Food Legume Improvement and Development

Proceedings of a workshop held at The University of Aleppo, Syria, 2-7 May 1978

Geoffrey C. Hawtin and George J. Chancellor, Editors

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Postal Address: Box 8500, Ottawa, Canada K1G 3H9
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Hawtin, G.C.
Chancellor, G.J.
International Center for Agricultural Research in the Dry Areas, Aleppo SY
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and the
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The views expressed in this publication are those of the individual author(s) and do not necessarily represent the views of ICARDA or IDRC.
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Food Legume Research and Development in the Sudan

Farouk A. Salih
Hudeiba Research Station, Plant Breeding Section, P.O. Box 31, Ed-Damer, Sudan

The Sudan, with the exception of the Red Sea hills, lies within the region of summer rainfall. The rains last for up to 9 months in the far south of the country where the total annual rainfall may reach 1500 mm, but the length of the season shortens and distribution becomes more erratic as one moves northward, precipitation being practically zero in the northern-most parts. Temperature conditions are correspondingly more extreme in the north, which may remain relatively cold for 3–4 months of the year. The cool winters and their long duration in these parts of the country (the Northern and Nile provinces, Fig. 1), coupled with the availability of irrigation water from the river Nile, permit the production of winter crops, which include broad beans, haricot beans, chick-peas, lentils, lupins, field peas, and berseem. Of these crops, broad bean (*Vicia faba* L.) is the most important, occupying 60% of the pulse acreage, followed by haricot bean (*Phaseolus vulgaris* L.), chick-pea (*Cicer arietinum*), and lentil (*Lens culinaris*) (see Table 1).

**Broad Bean (*Vicia faba* L.)**

Broad bean is grown as an irrigated crop in Northern Sudan and its cultivation is limited to the zone between latitudes 13°N and 22°N, primarily around the cities of Dongola, Berber, and Shendi (Fig. 1). An estimated area of 30 000 feddans (1 feddan = 0.42 ha) is cropped annually but yields vary greatly between years depending on climatic conditions.

**Agronomic Aspects**

The recommended sowing time is between mid-October and early November. Planting earlier than this causes considerable losses due to infections of wilt and root rot diseases soon after planting, the prevalence of which increases with temperature. Late-sown crops also suffer and those sown in December may give no yield at all due to high spring temperatures coinciding with flowering and causing a large amount of flower shedding. Many experiments have been conducted at the Hudeiba Research Station to investigate the effect of seed rate and spacing on broad bean yield. Results of these studies have shown that very large variations in plant population have little effect on grain yield due to the compensatory nature of its components. Large-seeded varieties (e.g., Rebaya 34) have been found to emerge earlier and produce larger plants than small-seeded types such as Baladi; however, this phenomenon has not been effectively translated into appreciably superior seed yield due to the relatively faster growth rates of the small-seeded varieties.

Considerable experimentation has yielded conflicting information on the effect of fertilization on broad bean seed yield: responses to fertilizer application range from zero to 23% increases in different investigations. The inconclusiveness of these studies has led to increased interest in rhizobial inoculation as a means of increasing seed yield. Inoculation with a Sudanese strain of *Rhizobium* has produced increases of 18% in the early nodulation
of plants, but the use of a French strain has been found to reduce nodulation. Nitrogen application has been shown to reduce nodulation in both strains, affecting the French type more than the native Sudanese type.

The high temperatures prevailing during the growing season have a considerable effect on the moisture regime of the plants, producing appreciable water stress at certain stages. Research has indicated that the frequency of irrigation is of great importance in minimizing this stress. A watering interval of 5 days gives significantly higher seed yields than longer intervals, and increasing the interval of watering at pod formation from 7 to 14 and 21 days has been shown to decrease seed yield by 36 and 76%, respectively. This appreciable effect may be due to the fact that water infiltration is slow as a result of soil type, and hence evaporation may be considerable.
TABLE 1. Total area (in '000 feddans*) and total production (in '000 metric tonnes) of broad bean, haricot bean, and chick-pea in the Sudan from 1967 to 1977.

