

# Indian Journal of Plant Genetic Resources

ISSN 0971-8184

*Towards Conservation and  
Sustainable Utilization  
of Plant Diversity*

*Published by*

**Indian Society of Plant Genetic Resources**

NBPGR Campus, New Delhi 110012 (India)

Vol. 17 No. 2 2004

## Status of Horticultural Crop Genetic Resources in India

Gunjeet Kumar, KK Gangopadhyay, VK Dobhal, KC Bhatt and BS Dhillon

National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi-110 012

Horticultural crops consist of fruits, vegetables, ornamentals, root and tuber crops, spices and condiments, plantation crops and medicinal and aromatic plants. However, the present paper deals with genetic resources of fruits, vegetables and ornamentals. India is endowed with presence of rich diversity in large number of fruit crops and their wild relatives e.g. citrus, mango and banana etc. found predominantly in North eastern region, western peninsular tract and Western Ghats. In vegetables namely, brinjal, luffa, cucumber, pointed gourd, Indian spinach, dolichos bean etc., India is considered as a primary centre of origin. India is also native of important flowers like orchids, rhododendrons, muskrose, begonia, balsam, lily, lotus and a number of ornamental trees like kachnar, pink cassia, flame of the forest etc. A substantial number of valuable germplasm of fruits, vegetables and ornamentals including trait specific accessions have been introduced from different countries mainly from USA and Taiwan. The region wise diversity for fruits, vegetables and ornamental crops are given separately. Horticultural crops being vegetatively or seed propagated require complementary conservation strategies employing both *in situ* and *ex situ* methods. The vegetatively propagated perennial horticultural crops are conserved in field gene bank (FGB) whereas the seed propagated horticultural crops are conserved in seed bank at  $-20^{\circ}$  C. Few horticultural crops, like banana and plantain (*Musa* spp.) either do not produce seeds or produce recalcitrant seeds such as coconut, cacao and many tree and shrub species, are conserved *in vitro*. The conservation of horticultural crop genetic resources is jointly managed by NBPGR along with National Active Germplasm Sites (NAGS).

**Key Words:** Fruits, Germplasm, India, Medicinal and Aromatic Plants, Ornamentals, Vegetables.

India is endowed with a large number of native horticultural crops. Rich diversity of about 50 different indigenous fruits and their wild relatives, totalling about 400 species exists in different agro-ecological regions of India (Rai and Gupta, 1996, Pareek *et al.*, 1998). The North-eastern region has maximum concentration of the wild relatives of fruits followed by the western peninsular tract and the western Himalayas. Rich diversity in North-eastern region is reported in citrus, mango and banana (Arora and Nayar, 1984; Ghosh, 1984). In citrus, *Citrus lemon*, *C. medica*, *C. jambhiri*, *C. ichangensis*, *C. latipes*, *C. macroptera*, *C. assamensis*, *C. indica* and *C. aurantium* are indigenous to this region. The Indian wild orange, *C. indica*, is found in the Naga hills, Garo hills of Meghalaya and Kaziranga forests of Assam. Similarly in mango, the wild forms of *Mangifera indica* and its allied species *M. sylvatica* occur in the forest of this region while *M. andamanica* is native to Andaman Islands. Rich diversity occurs in northwestern and eastern Himalayan region for *Pyrus*, *Rubus*, *Ribes* and *Prunus*. The Shillong plateau of Khasi hills in Meghalaya accounts for many *Prunus* species such as *P. nepaulensis*, *P. undulata* and *P. cerasoides*.

India is primary centre of diversity for aonla (*Emblia officinalis*), bael (*Aegle marmelos*), ber (*Ziziphus mauritiana*), citrus (*Citrus* spp.), jackfruit (*Artocarpus*

*heterophyllus*), jamun (*Syzygium cumini*), karonda (*Carissa carandas*), khejri (*Prosopis cineraria*), kokam (*Garcinia indica*), lasora (*Cordia mixa*), mango (*Mangifera indica*), phalsa (*Grewia subinequalis*), pilu (*Salvadora oleoides*), tamarind (*Tamarindus indica*) and woodapple (*Feronia limonia*) and secondary centre for banana, *Malus* spp., mulberry, pomegranate, *Prunus* spp., *Pyrus* spp. and *Rubus* spp.

The indigenous fruit species and their geographic distribution (Rai and Gupta, 1996) are presented in Table 1.

The Indian subcontinent has 80 species of major and minor vegetables apart from several wild species consumed as vegetables. India is primary centre of origin for brinjal (*Solanum melongena*), cucumber (*Cucumis sativus*), dolichos bean (*Lablab purpurens*), drumstick (*Moringa oleifera*), Indian lettuce (*Lactuca sativa*), Indian spinach (*Basella rubra*), ivygourd (*Coccinia cordifolia*), pointed gourd (*Trichosanthes dioica*), ridge gourd (*Luffa acutangula*), smooth gourd (*Luffa cylindrica*), sword bean (*Canavalia gladiata*) and winged bean (*Psophocarpus tetragonolobus*) and secondary centre for brassicas (*Brassica* spp.), chillies (*Capsicum* spp.), cowpea (*Vigna sinensis*), okra (*Abelmoschus* spp.) and pumpkin (*Cucurbita moschata*).

Overall, around 20-25 vegetable crops are commercially important and these comprise both indigenous and exotic species variability. Tropical

vegetable crops are grown throughout the country, as suitable agro-climates are available. The temperate vegetables have more specific requirements and are grown mainly in the Himalayan region and to some extent in higher ranges of the Western and Eastern Ghats.

Also these are well adapted as cool season crops in northern/north-western plains and in the tarai foothills. The diversity, both in cultivated and wild species of vegetable crops that occurs throughout India (Arora, 1991) is presented in Table 2.

Table 1. Region wise diversity for fruit crops and their wild relatives

| Sl. No. | Agroecological Region(s)                       | Crops/ Species                                                                                                                                                                                                                                                 |
|---------|------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.      | Western Himalayan region                       | <i>Citrus</i> , <i>Carissa</i> , <i>Malus baccata</i> , <i>Myrica esculenta</i> , <i>Prunus armeniaca</i> , <i>P. cerasoides</i> , <i>P. cornuta</i> , <i>P. persica</i> , <i>Punica</i> , <i>Pyrus pashia</i> , <i>P. pyrifolia</i> and their wild relatives. |
| 2.      | North-eastern Himalayan region                 | <i>Artocarpus</i> , <i>Citrus</i> , <i>Garcinia</i> , <i>Malus sikkimensis</i> , <i>Mangifera</i> , <i>Musa</i> , a few taxa of <i>Pyrus</i> viz. <i>P. sikkimensis</i>                                                                                        |
| 3.      | Eastern Peninsular region                      | <i>Aegle</i> , <i>Annona</i> , <i>Artocarpus</i> , <i>Averrhoa</i> , <i>Emblica</i> , <i>Elaeocarpus</i> , <i>Limonia</i> , <i>Musa</i> , <i>Spondias</i> , <i>Syzygium</i> , <i>Tamarindus</i> , <i>Vitis</i> and <i>Zizyphus</i>                             |
| 4.      | Western Arid/Semi arid region                  | <i>Capparis</i> , <i>Carissa</i> , <i>Cordia</i> , <i>Grewia</i> , <i>Phoenix</i> , <i>Prosopis</i> and <i>Zizyphus</i> spp.                                                                                                                                   |
| 5.      | Central region                                 | <i>Artocarpus</i> , <i>Buchanania</i> , <i>Carissa</i> , <i>Cordia</i> , <i>Mangifera</i> , <i>Phoenix</i> , <i>Syzygium</i> , <i>Tamarindus</i> , <i>Terminalia</i> and <i>Zizyphus</i> spp.                                                                  |
| 6.      | Western Peninsular region                      | <i>Artocarpus</i> , <i>Citrus</i> , <i>Emblica</i> , <i>Garcinia</i> , <i>Mangifera</i> , <i>Musa</i> , <i>Spondias</i> , <i>Syzygium</i> , <i>Tamarindus</i> , <i>Vitis</i>                                                                                   |
| 7.      | Island region (Andaman & Nicobar, Lakshadweep) | <i>Artocarpus</i> , <i>Garcinia</i> , <i>Mangifera</i> , <i>Syzygium</i> , <i>Vitis</i>                                                                                                                                                                        |

Table 2. Region wise diversity in vegetable crops and their wild relatives

| Sl. No. | Agroecological Regions                                 | Crops/ Species                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------|--------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.      | Humid Western Himalayan Region                         | Amaranth, brinjal, carrot, chillies, cowpea, cucurbits, fenugreek, okra, peas, radish, spinach, turnip, <i>Basella rubra</i> , <i>Sechium edule</i> , <i>Solanum khasianum</i> and <i>S. hirsutum</i>                                                                                                                                                                                                                            |
| 2.      | Humid Bengal / Assam Basin                             | Amaranth, brinjal, cowpea, chillies, cucurbits, okra, radish, spinach beet, <i>Abelmoschus manihot</i> ssp. <i>manihot</i> , <i>Basella rubra</i> , <i>Cucumis sativus</i> var. <i>sikkimensis</i> , <i>Edgeria dargelingensis</i> , <i>Melothria assamica</i> , <i>Momordica cochinchinensis</i> , <i>Sechium edule</i> , <i>Solanum indicum</i> , <i>S. khasianum</i> , <i>S. surattense</i> and <i>Tuladiantha cordifolia</i> |
| 3.      | Humid Eastern Himalayan Region and Bay Lands           | Amaranth, brinjal, chillies, cucurbits, cowpea, okra, peas, radish, spinach, <i>Abelmoschus manihot</i> ssp. <i>tetraphyllus</i> , <i>Cucumis hystrix</i> , <i>Luffa echinata</i> , <i>Sechium edule</i> , <i>Solanum ferox</i> , <i>S. khasianum</i> , <i>S. torvum</i> , <i>S. sisymbirifolium</i> and <i>S. verbasifolium</i>                                                                                                 |
| 4.      | Sub humid Sutlej Ganga Alluvial Plains                 | Brinjal, cucurbits, fenugreek, garlic, peas, okra, onion, radish, spinach beet, <i>Abelmoschus manihot</i> sp. <i>tetraphyllus</i> var. <i>pungens</i> , <i>A. tuberculatus</i> , <i>Cucumis hardwickii</i> , <i>C. trigonus</i> , <i>Solanum indicum</i> , <i>S. khasianum</i> , <i>S. torvum</i> , <i>S. surattense</i> and <i>S. hispidum</i>                                                                                 |
| 5.      | Humid Eastern and South-eastern Uplands                | Amaranth, brinjal, cucurbits, carrot, chillies, cowpea, garlic, okra, radish, spinach, <i>Abelmoschus manihot</i> sp. <i>manihot</i> , <i>Solanum surattense</i> and <i>S. torvum</i>                                                                                                                                                                                                                                            |
| 6.      | Arid Western Plains                                    | Amaranth, brinjal, cucurbits, carrot, chillies, cowpea, garlic, okra, radish, spinach beet, <i>Abelmoschus manihot</i> ssp. <i>manihot</i> , <i>Solanum surattense</i> and <i>S. torvum</i>                                                                                                                                                                                                                                      |
| 7.      | Semi arid Lava plateau and Central highlands           | Amaranth, brinjal, carrot, cauliflower, chillies, cowpea, cucurbits, garlic, okra, onion, radish, spinach beet, <i>Cucumis setosus</i> , <i>Luffa acutangula</i> var. <i>acutangula</i> , <i>Solanum nigrum</i> , <i>S. khasianum</i> , <i>S. surattense</i> , and <i>S. torvum</i>                                                                                                                                              |
| 8.      | Humid to semi arid Western Ghats and Karnataka plateau | Brinjal, chillies, cucurbits, okra, <i>Abelmoschus crinitus</i> , <i>A. angulosus</i> , <i>A. ficulens</i> , <i>A. moschatus</i> , <i>A. manihot</i> var. <i>tetraphyllus</i> , <i>Basella rubra</i> , <i>Luffa acutangula</i> var. <i>acutangula</i> , <i>Melothria angulata</i> , <i>Solanum indicum</i> , <i>S. insanum</i> , <i>S. pubescens</i> , <i>S. surattense</i> , <i>S. torvum</i> and <i>S. triobatum</i>           |

The important flowers native to India, are orchids, rhododendrons, musk rose (*Rosa moschata*), begonia (*Begonia* spp.), balsam (*Impatiens balsamina*), globe amaranth (*Gomphrena globosa*), gloriosa lily (*Gloriosa superba*), foxtail lily (*Eremurus himalaicus*), primula (*Primula denticulata*, *P. rosea*), Himalayan blue poppy (*Meconopsis aculeata*), lotus (*Nelumbo nucifera*), water lily (*Nymphaea* spp.), clematis (*Clematis montana*), and the wild tulip of Himalayas (*Tulipa stellata* and *T.*

*aitchisonii*). The important native ornamental trees are kachnar (*Bauhinia variegata*), amaltas (*Cassia fistula*), pink cassia (*Cassia nodosa*), flame of the forest (*Butea frondosa*), Indian coral tree (*Erythrina indica*, *Erythrina blakii*), pride of India (*Lagerstroemia flosreginae*, *L. thorelli*), scarlet cordia (*Cordia sebestena*), yellow silk cotton tree (*Cochlospermum gossypium*), karanj (*Pongamia glabra*), tecomella (*Tecomella undulata*), tulip tree or bhendi (*Thespesia populnea*), *Crataeva*

*roxburghii*, *Sterculia colorata*, chalta (*Dillenia indica*), Sita Ashok (*Saraca indica*), Arjun (*Terminalia arjuna*), *Mesua ferrea*, ficus (*Ficus benghalensis*, *F. religiosa*), *Michelia champaka*, kadamba (*Anthocephalus Kadamba*) and *Mimusops elengi*. Among the native shrubs and climbers, the most important ones are the jasmine (*Jasminum* spp.), madhavi (*Hiptage madablota*), *Mussaenda frondosa*, *Ixora*, (*I. coccinea*, *I. parviflora*, *I. barbata*, *I. undulata*), *Hamiltonia suaveolens*, *Holmskioldia sanguinea*, *Clerodendron inerme*, *Crossandra infundibuliformis*, *Plumbago rosea*, *Plumbago zeylanica*, *Tabernaemontana coronaria*, *Osmanthus fragrans*, *Passiflora leschenaultii*, *Clitoria*

*ternatea*, *Porana paniculata* and *Gloriosa suberba* (Swaroop, 1995). The distribution of diversity of various ornamental plants has been given in Table 3.

### Germplasm Introduction

A substantial number of valuable germplasm accessions of horticultural crops has been introduced into India. During recent years, introduction of germplasm was directed towards breeding new cultivars and use of genetic variability for biotic and a biotic resistance. Some important introductions of fruit crops are listed in Table 4.

Table 3: Region wise ornamental crops diversity in India

| Sl. No. | Agroecological Regions                                 | Crops/ Species                                                                                                                                                                                                                                                                                                                                                                     |
|---------|--------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.      | Humid Western Himalayan Region                         | <i>Aconitum</i> , <i>Acorus</i> , <i>Anemone</i> , <i>Arisaema</i> , <i>Arundinaria</i> , <i>Arundo donax</i> , <i>Barleria</i> , <i>Delphinium</i> spp., <i>Hedychium</i> , <i>Impatiens</i> spp., <i>Iris</i> , <i>Jasminum</i> , orchids, <i>Primula</i> , <i>Potentilla</i> , <i>Rhododendron</i> , <i>Ranunculus</i> , <i>Solidago</i> , <i>Rosa</i> spp., <i>Viola</i> spp.  |
| 2.      | Humid Bengal / Assam Basin                             | <i>Acacia</i> , <i>Aglaonema</i> , <i>Barleria</i> , <i>Bauhinia</i> , <i>Clerodendron</i> , <i>Cordylis</i> , <i>Crinum</i> , <i>Hiptage</i> , <i>Ixora</i> , <i>Jasminum</i> spp., <i>Magnolia</i> , <i>Mussaenda</i> , <i>Solidago</i> , Kadamba, neem, pride of India                                                                                                          |
| 3.      | Humid Eastern Himalayan Region and Bay Lands           | <i>Aconitum</i> , <i>Acorus</i> , <i>Anemone</i> , <i>Arisaema</i> , <i>Barleria</i> , <i>Hiptage</i> , <i>Impatiens</i> spp., <i>Jasminum</i> spp., <i>Ligustrum</i> , <i>Lilium</i> spp., <i>Litsea</i> , <i>Magnolia</i> , <i>Meconopsis</i> , <i>Michelia</i> , <i>Murraya</i> , <i>Mussaenda</i> , <i>Rhododendron</i> , <i>Solidago</i> , <i>Rosa</i> spp., orchids, primula |
| 4.      | Sub humid Suttlej Ganga Alluvial Plains                | <i>Acacia</i> , <i>Barleria</i> , <i>Impatiens</i> spp., <i>Ipomoea</i> , <i>Jasminum</i> spp.,                                                                                                                                                                                                                                                                                    |
| 5.      | Humid Eastern and South-eastern Uplands                | <i>Acacia</i> , <i>Barleria</i> , <i>Impatiens</i> spp., <i>Ipomoea</i> , <i>Ixora</i> , <i>Jasminum</i> spp. Neem                                                                                                                                                                                                                                                                 |
| 6.      | Arid Western Plains                                    | <i>Acacia</i> , <i>Delonix</i> , <i>Impatiens</i> , <i>Jasminum</i> spp., <i>Terminalia</i> , neem                                                                                                                                                                                                                                                                                 |
| 7.      | Semi arid Lava plateau and Central Highlands           | <i>Acacia</i> , <i>Bauhinia</i> , <i>Erythrina</i> , <i>Impatiens</i> spp., <i>Ixora</i> , <i>Terminalia</i> , <i>Jasminum</i> spp., neem, pride of India                                                                                                                                                                                                                          |
| 8.      | Humid to semi arid Western Ghats and Karnataka plateau | <i>Acacia</i> , <i>Acalypha</i> , Kadamba, <i>Clerodendron</i> , <i>Crinum</i> , <i>Erythrina</i> , <i>Hiptage</i> , <i>Impatiens</i> spp., <i>Ixora</i> , <i>Michelia</i> , <i>Murraya</i> , <i>Pongamia</i> , <i>Jasminum</i> spp. bamboo, neem, orchids, pride of India                                                                                                         |

Table 4. Some important introductions of fruit crops

| Species                   | EC Number(s)   | Source country | Trait(s)                        |
|---------------------------|----------------|----------------|---------------------------------|
| <i>Carica papaya</i>      | 300205         | Pakistan       | Ring spot virus tolerant        |
|                           | 300205, 301870 | USA            | Tolerant to ring spot virus     |
|                           | 363845-46      | USA            | Fruit with high TSS             |
| <i>Carica</i> sp.         | 100627         | West Indies    | Fruit pear shaped, sweet        |
| <i>Carica</i> sp.         | 100613, 16     | West Indies    | Pink fruit flesh, sweet         |
| <i>Carica</i> sp.         | 100614         | West Indies    | Pentagonal fruit, yellow flesh  |
| <i>Carica</i> sp.         | 100615         | West Indies    | Fruit large, cylindrical, sweet |
| <i>Carica</i> sp.         | 100617         | West Indies    | Fruit large, sweet              |
| <i>Carica</i> sp.         | 100620         | West Indies    | Fruit medium size               |
| <i>Carica</i> sp.         | 100625         | West Indies    | Fruit small, yellow flesh       |
| <i>Carica</i> sp.         | 100628, 30     | West Indies    | Pink flesh                      |
| <i>Carica</i> sp.         | 100631         | West Indies    | Fruit flesh yellow, sweet       |
| <i>Carica</i> sp.         | 100621         | West Indies    | Fruit pentagonal, red flesh     |
| <i>Citrus paradisiaca</i> | 110577         | USA            | Seedless                        |
| <i>Citrus</i> sp.         | 175471         | USA            | Troyer citrange hybrid          |
| <i>Citrus</i> sp.         | 313078         | Australia      | Disease resistant root stock    |
| <i>Citrus</i> sp.         | 310461-480     | USA            | Promising mandarin varieties    |
| <i>Citrus</i> sp.         | 309123         | USA            | Promising citrus variety        |

contd...

