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BIODIVERSITY UTILIZATION AND CONSERVATION IN UNDERUTILIZED PLANTS : INDIAN PERSPECTIVE*

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With ever increasing population pressure and fast depletion of natural resources, it has become extremely important to diversify the present day agriculture in order to meet various human needs. The underutilized plants which have tremendous potential for commercial exploitation but remained ignored, offer a good scope in this context. The Hindustani gene centre houses 160 cultivated species, out of which 56 species are less known food plants. In the present paper, an attempt has been made to enlist underutilized plants of economic value which could, in future, serve as new crops and supplement agricultural production in India. The results of recent efforts on this group of plants made by the All India Coordinated research Project on Undertuilized Crops, the National Bureau of Plant Genetic Resources, New Delhi and other institutions towards germplasm collection, evaluation, documentation and utilization have been enumerated. The status of germplasm conservation and the future strategies have also been discussed.

Agriculture is a resource which renews itself quickly and in abundant measure. It is the world's oldest profession, and also the noblest. It pulled man out of the animal world of killing, grabbing, garnering and devouring and developed in him the humane qualities of exploring, observing, growing and sharing. However, of the 80,000 edible plants explored since the beginning of

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civilization, man has never made a major use of more than 150 species. Today, less than 30 species meet 90 per cent of world's requirement.

Most experts think that it is dangerous to allow the future of 500 billion people to depend upon the performance of less than 0.4 per cent of the edible plants. We must learn to diversify our food base and try to find out better uses for the much ignored underutilized plants. Many of them are far superior to what our present-day cereals were when our ancesstors first sampled them. Underutilized plants are a veritable treasure-house, waiting to be explored, altered and improved upon to suit our needs and tastes. Resilient and adaptive, many of them are tolerant to adverse conditions and can grow on lands that do not support other plants. They do not require a high input technology and can be raised with comparatively lower management costs. Several of them are very nutritious and have often come to the rescue of people in times of crisis.

Agro-ecological regions in India

India is located between 8–38°N and 68–97.5°E and exhibits extreme variation in altitude, from sea level to heights above vegetational limits (3500 m) in the Himalayas. It is also characterised by a wide variety of climate, from the monsoon, tropical in the south to temperate and alpine in the north-western plains. It is floristically rich with more than 50 per cent of its botanical wealth comprising over 15,000 species of higher plants. This makes the Indian region botanically unique and interesting. Based on physiographic, climatic and cultural features, eight agro-ecological regions (Table 1) are recognised in India (Murthy and Pandey, 1978).

Underutilized plants of economic importance

The Hindustani (Indian) gene centre, with 160 cultivated species of economic plants, serves as a reservoir of a large number of useful plant species. The diversity of less known cultivated food plants is confined to 56 species. Further, about 320 species represent the truly wild and weedy counterparts as components of different vegetation types (Arora and Nayar, 1984). Information on plant genetic resources of these less known cultivated food plants and their wild relatives is well documented (Arora and Nayar, 1984;

Table 1 : Agro-ecological regions of India and their characteristics

S.No.	Region	Temperature	Rainfall	Soil
1.	Humid Western Himalayan Region	Jan. 8° -4°C July 5° -30°C	1500 mm	Forest and Hill, Mountain Meadow Soils
2.	Humid Bengal-Assam Basin	Jan. 10° -25°C	2000 mm	Alluvial, Red Sandy, Lateriate and Soils
3.	Humid Eastern Himalayan Region and Bay Islands	Jan. 11° -24°C	2000 mm	Riverine Alluvial, Red and Laterite Soils
4.	Sub-Humid Sutlej Ganga Alluvial Plains	Jan. 6° -23°C July 25° -41°C	1000 to 1500 mm	Riverine Alluvial Soils With saline and alkaline Patches
5.	Sub-Humid to Humid Eastern and South Eastern Uplands	Jan. 16° -28°C July 27° -35°C	750 to 1500 mm	Red and Yellow, Red Sandy, Black and Coastal Alluvial Soils
6.	Arid Western Plains	Jan. 10° -22°C July 28° -45°C	250 to 750 mm	Alluvial, Sandy Desert and Black soils
7.	Semi-Arid Lava Plateaus and Central Highlands	Jan. 13° -29°C July 26° - 42°C	500 to 1000 mm	Predominantly Black Soils, Red Sandy and Red Loamy Soils
8.	Humid to Semi-Arid Western Ghats and Karnataka Plateaus	Jan. 20° -29°C July 28° -38°C	750 to 2000 mm	Predominantly Red Sandy Soils, Black Coastal Alluvial and Laterite soils

Arora, 1985). There are also several introduced species which have a great potential to be exploited for various purposes in the country. An account of important underutilized plant species which await exploitation for food, fodder, energy and industrial purposes have been given earlier (Paroda and Bhag Mal, 1989; Bhag Mal, 1990).