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Broad bean</th>
<th>Haricot bean</th>
<th>Chick-pea</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967–68</td>
<td>22.9</td>
<td>13.0</td>
<td>9.5</td>
</tr>
<tr>
<td>1968–69</td>
<td>22.6</td>
<td>11.3</td>
<td>7.5</td>
</tr>
<tr>
<td>1969–70</td>
<td>22.7</td>
<td>15.6</td>
<td>7.8</td>
</tr>
<tr>
<td>1970–71</td>
<td>27.2</td>
<td>18.8</td>
<td>8.4</td>
</tr>
<tr>
<td>1971–72</td>
<td>43.7</td>
<td>38.1</td>
<td>7.9</td>
</tr>
<tr>
<td>1972–73</td>
<td>27.8</td>
<td>17.3</td>
<td>6.3</td>
</tr>
<tr>
<td>1973–74</td>
<td>35.0</td>
<td>20.6</td>
<td>8.0</td>
</tr>
<tr>
<td>1974–75</td>
<td>38.0</td>
<td>29.0</td>
<td>11.8</td>
</tr>
<tr>
<td>1975–76</td>
<td>35.9</td>
<td>30.7</td>
<td>11.6</td>
</tr>
<tr>
<td>1976–77</td>
<td>33.4</td>
<td>24.6</td>
<td>9.0</td>
</tr>
</tbody>
</table>

* 1 feddan = 4200 m² = 0.420 ha = 1.0379 acres.

TABLE 2. Effect on seed yield and yield components of harvesting broad beans at different stages of maturity, in the Sudan.

<table>
<thead>
<tr>
<th>Age of plant</th>
<th>Seed yield</th>
<th>Yield components (1977)</th>
</tr>
</thead>
<tbody>
<tr>
<td>at harvest</td>
<td>1976</td>
<td>1977</td>
</tr>
<tr>
<td>(days)</td>
<td>T.S.W. *</td>
<td>Pods/plant</td>
</tr>
<tr>
<td></td>
<td>(g)</td>
<td>Seed/pod</td>
</tr>
<tr>
<td>80</td>
<td>492</td>
<td>18.3</td>
</tr>
<tr>
<td>90</td>
<td>245</td>
<td>604</td>
</tr>
<tr>
<td>100</td>
<td>578</td>
<td>934</td>
</tr>
<tr>
<td>110</td>
<td>918</td>
<td>993</td>
</tr>
<tr>
<td>120</td>
<td>902</td>
<td>904</td>
</tr>
<tr>
<td>130</td>
<td>753</td>
<td>–</td>
</tr>
<tr>
<td>140</td>
<td>683</td>
<td>–</td>
</tr>
</tbody>
</table>

* T.S.W. = thousand seed weight.

Some farmers in the north of the Sudan harvest their broad bean crop after only 80 days, with the aim of getting high prices at the time of lowest supply. However, it has been found that the difference in price obtained will not compensate for the yield reduction due to early harvesting. Investigations have indicated that the highest seed yield can be obtained by harvesting at 110 and 120 days after planting, but this of course will vary with the environmental conditions of the season (Table 2).

Infestations of weeds also result in substantial yield reductions in broad beans. Weeding has been traditionally carried out by hand, but because of the increasing cost of labour there is now an urgent need to investigate alternative control measures.

**Varietal Improvement**

**Selection**

Broad bean breeding work was initiated in 1961–62, with selections from Rebaya 40 and Baladi varieties, to identify tolerance to powdery mildew combined with earliness and a high yield potential. Selection and testing in 1963, 1964, and 1965 led to the release of the variety Baladi in the 1967–68 season.

Single plant selections for high pod number were made from Baladi and Rebaya 40 in 1962–63. Continuous selection and yield testing led to the identification of the strain BF 2/2, which showed a 47.7% increase in yield over the Baladi parent. The variety was released for commercial production in the 1969–70 season.

