INTRODUCTION

Rainfed areas cover 75% of the total cropped area and account for 40-42% of the foodgrain output. So yield in drylands must increase. Even when the entire irrigation potential will be tapped, unirrigated area will continue to be very important. Almost all major crops have a significant area under rainfed conditions except sugarcane. The most important rainfed crops are cereals, millet, pulses, oilseed and cotton. It is found that 62% of the rice area and 30% of the wheat area are rainfed. More than 80% production of sorghum, pearl millet, small millets, pulses and oilseeds in India come from rainfed areas. Improvement in the productivity of these crops holds the key to the overall improvement of dryland agriculture.

Though in recent past technological developments have helped in increasing production in drylands through the choice of suitable crops and varieties, efficient cropping programmes, judicious use of fertilizers, water management and plant protection, the quantum jump, as witnessed under the irrigated conditions, is still awaited.

Evaluation and release of efficient and widely adapted varieties, particularly of cereals for the irrigated and intensive management conditions have played a pivotal role in revolutionising crop production. However, no concerted effort has so far been made to evolve high yielding and suitable varieties for rainfed areas. The varieties which are presently listed as dryland varieties were not specifically bred for such conditions. The general belief that the varieties which excel under intensive management conditions, would also do well under rainfed conditions, have been rather defied. The plant breeders face much stiffer challenge in evolving efficient varieties for dryland conditions because of extreme variability in the agro-climatic conditions of such stress areas.
Drought tolerance: The ability of cells surviving and metabolically functioning although the tissues are desiccated or are reduced with potentials.

BREEDING APPROACHES FOR DRYLAND CONDITIONS

The approaches may be classified in three groups:

(a) Physiological breeding: To increase efficiency of the plant population to make most efficient use of the solar and soil energy and the biotic factors so that total productivity as well as economic yields are maximised.

(b) Breeding for wide adaptability and stability.

(c) Removal of bottleneck genes: Breeding of varieties resistant to diseases and pests, improvement in nutritional and market quality of the ultimate products.

FEATURES OF VARIETIES SUITABLE FOR DRYLAND CONDITIONS

Plant Height and Early Vigour

Medium to medium tall varieties with high early seedling vigour are usually preferred so as to smother the weeds and to build up adequate biological yield. Extra dwarf varieties should be discouraged, varieties with moderately long, even droopy may have more plasticity in leaf rolling under stress conditions. It may be noted that this is in contrast to what constitutes an efficient plant type for intensive management conditions.

Branching Characteristics

Experiences have shown that in case of pulses and oilseed crops that moderately branched varieties consistently out yielded single stemmed varieties e.g. guar, til, etc.

Root/Shoot Ratio

Deep and branched root system is always preferred under dryland conditions. As a matter of fact positive correlations among root growth, stem height and seed weight have been revealed and since these traits are under genetic control, it would be possible to constitute genotype with above trait combinations suitable for rainfed conditions.

Earliness

Earliness confers escape from drought, however, it is negatively correlated with productivity. Efficient, early maturing genotypes with appreciable yielding ability which can match the rainfall pattern of the region are desirable. Early types are particularly useful for multiple/mixed cropping systems.

The plant type would depend on the climatic and edaphic environments under which a particular crop is to be grown. To illustrate, if the rainy season is short and distribution of rainfall is uniform within the season, a short duration variety with low to moderate level of drought avoidance may likely escape drought and produce satisfactory yields. If rainfall
distribution is abundant and uniform, any high yielding variety with medium late maturity and having low level of drought resistance might produce high yields when properly fertilised and weeded. But when the total rainfall is low and the distribution is rather erratic, an intermediate statured variety that is moderately branched, with deep and thick roots and other drought resistance properties, will provide reasonably good and stable yield under modest levels of management over the years. Therefore, the choice of an efficient plant type is more location specific for dryland conditions than for irrigated conditions. In all cases, however, the variety should have a high grain to straw ratio (harvest index) and a relatively high root to shoot ratio in order to yield efficiently.

**Harvest Index**

The proportion of the economic yield should be maximised per unit area/time/water.

**Photo- and Thermo-insensitivity**

For wide adaptability and multiple cropping a variety should be photo- and thermo-insensitive, the latter being most important for rabi crops, particularly those to be sown in October when temperature is still high.

**Genotypes Suitable for Inter/Mixed Cropping**

Selection of cultivator of different pulses and oilseed crops which are commonly grown as inter/mixed crops with Bajra, sorghum etc., the selection of both component genotypes should be done under actual conditions. Therefore, breeding for crop geometry would be another avenue for increasing water use efficiency and this increasing productivity.