Table 4 contd...

| Species                    | EC Number(s)      | Source country | Trait(s)                                           |
|----------------------------|-------------------|----------------|----------------------------------------------------|
| <i>Citrus sp.</i>          | 38793-94          | USA            | Mandarin hybrids                                   |
| <i>Citrus sp.</i>          | 310148-57         | Japan          | Promising citrus variety                           |
| <i>Ficus carica</i>        | 390352            | Iran           | Large fruit                                        |
| <i>Phoenix dactylifera</i> | 402391            | Iraq           | Early maturity                                     |
| <i>Prunus persica</i>      | 335035            | USA            | Medium size fruit                                  |
| <i>Prunus persica</i>      | 335036            | USA            | Extra large fruit                                  |
| <i>Psidium guajava</i>     | 336561-64         | USA            | Fruit large, white and red flesh.                  |
| <i>Psidium guajava</i>     | 343059-60         | USA            | Good fruit quality, resistant to fire blight       |
| <i>Punica granatum</i>     | 396385            | USA            | Red fruit                                          |
| <i>Punica granatum</i>     | 396386            | USA            | White fruit                                        |
| <i>Pyrus communis</i>      | 331116-17         | USA            | Late maturity, fruit maroon red with faint stripes |
| <i>Pyrus communis</i>      | 331112            | USA            | Fruit large, yellow, blight susceptible            |
| <i>Pyrus malus</i>         | 112092-95         | UK             | Root stock                                         |
| <i>Pyrus malus</i>         | 124252-53         | Canada         | Root stock                                         |
| <i>Pyrus malus</i>         | 124310-13         | UK             | Root stock                                         |
| <i>Pyrus sp.</i>           | 54900             | Taiwan         | Fruit green skinned                                |
| <i>Pyrus sp.</i>           | 54901             | Taiwan         | Large fruit                                        |
| <i>Vitis vinifera</i>      | 159386-87, 90     | Australia      | Seedless                                           |
| <i>Vitis sp.</i>           | 114712            | USA            | Early maturity, fruit white                        |
| <i>Vitis sp.</i>           | 114717            | USA            | Black fruit                                        |
| <i>Vitis sp.</i>           | 114713            | USA            | Early maturity, fruit black                        |
| <i>Vitis sp.</i>           | 100233            | Hungary        | Orange taste                                       |
| <i>Vitis sp.</i>           | 114716            | USA            | Scented fruit                                      |
| <i>Vitis vinifera</i>      | 315471-74         | USA            | Seedless, high yielding                            |
| <i>Vitis vinifera</i>      | 61861-66          | USA            | Wine type                                          |
| <i>Vitis vinifera</i>      | 117642            | Brazil         | Wine type                                          |
| <i>Vitis vinifera</i>      | 94806, 11         | USA            | Seedless                                           |
| <i>Vitis vinifera</i>      | 93528             | USSR           | Fruit white, large                                 |
| <i>Vitis vinifera</i>      | 61874-75          | USA            | Nematode resistant root stock                      |
| <i>Vitis vinifera</i>      | 61861-74          | USA            | Wine type                                          |
| <i>Vitis vinifera</i>      | 61874-75          | USA            | Nematode Resistant root stock                      |
| <i>Vitis vinifera</i>      | 28554-57          | West Germany   | Fruit red                                          |
| <i>Vitis vinifera</i>      | 28551-53          | West Germany   | Fruit white                                        |
| <i>Vitis vinifera</i>      | 251091-93, 209121 | USA            | High yielding                                      |
| <i>Vitis vinifera</i>      | 339104-105        | Australia      | Seedless, salt tolerant                            |

The temperate fruit and nut varieties grown in hilly regions of India are good examples of direct introductions (Table 5) as the farmers are using most of them as commercial varieties.

Since the inception of NBPGR in 1976, over 25,000 germplasm accessions of vegetable crops have been introduced. Some of the notable introductions are biotic resistant lines in tomato and melons, gynoeious lines in cucurbits and heat tolerant lines in chinese cabbage

(Table 6). Some of the introductions have adapted well in Indian conditions and are popular amongst farmers (Table 7).

Introduced varieties and species have contributed significantly to the improvement of ornamental horticulture in India (Randhawa and Mukhopadhyaya, 1986; Chadha and Choudhury, 1986). Some of these introductions have been used directly for cultivations (primary introductions) while others (secondary

Table 5. Temperate fruit and nut varieties introduced in hilly regions of India

| Crop    | Varieties                                                                                                                                                     |
|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Almond  | Nonpareil, Merced, Jordanale, Waris, Walnut WS-325, WS-328, Budgam 1, Wasan-2                                                                                 |
| Apple   | Irish Peach, Benoni, Jonathan, Cox's Orange Pippin, Ambri, Red Delicious, Golden Delicious, American Apirouge, White Dotted Red, Queen's Apple, Yellow Newton |
| Apricot | Charmagz, Kaisha, Frogmore Early, Gilgeti Sweet, Amba, Quetta Sweet Cherry, Guigne Noir Gross, Black Heart, Bigarreau Napoleon, Bigarreau Noir Gross          |
| Pear    | China Pear, Beurre-de-Amanlis, Citron-des-Carmos, Clapp's Favorite, Fertility, William Bartlett, Beurre Hardy                                                 |
| Peach   | World's Earliest, July Elberta, Peshawari, Elberta, Quetta                                                                                                    |
| Plum    | Sharp's Early, Formosa, Wickson, Satsuma, Burbank, Santa Rosa, Blue Imperative, Prune-d-Agen, Grand Duke                                                      |

Table 6. Important vegetable germplasm introduced

| Crop                                           | EC number     | Salient features                          | Country    |
|------------------------------------------------|---------------|-------------------------------------------|------------|
| <b>High yielding and desirable fruit types</b> |               |                                           |            |
| Cauliflower                                    | EC 348166     | High yielding early type                  | USA        |
| Chillies                                       | EC 391073     | Pungent type                              | Taiwan     |
|                                                | EC 391089-92  | Early maturity & Bunch type               | Taiwan     |
|                                                | EC 347263     | High Pungent type                         | Taiwan     |
| Cucumber                                       | EC 398030     | Early & determinate type                  | China      |
| Garlic                                         | EC 367655-58  | High yielding and bold clove              | Israel     |
| Onion                                          | EC 30802-11   | High bulb yielding                        | USA        |
|                                                | EC 378476-77  | High TSS & long shelf life                | UK         |
| Tomato                                         | EC391024      | Long shelf life                           | Australia  |
|                                                | EC310299      | Slow ripening gene                        | USA        |
|                                                | EC321425-26   | Paste type                                | Taiwan     |
| Watermelon                                     | EC 380989-92  | Yellow flashed, early maturing            | USA        |
|                                                | EC 393240-43  | Red flashed/round & small                 | USA        |
| <b>Male sterile restorer lines and hybrids</b> |               |                                           |            |
| Cabbage                                        | EC 304718-25  | Cytoplasmic male sterile & restorer lines | USA        |
|                                                | EC 187228-30  | Male sterile lines                        | Canada     |
| Cucumber                                       | EC 382737-39  | Gynoecious lines                          | USA        |
|                                                | EC 329300     | Gynoecious (G4)                           | USA        |
| Muskmelon                                      | EC 348140-43  | F1 Hybrid (Early & Sweet)                 | USA        |
|                                                | EC 382726-36  | Male sterile gene (MS2 to MS5)            | France     |
| Tomato                                         | EC 347359-68  | Hybrids (F1)                              | Taiwan     |
|                                                | EC 343391-95  | F1 Hybrids (Cherry Tomato)                | Taiwan     |
|                                                | EC346011      | Stamenless line (F2)                      | USA        |
|                                                | EC346013      | Green Pistillate type                     | USA        |
|                                                | EC346014      | Green Pistillate type                     | USA        |
| <b>Germplasm for abiotic resistance</b>        |               |                                           |            |
| Atriplex                                       | EC319095-96   | Salt tolerance                            | Australia  |
| Cabbage                                        | EC 350918-28  | Heat tolerance                            | USA        |
|                                                | EC 168041-42  | Heat tolerance                            | USA        |
| Capsicum                                       | EC 334206     | Water submergence                         | Taiwan     |
| Cauliflower                                    | EC 164414-16  | Heat tolerance                            | USA        |
| Chinese Cabbage                                | EC 345978     | Heat tolerance                            | Taiwan     |
| Muskmelon                                      | EC350603      | Sulphur tolerance                         | USA        |
|                                                | EC 342751-54  | Heat tolerance                            | Japan      |
| Tomato                                         | EC 399828-38  | Heat tolerance                            | USA        |
|                                                | EC 347359-68  | Heat tolerance                            | Taiwan     |
|                                                | EC 321425-26  | Heat tolerance                            | Taiwan     |
|                                                | EC 378682-83  | Low irrigation                            | Australia  |
| <b>Germplasm for biotic resistance</b>         |               |                                           |            |
| Cabbage                                        | EC 168041-42  | Club root & black root resistance         | Taiwan     |
| Cauliflower                                    | EC 175800-06  | Multiple diseases resistance              | USA        |
| Chilli                                         | EC 323333     | Multiple disease resistance               | USA        |
| Chinese cabbage                                | EC 345978     | Multiple disease resistance               | Taiwan     |
| Cucumber                                       | EC 320526     | Multiple diseases resistance              | USA        |
| Garlic                                         | EC 378476-77  | Pink rot Resistance                       | UK         |
| Okra                                           | EC 305616     | YVMV Resistance                           | Bangladesh |
| Muskmelon                                      | EC 350602     | Aphid resistance                          | USA        |
|                                                | EC 350603     | WMB resistance                            | USA        |
|                                                | EC 330956     | Multiple disease resistance               | USA        |
| Tomato                                         | EC 399828-38  | Multiple diseases resistance              | USA        |
|                                                | EC 347369-90  | TMV & BW resistance                       | Taiwan     |
|                                                | EC 321890-928 | Viral diseases resistance                 | Taiwan     |
| Watermelon                                     | EC 383809     | Fusarium wilt resistance                  | USA        |
|                                                | EC 378523-24  | Fusarium wilt resistance                  | USA        |
|                                                | EC 333659-69  | Wilt resistance                           | USA        |
|                                                | EC 217073-74  | Fusarium & Gummy stem blight resistance   | USA        |

**Table 7. Important vegetable introductions directly adopted for commercial cultivation**

| Crop        | Cultivar                                 |
|-------------|------------------------------------------|
| Cabbage     | Golden Acre                              |
| Capsicum    | California wonder                        |
| Carrot      | Nantes                                   |
| Cauliflower | Improved Japanese                        |
| Cowpea      | Pusa Barsati (selection ex- Philippines) |
| Frenchbean  | Contender                                |
| Lettuce     | Great Lakes                              |
| Pea         | Arkel, Bonneville                        |
| Tomato      | Sioux, La Bonita                         |
| Watermelon  | Asahi Yamato, SugarBaby                  |

introductions) have been used in breeding for improving quality, productivity and imparting resistance against biotic and abiotic stresses in the available cultivars. To cite a few examples of primary introductions, *Mussaenda philippica*, the double-bracted mussaenda with white,

pink and red colours from Thailand have acclimatized very well in the humid and mild climates of Kolkata, Bangalore and parts of Kerala. The introduction of many beautiful bougainvillea cultivars such as 'Lady Mary Baring', 'Golden Glow', 'Mahara' and 'Cherry Blossom' etc. has enriched Indian ornamental horticulture to a great extent. A variety called 'Hawaiian Hibiscus' introduced earlier by Lalbagh, Bangalore has considerably changed the aesthetics of many gardens in and around Bangalore. Similarly, a large number of varieties introduced in rose and gladiolus are widely cultivated in the country. Singh *et al.*, 1990, have highlighted earlier notable introductions of ornamentals. Some important introductions pertaining to trees, shrubs, bulbous ornamentals, annuals and herbaceous perennials and orchids are listed in Table 8.

**Table 8. Important introductions in ornamentals (1982-2002)**

| Species                                                                                                                                                                                                                                                                                                                                    | Accession No.     | Source Country |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------|
| <b>Trees</b>                                                                                                                                                                                                                                                                                                                               |                   |                |
| <i>Areca minuta</i> , <i>A. coccinea</i>                                                                                                                                                                                                                                                                                                   | EC 336080, 81     | UK             |
| <i>Bauhinia esculenta</i>                                                                                                                                                                                                                                                                                                                  | EC 153140         | USA            |
| <i>Bixa orellana</i>                                                                                                                                                                                                                                                                                                                       | EC 339279         | Brazil         |
| <i>Calamus acanthochlamys</i>                                                                                                                                                                                                                                                                                                              | EC 336082         | UK             |
| <i>Callistemon pallidus</i> , <i>C. viridifloris</i>                                                                                                                                                                                                                                                                                       | EC 154037, 45     | UK             |
| <i>Calospatha scortechinii</i>                                                                                                                                                                                                                                                                                                             | EC 336083         | UK             |
| <i>Camellia sasanqua</i>                                                                                                                                                                                                                                                                                                                   | EC 322327-322329  | USA            |
| <i>Chamaedorea</i> sp.                                                                                                                                                                                                                                                                                                                     | EC 336092, 93     | UK             |
| <i>Chrysophila</i> sp.                                                                                                                                                                                                                                                                                                                     | EC 336091         | UK             |
| <i>Colvillea racemosa</i>                                                                                                                                                                                                                                                                                                                  | EC 164651         | Hawaii         |
| <i>Cryptomeria japonica</i>                                                                                                                                                                                                                                                                                                                | EC 155219, 458266 | USA            |
| <i>Cupressus arizonica</i>                                                                                                                                                                                                                                                                                                                 | EC 155224         | USA            |
| <i>Labronesia koccides</i>                                                                                                                                                                                                                                                                                                                 | EC 159934         | UK             |
| <b>Shrubs</b>                                                                                                                                                                                                                                                                                                                              |                   |                |
| <i>Bougainvillea</i> cvs. Allison Davy, Audery Delap, Barnabee, Gloseburn, Crimson Glory, Improved, James Waker, Jamihuri, John Lattin, Lady Hudson, Lazat of Mysore, Magnifica Trailii, Mrs. Helen McClean, Orange Glory, Orange Glory, Princess Elizabeth, Raw Sawder, Rosenka, Ruby, San Diago, Snow White, Sun Rise, Variegatam, White | EC 174717-40      | Kenya          |
| <i>Jasminum abyssinicum</i> , <i>J. dispernum</i> , <i>J. laurifolium</i> f. <i>nitidum</i> , <i>J. fluminense</i> sub sp. <i>Holstii</i> , <i>J. fluminense</i> sub sp. <i>fluminense</i>                                                                                                                                                 | EC 415780-83, 86  | UK             |
| <i>Lagerstroemia</i> sp. cvs. Choctaw, Coddie, Tonto                                                                                                                                                                                                                                                                                       | EC 330228-30      | USA            |
| <i>Rosa mayesii</i> , <i>R. gallica</i> , <i>R. foetida</i> , <i>R. spinosissima</i> , <i>R. canina</i> , <i>R. acicularis</i> , <i>R. ornata</i> <i>sherardii</i> , <i>R. rubiginosa</i> , <i>R. pendulina</i> , <i>R. virginiana</i> , <i>R. rugosa</i>                                                                                  | EC 165797-07      | UK             |
| Rose cvs. Paulam Ingrid Bergaman, Poulal Sentimental, Poultex Texas, Poulvita inita, Teeny Weeny, Poulfillin, Poulcat Caterpillar, Poulred Red Bells                                                                                                                                                                                       | EC 165966-73      | Denmark        |
| Nobles, Mercedes, Golden Gate, First Red,                                                                                                                                                                                                                                                                                                  | EC 448148-51      | Israel         |
| <i>Rosa canina</i> , <i>R. inermis</i> , <i>R. heinsohnii</i> , <i>R. hookeriana</i> , <i>R. schmidtii</i> , <i>R. superba</i> , <i>R. rubiginosa</i> , <i>R. laxa</i> , <i>R. multiflora</i> , <i>R. smitsstekelloze</i>                                                                                                                  | EC 168020-29      | Netherlands    |
| <b>Bulbous plants</b>                                                                                                                                                                                                                                                                                                                      |                   |                |
| <i>Aconitum napellus</i>                                                                                                                                                                                                                                                                                                                   | EC 154191         | Germany        |
| <i>Cyclamen hederifolium</i>                                                                                                                                                                                                                                                                                                               | EC 171976-77      | UK             |

(Contd.)