Further yield tests over a range of locations in northern Sudan have produced the strain
Rebaya 29, which outyielded BF 2/2 as well as being stable over the range of environments. Rebaya 29 was released in the 1973–74 season.

In the 1972–73 season, a large-scale cooperative program between the Agricultural Research Corporation and ALAD provided the breeding efforts with thousands of varieties and segregating populations. Most of these were either susceptible to powdery mildew or mosaic virus, or flowered too late to give reasonable yields, but 53 promising lines were screened and adapted from this collection. Of these, a number of lines were found to outyield BF 2/2 and Hudeiba 72 by between 35 and 52% in trials during the 1975–76 season. Further yield testing has narrowed this down to 13 lines, which are entered in plot variety trials this season.

**Variatel Crosses**

Crossoes were made with the aim of combining good agronomic characters, such as high pod set percentage, high pod number per plant, good seed size, and tolerance or resistance to powdery mildew, from different parents into selected genotypes.

Single crosses involving 10 varieties were made in the 1969–70 season and selections made in the F2, F3, and F5 generations. Pilot yield trials have shown that the yields of all selections were greater than, or equal to, the controls used. Further yield trials are now under way on this material. In addition, the most promising crosses have also been crossed with Hudeiba 72 and some promising F2 material has been obtained. Breeding work has also involved the crossing of five varieties in a 5 x 5 dialled cross, and the subsequent growing out of all seed in isolation, while encouraging intermating and crossing in an attempt to break linked characters. The highest yielding 10 selections from this program have been included in further yield assessment trials.

**Specific Programs**

Correlation studies have shown broad bean yield to be highly dependent on the number of pods per plant or per unit area. As a result, selections for high numbers of pods per plant have been made from all varietal crosses, screening nurseries, and irradiated material. Selection for autofertility is currently being carried out in these lines.

Breeding for resistance or tolerance to powdery mildew is considered to be of major importance in view of the damage caused by this disease. Selection for tolerance was made in local selections from Baladi and Rebaya 40 in 1962–63, from the varietal crosses made in 1970–71, from the three-way crosses made in 1975–76, from the new set of single crosses made between ALAD introductions and promising local varieties, and from X-ray irradiated material of three local types. In addition, sources of resistance were introduced from Germany and Russia and have been included in a backcross program. Although results of all these selections and testings are not yet available, as a consequence of the relative failure of disease development in the country over the past 2 years, progress looks promising.

**Haricot Bean (Phaseolus vulgaris)**

The haricot bean, or dry bean, is one of the main cash crops of farmers in the Northern Province of Sudan, especially in the area around Shendi and Berber, which grows over 97% of the small dry white bean acreage of this province and where yields are of the order of 0.6 tons/feddan.

**Agronomic Aspects**

The optimum sowing date for dry beans is during the last 2 weeks of October, and early sowing will again result in yield reduction, this time from plant injury due to sodium toxicity. It has been shown that seed yield is highly positively correlated with decreasing plant spacings, a spacing of 60 x 20 cm giving the highest yield. Investigations on fertilization have revealed that applications of nitrogen at sowing give significantly increased yields, but that phosphate fertilizers have little or no effect. Nodulation was
appreciably improved and the nitrogen content of plants increased by inoculation with a local strain of *Rhizobium*. Short watering intervals of about 7 days result in substantially higher yields than either 14- or 21-day intervals, and this appears to be due to both a reduction of soil temperature and to the fact that sodium ions are kept at low concentrations, thus preventing damage to the crop, which is widespread when concentrations build up.