**Ear Characters**

It has been shown that with adequate water supply the number of ears had the most potent influence on grain yield whereas under moisture stress, number of grains per ear and sometimes 1000 grain weight has as much effect as ear number. Since tillering capacity was not fully expressed under non-irrigated cultivation, and the main axis produce most of the ear population, its yield (grain number and grain weight) should have an important influence on total grain yield per unit area.

**Leaf Growth**

Under condition of moisture stress, it would be desirable to maintain leaf areas commensurate with minimal water loss and optimum photosynthetic output and growth.

**Leaf Arrangement**

Under non-irrigated conditions where a high plant population cannot be sustained, horizontally disposed leaves will intercept light better. It has been reported that horizontal leaves in wheat retain dew better and longer than vertically disposed leaves and, therefore, maintain a better water balance under non-irrigated conditions.
AN IDEOTYPE OF WHEAT FOR NON-IRRIGATED CONDITION

Asana (1969) suggested a model for wheat plant for barani cultivation, the main characteristics are described below.

**Ear:** It must have a large number of fertile spikelets, or a fertile branched ear, to provide for a large number of grains.

**Peduncle:** Its length should form a substantial proportion of the length of stem, because photosynthesis in the peduncle and flag leaf-sheath contributes to yield.

**Leaves:** About seven on main axis (with a large sized flag leaf), preferably horizontally disposed.

**Root System:** Must be substantial in the third and fourth foot of soil depth.

**Time of earing:** The ear must emerge at such a time that grains can develop for at least five weeks at a mean maximum temperature around 25°C. Asana and Saini (1962) also emphasized the importance of seed number and 1000 grain weight under rainfed cultivation other attributes that will also be desirable under water stress are: long awns, hairy and light-green leaves, waxy stem etc.

PLANT TYPES FOR PULSES

As regard to pulses, they have been grown mostly in marginal lands characterised by moisture and fertility stress with the result that they have been selected for such primitive characteristics as a bushy, spreading, and in some cases indeterminate growth habit associated with prolonged maturity duration and non-synchronised development. Above all, they have a low harvest index. These characteristics are of considerable adaptive value in the dryland conditions but they also account for the fact that most of the energy and nutrients are diverted to the formation of vegetative parts rather than the grains. The total dry matter production in pulses like chickpea and pigeonpea are very high but only a small part of it is recovered in the form of grains. These traditional plant types/varieties are not able to take advantage of improved agronomic practices and they cannot be fitted in intensive cropping pattern.

The new strategy is, therefore, based on restructuring of pulses so as to evolve new plant type that can be fitted in a series of multiple and intercropping pattern with the cereal and other crops. The main effort in evolving these new plant types has been to reduce maturity duration to induce more synchronised development in terms of pod formation and to repartition the dry matter so that more of it will be diverted to the formation of seeds.

SCREENING VARIETIES FOR DROUGHT RESISTANCE

Many techniques have been developed and are modified in the past for measuring water stress in plants, however, no one method can be considered most reliable. For large scale screening it is suggested that under strictly rainfed conditions large population of germplasm or segregating materials may be raised at short intervals during the crop season, assuming that crop in each date of seeding will receive different amount of moisture. Genotypes which suffer least reduction in plant height, root number, root depth, dry matter production, harvest index and economic yield, would be considered drought tolerant/resistant. The threshold of the
different cultivars can be studied by varying soil moisture in controlled fashion. Plant response which may indicate drought resistance, such as:

(i) Plasticity in leaf rolling and unfolding during stress
(ii) Death of lower leaves
(iii) Injury to upper leaf
(iv) Degree of stunted growth
(v) Delay in flowering and other, may serve as guidelines for selection.

Physiological parameters which supplement the screening are the following:

(i) Cuticular resistance
(ii) Resistance to potassium chlorate toxicity or water absorption power of germinating seeds in specific solutions.
(iii) The water retention capacity of excised plants
(iv) And the changes in the sugar content of the seedling.

Certain changes in amino acid metabolism and protein synthesis have been associated with resistance to moisture stress the concentration of soluble nitrogen compounds being increased. The increased accumulation of proline in leaf tissues has been reported under stress conditions in cereals. It may be emphasised that the screening based on physiological and biochemical parameters should be correlated with findings from field experiments.

Accumulation of favourable genes adopting population improvement approaches coupled with multilocation testing, should prove effective in evolving desirable genotypes for dryland conditions.