In India, there are large areas which suffer with edaphoclimatic extremes of different kinds and the people face problems for their food and other requirements. However, there exist several indigenous plant species which can support life during difficult environments and emergency situations. Information on such plant species has been well documented (Gupta and Kanodia 1968; Bhandari, 1974; Saxena, 1979; Shankarnarayan and Saxena, 1989; Shankar, 1989 and Singh and Gupta 1989). The important plant species which can be successfully grown for food under harsh environmental conditions are listed in Table 2.

Table 2 : Food plants for emergency situations

Situation	Usage	Species
Hot desert	Grain	*Setaria verticillata, Haloxylon salicornicum, Citrullus colosynthis, C. lanatus, Echinochloa colonum, E. crus galli, Abutilon indicum, Eleusine compressa*
	Leaves, tender shoots	*Amaranths gracillis, A. hybridus, A. spinosus, Chenopodium album, Boerhavia diffusa, Euphorbia cacodifolia, Moringa oleifera, Portulaca oleracea, Aloe barbadense*
	Fruits	*Grewia tenax, Zizyphus nummularia, Cordia gharaf, Coccinia grandis, Cucumis callosus, Momordica dioica, Salvadora oleoides, S. persica*
	Tubers	*Cyprus rotundus, C. bulbosus, Asparagas racemosa, Ceropegia bulbosa, Butea monosperma, Portulaca tuberosa*
Cold desert	Grain	*Fagogyrum esculentum, F. tataricum*
	Leaves	*Allium leptophyllum, Aconitum heterophyllum, Cicer songarium, Polygonum viviparum, Sedum tibeticum, Scorzonera mollis*
Semi-arid region	Leaves	*Boerhaavia diffusa, Bryonica lacimosa, Triumfetta rhombifolia, Cocculus hirsutus, Amaranthus viridis, Leptadenia reticulata*
Saline areas	Fruit	*Salvadora oleoides, S. persica*
	Foliage	*Salicornia brachiata*
	Leaves	*Chenopodium album, Protulaca oleracea, Trianthema portulacastrum*
Marshy lands/ flood areas	Vegetables	*Alternanthera sessilis, Hygroryza aristata, Monochoria hastata*

Species prioritization

There is an increasing need to broaden the range of plant species for the diversification of Agriculture. A massive untapped potential of species exists for meeting the needs for food, fodder, feed, fibre, energy and industrial products. The prospects of these species to become agricultural crops vastly differ due to several factors. The cost of domesticating and bringing a new species into agriculture, horticulture or forestry is very high and the time required is many years. The change of environmental conditions poses problems and, therefore, an environment similar to the natural one should be selected for initial evaluation to understand the potential of the crop. The new crop has to find a place in the existing or modified cropping system or a place in an area not presently used. It should be sufficiently commercially attractive by justifying a change. Quality of the produce, marketability, profitability and people's preferance are also important considerations. Keeping in view the various factors, a few plants with a good promise for commercial exploitation have been selected for undertaking intensified research efforts under the All India Coordinated Research Project on underutilized plants. These species requiring priority attention are listed in Table 3.

Table 3 : Underutilized plants needing priority attention

Crops/species	Usage	Adaptation/Areas of cultivation
A. First Priority Crops		
Amaranth (*Amaranthus* spp.)	Grains, leafy vegetable	Northern hills, north and south Indian Plains.
Buckwheat (*Fagopyrum* spp.)	Grains, leafy vegetable	Temperate Himalayan region, southern India hills
Rice bean (*Vigna umbellata*)	Pulse, fodder	Hot humid climates, sub-tropical Hilly regions
Winged bean (*Psophocarpus tetrogonolobus*)	Pulse, vegetable, fodder, edible roots	Sub humid tropical parts of north-eastern region, central/ eastern peninsular region
Faba bean (*Vicia faba*)	Pulse, vegetable, fodder	Eastern, northern and penninsular India.
Tumba (*Citrullus colocynthis*)	Seed oil for industrial use; pulp of roots used in medicine	Warm arid and sandy tracts of north-west, central and southern India.
Jatropha (*Jatropha curcas*)	Seed oil used in oil mixtures; making soaps and candles	Marginal lands, gravelly sandy, clayey, eroded lands
Jajoba (*Simmondsia chinensis*)	Industrial oil, pharmaceuticals, cosmetics	Arid lands and coastal wasteland
B. Second Priority Crops		
Chenopod(*Chenopodium* spp.)	Grains, leafy vegetable	Himalayan region
Adzuki bean (*Vigna angularis*)	Pulse, vegetable	Northern hilly region
Kankora (*Momordica dioica*)	Vegetable	Central India
Guayule (*Parthenium argentatum*)	Good source of rubber	Arid lands
Paradise tree (*Simarouba glauca*)	Edible oil	Central, Eastern India
Cuphea (*Cuphea* spp.)	Industrial oil	North and north-eastern hills
Subabool (*Leucaena leucocephala*)	Fodder, fuel wood	Arid and semi-arid regions
Saltbush (*Atriplex* spp.)	Fodder	Arid situations, salt affected lands

Table 3 Contd. ....