**Varietal Improvement**

Selection work was initiated at Hudeiba in the 1962–63 season in an endeavour to discover a more suitable variety than the long-established white and medium Baladi type. Work also commenced on breeding for tolerance to a blastlike disorder observed during the active pod-filling phase of plant growth. Few selections matched the performance of the Baladi variety and it became clear that improvements in yield and seed quality could be best achieved in this crop by selection from the standard Baladi type. The strain R0/2/1, developed from selections from the original Baladi parent, was found to consistently outyield Baladi in trials in the 1966–67 and 1967–68 seasons, and in 1969 it was released to farmers. Since then it has remained the standard variety of dry bean in the Northern Province. In 1969–70, breeding work was initiated to develop resistance and tolerance to curly top virus disease, which is transmitted by the white fly and can cause serious yield losses. Single plant selections with desirable characters for resistance to this disease were made from Baladi, R0/2/1, and some introduced varieties. Slow progress is being made in this work. To select for plants tolerant to the blastlike disorder, which has been discovered to be mainly due to sodium toxicity, the whole collection of breeding material was subjected to a variety of sowing dates and hence to a variety of exposures to sodium toxicity. This procedure will continue for a number of years and hopefully produce some degree of tolerance.

**Chick-pea (Cicer arietinum L.)**

The cultivation of chick-pea in Sudan is confined to the northern provinces, where about 12 000 feddans are grown annually and where yields are generally very low due to the insufficiency of basic agronomic information in the farming community.

**Agronomic Aspects**

Sowing date trials have shown that all plants sown in September and early October died within 1 month of sowing. The highest yields appear to be obtained from mid- to late November plantings, and sowing 2 weeks earlier or later than this optimum time results in considerable yield reductions. The density of planting also has an appreciable effect on seed yield, and planting on both sides of a 70-cm ridge with an interplant spacing of 5 cm has been shown to give the highest yields. The optimum recommended between- and within-row spacings for production under irrigation are 60 cm and 5 cm with one plant per hole (or 10 cm with two plants per hole). Application of 36 kg N/feddan at sowing increased yield significantly, and splitting this dressing between sowing and flowering gave even greater yield benefits. However, no response has been reported to either phosphate or potash fertilization. The high response to nitrogen application suggests that the soils have a low N status and/or rhizobial activity is poor. Inspection of plant roots revealed no nodulation and this has led to the introduction of two rhizobial strains from ICRISAT, which, although final results are not yet available, have produced very good nodulation in trials so far. Investigations into watering intervals have shown no differences in seed yield between 7-day and 21-day irrigation cycles, demonstrating that chick-pea has a reasonable level of drought tolerance.

**Varietal Improvement**

Chick-pea breeding work began in the 1972–73 season in cooperation with ICRISAT and ALAD, who supplied a large number of germ-plasm entries, segregating populations,
disease-screening nurseries, and yield trials. The main aim of this effort is to produce varieties that combine a superior yielding ability with adaptation to a wide range of sowing dates, tolerance to sodium toxicity, and resistance or tolerance to diseases, especially wilt and stunt virus. At the same time the work emphasizes the evolution of varieties that can be fitted into improved cropping patterns.

Of the material collected from both within and outside the country, about 100 white seeded varieties were selected and grown in a large pilot trial in 1976–77. Twelve entries, outyielding the local variety Baladi by about 20%, have been entered into a standard variety trial this season and the results are being awaited.

**Lentil (Lens culinaris)**

In response to the high prevailing prices, small areas (not exceeding 200 feddans) of lentils are grown annually in the Dongola and Halfa vicinity, but crop failure is very frequent, as the climate tends to be too hot. Lack of suitable high-yielding, heat-tolerant genotypes and appropriate agronomic practices prevent the better performance of lentils in this area. However, lentil is the second-most important grain legume foodstuff in Sudan, and as a result every year the government has to import about U.S. $1 million worth of lentils to fill the gap between domestic production and consumption. To boost production and thereby replace imports, an improvement project was started at the Hudeiba Research Station in 1972.