**RECENT ADVANCES IN THE BREEDING OF VARIETIES OF OILSEED SUITABLE FOR DRYLAND AREAS**

Among nine oilseeds grown in the country groundnut and rapeseed-mustard together account for 62% of total oilseeds production. Total area under oilseeds was 25.26 million hectares with the annual production of 24.46 million tons (Anonymous 1997). The average productivity of oil seeds was 368 kg per ha. during 1951 while during 1995-96 it was 851 kg per hectare. The average productivity in India is very low as compared to the world average of 1262 kg per hectare.

The total oilseed production in Rajasthan is 3.1 million tons (Anonymous 1996-97) which is derived from groundnut, rapeseed-mustard, soybean, sesame, castor seed, niger seed and linseed (Table 2.1).

The major oilseed crops of the arid zone are sesamum and castor in **kharif** season and Rape-Mustard in **rabi** season. The other oilseed crops like sunflower and safflower also hold promise for the area.

**Sesame:** Sesame is grown in about 3 lac hectare area in western Rajasthan with 33.7 thousand metric tons of production. The average productivity is about 106 kg per ha. It is a major oilseed crop of western Rajasthan in **kharif** season.
**Advances in Plant Physiology**

**Table 2.1: Area, production and productivity of oilseed crops in Rajasthan**

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Area (‘000 ha.)</td>
<td>420</td>
<td>268</td>
<td>36</td>
<td>37</td>
<td>245</td>
<td>329</td>
<td>2816</td>
<td>2812</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>Production (000t)</td>
<td>88</td>
<td>53</td>
<td>48</td>
<td>47</td>
<td>273</td>
<td>369</td>
<td>2622</td>
<td>2041</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Productivity kg/ha</td>
<td>209</td>
<td>197</td>
<td>1352</td>
<td>1287</td>
<td>1112</td>
<td>1122</td>
<td>1002</td>
<td>726</td>
<td>550</td>
<td>549</td>
</tr>
</tbody>
</table>

**Castor:** India is one of the world’s principal producer of castor, contributing more than 40% of the total world production. Annually the crop is raised over an area of about 7.16 lakh hectares and its production in 8.9 lakh tons in India. With the availability of hybrid varieties, the productivity of castor sharply increased from 409 kg per hectare (1969-70) to 1243 kg per hectare (1997-98). In western Rajasthan, castor is grown to a limited extent only in some areas.

**Sunflower:** The commercial cultivation of sunflower in India began in 1972-73 with the introduction of open pollinated varieties of Russian origin. The area under the crop was 15,000-20,000 ha. in 1972-73 while in 1993-94 it touched 2.4 million hectares with a production of 1.6 million tons and a productivity of about 700 kg per hectare. The introduction of the crop in the arid zone was successful and promising. (Daulay, Singh and Henry, 1984).

**Rapeseed Mustard:** India is the largest mustard producing country, occupying an area of 6.47 million ha. and producing about 6.10 million tonnes which is about 32 per cent acreage of world under Rape/mustard. Rajasthan stands first in average and production i.e. 26.9 lakh; hectares and 23.68 lakh tons, respectively. (Agriculture in Rajasthan: some facts March, 1997 Directorate of Agriculture, Jaipur). The area under these crops was 13.68%.

**Safflower:** In the country it is grown in about 7.5 lakh hectare area mostly in peninsular states. The crop proved successful during rabi season in arid areas (Henry and Daulay, 1990, Henry and Kumar 1991).

**Breeding Objectives**

The major breeding objectives for the improvement of the productivity of these crops may be grouped as under:

(i) Adaptation of the species to the environment
(ii) Increasing yield of oil per hectare
(iii) Improvement or change in oil quality
(iv) Improvement in protein quantity and quality of oilseeds.

1. **Adaptation of the species to the environment:** Most oilseed crops, upon their introduction to a new area, give a less than promising performance. Adjustment can be of two types:
   (a) Modification of the environment, (b) Modification of heredity.

(a) **Modification of the environment:** It is identifying the best agricultural situation for a crop. Having identified the agricultural environment for the species, optimum production practices, in terms of dates of seeding, plant population, irrigation etc.
must be developed. In arid zone, castorbean has been introduced successfully and was found very promising. Similarly there is scope of introducing sunflower cultivation in *kharif* season. Sunflower holds promise during *rabi* season under limited irrigation conditions.

(b) **Modification of heredity:** The major adjustment on introducing a new crop to an area is in its heredity. Traditional breeding techniques are generally used, including evaluation of introduction, selection and hybridisation. Recently biotechnology is employed to develop high yielding varieties in mustard.

