES

Estimation of lawsone dye content

The relationship between concentration and spectral absorption of lawsone at the absorption peak of 452nm wavelength was studied. The concentration-absorption curve of the dye in aqueous solution was found to be curvilinear without any control of solution pH. However, the relationship appeared to become linear when uniform solution pH was maintained either pH 7.0 or pH 4.0. The slope (resolving power) of the concentration-absorption curve at neutral solution pH was greater than that at acidic solution pH. Based on this finding and the higher solubility of lawsone in alkaline water, suitable modification was proposed to the colorimetric estimation method of Pratibha & Korwar (1999). It was proposed to extract the leaf powder sample in alkaline pH 9.0 water at 80 degree C instead of normal water at room temperature and to neutralize the final sample aliquot to uniform pH 7.0 instead of uncontrolled pH of final extract. The modified procedure resulted in dye
estimates of the test genotypes similar to that obtained using the more precise solvent extraction method proposed by Vartanyan et al. (1986) (Table 11).

Table 11. Lawsone content of henna (mg g\(^{-1}\) dry leaves) estimated by different methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Sojat 8</th>
<th>Sojat 22</th>
<th>Sojat 16</th>
<th>Sojat 10</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pratibha &amp; Korwar (1999)</td>
<td>35.77</td>
<td>28.87</td>
<td>33.53</td>
<td>31.30</td>
<td>32.37</td>
</tr>
<tr>
<td>Pratibha &amp; Korwar (1999)</td>
<td>22.00</td>
<td>21.77</td>
<td>23.13</td>
<td>23.33</td>
<td>22.56</td>
</tr>
<tr>
<td>with modifications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vartanyan et al. (1986)</td>
<td>20.90</td>
<td>19.67</td>
<td>21.57</td>
<td>23.43</td>
<td>21.39</td>
</tr>
<tr>
<td>Mean</td>
<td>26.22</td>
<td>23.43</td>
<td>26.08</td>
<td>26.02</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>F value</th>
<th>CD5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>93.9**</td>
</tr>
<tr>
<td>Genotype</td>
<td>3.48*</td>
</tr>
<tr>
<td>Method x Genotype</td>
<td>2.09</td>
</tr>
</tbody>
</table>

*, ** indicate significance at \( P = 0.05 \) and 0.01, respectively; NS, non-significant; individual genotype values are mean of 3 replicates

Use of PGR

Effect of application of exogenous auxins was studied on the establishment of henna seedlings in field. The root portion of seedlings suitable for transplantation was drenched in IAA, IBA or NAA at 1000ppm, 2000ppm or 3000ppm concentration solution for 5 minutes period before transplantation in 2003 Kharif season. Observations were recorded on mean sprouted seedlings 7DAT, mean seedling establishment and branches/ plant at the end of growing season.

Treatment IBA1000 ppm recorded maximum sprouting of seedlings (69.0%) followed by IAA1000 ppm (64.6%) compared to 20.3% sprouted seedling 7 DAT (Table 12). Per cent seedling establishment was found to be lowest (37.7%) with NAA3000 ppm and highest (97.7%) with IBA1000 ppm treatment that was at par with that under IAA1000 ppm and control (untreated). No. of branches/ plant was maximum (3.07) under IAA1000 ppm followed by 2.00 under IBA1000 whereas control treatment recorded 1.73 branches/ plant. These indicated that treatment of IAA or IBA at 1000ppm concentration led to rapid establishment and better growth of henna seedling transplants under the rainfed conditions.
Table 12. Effect of PGR treatment on growth and development of henna transplants