Crops/species	Usage	Adaptation/Areas of cultivation
Casuarina (*Casuarina* spp.)	Fuelwood	Coastal wastelands
Bamboo	Cottage, paper industry, fuelwood, vegetable	North-eastern region, western ghats
C. Third Priority Crops		
Bambara groundnut (*Vigna subterranea*)	**Grains rich source of carbohydrate and lysine**	**Dry arid tracts**
Forage groundnut (*Arachis glabrata*)	**Green fodder, silage, leaf meal pellets**	**Rangalands in humid tropics and sub-tropids**
Vegetable wild rice (*Zizania coduciflora*)	Fodder	**Marshy lands, swampy, Waterlogged areas**
Euphorbia (*Euphorbia* spp.)	Source of hydrocarbons	**Sandy and rocky soils in arid regions**

Present status of research on Underutilized Plants

The research activities on various aspects of different underutilized plants are underway at several Institutions including the State Agricultural Universities, the Research Institutes under the Indian Council of Agricultural Research (ICAR) and the Council of Scientific and Industrial Research (CSIR) as well as the voluntary organisations. The All India Coordinated Research Project on underutilized and underexploited plants with its headquarters at the National Bureau of Plant Genetic Resources (NBPGR) and 25 centres including the cooperating centres in different agro-climatic zones of the country, coordinates the programme. A brief account of germplasm collection, evaluation, utilization and conservation relating to this group of plants is given here.

Germplasm acquisition

The germplasm building efforts are being made consistently through plant explorations for collecting the diversity available in particular crops in different parts of the country. The NBPGR organises periodic crop specific and multi-crop explorations. Sizeable germplasm has been collected in a few selected species mostly through multi-crop explorations. Five crop-specific explorations were conducted during the last decade and over 1000 accessions of amaranth were collected from Himachal Pradesh, Uttar Pradesh, Gujarat and eastern Maharashtra. However, it is felt that in multi-crop explorations, underutilized plants do not get the required emphasis and, therefore, there is a great need to conduct more crop-specific explorations for these crops to enrich the germplasm assemblage.

Useful germplasm is also introduced from different countries through the National Bureau of Plant Genetic Resources, New Delhi which maintains exchange links with about 70 countries of the world. The information on the source data etc. of the introductions made is regularly published in the Plant Introduction Reporters brought out quarterly. Crop inventories highlighting information on introduced materials have also been published by the NBPGR for different crops namely, winged bean and jojoba.

Table 4 : Germplasm assembled and evaluated in important under-utilized crops

Crop	No. of accessions	Source country
Amaranths	4100	India, Nepal, Malawi, Zambia, Poland, Taiwan, USA
Buckwheat	331	India, USSR
Chenopods	92	India, Poland, USA, Italy, Hungary, USSR
Rice bean	500	Nepal, China, India, Indonesia, Brazil, Nigeria
Winged bean	321	India, Ghana, Papua, New Guinea, Nigeria, Indonesia, Philippines, USA, Thiland, Sri Lanka
Faba bean	700	West Germany, Syria, USA, UK
Adzuki bean	70	Japan, USA, India
Bambara groundnut	192	Nigeria, India, Australia, UK, USA
Leucaena	574	Philippines, Australia, USA, Syria
Casuarina	65	Philippines, Australia, Tanzania
Bamboo	45	India
Guayule	80	USA, Mexico
Jojoba	75	USA, Israel, UK, Mexico
Jatropha	16	India, Brazil
Tumba	190	USA, India
Cuphea	30	USA, Germany
Euphorbia	56	USSR, USA, Philippines

Information on the total germplasm assembled through plant explorations within the country and the introductions from abroad alongwith source countries, is given in Table 4.

Genetic diversity and its utilization

Systematic evaluation and characterisation of indigenous and introduced materials have been done at the Bureau's headquarters, its regional stations and other centres involved in work on underutilized plants. Based on the evaluation carried out and the data recorded on various characters, crop catalogues were prepared for amaranth and winged bean and are in process for other crops. Promising accessions with specific desirable traits have been earmarked for use in the breeding programmes. Native and introduced germplasm variability has been successfully utilized in developing improved varieties through selection in a few selected species. The varieties released or identified for release and other strains identified promising are listed in Table 5.