1. The first step was to identify the species with most promise
2. The identification of genotypes within these species adapted to the new environment. Selection is an obvious first step in the improvement of introduction (what to select?)
3. The introduced selection can be improved upon by hybridisation of different types to combine good qualities of 2 or more introduction. The technique and role of hybridisation in the improvement of oilseed crops is discussed by Fehr and Hadley (1980).

In most oilseed crops, efforts have been made to develop hybrid cultivars. Greatest success have been achieved with sunflower (Fick, 1978) where a (cytoplasmic male sterile) line, B. (maintainer) lines and R (restore) lines were used to produce single cross hybrid. Seetharam et al (1980) developed 8 hybrids by using four male sterile lines and two fertility restorer lines. Out of these BSH-1 and BSH-2 were identified as the most desirable hybrids. Compared to open pollinated and synthetic cultivars, hybrid cultivars are higher in yield and more uniform in maturity.

Efforts are being made in other oilseed crops to develop hybrid cultivars, thus for with little success. Botoson and Gairdner (1921) discovered the cytoplasmic male sterility (CMS) in flax but no hybrid varieties have become available because of low yield of CMS lines in crossing block. In India, CMS lines, maintainer and restorer lines are available in rape and mustard. Genetic male sterility is available in safflower (Heaten and Knowles, 1982), but the cost of removal of male fertile types in crossing blocks has made the price of seed high. Rac (1982) also indicated tremendous potential of hybrid in safflower for raising per hectare yields and oil. In castor, after introduction of exotic pistillate line from Texas (USA) namely TSP-10R, India initiated systematic research efforts on hybrid castor. Six hybrids were released for commercial cultivation.

2. **Increasing yield of oil per hectare:** Increased yield of oil may be achieved in two ways (i) by increasing the seed yield per hectare (ii) and by increasing oil content of the seed. Increased seed yield can be achieved through combination of better cultivars and better production practices. Increased oil content can be achieved in 2 ways (a) by decreasing the proportion of the seed that is hull or seed coat area (b) by increasing the oil content of the embryo. For example, the first major step in the development of sunflower as an important oil crop was the development of thin hulled types in Russia. Seeds of such types had an oil content ranging from 40-45 per cent, whereas the older unimproved types had 25-35 per cent. Their introduction to other countries led to the development of many new breeding programmes on sunflower as an oil crop. A similar development has taken place in safflower (Rubis, 1967, Urie and Zimmer, 1970
and Urie, 1981) where reduction in hull has resulted in higher oil content. In rapeseed, yellow seeded cultivars have higher oil content because of thinner seed coats (Downey et al, 1975). Likewise in Flax, yellow seed cultivars have thinner seed coats and higher oil content than brown seeded cultivars.

Changes in the oil content of the embryo, have been achieved in soybeans, usually with opposite changes in protein content (Hartwig and Hinson, 1972). A similar situation sometimes prevails in cruciferous species (Downey et al, 1975).

3. Improvement or change in oil quality: Change or improvement in oil quality have been achieved in large part by modifying the fatty acid composition of the oil. Greatest success has been achieved in rapeseed species and in safflower. Canadian and European rapeseed breeders have been able to remove crucic and eicosonic acids from rapeseed oil (Downey et al, 1975). Thus providing a new oil crop with a fatty acid profile somewhat like that of soybean oil. The new oil was much more acceptable for use in edible products.

In safflower modification involves changes in the proportion of stearic, oleic and linoleic acids (Knowles, 1969, 1972). In safflower and to a large extent in rapeseed, genetic control of fatty acid composition was expressed in the embryo. Both embryo and sporophytic control of fatty acid composition was found in sunflower (Fernandez-Mand) and rapeseed (Kondra and Stefansoon, 1970). In soybean, Brim et al (1968) found only sporophytic control. Breeding procedures will be governed to some extent by the location of genetic control.

4. Improvement in protein quantity and quality of oilseeds: After extraction of the oil from oilseeds, the residue, which is a cake or meal, is high in protein. Most of the cake and meal is used as livestock and poultry feeds.

(i) Changes in protein quantity
As long as hull and/or seed coat amount remain constant, there is an inverse relationship between oil and protein content. The reduction in hull of safflower has resulted in increase in oil content, there has been a parallel increase in protein content also. A similar situation exists in rapeseed where the seed coat has been reduced (Downey et al, 1975).