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sprouted seedlings 7 DAT (%)</th>
<th>Seedling establishment (%)</th>
<th>Branches/plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>Arcsine</td>
<td>Observed</td>
</tr>
<tr>
<td>IAA 1000</td>
<td>64.6</td>
<td>54.54</td>
<td>95.7</td>
</tr>
<tr>
<td>IAA 2000</td>
<td>55.7</td>
<td>48.65</td>
<td>91.0</td>
</tr>
<tr>
<td>IAA 3000</td>
<td>40.0</td>
<td>38.43</td>
<td>86.7</td>
</tr>
<tr>
<td>NAA 1000</td>
<td>42.0</td>
<td>40.00</td>
<td>84.3</td>
</tr>
<tr>
<td>NAA 2000</td>
<td>17.7</td>
<td>20.12</td>
<td>48.7</td>
</tr>
<tr>
<td>NAA 3000</td>
<td>8.7</td>
<td>14.09</td>
<td>37.7</td>
</tr>
<tr>
<td>IBA 1000</td>
<td>69.0</td>
<td>56.38</td>
<td>97.7</td>
</tr>
<tr>
<td>IBA 2000</td>
<td>62.0</td>
<td>52.20</td>
<td>93.3</td>
</tr>
<tr>
<td>IBA 3000</td>
<td>28.7</td>
<td>31.81</td>
<td>78.0</td>
</tr>
<tr>
<td>Control</td>
<td>20.3</td>
<td>24.65</td>
<td>91.0</td>
</tr>
<tr>
<td></td>
<td>SE +</td>
<td>6.68</td>
<td>6.27</td>
</tr>
<tr>
<td></td>
<td>CD 5%</td>
<td>19.84</td>
<td>18.62</td>
</tr>
</tbody>
</table>

Relation of harvest time and henna leaf quality

Henna leaves of five accessions were harvested at monthly interval during the 2003 growing season (Jun-Oct) and tested for leaf dye content and powder colour (Table 13). The colour of the leaf powder varied from dark brown to green colour and the mean leaf dye content showed variation from 23.8 mg/g to 28.2 mg/g dry powder among the different months. Cutting of leaves in the month of October (at physiological maturity) resulted in higher leaf dye content and desirable green colour of powder.

Table 13. Quality of henna leaf powder obtained from cutting in different months

<table>
<thead>
<tr>
<th>Dye content</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sojat 8</td>
<td>25.2</td>
<td>24.3</td>
<td>26.6</td>
<td>24.3</td>
<td>21.5</td>
<td>24.38</td>
</tr>
<tr>
<td>Sojat 22</td>
<td>22.8</td>
<td>24.6</td>
<td>27.3</td>
<td>26.5</td>
<td>42.3</td>
<td>28.71</td>
</tr>
<tr>
<td>Marwar 1</td>
<td>20.3</td>
<td>29.5</td>
<td>29.0</td>
<td>25.8</td>
<td>25.5</td>
<td>26.02</td>
</tr>
<tr>
<td>Sojat 18</td>
<td>24.6</td>
<td>27.8</td>
<td>28.0</td>
<td>24.5</td>
<td>25.8</td>
<td>26.15</td>
</tr>
<tr>
<td>Sojat 21</td>
<td>26.3</td>
<td>27.8</td>
<td>26.8</td>
<td>29.0</td>
<td>26.3</td>
<td>27.24</td>
</tr>
<tr>
<td>Mean</td>
<td>23.8</td>
<td>26.8</td>
<td>27.5</td>
<td>26.0</td>
<td>28.2</td>
<td>27.24</td>
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</table>

<table>
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<tr>
<th>Powder colour</th>
<th>Dark reddish brown</th>
<th>Greenish brown</th>
<th>Brown</th>
<th>Yellowish brown</th>
<th>Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>All accessions</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Role of weather in dye expression

The leaf dye content of 25 accessions was studied with respect to seasonal weather parameters viz. mean daily maximum temperature, mean daily evaporation, daily sunshine hours and total seasonal rainfall during the period 1999 through 2001. A significant positive correlation ($r = 0.36^{**}$) was found between mean dye content of the genotypes and the mean sunshine period alone among the different weather parameters. It suggested that longer sunshine period promoted the expression of more dye in henna leaves.

12. Summary

The germplam collections originating from the major henna growing region in Pali district showed significant variation for dry leaf yield per plant and other morphological traits but not for leaf dye content during the initial four years of growth after establishment. The two types of henna accessions viz. desi and muraliya collected from the region were found to show reproductive isolation due to dissimilar length of juvenile period and also morphological divergence in leaf size, foliage colour, bark colour, plant habit and canopy structure. They appeared to represent different ecotypes of henna. Based on the average performance the desi accessions Sojat 22, Sojat 7, Sojat 8 and Sojat 21 were found promising for use in development of high yielding varieties.