Table 5 : Promising varieties released/identified in selected underutilized crops

Crop	Variety	Year of release/ identi-fication	Eco-nomic product	yield potential (q/ha)	Areas for which recommended
Grain amaranth	Annapurna	1984	Grain	22.50	North-west hill region
	GA-1	1991	Grain	25.00	Gujarat, Maharashtra
Buckwheat	Himpriya	1991	Grain	15.0	High altitude regions
	VL 7	1991	Grain	10.0	Mid-hills of Uttar Pradesh
Winged bean	AKWB-1	1991	Green pods	105.0	All winged bean growing areas
Rice bean	RBL-1	1986	Grain	15.0	Punjab State
	RBL-6	1991	Grain	18.0	North and North-eastern region
Guayule	Arizona-2	1986	Rubber	13.50	Arid and semi-arid regions
	HG 8	1991	Rubber	15.00	Arid and semi arid regions
Jojoba	EC 33198	1986	Oil	5.00	Arid regions and coastal areas

Information on available genetic diversity and its utilization in respect of a few important crops is briefly enumerated below :

I. FOOD PLANTS

Grain amaranth (*Amarunthus* spp.)

Evaluation of germplasm (2610 accessions) for 40 descriptors at NBPGR Regional Station at Shimla revealed a wide genetic variation for the production traits. Plant height, inflorescence length, 1000 grain weight, protein content and grain yield showed high coefficient of variability, heritability and genetic advance which suggested that these could be effectively used in the improvement programme. Distribution pattern of three main grain species suggested that there was a basic difference in their physiological adaptation. Some accessions of *Amaranthus caudatus* from chauhar valley in Himachal Pradesh had 150 cm long dropping inflorescence (Paroda and Joshi, 1990). Compared to landraces from Himachal Pradesh, those from the Uttar Pradesh hills were taller and higher yielding. Collections from the north eastern hills were less tall, stout and late maturing. Pink seeded types were confined to higher hills. A total of 852 accessions were evaluated at NBPGR Regional Station, Akola and a wide variation was observed for different charaders.

Hybridization work carried out at the National Botanical Research Institute, Lucknow revealed that intraspecific crosses between Indian and Mexican accessions of *A. cruentus* succeeded easily in both directions. However, interspecific crosses between *A. cruentus* and *A. hypochondriacus* succeeded only with *A. cruentus* as female parent. Close genetic homology of *A. retroflexus*, a weedy species, with cultivated species opened the possibilities of combining adaptability to cold and dry conditions of *A. retroflexus* with edible seed features of *A. cruentus*.

Based on multi-locational trials, selection IC 42258-1 was identified the best and released as 'Annapurna' for cultivation in the hill region. This variety possesses 15 per cent protein, drought tolerance and wider adaptability and is capable of producing 22.5 q/ha grain yield. Recently, another variety GA1 with long inflorescence, bold grains and high yield potential of 25.0 q/ha has been released for cultivation in Gujarat and Maharashtra states. Two other accessions IC 5564 and an exotic introduction of *A. edulis* from Taiwan were observed to be promising.

Buckwheat (*Fagopyrum* spp.)

Germplasm comprising 408 accession belonging to six species, namely, *F. esculentum, F. tataricum, F. cymosum, F. emarginatum, F. himalayanum* and *F. giganticum* were evaluated for 31 descriptors at NBPGR Regional station, Shimla and the information has been catalogued. The germplasm showed a wide range of variation for different agromorphological traits and promising types possessing specific desirable traits particularly early maturity (75-85 days), short height (65-85 cm), bold grains (3.8-5.0 g/100) and high seed yield (15-20g/plant) were identified for further use (Joshi and Paroda, 1991).

Evaluation of 19 accessions for fodder production at K.D. Farm, Srinagar revealed a good degree of variation in plant height (20.8-86.6 cm), number of leaves per plant (122-125) and green fodder yield (65.6-3432 q/ha) (Arora and Engels, 1992).

Concerted selection programmes at NBPGR Regional Station, Shimla and Vivekanand Parvatiya Krishi Anushandhan Shala, Almora and multi-locational testing of promising types under the auspices of All India Coordinated Project on Underutilized crops resulted in the release of variety 'Himpriya' for high altitude regions and VL7 for mid-hills of Uttar Pradesh.

Chenopod (*Chenopodium* spp.)

Eighty four germplasm accessions were evaluated for 12 characters at NBPGR Regional Station, Shimla. There was a wide variability in plant height, flowering and maturity period, leaf size, inflorescence size, seed size and grain yield. An accession NC 58613 was identified as the most promising. Promising types were identified based on multi-locational trials which included BDJ 476, BDJ 480, CH/LKW 10, CH/LKW 49. Tall growing strains of *Chenopodium album*, namely BDJ 171, BDJ 285, and BD 519 from hill region showed excellent growth under water stress situations in the northern plains. This offered a good scope for their exploitation as fodder types during the lean period of summer (May-June). Further studies for their use as fodder are underway.