(ii) Changes in meal quality
Protein quality of an oilseed meal may be measured by its amino acid composition. Almost all oilseed meals contain products that are toxic or undesirable in some way. Examples are trypsin inhibitors in soybean. Aflotoxin in groundnut, chlorogenic acid in sunflower, gossypol in cotton seed, matairesinal monoglucoside and lignan glicoside in safflower, oxalates in the seed coat of sesame and ricin in castorbean. In some these toxic substances removal or reduction is not possible by genetic means. The toxic glucosinolates in the meal of rapeseed were reduced by Canadian workers to very low levels by genetic means (Downey et al, 1975) such that meal quality was almost equivalent to that of soybean. The improved rapeseeds, free of erucic acid and much reduced in levels of glucosinates, are referred to as “double zero” or CANOLA types (Anonymous, 1981).
The evaluation of newly developed castor varieties indicated that by growing varieties like GAUCH-1 and Aruna, the higher yield potential can be obtained in arid regions of western Rajasthan (Henry and Daulay, 1985; Daulay, Singh and Henry, 1984).

**Sunflower (Helianthus annus L.)**

The following problems are associated with its production in India:

(i) Poor seed set and filling is one of the important constraints limiting its productivity. This refers to the large percentage of empty and partially filled seeds in the capitulum resulting in low test weight. This affects both seed and quality of the produce.

(ii) The varieties are highly heterogeneous and lack of uniformity appears to be a general feature.

(iii) Susceptibility to diseases like rust, alternaria leaf spot and various root and stem rot.

(iv) Bird damage.

(v) Problems associated with the marketing of the produce.

**Improvement Required**

Sunflower breeding in Soviet Union has made remarkable progress in improving seed oil content, from about 30 per cent in the early 1920’s to almost 50 per cent in the present-day varieties. They have used a modified form of recurrent selection similar to the ear to row method used in U.S. for maize. The discovery of cytoplasmic genetic male sterility has made possible the evolution of hybrids. These hybrids have removed the above-mentioned problems to some extent. Hybrid sunflower has the following special features.

(i) More production stability.

(ii) More self-fertility leading to superior seed set.

(iii) Uniformity in flowering.

(iv) More tolerance to diseases.

(v) Early in maturity and more drought tolerance.

(vi) Suitable of input intensive agriculture. The performance of newly evolved hybrid/varieties at CAZRI, Jodhpur indicated that hybrid BSH-1 MSFH-9 and MSFH-7 holds the promise for yield potential in the area (Daulay, Singh and Henry, 1984; Henry and Kumar, 1991).

**Safflower (Carthamus tinctorius L.)**

It is a drought hardy crop and can also be grown well under salt affected soil conditions and in light to heavy textured soils. It has a strong tap root which draws water from fairly deep layers of the soil profile and, therefore, is best suited to the arid regions. Compared to other oilseed crops, it is low in oil content (28-32%). Hence in safflower, breeding for high oil content assumes greater importance than any other trait. Another disadvantage associated is that all the native cultivars of safflower are handicapped by very thick pericarp which adversely limits the per hectare yield of oil as well as the quantity and quality of the meal in the crop, thereby, making its cultivation low and less attractive. Apart from their low yield potential, all available
germplasm sources of high oil content from outside sources display very poor adaptability to Indian conditions. The incorporation of alleles for low hull and/or high oil content into the genetic background of locally adapted agronomic base should form an important breeding activity in the immediate future. Like sunflower, poor seed filling is also a problem in case of safflower. Karve et al (1981) reported that this may be due to the presence of partial self-incompatibility, coupled with differences in insect pollinators.

The evaluation of newly evolved safflower varieties in the region revealed that varieties like Tara, JL28-7 and S-4, APPR-1 are most promising from yield point of view (Henry and Daulay 1990, Henry and Kumar 1991).

**Rape and Mustard (Brassicas spp.)**

Rape and mustard belong to the group of *Brassicas* species. Rape generally refers to the *Brassica campestris* and mustard or Raya to *B. junca*. Taramira (*Eruca sativa*) though belongs to a different genus but of the same family, is generally referred under rape and mustard. The following factors are responsible for the low yield of crops viz.

(i) Susceptibility to aphid attack
(ii) Frost damage to the crop
(iii) Lower content of oil in the seed
(iv) Low seed yield potential under conserved moisture.

**Improvement Required**

Model for increase yield: Drought resistance appeared to be associated with deep roots, waxy leaves and ability to drop most of the leaves under drought stress after the seed pods have been formed. This adaptation to stress appeared to be useful since most of photosynthate used for the production of seeds is produced by the green pods and stems. The mustard species appeared to have greater drought tolerance than rapeseed.