Table 8 (Contd.)

| Species                                                                                                                                                                                                                                       | Accession No.             | Source Country |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|----------------|
| <i>Gladiolus</i> cvs. Mirage, Bright Promise, Sussex                                                                                                                                                                                          | EC 154209-11              | USA            |
| Albures, Angel Face, Balalaika, Kompanjero, Jurentus, Ares 301, Oktijalr 442, Edith Schoffield, Valja, Tereskhowa, Dawan Watch 470, Utrennij Tuman 480, Gold Medal 412, Olenka 392, Leningradskaja, Vesna 472, Academic Eich Feld             | EC 155722-36              | USSR           |
| Boy Scout, Melody, Inspiration, Honor Gourd, Apricot Queen, Rosette, Blue Isle, Chanticle, Oscar, Pink Parassol, Accolade, Pozobotte Bareebe, Friendship, Dawn Watch                                                                          | EC 164724-37              | USSR           |
| Whimsical, High Fashion, Regalaire, Chorus Girl, Ivory Tower, Star Dom, Snow Mars, Sweet Ieilani, Butter&Jelly, Pink Mist, Pearly White, Monchen, Rose Gem, April Angel, Azure Skoy, Bhishing Maid, Pink Gem, Prominence, Twenty Four Karet   | EC 172789-2807            | USA            |
| Green Isle, RFZ Special, Red Majesty, Romance, Isica Cleuf, Lavender Star, Frolich, Gaploin Sallant, Suneet Bou                                                                                                                               | EC 197953-61              | USA            |
| Claret Royale, Mary Kittel, Soytime, Rou Dragon, Singh Joy, Snow Flower, Atom Dragon, Red Cocade, Lacy Lady, Wedding Sun, Star Sapphire, Happy Birthday, Departing Sun, Kachnar, Flock, Red Sea, Red Boutam, Ever Glow, Inspiration, Red Bird | EC 197965-83              | USA            |
| Slad Purple, Spring Fence, Lavender Spice, Spring Delagra, Life Line, Red Fort, Green Spire                                                                                                                                                   | EC 197985-88, 90, 92-94   | USA            |
| Dunasty, Encore, Lorilee, Cecilt, Spaitan, Laurita, Accolade, That&Pink, Promenade, Ciward, Golden Age, Ocapulco, Nacarar, Celebrity, Clafuarius, Dr. RO Magie, Queen, Highlight, Osage, Pink Lady                                            | EC 206773-92              | Canada         |
| Trader Horn, Novalux, White Projiate, Peter Pears, Rose Prince,                                                                                                                                                                               | EC 217062-66              | Israel         |
| Bid Time, Blue Spire, Day Dream, Little Gade Green, Olympus, Inspiration, Snow Sprite                                                                                                                                                         | EC 280567-73              | USSR           |
| Amybeth, Bellsello, Astro, Angel Fire, Annabel, Arroros                                                                                                                                                                                       | EC 331458-63              | USA            |
| <i>Gladiolus cantinalis</i>                                                                                                                                                                                                                   | EC 155737                 | USSR           |
| <i>Gladiolus byzantinus</i>                                                                                                                                                                                                                   | EC 165823                 | UK             |
| <i>Heliconia longiflora</i> , <i>H. lutea</i> , <i>H. necrobracteata</i> , <i>H. sarapiquensis</i> , <i>H. tatamancana</i> , <i>H. trichocarpa</i> , <i>H. umbrophil</i>                                                                      | EC 425429-35              | USA            |
| <i>Hippeastrum</i>                                                                                                                                                                                                                            | EC 175399-400             | USA            |
| <i>Iris aphylla</i>                                                                                                                                                                                                                           | EC 165822                 | UK             |
| <i>Lilium</i> sp.                                                                                                                                                                                                                             | EC 445976                 | Israel         |
| <b>Annuals and herbaceous perennials</b>                                                                                                                                                                                                      |                           |                |
| <i>Antirrhinum</i> sp. (cvs. Trumpet Serenade, Large Flowered, Coronette)                                                                                                                                                                     | EC 191657-191659          | UK             |
| <i>Artemisia absinthium</i>                                                                                                                                                                                                                   | EC 154270, 155464         | UK, France     |
| <i>Aster</i> sp. (cv. Ostrich Plume)                                                                                                                                                                                                          | EC 191676                 | UK             |
| <i>Bellis</i> sp.                                                                                                                                                                                                                             | EC 332183                 | Thailand       |
| <i>Calendula officinalis</i>                                                                                                                                                                                                                  | EC 305851                 | Egypt          |
| <i>Celosia argentea</i> , <i>C. plumosa</i>                                                                                                                                                                                                   | EC 151543, 178492         | Hungary, USA   |
| <i>Chrysanthemum carinatum</i>                                                                                                                                                                                                                | EC 207345                 | France         |
| <i>Chrysanthemum cinerarifolium</i>                                                                                                                                                                                                           | EC 178452-89              | Australia      |
| <i>Chrysanthemum frutescens</i> , <i>C. flosculosum</i>                                                                                                                                                                                       | EC 207347, 207348         | France         |
| <i>Chrysanthemum morifolium</i> (cv. Snow Down)                                                                                                                                                                                               | EC 461856                 | Israel         |
| <i>Chrysanthemum nivellei</i> , <i>C. coronarium</i> , <i>C. praealtum</i> , <i>C. segetum</i> , <i>C. serotinum</i>                                                                                                                          | EC 207349, 46, 50, 51, 53 | France         |
| <i>Chrysanthemum</i> sp. (cvs. Colli, Lamans, Pallet)                                                                                                                                                                                         | EC 445968, 73, 67         | Israel         |
| <i>Chrysanthemum vulgare</i> , <i>C. viscosum</i>                                                                                                                                                                                             | EC 207352, 54             | France         |
| <i>Cineraria maritima</i> (Silver Dust)                                                                                                                                                                                                       | EC 172750                 | USA            |
| <i>Cineraria</i> sp. (cvs. Large Flowered, Gay Dwarf)                                                                                                                                                                                         | EC 191664, 65             | UK             |
| <i>Cosmos</i> sp.                                                                                                                                                                                                                             | EC 332177, 84, 87         | Thailand       |
| <i>Delphinium</i> sp. (cvs. Mixed, Pacific Giant, Dwarf Blue)                                                                                                                                                                                 | EC 191661-63              | UK             |
| <i>Dianthus armeria</i> , <i>D. barbatus</i> , <i>D. carthusianarum</i> , <i>D. carrevonianus</i> , <i>D. deltoides</i> , <i>D. pinifolius</i> , <i>D. plumarius</i>                                                                          | EC 165809-16              | UK             |
| <i>Dianthus</i> sp. (cvs. Crimson Knight, Crimson Picotes Knight)                                                                                                                                                                             | EC 160241-42              | USA            |
| <i>Dianthus</i> sp. (cvs. Mixed, Indian Carpet)                                                                                                                                                                                               | EC 191673, 74             | UK (Contd.)    |

Table 8 (Contd.)

| Species                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Accession No.          | Source Country |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|----------------|
| <i>Dianthus</i> sp. (cvs. Scarlet Knight, Orange Knight)                                                                                                                                                                                                                                                                                                                                                                                                        | EC 160238, 43          | USA            |
| <i>Dianthus</i> sp. (cvs. White Knight, Yellow Knight)                                                                                                                                                                                                                                                                                                                                                                                                          | EC 160239, 40          | USA            |
| <i>Dianthus superbus</i> , <i>D. tukestanicus</i>                                                                                                                                                                                                                                                                                                                                                                                                               | EC 165817, 18          | UK             |
| <i>Digitalis grandiflora</i>                                                                                                                                                                                                                                                                                                                                                                                                                                    | EC 391046-48           | Kew            |
| <i>Digitalis purpurea</i>                                                                                                                                                                                                                                                                                                                                                                                                                                       | EC 391050-66           | Kew            |
| <i>Eschscholzia caespitosa</i>                                                                                                                                                                                                                                                                                                                                                                                                                                  | EC 198306              | USA            |
| <i>Eschscholzia californica</i> , <i>E. mexicana</i>                                                                                                                                                                                                                                                                                                                                                                                                            | EC 198307, 8           | USA            |
| <i>Geranium</i> sp. (cvs. Mustang, Picasso, Ringo Deep Scarlet, Pinto Salmon, Pinto Red, Ringo Scarlet, Ringo Salmon, Pinto Rose, Ringo Rose, Ringo White)                                                                                                                                                                                                                                                                                                      | EC 174209-18           | Netherlands    |
| <i>Gamphrena globosa</i>                                                                                                                                                                                                                                                                                                                                                                                                                                        | EC 165024              | USA            |
| <i>Gypsophylla paniculata</i>                                                                                                                                                                                                                                                                                                                                                                                                                                   | EC 462002              | Israel         |
| <i>Iberis amara</i> (cvs. Dwarf Fairy, Fairy)                                                                                                                                                                                                                                                                                                                                                                                                                   | EC 191666-67           | UK             |
| <i>Impatiens</i> sp.                                                                                                                                                                                                                                                                                                                                                                                                                                            | EC 332178              | Thailand       |
| <i>Lathyrus odoratus</i> (cvs. Flag Ship, Kneec Hi, Geam Elegance)                                                                                                                                                                                                                                                                                                                                                                                              | EC 191646-48           | UK             |
| <i>Limonium sinuatum</i>                                                                                                                                                                                                                                                                                                                                                                                                                                        | EC 445970-72           | Israel         |
| <i>Lisianthus</i> sp.                                                                                                                                                                                                                                                                                                                                                                                                                                           | EC 416708-13           | USA            |
| <i>Lunaria annua</i>                                                                                                                                                                                                                                                                                                                                                                                                                                            | EC 165825              | UK             |
| <i>Matricaria chamomile</i>                                                                                                                                                                                                                                                                                                                                                                                                                                     | EC 154026              | UK             |
| <i>Mesembryanthemum nodiflorum</i>                                                                                                                                                                                                                                                                                                                                                                                                                              | EC 154046              | UK             |
| <i>Molucella laevis</i>                                                                                                                                                                                                                                                                                                                                                                                                                                         | EC 280585              | USSR           |
| <i>Ornithogalum saundersiae</i>                                                                                                                                                                                                                                                                                                                                                                                                                                 | EC 152937              | UK             |
| <i>Ornithogalum virens</i>                                                                                                                                                                                                                                                                                                                                                                                                                                      | EC 152936              | UK             |
| <i>Pelargonium hortorum</i> , <i>P. capitatum</i> , <i>P. odoratissimum</i>                                                                                                                                                                                                                                                                                                                                                                                     | EC 152502-4            | USA            |
| <i>Pelargonium roseum</i>                                                                                                                                                                                                                                                                                                                                                                                                                                       | EC 153415, 151525      | USA            |
| <i>Petunia hybrida</i>                                                                                                                                                                                                                                                                                                                                                                                                                                          | EC 387074              | Taiwan         |
| <i>Phlox drummondii</i>                                                                                                                                                                                                                                                                                                                                                                                                                                         | EC 191660              | UK             |
| <i>Portulaca</i> sp.                                                                                                                                                                                                                                                                                                                                                                                                                                            | EC 332175              | Thailand       |
| <i>Salvia officinalis</i>                                                                                                                                                                                                                                                                                                                                                                                                                                       | EC 167545              | USA            |
| <i>Salvia officinalis</i>                                                                                                                                                                                                                                                                                                                                                                                                                                       | EC 165838              | USSR           |
| <i>Salvia sclarea</i>                                                                                                                                                                                                                                                                                                                                                                                                                                           | EC 154279              | UK             |
| <i>Mathiola incana</i> (cvs. Ten Weak, Brompton, Virginia, Night Scented)                                                                                                                                                                                                                                                                                                                                                                                       | EC 191668-71           | UK             |
| Sweet alyssum                                                                                                                                                                                                                                                                                                                                                                                                                                                   | EC 332181              | Thailand       |
| <i>Tagetes</i> sp. (cv. Queen Sophiya)                                                                                                                                                                                                                                                                                                                                                                                                                          | EC 173416              | USA            |
| <i>Tagetes erecta</i>                                                                                                                                                                                                                                                                                                                                                                                                                                           | EC 179949-179990       | Netherlands    |
| <i>Tropaeolum majus</i>                                                                                                                                                                                                                                                                                                                                                                                                                                         | EC 165826              | UK             |
| <i>Verbeena</i> sp.                                                                                                                                                                                                                                                                                                                                                                                                                                             | EC 332182              | Thailand       |
| <i>Verbena</i> sp.                                                                                                                                                                                                                                                                                                                                                                                                                                              | EC 191675              | UK             |
| <i>Vinca</i> sp.                                                                                                                                                                                                                                                                                                                                                                                                                                                | EC 332179              | Thailand       |
| <i>Viola</i> sp. (cvs. Imperial Silver, Imperial Orange, Imperial Golo, Imperial White)                                                                                                                                                                                                                                                                                                                                                                         | EC 341919-22           | USA            |
| <i>Viola</i> sp. (Majestic Giants)                                                                                                                                                                                                                                                                                                                                                                                                                              | EC 341918              | USA            |
| <i>Viola</i> sp. (cvs. Melody, Padparakja, Pansy 1099)                                                                                                                                                                                                                                                                                                                                                                                                          | EC 341931-33           | USA            |
| <i>Viola</i> sp. (cvs. Tezier Bred, Spring Maotic Ultra, Vernale, Mid Flue, Universal, Yellow)                                                                                                                                                                                                                                                                                                                                                                  | EC 341923-28           | USA            |
| <i>Viola wittrockiana</i> (Rock White)                                                                                                                                                                                                                                                                                                                                                                                                                          | EC 341935              | USA            |
| <i>Zinnia</i> sp.                                                                                                                                                                                                                                                                                                                                                                                                                                               | EC 332173, 86          | Thailand       |
| <b>Orchids</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                        |                |
| <i>Cattleya aclandiae</i>                                                                                                                                                                                                                                                                                                                                                                                                                                       | EC 341691              | UK             |
| <i>Cattleya mooreana</i> (Heid 3712), <i>Dendrobium formosum</i> (BEGR 16 3817), <i>Dendrobium melaloucapillum</i> (FAIK 3827), <i>Dendrobium tangerinum</i> (FLID 3788), <i>Dendrobium scopae</i> (FLID 3785), <i>Dendrobium lasianthera</i> (FLID 3791), <i>Dendrobium munificum</i> (SPRU), <i>Dendrobium unicum</i> (BEGR 17), <i>Dendrobium lineale</i> (Slag), <i>Dendrobium speciosum</i> var. <i>curvicaule</i> , <i>Coelogyne susanae</i> (CRMO 1922), | EC 385462-72           | UK             |
| <i>Laelia jongheana</i>                                                                                                                                                                                                                                                                                                                                                                                                                                         | EC 341701              | UK             |
| <i>Laelia perrinii</i> , <i>Laelia jongheana</i> , <i>Laelia pisteri</i> (WLTR)                                                                                                                                                                                                                                                                                                                                                                                 | EC 341700, 701, 345478 | UK             |
| <i>Paphiopedilum adductum</i> (ANLA 3769), <i>Paphiopedilum bullenianum</i> var. <i>celebesense</i>                                                                                                                                                                                                                                                                                                                                                             | EC 385475-76           | UK             |
| <i>Paphiopedilum</i> sp., <i>Paphiopedilum druryi</i>                                                                                                                                                                                                                                                                                                                                                                                                           | EC 341702, 703         | UK             |

### Germplasm Collection

Besides introductions from abroad, a large amount of germplasm of horticultural crops have been collected by NBPGR from diversity rich areas of India and presented in Table 9. A sizable number of accessions of brinjal (5207) and okra (2240) in vegetables and banana (645),

citrus (873), mango (298) and ber (353) in fruits were collected. There is a need for greater emphasis for the collection of horticultural crops from diversity rich areas of the country. The gaps in collections be identified and unexplored areas or the under explored areas may be covered extensively for germplasm collection.

Table 9. Horticultural germplasm collected by NBPGR

| Crop group/ crop          | Accessions (no.) | Crop group/ crop   | Accessions (no.) |
|---------------------------|------------------|--------------------|------------------|
| <b>Vegetables</b>         |                  | <b>Fruits</b>      |                  |
| Ash gourd                 | 515              | Tomato             | 502              |
| <i>Alocasia</i> sp.       | 6                | Water melon        | 128              |
| Bitter gourd              | 1018             | Other vegetables   | 300              |
| Bottle gourd              | 1267             | Almond             | 55               |
| Brinjal                   | 5207             | Aonla              | 128              |
| Broad bean                | 183              | Apple              | 21               |
| Cabbage                   | 38               | Apricot            | 16               |
| Carrot                    | 56               | Bael               | 129              |
| Cauliflower               | 150              | Banana             | 645              |
| Chillies                  | 3062             | Ber                | 353              |
| Chinese cabbage           | 9                | Cashew             | 55               |
| <i>Citrullus</i> sp.      | 39               | Chironjii          | 97               |
| <i>Colocasia</i>          | 929              | Citrus             | 873              |
| Cucumber                  | 801              | Custard apple      | 277              |
| <i>Cucumis</i> spp.       | 553              | Grapes             | 8                |
| <i>Cucumis hardwickii</i> | 59               | Guava              | 53               |
| Fababean                  | 39               | Hazelnut           | 38               |
| Fenugreek                 | 58               | Jackfruit          | 235              |
| French bean               | 1741             | Jamun              | 107              |
| Ivy gourd                 | 175              | Khirni             | 14               |
| Kale                      | 3                | Lakoocha           | 37               |
| Knol khol                 | 2                | Lasora             | 41               |
| Leafy brassica            | 27               | Malabar tamarind   | 139              |
| Lima bean                 | 7                | Mango              | 298              |
| Long melon                | 8                | Mangostein         | 6                |
| <i>Momordica dioica</i>   | 11               | Mulberry           | 16               |
| Musk melon                | 442              | Papaya             | 72               |
| Okra                      | 2507             | Passion fruit      | 14               |
| Onion                     | 718              | Peach              | 13               |
| Pea                       | 896              | Pear               | 42               |
| Pointed gourd             | 328              | Phalsa             | 187              |
| Pumpkin                   | 1503             | Pomegranate        | 295              |
| Radish                    | 234              | <i>Rubus</i> sp.   | 18               |
| Ridge gourd               | 725              | Sapota             | 17               |
| Round gourd               | 76               | Strawberry         | 3                |
| Satputia                  | 62               | Tamarind           | 110              |
| Sembean                   | 1056             | Walnut             | 297              |
| Snake gourd               | 79               | Wood apple         | 1                |
| Snap melon                | 718              | Other Fruits       | 123              |
| <i>Solanum gilo</i>       | 20               | <b>Ornamentals</b> |                  |
| Spinach                   | 215              | Canna              | 4                |
| Sponge gourd              | 973              | Marigold           | 18               |
| Summer Squash             | 11               | Orchid             | 150              |
| Sword bean                | 25               | Other ornamentals  | 36               |

### Conservation Approaches and Methods

In horticultural crops the conservation aspect has largely remained unorganised. Complementary conservation strategies employing both *in situ* and *ex situ* conservation are essential in this group of crops.