Evaluation of 9 entries of *C. album* during 1991 revealed a good degree of variation for days to flowering (51-65 days), days to maturity (95-125 days), plant height (71.6-146.3 cm), clusters per plant (13.5-24.2) and grain yield (5.8-16.0 q/ha). The range of variation in C. *quinova* entries was 58-148 days for flowering 34-297 cm per plant height, 0.58-4.06 cm for stem thickness, 8.3-39.0 for spikes per plant, 19.0-60.1 cm for spike length and 3.16-6.87 q/ha for grain yield (AICRP, 1992).

The analysis conducted at the National Botanical Institute (NBRI), Lucknow revealed that protein and amino acid present in a new species of *Chenopodium* collected from eastern Himalaya was comparable to that of *C. album* and *C. quinova* (M. Pal, personal communication). Analysis of foliage of 10 different species of *Chenopodium* at NBRI, Lucknow exhibited a wide variation for protein (26.0-64.0 g/kg), carotenoid (78.0-190.0 mg/kg), vitamins (0.5-2.4 g/kg), nitrate (2.6-5.0 g/kg) and oxalate (9.0-39.0 g/kg).

Rice bean (*Vigna umbellata*)

Over 500 accessions from north-eastern, central and east peninsular regions as well as introduced from other countries were evaluated at the NBPGR Regional Station, Shimla. The analysis of inter-regional diversity patterns for agro-morpholocial traits, biochemical constituents and disease and pest screening indicated a rich diversity in Indian germplasm. Cultivated forms are erect/semi-erect. Tendrillous types also occur in its region of distribution in Asia and Southeast Asia. Mainly intermediate forms are found in India. Considerable genetic polymorphism was observed for pod shape, size and colour. Several accessions with black, purple, red, violet, greenish, yellowish or mottled seeds were observed. Biochemical studies revealed its nutritional richness with high protein, calcium, iron and phosphorus alongwith comparatively high tryptophan and methoionine.

Hybridization between an early variety from China, a bold seeded variety from Mysore and a yellow seeded variety from Nepal led to the development of several promising lines combining earliness and high yield. A promising selection C X M_{12} $P_{2\text{-}3}$ capable of giving upto 25 q/ha grain yield under Shimla conditions holds good promise for cultivation in the hills. Variety RBL-1 has been developed at Punjab Agricultural University, Ludhiana, and has been released for cultivation in Punjab state. Another variety 'RBL6' with grain yield potential of 18 q/ha was released in 1991 for cultivation in north and north-eastern region. Mutation breeding involving an indeterminate landrace treated with 100 Kr gamma rays resulted in the production of an early, photo insensitive and determinate mutant (Singh and Tomar, 1989).

In multi-locational experiments conducted under the auspices of All India Coordinated Research Project on Underutilized crops, rice bean cultivars showed a grain yield range of 6-15 q/ha at hilly locations and 10-21 q/ha at different locations in the plains (AICRP, 1992). The crop has produced 200-220 q/ha green fodder after 70-80 days and is capable of giving upto 350 q/ha, if harvested after 120-130 days (Chandel *et al.*, 1988).

Winged bean (*Psophocarpus tetragonolobus*)

Rich genetic diversity was observed in the germplasm assembled from various sources and most of the agro-morphological traits exhibited polymorphism. Majority of the accessions were tall, viny and tentrillar which were vigorous in growth and biomass production. The accessions from India had condensed internodes and were less vigorous compared to exotic strains from Indonesia. Some strains flowered in 60 days but majority were late, taking 140 days for flowering. Indonesian types were better in pod and seed characters. The information on different aspects is well documented (Chandel *et al.*, 1984).

Promising strains were tested in multilocational trials and four selections namely, EC 38821, EC 38821B, EC 38955 and IIHR-13 a yield level of 105 q/ha for green pods has been released for cultivation as a vegetable type in the winged growing areas in the country. A few introductions viz., Blue course (EC 27884), Blue Fine (EC 28854) both from Ghana, Molk (EC 38855) for Papua New Guinea and EC 116886 and EC 121818 appeared promising in grain yield. Promising early types included EC 121296 from Nigeria and EC 37755A, EC 38823A, EC 38825 and EC 27886A from Papua New Guinea. Mutation breeding programme at the University of Agricultural Sciences, Bangalore resulted in the development of promising mutants with bushy, dwarf, determinate/semi-erect growth habit and early maturity (Shivshankar, 1982; Veeresh, 1986; Savithramma, 1987).