It is indicated that early maturing cultivars should have adequate sink capacity. Sinks have been defined as areas in the plant where the products of photosynthesis are utilized for the formation of grains. The plant should not have more than 12 leaves. The first 3-4 leaves should be fairly large to provide leaf area as quickly as possible and thus provide nutrients for the production of plant structures, such as roots, stems and leaves. The remainder of the leaves should be progressively smaller to provide a pyramidal form which will permit the maximum penetration of sunlight into the plant canopy. The plant probably should not have more than 3-6 branches near the top and should have very little basal branching. Stem strength should be sufficient to prevent early lodging but slight lodging near maturity may be beneficial in reducing wind damage to the crop. The variety should also be resistant to aphid attack and frost damage for realising higher yield potential. This idiotype should result plants which are not highly competitive in a mixture of genotypes.

Large number of genotypes of rape and mustard were evaluated over the years at CAZRI, Jodhpur, under limited moisture supply conditions.
Breeding Efficient Crops and Varieties for Dryland Conditions

Yellow Sarson (*Brassica campestris* sub sp. *Sarson prain* Var. *Yellow Sarson*)

Five important genotypes of yellow sarson were evaluated for their performance during the 3 winter seasons under limited moisture supply condition. Genotype YID-1 gave the highest mean seed yield and was suitable for favourable growing conditions. DYS-3 and YID-3 also had high seed yield and had responses near to unity. However, response of YID-3 was only stable (Henry and Daulay, 1990).

The salient features of the important varieties of the oilseed crops are given Table 2.2.

<table>
<thead>
<tr>
<th>Table 2.2: Salient features of oilseed varieties</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Name of crop</th>
<th>Name of the variety</th>
<th>Maturity</th>
<th>Yield (kg/ha)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sesame</td>
<td>RT-46</td>
<td>85-90</td>
<td>400-500</td>
<td>It is a white seeded branched variety. It is found resistant towards ooze disease complex.</td>
</tr>
<tr>
<td></td>
<td>RT-127</td>
<td>80-90</td>
<td>500-600</td>
<td>It is identified for cultivation in Rajasthan state in 1998</td>
</tr>
<tr>
<td></td>
<td>TC-25</td>
<td>85-90</td>
<td>400-500</td>
<td>It is a white seeded branched variety having a wide adaptability</td>
</tr>
<tr>
<td></td>
<td>T-13</td>
<td>90</td>
<td>350-400</td>
<td>It is a white seed branched variety having a wide adaptability</td>
</tr>
<tr>
<td>Castor</td>
<td>Aruna (Mutant of HC-6)</td>
<td>115-120</td>
<td>600-700</td>
<td>It is a early maturing variety.</td>
</tr>
<tr>
<td></td>
<td>Bhagya (R 63)</td>
<td>130</td>
<td>500-600</td>
<td></td>
</tr>
<tr>
<td>Hybrid varieties</td>
<td>GCH-3 (TSP-10R)</td>
<td>—</td>
<td>—</td>
<td>It is a high yielding hybrid variety</td>
</tr>
<tr>
<td></td>
<td>GAUCH-1 (VP-1XVI-9)</td>
<td>130</td>
<td>800-900</td>
<td>Green stem, spiny capsule, triple bloom.</td>
</tr>
<tr>
<td></td>
<td>GCH-2 (VP-IXII-35)</td>
<td>—</td>
<td>(1700-1800)</td>
<td>Green stem, non-shattering triple bloom</td>
</tr>
<tr>
<td></td>
<td>GCH-4 (All India)</td>
<td>—</td>
<td>(1900-2000)</td>
<td>Wilt resistant and monogamy stem, triple bloom.</td>
</tr>
<tr>
<td></td>
<td>GCH-5 (All India)</td>
<td>—</td>
<td>(2600-2700)</td>
<td>Double bloom, wilt resistant and monogamy</td>
</tr>
<tr>
<td></td>
<td>TMVCH-1 (T-N)</td>
<td>—</td>
<td>(1100-1200)</td>
<td>Red stem, non-dehiscent, spiny capsule</td>
</tr>
<tr>
<td>Sunflower</td>
<td>Morden</td>
<td>75-80</td>
<td>600-800</td>
<td>36-38% oil content. All States.</td>
</tr>
<tr>
<td></td>
<td>EC-68414</td>
<td>100-110</td>
<td>800-1000</td>
<td>40-42% oil content. All States.</td>
</tr>
<tr>
<td></td>
<td>TNAU-SUF-7</td>
<td>90-95</td>
<td>800-1200</td>
<td>38-42% oil content. All States.</td>
</tr>
<tr>
<td></td>
<td>GAU-SUF-15</td>
<td>90-95</td>
<td>800-1200</td>
<td>38-42% oil content. All States.</td>
</tr>
<tr>
<td>Hybrid</td>
<td>BSH-1</td>
<td>85-90</td>
<td>1000-1500</td>
<td>40-42% oil content. All States.</td>
</tr>
<tr>
<td></td>
<td>KBSH-1</td>
<td>90-95</td>
<td>1200-1500</td>
<td>42-44% oil content. All States.</td>
</tr>
<tr>
<td></td>
<td>APSH-11</td>
<td>90-95</td>
<td>1000-1500</td>
<td>40-42% oil content. All States.</td>
</tr>
</tbody>
</table>
### Table 2.2 Contd.