#### (I) *Ex situ* conservation

When germplasm conservation is attempted outside its natural habitat, it is known as *ex situ* conservation. Germplasm is conserved in the form of clonal material, seedlings, seed, pollen and DNA. *Ex situ* collections may

also be established to ensure the ready availability of reproductive material, either through a genebank or through a production source in the area where the material is to be used.

(a) *Field gene bank*

Many horticultural species are either difficult or impossible to conserve as seeds because of seeds being recalcitrant or reproduce vegetatively. Hence they are conserved in field genebanks (FGBs). In species with long juvenile phase as in tree fruits species, FGBs provide easy and ready access to conserved material for research and utilisation. Further for a number of plant species, the alternative conservation methods are not fully developed yet so that they can be effectively used. However, FGBs may run a risk of being damaged by natural calamities, infection, neglect or abuse. *Ex situ* conservation of tree species using FGBs require a substantial number of individual genotypes to be an effective conservation

measure hence FGBs require more space, especially for large tree species, and they may be relatively expensive to maintain. The alternative/supplementary method of FGBs in vegetatively propagated crops could be maintenance of plants in Clonal Repository. The advantages of this method over FGBs are less space requirement, easy management and cost effectiveness. In addition, clonal collections being dwarf in size can be maintained in protected controlled green houses and the danger of natural calamities is minimal.

Thus it is clear that establishment of FGBs plays a major role in conservation strategy for horticultural genetic resources. Field collections of horticultural germplasm are located in the NBPGR network of regional stations besides horticultural crop based National Active Germplasm Sites (NAGS). Status of fruit and ornamental germplasm in field genebank at various locations has been presented in Table 10 and 11 respectively.

Table 10. Status of fruit germplasm in field genebank at various locations

| Crop                   | Location                                                                                                                                                                                                                                                                      |
|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Almond                 | CITH (15), HPKV (4), NBPGR Bhowali (5), NBPGR Shimla (15), YSPUHF (62)                                                                                                                                                                                                        |
| Aonla                  | CIAH (34), FRS Aurangabad (10), GBPUAT (10), HAFRP (10), NBPGR Bhowali (4), NBPGR Issapur (4), NBPGR Ranchi (10), NBPGR Shillong (9), NBPGR Thrissur (53), NRCAF (6), PDKV Katol (4), TNAU (2)                                                                                |
| Apple                  | CITH (143), NBPGR Bhowali (22), NBPGR Shimla (144), YSPUHF (79)                                                                                                                                                                                                               |
| Apricot                | HPKV (2), CITH (2), NBPGR Bhowali (5), NBPGR Shimla (42), YSPUHF (5)                                                                                                                                                                                                          |
| Bael                   | CIAH (16), GBPUAT (34), HAFRP (10), NBPGR Bhowali (7), NBPGR Issapur (10), NBPGR Jodhpur (2), NBPGR Ranchi (28), NRCAF (3)                                                                                                                                                    |
| Banana                 | CISH, (112), NBPGR Shillong (103), NBPGR Thrissur (303), NRC Banana (1141)                                                                                                                                                                                                    |
| Ber                    | CARI (12), CIAH (323), FRS Aurangabad (45), GAU Anand (42), GBPUAT (23), MPKV Rahuri (9), NBPGR Amravati (14), NBPGR Issapur (11), NBPGR Jodhpur (42), NBPGR Ranchi (3), NBPGR Bhowali (3), NBPGR Shimla (11), NRCAF (6), PDKV Sindhewahi (6), UAS RS Raichur (13)            |
| Cactus pear            | CIAH (103), NRCAF (5)                                                                                                                                                                                                                                                         |
| Cashew                 | ARS Chintamani (104), CRS Bapatla (129), CRS BBSR (9), CRS Madakkathara (113), FRS Aurangabad (7), GAU Ahmedabad (5), NRC Cashew (451), RARS Piliode (64), RFRS Vengurla (161), RRS Jhargram (83), RRS Vridhachalam (263)                                                     |
| Cherry                 | CITH (7)                                                                                                                                                                                                                                                                      |
| Chestnut               | NBPGR Shimla (2)                                                                                                                                                                                                                                                              |
| Citron                 | NBPGR Bhowali (11), NRCC (13)                                                                                                                                                                                                                                                 |
| Citrus hybrids         | NBPGR Bhowali (4), NRCC (25)                                                                                                                                                                                                                                                  |
| <i>Citrus indica</i>   | NBPGR Thrissur (2), NRCC (4)                                                                                                                                                                                                                                                  |
| <i>Citrus jambhiri</i> | NBPGR Bhowali (12), NRCC (54)                                                                                                                                                                                                                                                 |
| <i>Citrus spp.</i>     | ICARRCNEH (65), NBPGR Bhowali (34), NBPGR Shillong (74), NBPGR Thrissur (2), NRCC (85)                                                                                                                                                                                        |
| Custard apple          | HAFRP (25), IIHR (11), MPKV Rahuri (17), NBPGR Jodhpur (1), NBPGR Ranchi (24), UAS RS Raichur (5)                                                                                                                                                                             |
| Datepalm               | CIAH (93), NBPGR Jodhpur (3), GAU RS Mundra, Kachchh (27), RAU Bikaner (34)                                                                                                                                                                                                   |
| European plum          | YSPUHF (9)                                                                                                                                                                                                                                                                    |
| Fig                    | CARI (2), FRS Aurangabad (3), IIHR (8), MPKV Rahuri (9), NBPGR Bhowali (7), NBPGR Shimla (4), UAS RS Raichur (2)                                                                                                                                                              |
| Filbert                | NBPGR Shimla (2)                                                                                                                                                                                                                                                              |
| Fortunella             | NRCC (2)                                                                                                                                                                                                                                                                      |
| Grape                  | CARI, A&N island (12), CISH, (14), GBPUAT (4), IIHR (101), MPKV Rahuri (60), NBPGR Bhowali (5), NBPGR Shimla (11), NRCC (323), UAS Bangalore (6), UAS Dharwad (23), UAS RS Raichur (9)                                                                                        |
| Guava                  | BAC Sabour (14), CARI (2), CISH, (95), GAU Ahmedabad (5), GBPUAT (16), GKVK Bangalore (6), HAFRP (48), HPKV (3), ICARRCNEH (25), IIHR (38), KAU (4), NBPGR Shillong (15), NRCAF (2), PDKV RS Sindhewahi (3), TNAU (2), UAS Bangalore (6), UAS Dharwad (3), UAS RS Raichur (2) |

(Contd.)

Table 10 (Contd.)

| Crop            | Location                                                                                                                                                                                                                                                                                                                                                  |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Hazelnut        | NBPGR Bhowali (2), NBPGR Shimla (2)                                                                                                                                                                                                                                                                                                                       |
| Jackfruit       | GBPUAT (9), HAFRP (111), NBPGR Bhowali (2), NBPGR Ranchi (55), NBPGR Thrissur (72), UAS Bangalore (20)                                                                                                                                                                                                                                                    |
| Jamun           | HAFRP (7), KAU (3), NBPGR Ranchi (26), PDKV Sindhewahi (2)                                                                                                                                                                                                                                                                                                |
| Karonda         | CIAH (5), GBPUAT (9), KAU (2), NBPGR Bhowali (6), NBPGR Issapur (3), NBPGR Jodhpur (12)                                                                                                                                                                                                                                                                   |
| Ker             | CIAH (65), NBPGR Jodhpur (141)                                                                                                                                                                                                                                                                                                                            |
| Khejri          | CIAH (30)                                                                                                                                                                                                                                                                                                                                                 |
| Kiwifruit       | CITH (6), HPKV (5), ICARRCNER Meghalaya (7), NBPGR Shimla (8), YSPUHF (7)                                                                                                                                                                                                                                                                                 |
| Lasora          | CIAH (64), NBPGR Bhowali (4), NBPGR Jodhpur (110), NBPGR Ranchi (5), NRC Af (2)                                                                                                                                                                                                                                                                           |
| Lemon           | HAFRP (1), NBPGR Bhowali (7), NBPGR Issapur (2), NBPGR Jodhpur (2), NBPGR Thrissur (3), NRCC (17)                                                                                                                                                                                                                                                         |
| Lime            | HAFRP (2), HPKV (5), NBPGR Bhowali (33), NBPGR Issapur (4), NBPGR Thrissur (3), NRCC (55), PDKV RS Katol (4)                                                                                                                                                                                                                                              |
| Litchi          | BAC Sabour (20), CISH (33), GBPUAT (17), HAFRP (51), HPKV (5)                                                                                                                                                                                                                                                                                             |
| Macadamia       | YSPUHF (6)                                                                                                                                                                                                                                                                                                                                                |
| Mandarin        | NBPGR Bhowali (21), NBPGR Issapur (1), NRCC (29), PDKV RS Katol (35)                                                                                                                                                                                                                                                                                      |
| Mango           | BAC Sabour (157), CARI (24), CISH (686), FRS Aurangabad (51), GAU Ahmedabad (188), GBPUAT (93), GKVK Bangalore (20), HAFRP (248), IHR (256), MPUAT Udaipur (35), NBPGR Issapur (3), NBPGR Ranchi (22), NBPGR Thrissur (128), NRCAF (4), PDKV RS Katol (19), PDKV RS Sindhewahi (16), TNAU (29), UAS Bangalore (20), UAS Dharwad (47), UAS RS Raichur (24) |
| Moringa         | CIAH (3), NBPGR Bhowali (2)                                                                                                                                                                                                                                                                                                                               |
| Mulberry        | NBPGR Bhowali (2), NBPGR Issapur (4), NBPGR Jodhpur (16)                                                                                                                                                                                                                                                                                                  |
| Oilpalm         | GAU Mundra (12), NRC Oilpalm (96)                                                                                                                                                                                                                                                                                                                         |
| Olive           | YSPUHF (19)                                                                                                                                                                                                                                                                                                                                               |
| Papaya          | CARI (6), GBPUAT (24), IHR (20), NBPGR Amravati (24), UAS RS Raichur (6)                                                                                                                                                                                                                                                                                  |
| Passion Fruit   | NBPGR Shillong (4)                                                                                                                                                                                                                                                                                                                                        |
| Peach           | CITH (2), GBPUAT (18), HAFRP (5), HPKV (5), ICARRCNER Meghalaya (13), NBPGR Bhowali (6), NBPGR Shimla (41), YSPUHF (53)                                                                                                                                                                                                                                   |
| Pear            | CITH (9), GBPUAT (17), HPKV (4), NBPGR Bhowali (10), NBPGR Shimla (60), YSPUHF (39)                                                                                                                                                                                                                                                                       |
| Pecan nut       | CITH (2), HPKV (6), NBPGR Shimla (11), YSPUHF (6)                                                                                                                                                                                                                                                                                                         |
| Persimmon       | HPKV (3), NBPGR Bhowali (3), NBPGR Shimla (8)                                                                                                                                                                                                                                                                                                             |
| Phalsa          | CIAH (5), NBPGR Jodhpur (5)                                                                                                                                                                                                                                                                                                                               |
| Pilu            | CIAH (2)                                                                                                                                                                                                                                                                                                                                                  |
| Pineapple guava | NBPGR Shimla (4)                                                                                                                                                                                                                                                                                                                                          |
| Pistachio nut   | NBPGR Shimla (2)                                                                                                                                                                                                                                                                                                                                          |
| Plum            | CITH (6), GBPUAT (22), HPKV (7), NBPGR Bhowali (5), NBPGR Shimla (32), YSPUHF (38)                                                                                                                                                                                                                                                                        |
| Pomegranate     | CARI (3), CIAH (185), CITH (7), GKVK Bangalore (4), HAFRP (8), IHR (13), MPKV Rahuri (52), NBPGR Amravati (20), NBPGR Bhowali (2), NBPGR Issapur (49), NBPGR Jodhpur (25), NBPGR Shimla (155), UAS Bangalore (4), UAS Raichur (4), YSPUHF (36)                                                                                                            |
| Poncirus        | NRCC (18)                                                                                                                                                                                                                                                                                                                                                 |
| Pummelo         | NBPGR Thrissur (2), NRCC (52)                                                                                                                                                                                                                                                                                                                             |
| Quince          | NBPGR Shimla (3)                                                                                                                                                                                                                                                                                                                                          |
| Rangpur Lime    | NRCC (29)                                                                                                                                                                                                                                                                                                                                                 |
| Ribes           | NBPGR Bhowali (26)                                                                                                                                                                                                                                                                                                                                        |
| Rubus           | NBPGR Bhowali (21), NBPGR Shimla (24)                                                                                                                                                                                                                                                                                                                     |
| Sapota          | CARI (3), FRS Aurangabad (2), GBPUAT (5), GKVK Bangalore (9), HAFRP (12), KAU (7), PDKV Katol (2), PDKV RS Sindhewahi (2), TNAU (10), UAS Bangalore (9), UAS Dharwad (9), UAS RS Raichur (3)                                                                                                                                                              |
| Sour Orange     | NBPGR Bhowali (3)                                                                                                                                                                                                                                                                                                                                         |
| Strawberry      | CITH (36), HPKV (10), NBPGR Bhowali (72), NBPGR Shimla (24), YSPUHF (20)                                                                                                                                                                                                                                                                                  |
| Sweet Lime      | NBPGR Bhowali (42), NBPGR Issapur (3), NRCC (5)                                                                                                                                                                                                                                                                                                           |
| Sweet Orange    | NRCC (43), PDKV RS Katol (4), UAS RS Raichur (1)                                                                                                                                                                                                                                                                                                          |
| Tamarind        | FRS Aurangabad (3), GAU Ahmedabad (2), HAFRP (30), NBPGR Jodhpur (1), NBPGR Ranchi (51), TNAU (3), UAS Bangalore (21)                                                                                                                                                                                                                                     |
| Tree tomato     | NBPGR Shimla (2)                                                                                                                                                                                                                                                                                                                                          |
| Vaccinium       | NBPGR Bhowali (5)                                                                                                                                                                                                                                                                                                                                         |
| Viburnum        | NBPGR Shimla (2)                                                                                                                                                                                                                                                                                                                                          |
| Walnut          | CITH (38), NBPGR Bhowali (27), NBPGR Shimla (83), YSPUHF (18)                                                                                                                                                                                                                                                                                             |

Table 11. Status of important ornamental crops at different locations

| Crop          | Location                                                                                                                                       |
|---------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| Anthurium     | BCKVV (8), IIHR (11), KAU (27), TNAU HRS, Yercaud (55), UBKVV (11)                                                                             |
| Carnation     | BCKVV (6), PAU (7), SKUAS&T (8), YSPUHF (32)                                                                                                   |
| Chrysanthemum | AAU (23), ANGRAU (22), RAU (45), IIHR (76), MPKV Pune (28), MPUAT (39), NBRI (129), RPRC (104), SKUAS&T (40), TNAU (75), UAS (23), YSPUHF (55) |
| Gerbera       | RAU (11), BCKVV (16), GBPUA&T (20), ICARRC, Meghalaya (62), IIHR (25), MPKV Pune (22), PAU (8), SKUAS&T (13), TNAU HRS, Yercaud (46)           |
| Gladiolus     | ANGRAU (27), BAU (15), GBPUA&T (42), IARI (47), IIHR (74), MPKV Pune (50), MPUAT (63), PAU (36), SKUAS&T (60), IARI Katrain (29)               |
| Orchids       | BCKVV (24), ICAR RC, Meghalaya (15), KAU (67), TNAUHRS, Yercaud (13), UBKVV (125)                                                              |
| Rose          | IIHR (517), MPKV (24), NBRI (7), PAU (169), RAU (118), RPRC (111)                                                                              |
| Tuberose      | AAU (6), BCKVV (6), GBPUA&T (4), KAU (4), MPKV (7), NBRI(2)                                                                                    |

(Source: Bhattacharjee *et al.* 2002)

The designated NAGS for different horticultural crops are as presented in Table 12. These designated sites have the responsibility of overall germplasm management including conservation of the allotted crop(s) and work in association with the NBPGR. There is need to designate

more sites as field repositories for the horticultural crops like the temperate vegetables (IARI, Katrain, HP), tropical vegetables and ornamentals (IIHR Bangalore) and apple (FRS Mashobra, HP).

Table 12. Designated National Active Germplasm Sites (NAGS) for horticultural crops

| Crop (s)                     | Designated NAGS                                            |
|------------------------------|------------------------------------------------------------|
| Arid fruits                  | NRC on Arid Horticulture, Bikaner                          |
| Banana                       | NRC on Banana, Tiruchirappalli                             |
| Cashew                       | NRC for Cashew, Puttur                                     |
| Citrus species               | NRC on Citrus, Nagpur                                      |
| Grapes                       | NRC for Grapes, Pune                                       |
| Aonla, Bael & Litchi         | Central Horticultural Experiment Station, Ranchi           |
| Jackfruit                    | Indian Institute of Horticultural Research, Bangalore      |
| M & AP                       | NRC on M & AP, Anand                                       |
| Mango                        | Central Institute for Sub-Tropical Horticulture, Lucknow   |
| Mulberry                     | Central Silk and Mulberry Genetic Resources Centre, Hosur  |
| Oil Palm                     | NRC on Oil Palm, Eluru                                     |
| Onion & Garlic               | NRC for Onion & Garlic, Nasik                              |
| Orchids                      | NRC for Orchids, Gangtok                                   |
| Ornamentals crops            | National Botanical Research Institute, Lucknow             |
| Plantation crops             | Central Plantation Crops Research Institute, Kasargod      |
| Potato                       | Central Potato Research Institute, Shimla                  |
| Spices                       | Indian Institute of Spices Research, Bangalore             |
| Temperate horticulture crops | Central Institute of Temperate Horticulture, Srinagar      |
| Tropical fruits              | Indian Institute of Horticultural Research, Bangalore      |
| Tuber crops                  | Central Tuber Crops Research Institute, Thiruvananthapuram |
| Vegetables                   | Indian Institute of Vegetables Research, Varanasi          |

### (b) Seed Gene Bank

This method is almost universally applied to the orthodox seed species like vegetables. Due to the extended life span of seeds stored under optimum conditions, it will not be necessary to regenerate the seeds at frequent intervals. Reducing frequency of regeneration results in cost-effective maintenance of germplasm. More

importantly it minimises the genetic erosion resulting from genetic drift in small populations that may be grown for regeneration; genetic shifts resulting from natural selection when material is grown out in the field. Two types of collections are maintained in gene bank (i) active collections under medium term condition (4°C) from which samples are drawn for evaluation and distribution

and (ii) base collections are maintained at (-20°C) for long term storage. Work is also in progress on alternative methods of storage of seeds such as the maintenance of seed imbibed storage (recalcitrant seed storage at higher moisture content), cryopreservation of seeds (for extended life span than in long term storage), and storage of ultra

dry seeds (drying to moisture content of 2.5%) in hermetically sealed containers under ambient conditions. Status of vegetable germplasm stored in National Gene Bank, NBPGR, New Delhi has been presented in Table 13.