Faba bean (*Vicia faba*)

Evaluation of 607 germplasm accessions at NBPGR, New Delhi revealed wide variability in pod size, seed size and seed colour. Evaluation studies at Haryana Agricultural University, Hisar (Chhabra, 1983) indicated a good degree of variation for flowering time (68-94 days), maturity period (121-188 days), plant height (44.1-100 cm), branches per plant (1-6), internode length (1.4-4.0 cm), clusters per plant (4.0-46.3), pods per plant (4.7-73.6), seeds per pod (2.0-3.0), 100 seed weight (18.3-78.9 g), and seed yield per plant (2.4-49.8 g). Significant differences among genotypes were observed for seed yield, harvest index, 100 seed weight and seed protein both under water-stress (rainfed) and non-stress (irrigated) conditions.

A high yielding selection VH 82-1 possessing indeterminate growth habit, medium bold seeds, high yield potential (25-35 q/ha) and maturity duration of 155-160 days has been identified promising (Akbar *et al.*, 1992). Other promising types include HB 24, HB 123, HB 180 and HB 186.

Adzuki bean (*Vigna angularis*)

Thirty one accession were evaluated at NBPGR Regional station, Shimla and a wide range of variation was observed for plant height (25-49 cm), branches per plant (3-8), clusters per plant (6-10), pods per cluster (3-5), pods per plant (11-30), pod length (6-10 cm), seeds per pod (6-9) and seed yield per plant (9-16 g).

Systematic screening resulted in identification of EC 108080, IC 15256 and EC 120460 giving high seed yields with higher mean values for pods per plant, pod length and seeds per pod. EC 108080, EC 120460 and EC 241041 appeared promising in northeastern hill region, while HPABT, HPAB 9 and HPAB 21 showed better performance in Uttar Pradesh and HPU 51 in Himachal Pradesh. A selection VL Gruns 5 was also observed promising.

Bambara groundnut (*Vigna subterranea*)

Germplasm comprising 30 accessions was evaluated at NBPGR Regional Station and a good degree of variation was observed in pod size, seed size and grain yield. Testing of 12 promising accessions revealed that EC 134511, EC 37527 and EC 27881 were high yielding types.

II. FODDER PLANTS

Forage groundnut (*Arachis glabrata*)

Studies conducted at the Indian Grassland and Fodder Research Institute, Jhansi indicated that this species which surpasses the growth of perennial weeds like *Parthenium, Saccharum* and *Desmostachya* is capable of producing upto 950 q/ha green fodder in six cuts in a year. Another species *Arachis hagenbeckii* showed better yield potential and persistancy. Animal feeding of *A. glabrata* forage indicated the absence of anti-nutritional factors.

Vegetable wild rice (*Zizania caduciflora*)

Trial plantations of this species at the University of Agricultural Sciences, Bangalore indicated its good adaptability yielding 436 q/ha green fodder in four cuts in a year. Exploratory studies conducted at NBPGR, New Delhi revealed its good establishment and very fast growth under water-logged conditions. Further studies need to be conducted to assess the yield potential of this species.

Leucaena (*Leucaena leucocephala*)

Evaluation of 574 germplasm accessions indicated a wide range of variation for several traits. This species has been found to perform well in agro-forestry system. Hybridization involving Hawaiian Salvador and Peru types of *L. leucocephala* and *L. pulverulenta* has been attempted and promising types combining useful characters have been developed. K-8 (EC 124343) from Phillippines and El Salvador (EC 123866) from Australia proved superior for fodder and fuel in Gujarat and Kerala states. Silvi- 4 and K-28 were observed to be the best in above-ground biomass yield. In varietal trials at Urlikanchan, FG7, FG32, FG24, K-8, EC 150183 and EC 123519 proved superiod.

Salt bush (*Atriplex* spp.)

Nine species, namely, *A. amnicola, A. bunburyana, A. cinerae, A. lentiformis, A. paludosa, A. undulata, A. nummularia, A. canescens* and *A. halimus* have established well in arid zones at Jodhpur. Accession EC 129766 of *A. nummularia*, EC 129767 of *A. halimus* and EC 129768 of *A. canescens* showed good performance under extreme arid situations. Fodder yield potential of these species under saline-alkali soils needs to be determined through well planned experimentation.

Casuarina spp.

Sixty five accessions of different species, viz., *Casuarina equisetifolia, C. cunninghumiana* and *C. cristata* have been evaluated at Mattupalayam (Tamil Nadu) for different growth traits. An accession of *C. equisetifolia* from Philippines was observed promising. Accession No. 13223 of *Alcocasuarina corniculata* with higher plant growth and basal diameter was identified promising. This species with short side branches and straight bole is desirable for agro-forestry. The studies conducted at the Central Soil Salinity Research Institute, Karnal revealed that *C. equisetifolia* showed 90-95% survival both in surface planting and channel planting methods under high salinity levels (Tomar and Gupta, 1985).