<table>
<thead>
<tr>
<th>Name of crop</th>
<th>Name of the variety</th>
<th>Maturity (Days)</th>
<th>Yield (kg/ha)</th>
<th>Remarks</th>
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<tr>
<td><strong>Rapeseed/ Mustard</strong></td>
<td>PKVSH-27, MSFH-1, MSFH-8, MSFH-10</td>
<td>75-80 High yielding hybrids</td>
<td>800-1100</td>
<td>38-40% oil content. All Maharashtra.</td>
</tr>
<tr>
<td><strong>Brown Sarson</strong></td>
<td>T-9</td>
<td>95-100</td>
<td>1000-1200</td>
<td>Oil content 44.3%</td>
</tr>
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<td></td>
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<td>1200-1500</td>
<td>Oil content 44.2%</td>
</tr>
<tr>
<td></td>
<td>TH 63 (Suman)</td>
<td>85-90</td>
<td>1500-1700</td>
<td>Oil content 43.9%</td>
</tr>
<tr>
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<td>Pusa Kalyani</td>
<td>130-135</td>
<td>1300-1500</td>
<td>Oil content 45%</td>
</tr>
<tr>
<td></td>
<td>BSH-1</td>
<td>130-140</td>
<td>1200-1500</td>
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<td>Raudys 89-115</td>
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**IMPROVEMENT ASPECTS OF PULSES**

In pulses following are the main constraints to increased productivity.

*Evolutionary and Ideotype Constraints*

- Narrow base of different germplasm sources
- Mostly grown in marginal lands characterised by moisture and fertility stress with the result that they have been selected for such primitive characteristics as a bushy, spreading and in some cases indeterminate growth habit associated with prolonged maturity duration and non-synchronised development.
- Non-uniform partitioning of dry matter both in vegetative and reproductive phase.
- Lack of ideal plant type for inter and multiple cropping systems.
- Flower drop and dehiscence of pods before harvest are known to affect grain yield considerably.
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enough genetic variability which can be utilised with advantage for breeding high yielding varieties (Henry and Krishna, 1986). The development of high yielding varieties is the basic requirement in Mothbean (Henry and Singh 1985). In evaluation of Mothbean varieties for inter/mixed cropping with pearl millet, it was revealed that variety JMM-259 gave better performance in inter-cropping while var. T-18 gave better performance in mixed cropping.

**Clusterbean or Guar**

- To identify/evolve a variety, which can be adapted to the agro-climatic conditions of the region at the same time their growth rhythms matching the rainfall pattern of the region.
- To evolve varieties resistant to *Alternaria* blight, bacterial blight and dry root rot diseases.
- To evolve variety having high galactomanan content in the endosperms of the seeds.
- To evolve determinate plant type.

Breeding programmes to bring about genetic improvement in clusterbean was started in erstwhile dry farming centre at CAZRI (Singh and Henry 1981). More than 5 thousand germplasms of this crop are evaluated and characterised for different characteristics. Studies on genetic diversity in the indigenous material indicated that enough genetic variability and diversity are present in the available germplasm for utilisation in the hybridisation programme (Henry et al, 1984, Henry et al, 1986, Henry and Krishna 1990). High yielding genotypes evolved through crossing programmes are being tested at various locations through All India Co-ordinated Varietal trials. Clusterbean crop has a indeterminate growth habit, where flowering, vegetative growth and pod formation take place simultaneously with the result at maturity upper portion of the plant remains seen and upper portion pods also remains immature and result in dry matter loss at harvesting. To avoid such loss, it was envisaged to evolve a determinate plant type, which is not available in the existing germplasm, through mutation breeding. For the purpose seeds of variety FS-277 were treated with chemical Mutagen, EMS. Variants having determinate growth habit were selected from the segregating generations. These mutants gave better performance over parent-FS-277 (Henry and Daulay, 1987). Its further testing with other promising varieties like HG-75, G-1 indicated at par performance while with vars. like RGC-936, Suvidha, it gave better performance (Henry 1999). In the identification of the suitable varieties, it was indicated that varieties like HG-75, HG 182, D. safed, 2470/12, are suitable ones (Henry and Daulay; 1983, Kackar and Henry, 1984) among medium late maturity group. Among the single stemmed varieties, varieties like HFG-314, PLG-119, PLG-85 proved superior. Among early maturing groups, varieties like HG 7-2 (Naveen) and Suvidha proved superior (Henry and Daulay, 1984; Henry, 1993). Varieties were evaluated against different rhizobial strains (Daulay and Henry, 1997).