Table 13. Status of horticulture germplasm stored in National Gene Bank, NBPGR, New Delhi

| Crop (s)                        | Accession stored (no.) | Crop (s)            | Accession stored (no.) |
|---------------------------------|------------------------|---------------------|------------------------|
| Ash gourd                       | 15                     | Musk melon          | 104                    |
| Atriplex                        | 12                     | Okra                | 1350                   |
| Bitter gourd                    | 196                    | Okra (wild)         | 366                    |
| Bottle gourd                    | 157                    | Onion               | 897                    |
| Brinjal and <i>Solanum</i> spp. | 2079                   | Papaya              | 23                     |
| Cabbage                         | 46                     | Pea                 | 2645                   |
| Carrot                          | 35                     | Pumpkin             | 75                     |
| Chilli                          | 1914                   | Radish              | 149                    |
| Chinese cabbage                 | 108                    | Ridgegourd          | 49                     |
| Cluster bean                    | 2594                   | Round gourd         | 13                     |
| Coriander                       | 287                    | Round melon         | 15                     |
| Cowpea                          | 2479                   | Snake cucumber      | 8                      |
| Cucumber                        | 121                    | Sowa                | 59                     |
| Custard apple                   | 57                     | Spinach             | 52                     |
| Fenugreek                       | 412                    | Sponge gourd        | 33                     |
| French bean                     | 1065                   | Sponge gourd (wild) | 18                     |
| Lablab bean                     | 384                    | Tomato              | 997                    |
| Long melon                      | 14                     | Water melon         | 45                     |

### (c) *In vitro* Conservation

Some crop species such as banana and plantain (*Musa* spp.) do not produce seeds or produce recalcitrant seeds such as coconut, cacao, and many tree and shrub species. Crops such as potato, yam, cassava and sweet potato have either sterile genotypes or produce orthodox seeds which are highly heterozygous, therefore, making seed storage of limited interest for the conservation of particular gene combinations. These species are mainly propagated vegetatively to maintain clonal genotypes. At present the most common method to conserve the genetic resources of these difficult crops is as whole plants in the field. There are, however, several serious problems with field genebanks as described earlier. In addition, distribution and exchange from field gene bank is difficult because of the vegetative nature of the material and the greater risk of disease transfer. The conservation of rare and endangered plant species has also become an issue of concern. Plant tissue culture repository and cryopreservation techniques are employed to conserve the above described genetic resources.

Tissue culture techniques are of great interest for collecting, multiplication and storage of plant germplasm. Tissue culture systems allow propagation of plant material

with high multiplication rates in an aseptic condition. Virus free plants can be obtained through meristem culture in combination with thermotherapy, thus ensuring disease free plants and simplifying quarantine procedures. The miniaturizations of explants allow reduction in space requirements and reduce labour costs. Among horticultural crops germplasm conserved at *in vitro* repository, NBPGR, New Delhi include *Allium sativum* (117 accessions), *Allium* spp. (14), *Musa* spp. (341), *Actinidia chinensis* (3), *Aegle marmelos* (1), *Fragaria* spp. (48), *Prunus* sp. (2), *Rubus* spp. (5), *Malus* spp. (4), *Morus* sp. (42) and *Vitis vinifera* (1). However there are two technical problems associated with this method and need improvement. Firstly, the genetic instability of the material conserved as tissue culture due to somaclonal variation at the time of regeneration of the tissue into seedlings, and secondly, the length of storage the tissue is limited.

### (d) Cryopreservation

Cryopreservation involves storage of plant material at low temperature in liquid nitrogen or nitrogen vapour (-154°C to -196°C). At this temperature the cell division and metabolic processes stop and hence the plant material can be stored for larger period without alteration. Cryopreservation of those species that can easily be

regenerated into whole plant from the stored propagules is a promising option for safe, long-term storage of germplasm. Status of cryopreserved germplasm of horticultural crops at the cryobank NBPGR, New Delhi include 389 accessions of vegetables (*Abelmoschus* spp., *Capsicum annuum*, *Lycopersicon* spp., *Solanum* spp.) covering 55 species and 1071 accessions of fruits and nuts (*Aegle marmelos*, *Citrus* sp., *Capparis decidua*, *Juglans regia*, *Prunus* sp., *Zizyphus* sp.) covering 111 species. Cryopreservation requires limited space, involves very little maintenance and is considered to be a cost-effective option. Engelmann (1997) has reviewed cryopreservation protocols developed using different techniques. Once these techniques are further refined, large-scale adoption should be possible.

#### (f) Pollen Storage

Pollen storage was mainly developed as a tool for controlled pollination of asynchronous flowering genotypes especially fruit tree species. The potential advantage of this method in conserving germplasm can be readily appreciated; the relatively small quantity of the specimen required for a single accession, and exchange of germplasm through pollen poses fewer quarantine problems compared with seed or other propagules. In recent years, cryopreservation techniques have been developed for pollen of an increasing number of species and cryobanks of pollen have been established for fruit tree species in several countries (Alexander and Ganeshan, 1993). However, pollen storage alone cannot conserve the cytoplasmic genetic diversity of a species. There is a need to assess the potential drawbacks of excluding maternal genes and the feasibility of ovule storage and *in vitro* fertilization techniques. In addition, effective sample techniques to cover a population or gene pool are needed.

#### (g) DNA Storage

Storage of DNA is another approach to conservation. Genetic engineering has broken down the crossability barriers and transgenic plants incorporating genes from virus, bacteria, fungi and even mice have become reality. Such efforts have lead to realisation of storage of total genomic information in the form of DNA libraries. However, strategies and procedures have to be developed on how to use the material stored in the form of DNA. Therefore, the role and value of this method for PGR conservation is not completely clear as yet.

#### (h) Botanical/Herbal Gardens

The role of most botanical gardens in conserving intra-species diversity is limited because these conserve only a few accessions per species or taxon. However, this plays a greater role in public awareness and education. Botanical gardens are mainly used to display a great number of different exotic species. There is a possibility that a few well-managed gardens lay emphasis on conservation of certain group of species as living collections. Herbal gardens resemble botanical gardens except that these maintain medicinal and aromatic plants. Herbal gardens are getting more importance these days because the medicinal and aromatic plant groups is the most threatened among horticultural plants.

#### (i) In Situ Conservation

In *in situ* conservation, plant species are promoted to grow in their natural habitats where evolutionary processes continue to operate, making it a dynamic system. Genetic variability is generated through mutation, pollen and seed dispersal, and recombination within and among populations. Selection operates on this variability leading to the development of new plant types with improved adaptability. *In situ* conservation, in addition to natural habitats in protected areas and national reserves, also needs to be carried on-farm in the areas where landraces and locally adapted farmers' varieties are cultivated. This requires active farmers' participation to conserve landraces and traditional farmers' varieties. The novel genetic resources may be conserved even in home gardens. On-farm conservation is of particular importance in countries like India, to conserve local genetic diversity and to provide diverse food and other products for household needs and local markets, where livelihood depends on traditional subsistence farming systems. Some on-farm conservation models have been developed to define priorities for what and where to conserve, based on biological and socio-economic criteria.

#### Registration of Plant Germplasm

Unlike the developers of released cultivars, scientists associated with the development of improved germplasm and genetic stocks (new sources of resistance, male sterility, varied types of mutants, cytogenetic stocks etc.) have no mechanism for recognition. Lack of formal recognition of such useful materials and the role of scientist in development of these materials, discourages them from sharing the valuable materials with other workers. Consequently, most of such valuable material

remains underutilized or get lost. With the recent developments concerning IPR and other related issues, due recognition of these materials has become all the more important.

Keeping these considerations in view, the Indian Council of Agricultural Research has identified National Bureau of Plant Genetic Resources (NBPGR) as the nodal agency for implementation of plant germplasm registration. The elite material/ genetic stocks registered at NBPGR pertaining to horticultural crops are aonla (1 line), ber (3), cashew (9), mango (1) among fruits; round melon (1) and snap melon (2), bitter gourd (1), bottle gourd (2), brinjal (2), chilli/sweet pepper (3), cucumber (2), fenugreek (2), garlic (2), kachri (2), pea (5) pointed gourd (1), potato (1) and tomato (3) among vegetables and balsam (1), gladiolus (4) and orchid (2 lines) among ornamentals. These are maintained at National genebank, NBPGR, New Delhi.

#### Future Thrusts

- Priority for collection of wild relatives and under exploited genetic resources.
- Introduction of targeted germplasm for crop improvement.
- Establishment of core collection.
- Evaluation of germplasm for yield, quality, shelf life, and resistance to biotic and abiotic stresses.
- Genetic enhancement / prebreeding involving collections from primary, secondary and tertiary gene pools.
- The morphological, biochemical and molecular characterization of valuable genetic resources.
- Registration of germplasm, breeding lines and parental lines.

- Conservation of germplasm.
- Awareness generation related to Patenting, Farmer's right and Benefit sharing.

#### References

- Alexander MP and S Ganeshan (1993) Pollen storage. In: KL Chadha and OP Pareek (eds) *Advances in Horticulture*, Vol. I, Malhotra Publishing House, New Delhi, pp 481-496.
- Arora RK (1991) Plant diversity in the Indian gene centre. In: Paroda RS and RK, Arora (eds) *Plant Genetic Resources-Conservation and Management, Concept and Approaches*. IBPGR, Regional Office for South & SE Asia, New Delhi, pp 25-54.
- Arora RK and ER Nayar (1984) *Wild Relatives of Crop Plants in India*. NBPGR Sci. Monograph No. 7, 90p.
- Bhattacharjee SK, Suchitra Pushkar and P Naveen Kumar (2002) *Passport Data of Flower Crops Germplasm*. AICRP on Floriculture (ICAR), Div. of Floriculture and Landscaping, IARI, New Delhi, 210p.
- Chadha KL and Choudhury B (1986) *Ornamental Horticulture in India*. ICAR, New Delhi, 217p.
- Engelmann F (1997) Present development and use of *in vitro* culture techniques for the conservation of Plant Genetic Resources. *Acta Hort.*, **447**: 471-75.
- Ghosh SP (1984) *Horticulture in North-eastern India*. Assoc. Publi, New Delhi.
- Pareek OP, Sharma S and Arora RK (1998) *Underutilised Edible Fruits and Nuts*. An Inventory of Genetic Resources of their Regions of Diversity. IBPGR, Regional Office For South & SE Asia, New Delhi, 235p.
- Rai M and PN Gupta (1996) Distribution and diversity of indigenous tropical fruits. In: *Genetic Resources of Tropical Fruits*. NBPGR, New Delhi, pp 19-43.
- Randhawa GS and Mukhopadhyay A (1986) *Floriculture in India*. Allied Publishers, New Delhi, 654p.
- Swaroop V (1995) *Garden Flowers*. National Book Trust, N. Delhi, 276p.
- Singh, BP, Gupta PN and Rana RS (1993) New Introductions in ornamentals. *J. Ornamental Hort.* **1**(1): 68-72.

#### ABBREVIATIONS

|                 |                                                                        |
|-----------------|------------------------------------------------------------------------|
| AAU             | - Assam Agricultural University, Jorhat, Assam                         |
| ANGRAU          | - Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad |
| ARS, Chintamani | - Agricultural Research Station, Chintamani                            |
| BAC, Sabour     | - Bihar Agricultural College, Sabour                                   |
| BAU, Ranchi     | - Birsa Agricultural University, Ranchi                                |
| BCKVV           | - Bidhan Chandra Krishi Vishwavidyala, Mohanpur                        |
| CARI            | - Central Agricultural Research Institute, Andaman & Nicobar Islands   |
| CIAH            | - Central Institute of Arid Horticulture, Bikaner                      |
| CISH            | - Central Institute of Sub-Tropical Horticulture, Lucknow              |
| CITH            | - Central Institute of Temperate Horticulture, Srinagar                |
| CRS, Bapatla    | - Cashew Research Station, Bapatla                                     |

|                   |                                                                             |
|-------------------|-----------------------------------------------------------------------------|
| CRS, BBSR         | - Cashew Research Station, Bhuwaneswar                                      |
| CRS, Madakkathara | - Cashew Research Station, Madakkathara                                     |
| FRS, Aurangabad   | - Fruit Research Station, Aurangabad                                        |
| GAU, Ahmedabad    | - Gujarat Agricultural University, Ahmedabad                                |
| GAU, Anand        | - Gujarat Agricultural University, Anand                                    |
| GAU, RS Mundra    | - Gujarat Agricultural University, Regional Station Mundra                  |
| GBPUAT            | - G.B.Pant University of Agriculture & Technology, Pantnagar                |
| GKVK, Bangalore   | - University of Agriculture Sciences, GKVK campus, Bangalore                |
| HAFRP             | - Horticulture and Agroforestry Research Programme, Ranchi                  |
| HPKV              | - Himachal Pradesh Krishi Vishwavidyalaya, Palampur                         |
| IARI              | - Indian Agricultural Research Institute, New Delhi                         |
| IARI              | - Indian Agricultural Research Institute, Regional Station Katrain          |
| ICARRCNEH         | - ICAR Research Complex for North Eastern Region, Barapani                  |
| IIHR              | - Indian Institute of Horticultural Research, Bangalore                     |
| KAU               | - Kerala Agricultural University, Veilankara                                |
| MPKV, Pune        | - Mahatma Phule Krishi Vidyapeeth, Pune Campus                              |
| MPKV, Rahuri      | - Mahatma Phule Krishi Vidyapeeth, Rahuri                                   |
| MPUAT             | - Maharana Pratap Univ. of Agric. & Tech., Udaipur                          |
| NBPGR, Amravati   | - National Bureau of Plant Genetic Resources, Regional Station Amravati     |
| NBPGR, Bhowali    | - National Bureau of Plant Genetic Resources, Regional Station Bhowali      |
| NBPGR, Issapur    | - National Bureau of Plant Genetic Resources, Experimental Station Issapur  |
| NBPGR, Jodhpur    | - National Bureau of Plant Genetic Resources, Regional Station Jodhpur      |
| NBPGR, Ranchi     | - National Bureau of Plant Genetic Resources, Regional Station Ranchi       |
| NBPGR, Shillong   | - National Bureau of Plant Genetic Resources, Regional Station Shillong     |
| NBPGR, Shimla     | - National Bureau of Plant Genetic Resources, Regional Station Shimla       |
| NBPGR, Thrissur   | - National Bureau of Plant Genetic Resources, Regional Station Thrissur     |
| NBRI              | - National Botanical Research Institute, Lucknow                            |
| NRC Banana        | - National Research Centre for Banana, Trichy                               |
| NRC Cashew        | - National Research Centre for Cashew, Puttur                               |
| NRCAF             | - National Research Centre for Agroforestry, Jhansi                         |
| NRCC              | - National Research Centre for Citrus, Nagpur                               |
| NRCG              | - National Research Centre for Grape, Pune                                  |
| PAU               | - Punjab Agricultural University, Ludhiana                                  |
| PDKV, Katol       | - Dr. Punjab Rao Deshmukh Krishi Vishwavidyalay, Regional Station, Katol    |
| PDKV, Sindewahi   | - Dr. Punjab Rao Deshmukh Krishi Vishwavidyalay, Regional Station Sindewahi |
| RARS, Pilicode    | - Regional Fruit Research Station, Pilicode                                 |
| RAU               | - Rajendra Agricultural University, Pusa                                    |
| RAU, Bikaner      | - Rajasthan Agriculture University, Bikaner                                 |
| RFRS, Vengurla    | - Regional Fruit Research Station, Vengurla                                 |
| RPRC              | - Regional Plant Resources Centre, Bhuwaneswar                              |
| RRS, Jhargram     | - Regional Research Station, Jhargram                                       |
| SKUAS&T           | - Sher-e-Kashmir University of Agriculture Science and Technology, Srinagar |
| TNAU              | - Tamilnadu Agriculture University, Coimbatore                              |
| TNAUHS            | - Tamil Nadu Agriculture University, Horticulture Research Station Yercaud  |
| UAS, Bangalore    | - University of Agricultural Sciences, Bangalore                            |
| UAS, Dharwad      | - University of Agricultural Sciences, Dharwad                              |
| UAS, RS Raichur   | - University of Agricultural Sciences, Regional Station Raichur             |
| UBKV              | - Uttar Banga Krishi Vishwavidyalay, Coochbihar                             |
| YSPUHF            | - Dr YS Parmar University of Horticulture & Forestry, Solan                 |

## Introduction, Collection, Evaluation and Utilization of Fruit Germplasm

**SN Pandey\* and AK Singh**

*Division of Fruits and Horticultural Technology, Indian Agricultural Research Institute, New Delhi-110 012*

In order to strengthen the germplasm pool of various fruit crops, steps were taken to collect, evaluate, maintain and utilize as commercial cultivars, rootstock and breeding material in crop improvement programmes. Germplasm of 25 fruit crops numbering 1529 accessions were collected from various exotic and indigenous sources, and evaluated for various purposes in the last 50 years at the Indian Agricultural Research Institute, New Delhi. In all, 88 accessions have been utilized for one or the other purposes. It is a matter of interest that out of 979 collections made from exotic sources only 92 (9.39%) survived in the field/nursery as against 38.2% survival in indigenous collections. This indicates that more care is needed to handle exotic germplasm in our country and make duplicate sets of material available at different places to avoid risk on their survival during various phases of their growth and development.

**Key Words:** Evaluation, Fruit Germplasm, Introduction, Utilization

Genetic variability is a pre-requisite for improvement in fruit crops. Whereas considerable diversity exists in agronomic traits in different fruit crops, the diverse genotypes combining sources of resistance to several biotic and abiotic stresses and fruit quality traits together are scarce in India. Therefore, it was considered appropriate to tap exotic and unexplored indigenous sources of germplasm of potential fruit crops. Genetically diverse types could thus effectively be employed to incorporate desirable traits of fruit quality, productivity, dwarf plant stature, tolerance to biotic and abiotic stresses, etc. to expand crop areas in unconventional geographical locations by evolving/selecting suitable scion variety and root stock to realize higher production of quality fruits. The Division of Fruits and Horticultural Technology of the Indian Agricultural Research Institute, New Delhi, since its inception as the Division of Horticulture in 1956 therefore, placed greater emphasis on collection and introduction of fruit germplasm by mutual germplasm exchange through personal contacts and later on through the National Bureau of Plant Genetic Resources (NBPGR) and its management in an organized manner.