A minimal set of descriptors involving 22 quantitative and qualitative plant traits was identified for characterization of henna plant material.

Evaluation of single plant progenies under the rainfed conditions revealed low heritability estimates ($h^2_{ps}$) ranging between 0.224 and 0.33 for plant height, dry stem weight per plant and dry leaf weight per plant.

Dry leaf yield per plant was found to be positively correlated with plant height, primary branches per plant and secondary branches per plant. Primary branches had the maximum direct effect on leaf yield.

Agronomic studies reveal a spacing of 45 cm between rows and 30 cm between plants gave maximum dry leaf yield. Application of 60 kg N ha$^{-1}$ led to significant increase in dry leaf yield as compared to control. Application of farmyard manure at 5tonnes per hectare increases 10-12 per cent in dry leaf yield. Leaf dye content varies significantly due to crop spacing. Application of nitrogen has significant effect on leaf dye content of henna. A significant and negative correlation was estimated between dye content and seasonal rainfall.

Based on the standard concentration-absorbance relationship of lawsone (henna dye) in aqueous solution at the peak absorbance wavelength 452nm and the greater solubility of the dye molecule in alkaline medium modifications were suggested to the procedure of colorimetric estimation of dye given by Pratibha & Korwar (1999) for obtaining better dye estimates of leaf powder samples.

Root treatment of seedlings prior to transplantation with IAA or IBA at 1000ppm concentration for 5 min period was found to improve speed of seedling establishment and seedling growth under rainfed conditions.

Cutting of henna for leaves in the month of October instead of earlier in the season was found to give better quality leaf in terms of dye content and desirable green powder colour.
13. Results which can be exploited in pilot or field scale

The area and production of high quality henna leaves need to be increased to meet future requirements. It was concluded that growing of henna at inter-row spacing of 45 cm or 60 cm with constant intra-row spacing of 30 cm is advantageous for increasing dry leaf yield in arid to semi-arid subtropics. Further, application farmyard manure at 5 ton and N at 60 kg ha\(^{-1}\) proved encouraging for higher productivity and leaf quality in arid fringes.

14. Papers/Articles prepared/published

Rao SS, PK Roy and PL Regar 2002 Henna Cultivation in arid fringes *Indian Farming* 52 (5): 14-20


15. Suggestions for future lines of research

To boost the production of henna and its trade in national and international market there is need for better understanding of problems at various levels and finding their joint solutions through combined efforts of farmers, businessmen and industrialists. It is felt that there is need for extending the area under henna, increasing productivity per unit area through better management and selection of high yielding genotypes and enhancing the value added components for higher earning of foreign exchange. Sojat being major henna production area, should receive the prime attention and be developed as centre of excellence by focusing R&D efforts in this region. Problems related to cultivation need to be addressed systematically. The interaction with the henna growers, traders and manufacturing partners
revealed the need for scientific approach for nursery raising, plant protection, soil management, harvesting, quality testing, post-harvest storage and processing.

Keeping above in view and the emergent findings of work done under the project following suggestions are made in the context of future research on henna:

**Genotype improvement**
- Assessment of variability for phenological and quality characters in henna
- Comparison of effect of physical and chemical mutagens
- Evaluation of selected genotypes for improvement in leaf dye synthesis, water use efficiency and leaf yield potential
- Development of high yielding, quality and water use efficient genotypes of henna and on farm evaluation.

**Agronomic practices (on-farm studies)**
- Study on soil surface management for improved infiltration and soil moisture content
- Integrated nutrient management of henna using organic, inorganic and bio-fertilizers
- Crop-weather interaction studies
- Cropping system studies based on henna as perennial component

**Crop protection**
- Evaluation of efficacy of various bio-agents, pesticides and cultural practices on control of important foliar and root diseases in the region.

**Harvesting tool**
- Development and evaluation of harvesting tool

**Post-harvest practices**
- Assessment of effect of crop drying conditions on leaf quality
- Identification of proper storage conditions for henna.

16. Acknowledgement

The financial assistance extended by ICAR and valuable support of Director, Central Arid Zone Research Institute, Jodhpur for providing necessary facilities for the project work are gratefully acknowledged.

17. Signature

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Designation: Principal Investigator

Date: 25.3.06