Variant selected from the germplasm like 2470/12 gave better performance over check varieties in All India Co-ordinated Varietal trials. Its further testing in adaptive trials and minikit trials indicated its superior performance over the other check varieties tested. Based on its superior performance, it was released and notified for general cultivation by Central Seed Committee in Nov. 1986 under the name Maru-Guar (Henry et al, 1992). In evaluation of
Selection (light dark seed coat colour) were high yielding and stable genotypes for various situations (Henry and Daulay, 1988). Genotype PI-Selection was tested under diverse agro-climatic zones of the country over the years in All India Co-ordinated Varietal trials, and gave the highest mean performance, over the other varieties tested. Based on its superior performance, genotype PL-selection was released and notified for general cultivation by central seed committee in year 1989 under the name Maru-Kulthi-1.

**Chickpea (Gram)**

It is grown to a limited extent in Ganganagar, Nagaur district under limited moisture supply conditions. The objective in varietal improvement of gram in order of priorities are high grain yield with good consumer acceptance parameters (cooking quality, palatability, seed colour, size) and stability in performance by incorporating resistance to diseases like wilt, blight and rust and insect-pests.

The testing of promising varieties of chickpea under limited moisture supply conditions revealed that variety ICCC-42 and Manak (14-16 q ha\(^{-1}\)) holds promise or the area.

**Pigeonpea (Arhar)**

With the availability of the extra-early maturity strains in pigeonpea, it was envisaged to evaluate its performance under both rainfed conditions during monsoon season and under limited moisture supply conditions during winter season in the arid regions to see its suitability. The variety should be of short duration and should carry resistance to the three major diseases, viz., wilt, sterility mosaic and *phytophthora* blight as well as to pests particularly pod borer and pod fly.

**Table 2.3:** The performance of improved var. of grain legumes at CAZRI, Jodhpur

<table>
<thead>
<tr>
<th>Grain legumes</th>
<th>Variety</th>
<th>Maturity (Days)</th>
<th>Mean productivity (kg ha(^{-1})) (Long term)</th>
<th>State average (kg ha(^{-1})) (Long term)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clusterbean</td>
<td>Maru Guar HG-75 G-1</td>
<td>Branch medium late varieties</td>
<td>97-105</td>
<td>750-850</td>
</tr>
<tr>
<td></td>
<td>Suvidha, Naveen, RGC-936</td>
<td>Branch early varieties</td>
<td>80-85</td>
<td>800-900</td>
</tr>
<tr>
<td>Mothbean</td>
<td>FS-277, PLG-119, PLG-85, HFG-314</td>
<td>Unbranched varieties</td>
<td>90-95</td>
<td>600-800</td>
</tr>
<tr>
<td></td>
<td>CAZRI Moth-1, Maru Moth-1, Jadia Jwala</td>
<td>Medium maturing varieties</td>
<td>80-85</td>
<td>400-600</td>
</tr>
<tr>
<td>Greengram</td>
<td>IPCMO-880, T-18</td>
<td>Medium late varieties</td>
<td>90-95</td>
<td>300-500</td>
</tr>
<tr>
<td></td>
<td>S-8, K-851</td>
<td></td>
<td>60-65</td>
<td>700-900</td>
</tr>
<tr>
<td>Cowpea</td>
<td>Charodi-1, FS-68</td>
<td></td>
<td>60-65</td>
<td>700-900</td>
</tr>
<tr>
<td>Horsegram</td>
<td>Maru-Kulthi-1</td>
<td></td>
<td>100-105</td>
<td>600-700</td>
</tr>
</tbody>
</table>
The evaluation of extra-early germplasm during monsoon revealed that there exist genetic variability for all the important characters as well as genetic diversity among the genotypes so that the same could be utilised with advantage in crossing programmes (Henry and Krishna 1990, 1992). The performance of different varieties of pigeonpea during winter season revealed that varieties ‘Basant’ and ‘Bahar’ are suitable for the post-rainy season cultivation under limited moisture supply conditions (Henry and Daulay, 1988).

The performance of improved var. of grain legumes at CAZRI, Jodhpur are presented in Table 2.3.

REFERENCES