### Materials and Methods

Germplasm of 25 fruit crops viz, mango, citrus, grape, guava, apple, pear, peach, fig, loquat, papaya, phalsa, strawberry, pomegranate, tamarind, nectarine, litchi, cashew nut, macademia nut, avocado, khirni, *Annona* species, capegooseberry and bael was collected from

within the country and exotic sources using appropriate collection methodology under strict quarantine and maintained in the fields following appropriate cultural practices. Seed material was germinated in sterilized sand and/or soil after seed treatment. Germinated seedlings and plants raised from cuttings were maintained with utmost care. These germplasm were evaluated for various attributes and characterized using IPGRI descriptors list for morphological and molecular characters.

### Results and Discussion

Indigenous and exotic germplasm collections of various fruit crops were evaluated for survival, growth and fruiting, fruiting quality and also for their utility as breeding material. The head-wise results are presented below:

#### *Germplasm Collection, Documentation and Utilization*

In all, 1529 accessions were assembled in a phased manner from various indigenous and exotic sources, of which 302 exist in the fields. Germplasm was subjected to field evaluation and characterization before utilization (Table 1). Eighty eight accessions have so far been utilized for various purposes. Despite reasonable efforts, large numbers of collections have vanished due to one or the other unfavorable factors. It is evident from the data (Table 1) that out of 550 accessions collected from indigenous sources, 210 (38.2%) survived in the field. Among 998 introduced accessions from the exotic sources only 92 (9.3%) survived.

\*Former Head of the Division. Presently, Assistant Director General (Horticulture), ICAR, KAB-II, Pusa Campus, New Delhi-110 012  
E-mail: snpandey\_fht@yahoo.com

Table 1. Fruit germplasm holding and utilization at IARI, New Delhi (1956-2001)

| S. No. | Crop                  | No. of collections made |        |       | No. of collections existing |        |       | No. of collections utilized |        |       |
|--------|-----------------------|-------------------------|--------|-------|-----------------------------|--------|-------|-----------------------------|--------|-------|
|        |                       | Indigenous              | Exotic | Total | Indigenous                  | Exotic | Total | Indigenous                  | Exotic | Total |
| 1      | <i>Annona</i> species | 3                       | 1      | 4     | 2                           | 0      | 2     | 0                           | 0      | 0     |
| 2      | Cape gooseberry       | 0                       | 9      | 9     | 0                           | 0      | 0     | 0                           | 0      | 0     |
| 3      | Citrus                | 10                      | 268    | 278   | 10                          | 23     | 33    | 8                           | 8      | 16    |
| 4      | Fig                   | 0                       | 18     | 18    | 0                           | 0      | 0     | 0                           | 0      | 0     |
| 5      | Grape                 | 115                     | 437    | 552   | 11                          | 25     | 36    | 2                           | 11     | 13    |
| 6      | Guava                 | 10                      | 6      | 16    | 6                           | 0      | 6     | 2                           | 0      | 2     |
| 7      | Loquat                | 0                       | 5      | 5     | 0                           | 0      | 0     | 0                           | 0      | 0     |
| 8      | Mango                 | 157                     | 69     | 226   | 74                          | 17     | 91    | 20                          | 2      | 22    |
| 9      | Papaya                | 56                      | 36     | 92    | 2                           | 0      | 2     | 6                           | 0      | 6     |
| 10     | Pear                  | 12                      | 4      | 16    | 5                           | 0      | 5     | 2                           | 1      | 3     |
| 11     | Peach                 | 30                      | 54     | 84    | 0                           | 1      | 1     | 0                           | 1      | 1     |
| 12     | Phalsa                | 5                       | 1      | 6     | 5                           | 1      | 6     | 5                           | 1      | 6     |
| 13     | Plum                  | 18                      | 6      | 24    | 0                           | 0      | 0     | 1                           | 1      | 2     |
| 14     | Pomegranate           | 20                      | 21     | 41    | 20                          | 21     | 41    | 6                           |        | 6     |
| 15     | Strawberry            | 31                      | 29     | 60    | 0                           | 0      | 0     | 0                           | 0      | 0     |
| 16     | Apple                 | 10                      | 6      | 16    | 8                           | 1      | 9     | 2                           | 01     | 3     |
| 17     | Tamarind              | 0                       | 1      | 1     | 0                           | 0      | 0     | 0                           | 0      | 0     |
| 18     | Nectarine             | 0                       | 3      | 3     | 0                           | 0      | 0     | 0                           | 0      | 0     |
| 19     | Litchi                | 7                       | 0      | 7     | 2                           | 0      | 2     | 0                           | 0      | 0     |
| 20     | Cashewnut             | 3                       | 0      | 3     | 0                           | 0      | 0     | 0                           | 0      | 0     |
| 21     | Macadamia nut         | 0                       | 1      | 1     | 0                           | 0      | 0     | 0                           | 0      | 0     |
| 22     | Ber                   | 60                      | 2      | 62    | 50                          | 2      | 52    | 8                           | 2      | 10    |
| 23     | Avocado               | 1                       | 1      | 2     | 1                           | 1      | 2     | 0                           | 0      | 0     |

### Mango (*Mangifera indica* L.)

Of 226 collections made from exotic and indigenous sources, 91 survived in the field and 22 have so far been utilized for various purposes. Exotic collection 'Eldon' has been identified and released with popular name as 'Pusa Surya' for commercial cultivation. Fruit of this variety has thick peel with red colour on apricot yellow surface exposed to sun and long shelf-life making it suitable for long distance transport. 'Dushehari' and 'Neelam' have been utilized as parents for developing Amrapali and Mallika cultivars. Exotic 'Sensation' has been utilized as a pollen parent with 'Amrapali' for developing promising hybrid H-13-1 with red peel and long shelf life (Pandey, 1993), which has now been released as cv. Pusa Arunima. Other germplasm collections are under investigation for their utility either as a variety or parent for using in breeding programme. 'Anupam' has been found to be a dwarfing inter-stock for 'Amrapali' on seedling rootstock thus making it possible to induce dwarfness further for accommodating

more number of trees per unit area (Pandey 1990). 'Kurukan' has been found as a potential salt tolerant rootstock and 'Bhadauran' possesses resistance to malformation malady.

### Grape (*Vitis* spp.)

In grape, accessions were made from exotic (437) and indigenous (115) sources, which were evaluated and characterized morphologically (Singh, *et al.*, 1971 and 1972; Yadav, *et al.*, 1971 and 1976). Due to some natural adverse conditions, most of them were damaged and 36 exist in the field. Thirteen accessions have so far been utilized for a variety of purposes. Exotic cv Thompson Seedless and Perlette have become successful commercial cultivars in India. Other exotic collections like Katta Kurghan, Beauty Seedless, Madeleine Angevine, Rubired, Angoor Kalan and indigenous cv. Hur were utilized as parents in breeding programmes (Singh, *et al.*, 1972, Jindal *et al.*, 1984). Seeded cultivar Hur was made seedless with gibberellic acid application

(Yadava, *et al.*, 1977). Pusa Seedless, is a clonal selection of Thompson Seedless; Pusa Urvashi (Hur x Beauty Seedless), Pusa Navrang (Madeleine Angevine x Rubired) have been evolved and released for commercial cultivation (Jindal, *et al.*, 2004). The latter two varieties have shown field resistance against anthracnose. Salt Creek and Dogridge have been found to be of great

potential as salt tolerant rootstocks. Solonis x Othello-1613, an interspecific hybrid, has been found tolerant to nematodes.

### Citrus Species

A total of 278 exotic (268) and indigenous (10) accessions was made, of which 33 now exist in the field.

Table 2. Some of the important accessions of fruits utilized for specific purposes

| S.No. | Species                                                                                | Attributes                                                                       | Utilization                                                                               |
|-------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| 1     | Mango ( <i>Mangifera indica</i> L.)                                                    |                                                                                  |                                                                                           |
|       | Eldon                                                                                  | Red colour and thick peel                                                        | As variety                                                                                |
|       | Neelum                                                                                 | Regular bearing and dwarf in North India                                         | As parent                                                                                 |
|       | Mallika                                                                                | Good fruit quality                                                               | As variety                                                                                |
|       | Sensation                                                                              | Red peel, long shelf life                                                        | As parent                                                                                 |
|       | Anupam                                                                                 | Dwarfing interstock                                                              | As interstock for Amrapali                                                                |
|       | Kurakan                                                                                | Salt tolerant                                                                    | As rootstock                                                                              |
|       | Bhadauran                                                                              | Resistant to malformation                                                        | As parent                                                                                 |
| 2     | Grape ( <i>Vitis vinifera</i> L.)                                                      |                                                                                  |                                                                                           |
|       | Thompson Seedless                                                                      | Raisin variety and wider adaptability                                            | As table and raisin variety and breeding material for good yield, quality & seedlessness. |
|       | Perlette (EC-28410)                                                                    | Translucent berry, early ripening, seedlessness                                  | As a table variety & breeding material                                                    |
|       | Katta Kurghan (EC-42365)                                                               | Large berry                                                                      | Seeded material for increased berry size, breeding material.                              |
|       | Beauty Seedless (EC-28389)                                                             | Prolific bearing and earliness                                                   | As juice variety & parent                                                                 |
|       | Madeleine Angevine                                                                     | Wine making, earliness, low vigour                                               | As a parent for earliness, wine making                                                    |
|       | Rubired (EC-28415)                                                                     | Wine making                                                                      | As a parent for red coloured berry                                                        |
|       | Cardinal (EC-24662)                                                                    | Early maturity & loose cluster red peel                                          | As table variety and parent for beg berry and red colour                                  |
|       | Hur                                                                                    | Reflex stamen, sweetness                                                         | As breeding material                                                                      |
|       | Salt Creek                                                                             | Salt tolerance                                                                   | As rootstock                                                                              |
|       | Dogridge                                                                               | Salt tolerance                                                                   | As rootstock                                                                              |
|       | Solonis x Othello-1613                                                                 | Nematode resistance                                                              | Nematode resistant rootstock                                                              |
| 3     | Citrus species                                                                         |                                                                                  |                                                                                           |
|       | Kinnow ( <i>C. nobilis</i> X <i>C. deliciosa</i> )                                     | Excellent fruit quality, juiciness                                               | Commercial cultivation                                                                    |
|       | Rangpur lime (EC-18981)                                                                | Salt tolerance                                                                   | Rootstock                                                                                 |
|       | Mosambi & Pineapple ( <i>Citrus sinensis</i> Osbeck) (EC-115795)                       | Sweet juicy fruit                                                                | As a variety                                                                              |
|       | Kagazi Kalan                                                                           | Tolerant to canker                                                               | As a variety                                                                              |
|       | Rough lemon ( <i>Citrus jambhiri</i> ) (EC-25833)                                      | Vigorous rootstock, wide adaptation, resistant to Phytophthora                   | As a rootstock                                                                            |
|       | Grapefruit (EC-36731)                                                                  | Juice making                                                                     | Many varieties for commercial cultivation                                                 |
|       | Cleopatra mandarin ( <i>Citrus reticulata</i> ) (EC-18989)                             | Tolerant to salt, tristeza, exocortis and xyloporosis                            | As a rootstock                                                                            |
|       | Citranges cv. Troyer citrange ( <i>C. sinensis</i> x <i>P. trifoliata</i> ) (EC-22050) | Adapts well to wide range of soil, & resistant to soil-borne diseases, nematodes | As semi-dwarfing rootstock                                                                |
|       | Trifoliate orange ( <i>Poncirus trifoliata</i> ) (EC-31974)                            | Cold hardiness, dwarf, resistance to soil borne diseases and nematodes           | As rootstocks                                                                             |
| 4.    | <i>Mallus</i> , <i>Pyrus</i> and <i>Prunus</i>                                         |                                                                                  |                                                                                           |
|       | <i>Mallus baccata</i> var. Himalaica                                                   | Dwarf                                                                            | As dwarfing rootstock, resistant to Collar rot and root rot                               |
|       | <i>Mallus sikkimensis</i>                                                              | Dwarf (Apomictic), resistant to root rot                                         | As dwarfing rootstock, resistant to powdery mildew                                        |
|       | <i>Pyrus pashia</i>                                                                    | Dwarf                                                                            | As a rootstock                                                                            |
|       | <i>Pyrus pyrifolia</i> var. kumaoni                                                    | Dwarf                                                                            | Dwarf rootstock                                                                           |
|       | Paja ( <i>Prunus cerasioides</i> )                                                     | Evergreen                                                                        | Avenue plantation                                                                         |
|       | <i>Prunus salicina</i>                                                                 | Adaptable to wide range of soils                                                 | Commercial cultivation.                                                                   |

Most of the germplasm was damaged in phases due to decline. Exotic collection Kinnow mandarin was recommended for commercial cultivation in North West plains. Nagpur mandarin, Pineapple, Malta and Mosambi sweet oranges and Kagzi Kalan lemon attained commercial status, and occupy a sizable area in different parts of India. Rough lemon, Troyer citrange, Cleopatra mandarin, citranges and trifoliate orange have been found useful as root stocks for various purposes.

#### Papaya (*Carica papaya* L.)

A total of 92 collections was made from exotic (36) and indigenous (56) sources. Papaya breeding programme was undertaken with cv. 'Ranchi' as base material for selection at IARI Regional Station, Pusa (Bihar), resulting into the development and release of several varieties like Pusa Delicious, Pusa Majesty, Pusa Giant and Pusa Dwarf. Among them Pusa Majesty and Pusa Delicious are gynodioecious lines by selection for several generations. Pusa Nanha is a mutant induced by physical mutagenesis.

#### Guava (*Psidium guajava* L.)

In guava, 16 collections were made from various sources, of which 3 cultivars occupy the place of commercial importance. Guava aneuploid No. 82 has been developed through crossing diploid with seedless (triploid) variety using indigenous germplasm (Sharma, 1992). This aneuploid No. 82 imparts dwarfness to vigorous cv. Allahabad Safeda, which enables to raise guava in high-density plantation (Sharma *et al.*, 1992).

#### Ber (*Ziziphus* sp.)

In ber, 62 indigenous collections were made, of which 52 exist in the fields. All the genotypes are under assessment for their suitability for commercial cultivation and as sources of resistance against biotic and abiotic stresses (Sharma, 1997). 'Tikadi' and 'Ilaichi' escaped fruit fly and powdery mildew. *Ziziphus nummularia* and *Ziziphus rotundifolia* have been found useful as dwarfing rootstock for cultivar of *Z. mauritiana*. Molecular characterization of ber using different DNA markers has been taken up by this division (Fig. 1).

Genetic diversity among 41 accessions of ber (*Ziziphus* spp.) belonging to cultivated *Ziziphus mauritiana* and wild relative *Z. nummularia* have been investigated using RAPD, ISSR and AFLP. The level of polymorphism recorded within each species was 72.3% for *Z. mauritiana* and 87.1% for *Z. nummularia*. Several

species-specific and unique fragments were identified, which could be effectively used to distinguish different accessions from each other. Similarly, coefficients ranging from 0.145-0.86 suggested that *Ziziphus* belonging to India has genetic relationship among the accessions based on broad genetic base. Cluster analysis revealed complete separation of the accessions of the two species into distinct groups.

#### Pomegranate (*Punica granatum* L.)

Forty-one collections made from various sources are maintained in the fields. Several genotypes are under evaluation for their suitability as a variety or as breeding material.

#### Temperate Fruit Crops

Germplasm of apple, peach, plum and pear collected under temperate and sub-tropical conditions (Table. 1) include pomes and stone fruits collected from indigenous sources (Randhawa, 1987). Collections of temperate fruit crops have been maintained at IARI, Regional Station, Amartara Cottage, Shimla. In all, 16 collections of *Malus* were made from indigenous and exotic sources. *Malus baccata* var. *himalaica* appeared to be a dwarfing rootstock with a great degree of compatibility with Golden Delicious. It has also been found to be partially resistant to collar rot (*Phytophthora cactoris*), root rot (*Dematophora necatrix*) and wooly aphid (*Eriosoma lanigera*). *Malus sikkimensis* has been found to be resistant to powdery mildew and collar rot. Sixteen collections of *Pyrus* species were made from indigenous and exotic sources. *Pyrus pashia* is an easy rooting material by stooling (Yadav *et al.* 1971) and as a root stock, it has been found to impart dwarfness and *Pyrus pyrifolia* var. *Kumaoni* offers resistance to powdery

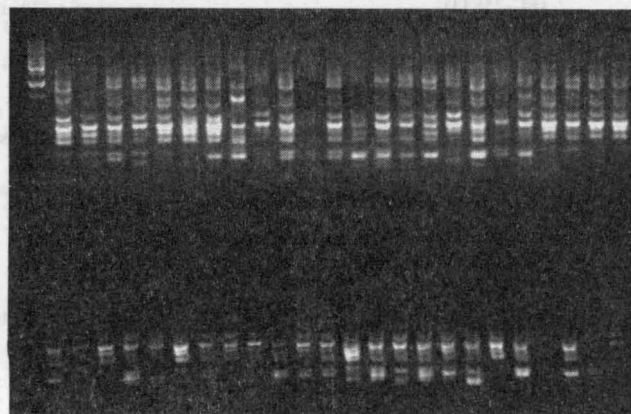


Fig. 1: RAPD profile of *Ziziphus* spp. with OPD-7

mildew. For genus *Prunus*, 30 collections were made from different sources for evaluation and utilization. Seeds of *Prunus rufa* failed to germinate. *Prunus jenkinsii* was found susceptible to severe cold. *Prunus cerasoides* is an evergreen plant and could best be utilized as an avenue plantation. *Prunus salicina* has been found to make a satisfactory union with plum cvs. Santa Rosa and Satsuma. The seedlings of *Prunus persica* have been found to be a successful root stock for peach, plum, apricot and almond. Germplasm evaluation of strawberry has revealed potential for commercial cultivation (Kaul, 1962; Rajput, 1965).