Bamboo

Germplasm comprising 36 accessions of 30 species belonging to 8 genera, *Arundinacea* (2), *Bambusa* (16), *Cephalostachyum* (3), *Chimonobambusa* (3), *Phyllostachys* (2), *Pseudostachyum* (1), *Dendrocalamus* (8) and *Teinostachyum* (1) were established at Basar (Arunachal Pradesh). The widest diversity was observed in *Bambusa* (12 species and 4 morphotypes) followed by *Dendrocalamus* (6 species and 2 morphotypes). Initial screening of the established clumps indicated three distinct classes, viz., tall, less prolific; medium tall, medium prolific and short, highly prolific which could be put into three utility classes (i) pulping and timber (ii) handicraft making and (iii) live fencing, respectively.

Population behaviour of three species, *Bambusa tulda, B. pallida* and *Denodrocalamus hamiltonii* was studied at two locations (240 m and 690 m above msl). The vigour of all the three species was expressed better at the lower altitude. In *B. pallida,* ethral treated variants showed increased vigour and proficiency, while colchicine treatment affected dwarf and bushy appearance. Fifteen mutant selections are being further studied.

III. INDUSTRIAL PLANTS

Guayule (*Parthenium argentatum*)

Eighty accessions introduced from Mexico and the United States were evaluated for growth attributes and a wide range of variation was observed for plant height, stem thickness, branching and biomass yield. Promising accessions were tested in multi-locational trials and Arizona-2, G-4, HG 8 and HG 9 were identified superior in biomass yield. EC 148913 and HG 9 were observed to be high rubber and resin producers. Based on multilocational trials over the years, HG 8 has been released for commercial exploitation as an additional source of rubber in the arid and semi-arid zones of the country.

Efforts were also made to hybridize guayule with other Parthenium species like *P. incanum*, *P. tomentosum* and *P. stramonium* and the hybrids with *P. tomentosum* and *P. stramonium* showed considerable promise (Patel *et al.*, 1986).

Jojoba (*Simmondsia chinensis*)

Evaluation of germplasm comprising 75 accessions revealed wide range of variation in growth and seed yield attributes. This plant species has been tried at several sites with variable edapho-climatic conditions and has been found successful on arid lands and coastal wastelands. Accession EC33198 from USA has been found promising and recommended for large scale cultivation. Three other accessions, namely, EC 124381, EC 99690 and EC 99691 were also observed promising. Breeding work at the NBPGR Regional station, Jodhpur revealed the possibility of developing early fruiting types. Agro-techniques for raising a good crop have been standardised. Propagation through cuttings has been perfected. Standardization of techniques for micropropagation through tissue culture is in progress at the NBPGR, New Delhi.

Plant height and plant spread were observed to be significantly correlated with seed yield, number of seeds per plant and 100 seed weight. Investigations were also conducted at the central salt and Marine chemicals Research Institute, Bhavnagar on physiological and biochemical characterisation of male and female plants to identify sex at an early stage. Important metabolic constituents i.e. nucleic acids, total proteins and carbohydrates were found accumulated more in female plants than males. Electrophoretic analysis of proteins showed difference in the banding pattern in male and female plants and specific bands were absent in males.

Jatropha curcas

A wide variation in plant height, branching, 100-seed weight and grain yield was observed in 16 accessions collected from

Banaskantha and Mehsana districts of north Gujarat. Good performing genotypes, both in small seeded and large seeded groups, were earmarked. Multi-locational testing revealed the superiority of Dantiwada bold, Patan local and S.K. Nagar local.

Tumba (*Citrullus colocynthis*)

Germplasm comprising 360 accessions were evaluated for seed yield and other characters at Mandore (Rajasthan) and considerably high range of variation was observed for seed yield, 1000 seed weight and seed weight per fruit, the top ranking genotypes being GP 285, GP 116 and GP 294, respectively. Interspecific hybridization was attempted involving different forms of *tumba (Citrullus colocynthis* and *Citrullus lanatus*) and the material has been advanced to F_4 and F_5-generations. Crosses were also attempted between GP3 and superior segregants to incorporate bold seeded, thin testa and high seed yield. Mutation breeding programme was also undertaken and the bulk seed harvested from F_3 generation of interspecific cross, *C. colocynthis* x *C. lanatus*, was irradiated with 30 and 50 kr. gamma rays. Single fruits were harvested on the basis phenotypic appearance of desirable traits for further studies.

***Cuphea* spp.**

Germplasm evaluation of 30 accessions belonging to different *Cuphea* species, namely *C. wrightii, C. lutea, C. painteri, C. procumbens* and *C. carthagonosis* revealed a wide variation for different traits. A few promising types were selected for further testing. These high seed yielding accessions were EC 133501, EC 133506, EC 133508, EC 258142 and EC 258150.