**Agronomic Aspects**

In general the optimum sowing date for lentils is well defined in the last week of November, deviations resulting in dramatic yield reductions. However, highly significant interactions have been found between sowing date and soil type as affecting seed yield, the highest yields being obtained from plantings around early to mid-November on the lighter soils, and in mid- to late November for the heavier types (Table 3). Although yield increases with seed rate up to 100 kg/feddan, diminishing returns from the higher rates make the optimum rate around 60 kg/feddan. Drought stress is a very important consideration in lentil production in the Sudan, and investigations have shown that increasing the watering interval from the optimum of 7 days produced appreciable yield reductions. Neither nitrogen, phosphate, nor potash applications had any effect on seed yield, and studies have shown that this is probably due to the excessively high levels of soil salinity under which the crops are grown. Soil salinity and sodicity (excess salt in the soil ion-exchange complex) are major problems of crop production in northern Sudan. Lentils may be particularly badly affected by these conditions and studies are currently under way to investigate the levels and mechanisms of salt tolerance within the crop.

**Table 3. Effect of sowing dates and different soil types on seed yield (kg/feddan) of lentils in the Sudan.**

<table>
<thead>
<tr>
<th>Sowing date</th>
<th>Sandy clay lean</th>
<th>Lean clay</th>
<th>Heavy clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Oct.</td>
<td>4.6</td>
<td>5.9</td>
<td>13.4</td>
</tr>
<tr>
<td>22 Oct.</td>
<td>466.8</td>
<td>134.8</td>
<td>42.4</td>
</tr>
<tr>
<td>5 Nov.</td>
<td>671.0</td>
<td>671.0</td>
<td>353.4</td>
</tr>
<tr>
<td>19 Nov.</td>
<td>650.8</td>
<td>702.1</td>
<td>640.8</td>
</tr>
<tr>
<td>3 Dec.</td>
<td>331.9</td>
<td>81.1</td>
<td>308.8</td>
</tr>
<tr>
<td>17 Dec.</td>
<td>163.4</td>
<td>31.1</td>
<td>91.2</td>
</tr>
<tr>
<td>26 Dec.</td>
<td>18.1</td>
<td>0.8</td>
<td>2.1</td>
</tr>
<tr>
<td>14 Jan.</td>
<td>1.3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* Source: Annual Report, Hudeiba Research Station, Ed-Damer, Sudan.
Varietal Improvement

Breeding activities in lentils were initiated in 1973 at the Hudeiba Station. Since then they have mainly focused on the screening of both domestic and imported genetic stocks, on the basis of yielding ability and agronomic traits to provide a base for future breeding programs. Cooperative programs were established with ALAD in 1973 and latterly with ICARDA in 1977 and these supply all the genetic stocks and materials for the breeding work.

The Future Scope for Legume Crops

For the last 10 years, about 46 000 feddans of land have been devoted to legume production in the Northern and Nile provinces of the Sudan. To satisfy the projected growth in domestic consumption, and hence demand, for these commodities, considerable increases in production must be achieved over the next 10 years. This can be accomplished through an expansion in cultivated area to approximately 120 000 feddans or a similarly large increase in average yields of the existing area under cultivation. Obviously, any reasonable expansion must involve a combination of these two aspects; increasing the acreage in the northern provinces and initiating production on an increasing scale in those areas such as the White Nile and Kassala provinces, which are not traditional foci of legume production, while at the same time developing varieties that will give improved yields under the production conditions of the areas in question.

Special emphasis should be given to crops such as lentils, for import replacement, and dry white beans, the production of which has dropped appreciably in recent years as a result of marketing problems, as well as the more traditionally important and widely grown broad bean.

With the research programs geared to the evolution of high-yielding varieties with a good response to irrigation and other agronomic factors, including population density, sowing date, and fertilizer application with rhizobial inoculation, and with the potential for expansion as a substitute for cotton in the White Nile provinces schemes, the future for legume crops in the Sudan looks bright. Of course there are problems, but the continuing expansion in the scope and the emphasis of both the breeding and agronomic components of research is reducing these problems to a manageable size.