## References

- Ambadan SN Pandey and JC Anand (1977) Studies on raisin production from grapes (*Vitis vinifera* L.) grown under Delhi conditions. *Indian J. Hort.* **34**: 215-219.
- Deseudde J (1992) Cryopreservation of *in vitro* cultures of plant cells and organs by vitrification and dehydration. In: Dattee Y, Dumas C and Gallais A (eds) *Reproductive Biology and Plant Breeding*. Springer Verlag, Berlin, pp 291-300.
- Englemann F (1997) *In vitro* conservation methods. In: Ford-Lloyd BV, Newbury, HJ and Callow JA (eds), *Biotechnology and Plant Genetic Resources: Conservation and Use*, CABI, Wallingford, UK, 119-162.
- Morico G, Cerassi F and Fideghelli C (1999) Horticultural Crop Diversity: Conservation and Sustainable Utilization and Related International Agreements. *Acta Hort.* **495**: 233-244.
- Jindal PC, Singh Kashmir and Pandey SN (1984) A note on choice of parents in grape hybridization for seedlessness. *Haryana J. Hort. Sci.* **13**: 33-34.
- Kaul GL (1962) *Effect of GA on growth and fruit development of strawberry*. Ph.D. Thesis. P.G. School, IARI, New Delhi.
- Mukherjee SK (Principal author), SN Pandey, JP Singh, AI Ojeda, CT Chizala, S Sastrapradja, KL Chadha and Kumar Devendra (Comment contributors) (1989) Descriptors for mango: International Board of Plant Genetic Resources, Rome, 22p.
- Pandey SN (1989) Nomenclature and registration of mango cultivars. *Acta Hort.* **231**: 125-31.
- Pandey SN and RM Pandey (1987) *Improvement in Mango (Mangifera indica L.): Present Position and Future Prospect. Breeding of Horticultural Crops*. Proc. Int. Symp. On Horticultural Breeding, Taiwan, FFTC Book Series No. 35.
- Pandey SN and OP Singh (1990) Effect of interstock on growth and yield of mango (*Mangifera indica* L.) cv. Amrapali. Int. Sem. New Frontiers in Horticulture. Bangalore, Nov. 25-28, Abst. pp. 100.
- Pandey SN (1984) *International Check List of Mango Cultivars*. Division of Fruits and Horticultural Technology, IARI, New Delhi, 284p.
- Pandey SN (1984) Mango cultivar registration. *Chronica Horti.* **24**: 3.
- Pandey SN (1986) Mango cultivars. Nomenclature and Registration. *Acta Hort.* **182**: 259-264.
- Pandey SN (1986) Registration for proper nomenclature of mango cultivars. (*Mangifera indica* L.). 22<sup>nd</sup> Int. Hort. Cong., University of California, Davis, USA. Abstr. No. 614.
- Pandey SN (1993) Breeding mango for colour. Golden Jubilee Symposium on Horticultural Research: Changing Scenario, Horticultural Society of India, Abstract, pp 95.
- Pandey SN and OP Singh (1993) Evaluation of mango germplasm to select superior genotypes. ISPGR Dialogue on *Plant Genetic Resource-I. Developing National Policy: Present Status and Emerging Trends*. Abstract pp. 42-43.
- Rajput CBS (1965) *Status on Morphology, Fruit Setting and Cytology of Strawberry*. Ph.D. Thesis, P.G. School, IARI, New Delhi.
- Randhawa SS (1987) *Wild Germplasm of Pome and Stone Fruits*. ICAR, New Delhi, India.
- Sharma RR, R Singh and SK Saxena (2001) Effect of rootstock on fruit drop in Kinnow mandarin under high density planting. *South Ind. Hort.* **49**: 20-22.
- Sharma VP, O Lal, SB Rohidas and PK Pramanik (1997) Varietal resistance in ber against the fruit fly (*Carpomya vesuviana*) under field conditions. *J. End. Res.* **21**: 1-5.
- Sharma YK, AM Goswami and RR Sharma (1992) Effect of dwarfing aneuploid guava rootstock in high density orcharding. *Ind. J. Hort.* **49**: 31-36.
- Singh RN, IS Yadav and SN Pandey (1971) Performance of new introductions. II. Swiss and Yugoslavian Grapes. *The Punjab Hort. J.* **10**: 138-145.
- Singh RN, IS Yadav and SN Pandey (1972) Grape improvement work at the Indian Agricultural Research Institute. Viticulture in Tropics. *Proc. Working Group on Viticulture in South East Asia*, 63-70.
- Yadav IS, SN Pandey and MP Singh (1971) Clonal propagation of *Pyrus pashia* Ham., a pear rootstock. *Indian J. Hort.* **28**: 210-18.
- Yadav IS, SN Pandey and RN Singh (1971) Performance of new introduction. III. Australian and Japanese Grapes. *Prog. Hort.* **3(3)**: 71-83.
- Yadav IS, SN Pandey and KB Nigam (1976) Performance of new introduction. IV. Italian Grapes. *Prog. Hort.*, **8(4)**: 5-13.
- Yadav IS, SN Pandey, PC Bose and K Singh (1977) Induction of seedlessness by gibberellic acid in grape cv. Hur (*Vitis vinifera* L.). *Prog. Hort.* **9(3)**: 75-8.

## Evaluation of Wheat (*T. aestivum* L.) Germplasm for Yield and Yield Attributes

**Ravi Kant and Rajendra Prasad**

*Department of Plant Breeding, Rajendra Agricultural University, Pusa (Samastipur)-848 125*

Four hundred ninety five germplasm lines of wheat including two checks were grown during the *rabi* season of 1999-2000 at the research farm of RAU, Pusa, Bihar, Samastipur, to evaluate yield and yield attributing characters. Observations were recorded on grain yield per plant and six other characters. Correlation and path coefficient analyses were done to find out associations between characters and to assess the direct and indirect influence of each character on seed yield.

Large variation was observed for all the characters studied. Correlation and path coefficient analyses showed that number of productive tillers per plant, 1000 grain weight and number of grains per ear were major direct contributor to grain yield per plant. Based on the multiple regression coefficient of six quantitative traits taken, number of productive tillers per plant, number of grains per ear and 1000 grain weight were found to be significant contributors towards grain yield. Therefore, these characters should receive maximum attention while selecting high yielding plants in wheat breeding.

**Key Words:** Correlation, Germplasm, Multiple regression, Path correlation, Selection criteria

Germplasm is the reservoir of genetic diversity which is often exploited for developing improved varieties of a crop. Considerable amount of genetic variability should exist in the germplasm for their utilization in breeding superior cultivars. The importance of genetic diversity for selecting specific parents and recombining them to recover specific genotype (depending upon ones objectives) in autogamous crops has been emphasized many times (Murty *et al.*, 1966, Jatasara *et al.*, 1983 and Cox *et al.*, 1990). Selection of specific parent from existing germplasm is totally dependent upon the availability of characterization of those germplasm for their different traits. The precise information regarding nature and degree of genetic diversity present in germplasm could help the plant breeder to select proper parents for evolving superior varieties. In view of these facts, 495 germplasm were:

- a) Studied for yield and yield attributing characters to work out association between components characters.
- b) Computation of correlation coefficient and to select elite germplasm lines between yield and yield component characters.

### Materials and Methods

A total of 495 germplasm of wheat (mostly the entries from different international wheat screening nursery) available at wheat breeding section of RAU, Pusa, were evaluated for yield and yield attributing characters. These accessions were sown in the *rabi* of 1999-2000

at the research farm of RAU, Pusa (25°59'N latitude and 84° 40'E longitude, altitude 51.81 m). Each accession was grown in a single row of 3 m length, spaced 23 cm apart from row to row and 10 cm from plant to plant. The recommended package of practices was followed to raise good crop.

Observations were recorded on days to 75 percent flowering, plant height, number of productive tillers per plant, length of ear head, number of grains per ear, 1000 grain weight and grain yield per plant. Observations were recorded on five randomly taken competitive plants except for days to 75 percent flowering which were recorded on visual observation for flowering of approximately 75 percent of plants in each row.

Mean, range (minimum and maximum), variance and phenotypic coefficient of variability (CV%) were determined for all characters undertaken. Simple correlation and path coefficient analyses were done to determine the interrelationship between two characters and for their direct and indirect effect to seed yield (Li, 1956). Multiple regression analysis was worked out and on that basis selection indices were formulated to selected germplasm with high score.

### Results and Discussion

There was considerable range of variation for all 7 characters under study (Table 1). The coefficient of variation was high (>30%) for grain yield per plant, number of productive tillers per plant and 1000 grain weight, medium (between 15% and 30%) for number

**Table 1. Range, mean, variance and coefficient of variation among four hundred ninety five germplasm of wheat for seven quantitative characters**

| Sl.No. | Characters                             | Range mean   | General | Variance of variance | Coefficient |
|--------|----------------------------------------|--------------|---------|----------------------|-------------|
| 1.     | Days to 75 percent flowering           | 66.00-100.00 | 80.23   | 24.93                | 6.22        |
| 2.     | Plant height (cm)                      | 34.67-135.00 | 88.06   | 99.21                | 11.31       |
| 3.     | Number of productive tillers per plant | 2.00-14.00   | 5.89    | 3.93                 | 33.63       |
| 4.     | Ear length (cm)                        | 5.17-30.70   | 10.33   | 2.30                 | 14.69       |
| 5.     | Number of grains per ear               | 25.76-90.00  | 57.25   | 98.29                | 17.32       |
| 6.     | 1000 grain weight (g)                  | 18.80-66.22  | 40.49   | 171.71               | 32.36       |
| 7.     | Grain yield per plant (g)              | 7.30-88.18   | 35.57   | 177.87               | 37.49       |

of grains per ear and small (<15%) for ear length, plant height and days to 75 percent flowering. Singh (1983) and Tiwary (1983) got similar result for tillers per plant and yield per plant. Kumar (2000) observed maximum coefficient of variation for length of ear head.

Correlation analysis showed (Table 2) that grain yield per plant had positive and significant correlation with plant height, number of productive tillers per plant, ear length, number of grains per ear and 1000 grain weight. Plant breeder should give more emphasis for high tillering ability of a genotype grains per ear and also 1000 grain weight, as it is directly associated with grain yield. Similar approach was also followed Nanda *et al.* (1980).

Days to 75 percent flowering had positive and significant correlation with number of productive tillers per plant and number of grains per ear but had negative and highly significant interrelationship with 1000 grain weight. Furthermore, it has negative correlation with grain yield per plant. Plant height had significant and positive correlation with all other component traits. Number of productive tillers per plant had positive and significant correlation with number of grains per ear. Ear length had significant and positive correlation with number of grains per ear and 1000 grain weight whereas

number of grains per ear had negative and significant correlation with 1000 grain weight.

Kumar (2000) observed significant and positive correlation between yield per plant and tiller per plant. The significant and positive correlation between yield per plant and grain weight was also reported by Mikheev (1992), Deswal *et al.* (1997). Significant and negative association of 1000 grain weight with grain yield was reported by Khan *et al.* (1999).

#### **Path Correlation Co-efficient**

Phenotypically, number of productive tillers per plant had maximum positive direct effect on yield per plant followed by 1000 grain weight and number of grain per ear and also these traits showed highly significant positive correlation with grain yield per plant. Therefore, these traits may be considered as important yield components for wheat improvement (Table 3).

Ear length also has highly significant positive correlation as well as positive direct effect of medium magnitude on grain yield per plant. Plant height showed negative direct effect on grain yield per plant however, its indirect effects via all other yield contributing traits were positive which ultimately showed a significant and positive correlation between plant height and grain

**Table 2. Phenotypic correlation coefficient between different pairs of quantitative characters in wheat germplasm**

| Characters                                               | Plant height<br>(X <sub>2</sub> ) | Number of<br>productive<br>tillers per plant<br>(X <sub>3</sub> ) | Ear length (cm)<br>(X <sub>4</sub> ) | Number of<br>grains per ear<br>(X <sub>5</sub> ) | 1000-grain<br>weight (g)<br>(X <sub>6</sub> ) | Grain yield<br>per plant (g)<br>(Y) |
|----------------------------------------------------------|-----------------------------------|-------------------------------------------------------------------|--------------------------------------|--------------------------------------------------|-----------------------------------------------|-------------------------------------|
| Days to 75 percent flowering (X <sub>1</sub> )           | -0.053                            | 0.151**                                                           | -0.057                               | 0.196**                                          | -0.482**                                      | -0.032                              |
| Plant Height (X <sub>2</sub> )                           |                                   | 0.091*                                                            | 0.230**                              | 0.093*                                           | 0.248**                                       | 0.174**                             |
| Number of productive tillers per plant (X <sub>3</sub> ) |                                   |                                                                   | 0.027                                | 0.233**                                          | -0.081                                        | 0.809**                             |
| Ear length (cm) (X <sub>4</sub> )                        |                                   |                                                                   |                                      | 0.175**                                          | 0.203**                                       | 0.170**                             |
| Number of grains per ear (X <sub>5</sub> )               |                                   |                                                                   |                                      |                                                  | -0.176**                                      | 0.376**                             |
| 1000-grain weight (g) (X <sub>6</sub> )                  |                                   |                                                                   |                                      |                                                  |                                               | 0.217**                             |

\*, \*\* Significant at 5 and 1 percent levels of significance, respectively

**Table 3. Direct (diagonal) and indirect phenotypic effect of different characters towards grain yield in wheat germplasm**

| Sl.No. | Characters                             | Days to 75 per cent flowering | Plant height (cm) | Number of productive tillers per plant | Ear length (cm) | Number of grains per ear | 1000 grain weight (g) | Grain yield per plant (g) |
|--------|----------------------------------------|-------------------------------|-------------------|----------------------------------------|-----------------|--------------------------|-----------------------|---------------------------|
| 1.     | Days to 75 percent flowering           | <b>-0.0574</b>                | -0.0003           | 0.1181                                 | 0.0026          | 0.0487                   | -0.1391               | -0.0320                   |
| 2.     | Plant height (cm)                      | 0.0030                        | <b>-0.0052</b>    | 0.0712                                 | 0.0103          | 0.0231                   | 0.0716                | 0.1740**                  |
| 3.     | Number of productive tillers per plant | -0.0087                       | 0.0005            | <b>0.7824</b>                          | 0.0012          | 0.0579                   | -0.0234               | 0.8090**                  |
| 4.     | Ear length (cm)                        | 0.0033                        | -0.0012           | 0.0211                                 | <b>0.0447</b>   | 0.0435                   | 0.0586                | 0.1700**                  |
| 5.     | Number of grains per ear               | -0.0113                       | -0.0005           | 0.1823                                 | 0.0078          | <b>0.2484</b>            | -0.0508               | 0.3760**                  |
| 6.     | 1000-grain weight (g)                  | 0.0277                        | -0.0013           | -0.0634                                | 0.0091          | -0.4370                  | <b>0.2886</b>         | 0.2170**                  |

The residual effect =0.4499

\*\* Significant at 1 percent level of significance

yield per plant in the present study. Direct and positive effect of grain weight on yield per plant was also reported by Mandal *et al.* (1997). In wheat positive direct effect of effective tillers per plant on yield per plant in the present study was also observed by Rao *et al.* (1993).

Number of grains per ear had direct positive phenotypic effect on yield per plant. Similarly direct positive phenotypic effect of number of grains per ear on grain yield per plant was also observed by Mandal *et al.* (1995).

Thus path coefficient analysis suggested that number of productive tillers per plant, 1000 grain weight and number of grains per ear were important characters which may be given due importance for the improvement of grain yield per plant.

Phenotypic residual effect indicated that there were other characters which should have been identified and included in the study in order to reduce it.

#### Multiple Regression Analysis and Selection Index

The partial regression coefficient for grain yield per plant on days to 75 percent flowering, plant height, number of productive tillers per plant, ear length, number of grains per ear and 1000 grain weight were computed and presented in Table 4. The dependent variable i.e. grain yield per plant has non-significant relationship with two independent variables i.e. plant height and ear length. After that two multiple regression-equation were formulated (Table 4), first by taking all six component characters and second after deleting plant height and ear length. It was done because partial regression coefficient due to above mentioned two dropped characters were insignificant. The efficiency of multiple regression equations were determined and

found to be  $r^2$  (I)- 79.8 and  $r^2$  (II)=79.6. Obviously, in the selection programme stress on the days to 75 percent flowering, number of productive tillers per plant, number of grains per ear, 1000 grain weight would be more rewarding than taking the all six characters.

Relative ranking and selection score of 495 germplasm including two checks for yield per plant on the basis of six and four yield contributing characters were worked out. The rank correlation coefficient was 0.88 and 0.83 between observed grain yield per plant and predicted grain yield per plant for six and four yield attributing characters, respectively. Following top ten line and also two checks (HP 1731 and HUW 234), exhibited same ranking for both criteria are 7<sup>th</sup> SMN-

**Table 4. Multiple regression coefficient of different quantitative characters on grain yield in wheat germplasm.**

| Sl.No. | Multiple regression of yield per plant on | When all the six characters were included | After deleting two characters i.e. plant height and ear length |
|--------|-------------------------------------------|-------------------------------------------|----------------------------------------------------------------|
| 1.     | Days to 75 percent flowering              | -0.151*±0.0629                            | -1.49*±0.003                                                   |
| 2.     | Plant height                              | -0.008±0.029                              |                                                                |
| 3.     | Number of productive tillers per plant    | 5.265**±0.142                             | 5.260**±0.141                                                  |
| 4.     | Ear length                                | 0.394±0.189                               |                                                                |
| 5.     | Number of grains per ear                  | 0.334**±0.029                             | 0.345**±0.029                                                  |
| 6.     | 1000-grain weight                         | 0.500**±0.042                             | 0.516**±0.040                                                  |

$R^2$  value for all six characters= 0.789

$R^2$  value for four characters=0.796 (after deleting plant height of ear length)

\*, \*\* Significant at 5 percent and 1 percent significant: levels, respectively

Two regression equations were

$$Y = -26.065 - 0.151 X_1 - 0.008 X_2 + 5.264 X_3 + 0.394 X_4 + 0.334 X_5 + 0.500 X_6 \quad \dots\dots\dots (1)$$

$$Y = -24.165 - 0.149 X_1 + 5.260 X_2 + 0.345 X_3 + 0.516 X_4 \quad \dots\dots\dots (2)$$

(After deleting two characters i.e. Plant height and ear length)

22, 6<sup>th</sup> HTWYT-14, 6<sup>th</sup> HTWYT-27, 6<sup>th</sup> HTWYT-23, 7<sup>th</sup> SMN-12, 6<sup>th</sup> HTWYT-15, 6<sup>th</sup> HTWYT-19, 7<sup>th</sup> SMN-20, 6<sup>th</sup> HTWYT-31 and 7<sup>th</sup> SMN-15. Mean performance of top ten high yielder wheat germplasm for seven quantitative characters was given in Table 5.