***Euphorbia* spp.**

Thirty seven accessions of *Euphorbia caducifolia* were evaluated at Sardar Krushinagar and the genotypes viz., Sabarmati-1, Vijapur, Keva-2 and Jesanpura were observed to be high dry matter producing types. Evaluation of 15 accessions of *E. tirucalli* revealed that Chandisor-1 was the best in growth performance. *E. antisyphlitica* which is a good source of candellila wax was observed to perform well under arid conditions at Jodhpur. Other species which could be exploited for hydrocarbon include *E. lathyrus, E. nerifolia, E. nivulea* and *E. trigona.*

Germplasm conservation

The National Bureau of Plant Genetic Resources, New Delhi maintains the valuable germplasm of different under-utilized and under-exploited plants at the Headquarters and its Regional Stations located in different agro-climatic zones of the country. Also, a few selected centres of the All India coordinated Research Project on under-utilized Plants have the responsibility for maintenance of germplasm of particular plant species. The germplasm holdings of important under-utilized crops at different centres are given in Table 6. The germplasm is presently being maintained through periodic rejuvenation. However, cold storage facilities are being developed at the crop based Institutes of the Indian council of Agricultural Research as well as the Regional Stations of the Bureau. For long term storage of base collections, five cold storage modules have been commissioned to maintain the germplasm at –20°C. Currently, over 1,40,000 accessions of different crops including the under-utilized plants are maintained in laminated alluminium foil packets in these modules. The construction of the new National Gene Bank building under the Indo-USAID project on Plant Genetic Resources already operative at the NBPGR is underway and with this facility, Bureau's capability for long term storage will increase to 600,000 accessions.

Future strategies

The need for reducing dependence on a few species, man's desire for novelty and new useful compounds, continued interest in increasing crop returns and reducing imports and surplus are some important consideration in the search for new useful crops. Such crops may also be important for new agricultural systems and for expanding the productive area into marginal regions where few known crops are in cultivation. Therefore, careful planning needs to be done towards the choice of proper species, their genetic improvement aimed at developing better varieties, standardization of cultivation practices, popularization and their proper utilization.

Concerted efforts to build-up the germplasm of prioritized species from indigenous and exotic sources need to be made. Crop specific exploration programmes need to be undertaken to collect the available diversity. Adaptability studies will help a great deal in finding out suitable agro-climatic conditions for different species. Standardization of package of practices for their efficient cultivation

Table 6 : Current germplasm holdings of important underutilized plants

Institution	Location	Crops	Accessions
ICAR Institutes			
National Bureau of Plant Genetic Resources	New Delhi	Amaranth	824
		Buckwheat	250
		Faba bean	220
		Guayule	23
NBPGR Regional Stations	Shimla	Amaranth	3133
		Buckwheat	543
		Chenopods	90
		Rice bean	340
		Adzuki bean	38
		Cuphea	30
	Jodhpur	Tumba	190
		Jojoba	33
		Bambara groundnut	30
		Atriplex	11
	Akola	Amaranth	1065
		Winged bean	242
		Faba bean	108
	Shillong	Ricebean	338
		Adzuki bean	48
	Trichur	Winged bean	153
Indian Grassland & Fodder Research, Institute	Jhansi	Leucaena	174
Research complex for NEH Region	Basar	Bamboo	36
State Agricultural Universities			
Gujarat Agricultural University	S.K. Nagar	Jatopha	16
		Euphorbia	56
Tamil Nadu Agricultural University	Mattupalayam	*Casuarina*	65
Rajasthan Agricultural University	Mandor	Tumba	154
Haryana Agricultural University	Hisar	Guayule	20

is also necessary. Well planned plant breeding efforts are also required to develop genetically superior strains for raising the level of productivity. Efforts are also required to be made to examine the possibility of introduction of new crops into the existing cropping systems/land use systems. This would greatly help in promoting these crops as supplementary crops and not as substitute crops. For crops that produce raw materials for the industry, simultaneous arrangements for setting up required infra-structure for processing the products as well as their marketing need to be made. Many of these species, though economically important yet are less known and hence must be given due attention for their popularisation. Also appropriate research and development efforts are required to be made for their utilisation. The entire genetic diversity built-up is required to be maintained through appropriate long and short term conservation measures.

The All India coordinated Research Projected Unit maintains close linkage with National Bureau of Plant Genetic Resources and its Regional Stations, selected ICAR crop based Institutes, CSIR Institutes, State Agricultural Universities and other Govt. Departments for effective implementation of the programme on underutilized plants. There is an active interaction with other National Coordinated programmes on pulses, oilseeds, forage crops and agro-forestry which also deal with some under-utilized plants in respective groups. Such linkages need to be further strengthened to create an effective national network to undertake multi-disciplinary research efforts on underutilized plants of promise. Linkage also needs to be established with International centre on Underutilized crops, London (U.K.), International Board for Plant Genetic Resources, Rome (Italy) and other related International Organisations to give a boost to the Indian programme on this group of plants.

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