Obviously, in the selection programme based on days to 75 percent flowering, number of productive tillers per plant, number of grains per ear and 1000 grain weight is easier to follow and equally rewarding than taking all six characters. The importance of effective tillers per plant and grain weight in selection programme was also supported by the results of Das and Dasgupta (1980)

and Raut and Khorgade (1989). The importance of grains per ear, plant height, spike length was also suggested by Madhy (1988). The importance of ear length in selection criteria was suggested by Kumar (2000).

#### Acknowledgements

The authors express their sincere thanks to Dr. V.P. Gupta (Ex. Vice-Chancellor) and Dr. P.B. Jha, Associate Professor (Plant Breeding), RAU, Pusa, Samastipur for valuable suggestions during the course of this studies. The author also acknowledges the financial assistance received in the form of fellowship during the course of investigation from above university.

Table 5. Mean performance of top ten high yielder wheat germplasms for seven quantitative characters

| Sl. No.        | Germplasm                | Days to 75 per cent flowering | Plant height | Tillers per plant | Ear length | Number of grains per ear | 1000 grain | Grain yield per plant |
|----------------|--------------------------|-------------------------------|--------------|-------------------|------------|--------------------------|------------|-----------------------|
| 1.             | 7 <sup>th</sup> SMN-22   | 83                            | 90.67        | 14.00             | 10.83      | 61.67                    | 46.60      | 88.18                 |
| 2.             | 6 <sup>th</sup> HTWYT-14 | 83                            | 77.43        | 14.00             | 8.27       | 58.00                    | 38.60      | 72.42                 |
| 3.             | 6 <sup>th</sup> HTWYT-27 | 86                            | 92.73        | 12.00             | 9.27       | 68.00                    | 45.64      | 72.64                 |
| 4.             | 6 <sup>th</sup> HTWYT-23 | 73                            | 74.67        | 12.00             | 10.87      | 54.67                    | 40.80      | 61.42                 |
| 5.             | 7 <sup>th</sup> SMN-12   | 80                            | 84.67        | 11.67             | 10.00      | 54.00                    | 47.52      | 73.22                 |
| 6.             | 6 <sup>th</sup> HTWYT-15 | 83                            | 76.47        | 11.67             | 8.67       | 69.33                    | 37.88      | 58.72                 |
| 7.             | 6 <sup>th</sup> HTWYT-19 | 83                            | 94.50        | 10.66             | 11.67      | 68.00                    | 42.20      | 76.04                 |
| 8.             | 7 <sup>th</sup> SMN-20   | 79                            | 83.33        | 11.33             | 9.17       | 53.33                    | 43.90      | 60.08                 |
| 9.             | 6 <sup>th</sup> HTWYT-31 | 87                            | 85.67        | 11.33             | 10.77      | 60.33                    | 38.20      | 52.34                 |
| 10.            | 7 <sup>th</sup> SMN-15   | 83                            | 90.33        | 10.67             | 10.93      | 57.67                    | 45.60      | 65.98                 |
| C <sub>1</sub> | HP-1731                  | 74                            | 81.50        | 6.67              | 10.88      | 57.00                    | 34.60      | 47.15                 |
| C <sub>2</sub> | HUW-234                  | 68                            | 91.83        | 8.00              | 9.57       | 52.67                    | 47.24      | 52.00                 |

#### References

- Cox TS and JP Murphy (1990) Effect of parental divergence of F<sub>2</sub> heterosis in winter wheat crosses. *Theor. Appl. Genet.* **79**: 241-250.
- Das PK and T Dasgupta (1980) Studies on selection for higher yield in durum wheat (*T. durum*) under late sown rainfed condition of West Bengal, *Indian Agriculturist*, **24**: 11-22.
- Deswal RK, SS Grkah and VP Singh (1997) Association of grain yield with yield contributing traits in wheat. *Haryana Agri. Univ. J. Res.* **27**: 39-43.
- Jatasara DS and RS Paroda (1983) Genetic divergence in wheat, *Ind. J. Genet.*, **43**: 63-67.
- Khan HA, Mohammad Shaik and S Mohammad (1999) Character association and path coefficient analysis of grain yield and yield components in wheat, *Crop Research Hissar*, **17**: 229-233.
- Kumar S (2000) *Choice of advance heterogenous population for wheat (T. aestivum L.) improvement* M.Sc. (Ag.) thesis, Plant Breeding, RAU, Pusa.
- Li CC (1956) The concept of path coefficient and its impact on population genetics. *Biometrics*.
- Madhy EE (1988) The efficiency of some selection procedure in wheat (*T. aestivum* L.) *Assint J. Agri. Sci.* **19**: 291-300.
- Mandal AB, OP Sadhey and KK Sarkar (1997) Correlation and path analysis in bread wheat. *Environment and Ecology* **15**: 537-539.
- Mikheev LA (1992) Correlation of grain weight per ear with yield components in wheat hybrids. *Selectsiyai Semnovodstovo Moskvaj* **2-3**: 17-2.
- Murty BR and IJ Anand (1966) Combining ability and genetic divergence in some varieties of *Linum ustitassimum*. *Indian J. Genet.* **26**: 21-26.
- Nanda GS, GN Hazarika and GS Gill (1980) Association analysis in wheat, *Sci. Cul.* **46**: 200-202.
- Rao DSRM, H Singh and OPS Khola (1993) Correlation and path analysis in late sown bread wheat (*T. aestivum* L.) cv. wt. 291 *Crop Res.* **6**: 77.
- Raut SK and PW Khorgade (1989) Regression studies in bread wheat and their implication in selection, *J. Maharashtra Agric. Univ.* **14**: 363-364.
- Singh SB (1983) *Studies on phenotypic and genotypic variability and association among quantitative traits in promising strains of wheat (T. aestivum L.) under normal timely sown irrigated condition*. M.Sc. (Ag.) thesis, Plant Breeding, RAU, Pusa.
- Tiwary AK (1983) *Variability and correlation studies in pre-related stains of wheat (T.aestivum L.) under late sown irrigated condition*, M.Sc. (Ag.) thesis, RAU, Pusa.

## Evaluation of Genetic Variability in Mungbean (*Vigna radiata* (L.) Wilczek) Germplasm

Rakesh Kumar, JL Tickoo, N Chandra and HK Dikshit

Division of Genetics, Indian Agricultural Research Institute, New Delhi-100 012

Four hundred and sixty eight (468) mungbean germplasm lines were evaluated in kharif season during 2001 and 2002 at Indian Agricultural Research Institute, New Delhi. The evaluated germplasm lines included 87 exotic and 381 indigenous collections. Wide range of variability was recorded in the studied qualitative traits like growth habit, growth pattern, leaf colour, leaf shape, internode length and seedling vigour. The descriptive statistics generated from quantitative traits (days to 50% flowering, number of primary branches, plant height (cm), number of clusters per plant, number of pods per cluster, number of pods per plant, pod length (cm), number of seeds per pod, seed yield per plant (gm), 100 seed weight (gm) and days to maturity) revealed adequate variability in the studied germplasm lines. Genotype PLM 694 exhibited high number of primary branches/plant, pods/plant, clusters / plant and optimum seed yield/plant. For higher 100 seed weight the promising genotypes identified were EC 52195, EC 52194, PLM 59 etc. Nine genotype viz. P312, VC 2777-21-B-B-3-B, EC 146298, EC 146323A, EC 146323B, EC 146328 B, ML 610, Ganga-2 and TARM-1 were tolerant against mungbean yellow mosaic virus.

**Key Words:** Germplasm evaluation, Genetic variability, Mungbean

Mungbean (*Vigna radiata* (L.) Wilczek) is an important grain legume crop in India, occupying 2.75 m ha area, with production of 0.98 m tons in the year 2002-2003 (Anonymous 2004). In spite of the release of 75 varieties in this crop till date, the national average productivity is quite low at 356 kg/ha as against 800 kg/ha in Srilanka, Pakistan, Thailand etc. and more than 1000 kg/ha in China. The main reason for the low productivity is the narrow genetic base of the released cultivars (Kumar *et al.*, 2004), susceptibility to biotic and abiotic stresses and poor seed replacement rate (Anonymous 2000). Mungbean is grown in spring/summer, *kharif* and *rabi* seasons in different parts of the country. Suitable plant types are required for each of these seasons that meet the demands of the individual agro-climatic regions. Resistance to biotic stresses like mungbean yellow mosaic virus, powdery mildew and *Cercospora* leaf spot must be incorporated into these plant types. Pre-harvest sprouting is a major abiotic stress and materials with top bearing, pods without pubescence but with a higher content of wax and thick, impermeable pod walls and possibly with 7 to 10 days seed dormancy must be selected and used in the hybridization programmes. The narrow genetic base of the released varieties notwithstanding, several workers have reported wide variability for various morphological characters in mungbean germplasm (Malik and Singh, 1991; Reddy *et al.*, 1991; Kawalkar *et al.*, 1996; Sharma *et al.*, 1997; and Chen *et al.*, 1998). The nature and amount of variability in plant populations determines

the success of breeding programmes undertaken. So, with the aim of evaluation of the variability for the mentioned important traits, both indigenous and exotic germplasm lines of mungbean were evaluated and characterized to identify the potential donors for different agronomic traits and biotic and abiotic stresses.

### Materials and Methods

Four hundred and sixty eight mungbean germplasm lines were evaluated during 2001 and 2002 kharif seasons at Indian Agricultural Research Institute, New Delhi. The evaluated germplasm lines included both indigenous and exotic collections. These germplasm lines were evaluated in an augmented design with three checks viz. Pusa Vishal, Pusa 105 and M 1319 B. The row length was 4 m with row-to-row spacing of 30 cm and plant-to-plant distance of 10 cm. Recommended package of practices were followed to raise the crop (Sadaphal 1988). The observations were recorded on growth habit (erect, semi erect and spreading), leaf colour (dark green, light green, and green), growth pattern (determinate and indeterminate types), leaf shape (deltoid, ovate and acute), internodes length (long, medium and short), seedling vigour (vigorous, medium and poor as assessed at 15 days after emergence), internodes length (long, medium and short), days to 50% flowering, number of primary branches, plant height, number of clusters per plant, number of pods per cluster, number of pods per plant, pod length (cm), number of seeds per pod, 100 seeds weight, days to

maturity and Mungbean Yellow Mosaic Virus (MYMV) resistance. Preliminary observations were also recorded for resistance to pre-harvest sprouting. For quantitative traits, observations were recorded on ten plants, selected randomly within a line. The data on numerical descriptor were analyzed in an augmented design to obtain adjusted values of means as suggested by Feder and Raghava Rao (1975) and as further elaborated by Paterson (1985). These data were used to create a database in standard format with the help of 'DIPVIEW' software package.

### Results and Discussion

Significant variability was recorded for all qualitative and quantitative traits studied in the evaluated germplasm lines. The range of variability recorded is presented in Tables 1 and 2. Table 3 exhibits promising germplasm lines identified for different traits. The percentage frequency of genotypes for qualitative traits and descriptive statistics for quantitative traits indicated adequate variability for the studied traits in the evaluated germplasm lines.

Determinate types in general were early in maturity in comparison to the indeterminate types. The former

(P 384, LM 234, LM 238, PLM 379, IC 39432 etc) are suited for summer season, where farmers get hardly 60-70 days in between wheat harvest and the subsequent planting of the *kharif* crops. Days to flowering ranged from 32 to 53 days, the earliest flowering lines were P 285, 76-56 and LM 447 that flowered in around 32 days. These earliest flowering lines matured in about 60 days, a character of top priority to be incorporated into the varieties for summer cultivation. Germplasm lines LGG 458, LGG 468, LGG 480, LGG 40, LGG 316 and MGG 136 were bushy and exhibited heavy foliage. These lines are suitable for fodder purpose and can also be used for green manuring. Varieties with this habit will not be suitable for intensive cropping systems. Most of the mungbean materials produce enough biological yields per unit area. The objective here should be to channelise maximum possible of this biological yield into economical yield. In other words concerted efforts must be made to enhance the harvest index of the new varieties.

IC 102955 and IC 734656 revealed terminal pod bearing. This trait is useful for mechanical harvesting of the crop. Varieties with this trait will be preferred in states like Punjab and Andhra Pradesh, where machine harvesting is practiced. Plant height ranged from 21 to 71cm. The short stature genotypes identified were LGG 498, LM 17, 2184 B, 2984, 3184 B-1 and tall types were LGG 502, LGG 458, LGG 429. Shorter genotypes matured in around 60 days. Studies in soybean and others crops have shown that tall but determinate genotypes are positively correlated with grain yield through more number of pod bunches and pod number itself per plant. However, for spring/summer cultivation in northern plains after wheat harvest, short plant structure with earliness is desirable. The tall but determinate habit will be more suitable for spring (March sowing after mustard, sugarcane, potato etc.) and *kharif* plantings. The number of primary branches ranged from 1.0 to 5.0. Two to four erect branches per

Table 1. Variability recorded for qualitative traits in mungbean germplasm

| Character         | Classification | No of Accession |
|-------------------|----------------|-----------------|
| Growth habit      | Erect          | 416             |
|                   | Intermediate   | 41              |
|                   | Prostrate      | 11              |
| Growth pattern    | Determinate    | 89              |
|                   | Indeterminate  | 379             |
| Leaf colour       | Dark green     | 78              |
|                   | Light green    | 39              |
|                   | Green          | 351             |
| Leaf shape        | Deltoid        | 368             |
|                   | Ovate          | 95              |
|                   | Acute          | 5               |
| Inter node length | Long           | 89              |
|                   | Medium         | 336             |
|                   | Short          | 43              |
| Seedling vigour   | Vigorous       | 92              |
|                   | Medium         | 173             |
|                   | Poor           | 293             |

Table 2. Descriptive Statistics for quantitative traits in 468 mungbean germplasm lines

| Characters    | Plant height (cm) | Number of primary branches | Days to 50% flowering | Days to maturity | Number of pods/ cluster | Number of pods / plant | Pod length (cm) | Number of seeds per pod | 100 seed weight (gms) | Seed yield/ Plant (gms) |
|---------------|-------------------|----------------------------|-----------------------|------------------|-------------------------|------------------------|-----------------|-------------------------|-----------------------|-------------------------|
| Mean value    | 42.6              | 2.2                        | 43.5                  | 66.7             | 2.8                     | 15.4                   | 6.6             | 10.1                    | 3.1                   | 4.2                     |
| Maximum value | 71                | 5                          | 53                    | 80               | 14                      | 63                     | 10.5            | 13.3                    | 5.9                   | 25.1                    |
| Minimum value | 21                | 1                          | 32                    | 56               | 1                       | 1.4                    | 3.2             | 1                       | 1.6                   | 0.4                     |
| Variance      | 67.7              | 0.8                        | 19.3                  | 17.0             | 1.5                     | 67.4                   | 0.7             | 1.6                     | 0.3                   | 11.2                    |
| SD            | 8.2               | 0.9                        | 4.8                   | 4.8              | 1.3                     | 8.2                    | 0.85            | 1.2                     | 0.5                   | 3.2                     |
| Skewness      | 0.07              | -0.59                      | -1.39                 | -0.11            | 3.29                    | 1.250                  | 0.64            | -1.3                    | 0.28                  | 2.6                     |

plant are desirable which arise at an angle of 15 to 30 degrees with the main axis. This sort of plant architecture was found in lines VC 4735-4-B and 76-20.

**Table 3. Promising mungbean germplasm lines for important traits Recommended to be used as donors in the new cultivar development**

| Sl.No. | Characters                           | Promising lines                                                               |
|--------|--------------------------------------|-------------------------------------------------------------------------------|
| 1.     | Days to maturity (<60 days)          | PS 63-1, 76-27, LM 72, LM 62 B                                                |
| 2.     | Cluster per plant (>17cluster/plant) | P 604, P 522 II, P 562 A, Sel.513, 1315++, Pusa 103                           |
| 3.     | Pods per plant (> 40pods/plant)      | LGG 505, PLM 694, PLM 748                                                     |
| 4.     | Seed per pod (>13 seeds/pod)         | LGG 498, P 269-1, PLM 694                                                     |
| 5.     | 100 seed weight (> 4.5 gm)           | ET 52194, ET 52195, PLM 759, LGG 488, 137-1, HUM 4                            |
| 6.     | Seed yield per Plant (>15 g/plant)   | ML 337, 76-6, EC 146286 B, VC 2719-29-1-B-12-1-B, EC 146333, LGG 490, LGG 463 |

The maximum number of 19.3 pod clusters/plant was recorded for genotype P 604 and this character ranged from 1.6 to 19.3 in the germplasm lines. An ideal plant type in mungbean will be the one in which pod clusters start from basal nodes itself with shorter internodes. But plant has to be erect and compact, so that the pods of the basal clusters develop fully, have well filled seeds and do not get damaged by irrigation water. The exotic germplasm line EC 10148 exhibited 14 pods/cluster. More than 40 pods/plant were recorded for germplasm lines LGG 505, PLM 694, and PLM 748. This character, as reported by almost all mungbean breeders, is positively correlated with seed yield/plant and hence is the most important yield component. The pod length ranged from 9 to 10.5 cm., the longest pods being exhibited by ET 52195, PLM 88 and PLM 258B. The maximum numbers of seeds/pod (>13) were recorded in germplasm lines LGG 498, P296-1 and PLM 694.

**Table 4. Donors for hybridization programme in mungbean with two or more desirable characters.**

| Characters                                                                                                           | Days to maturity                                                                                                 | No of pods per plant                                                                                                   | Plant height (cm)                                                                       | No of Pr. Branches/plant                                                          |
|----------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Days to maturity                                                                                                     | PS 63-1, 76-27, LM 72, LM 62 B (<60 days)                                                                        |                                                                                                                        | LGG 502 (60 days/71cm)                                                                  | P 123(5br./60 days)                                                               |
| No of Clusters per plant (>17)<br>P 604, P 522II,<br>P 562 A, Sel.513,<br>1315++, Pusa 103                           | 1315** (60 days/17.7 cl.)                                                                                        | Pusa 103 (39.0 pods/ 17.3 cl.)                                                                                         | P604 (42cm/19.3 cl.)<br>P 522II(40cm/19.0 cl.)                                          | P604 (3.6 br./19.3 cl.)<br>P 522 II (4 br./ 19.0 cl.)                             |
| No of Pods per plant                                                                                                 | TARM-2 (60 days/ 37.3 pods)<br>13160 (60 days/ 33.7 pods)                                                        | LGG 505, PLM 694, PLM 748<br>( >40 pods/plant)                                                                         | PLM 748 (56.7cm/ 63 pods)<br>Pusa 103 (56.7 cm/ 39 pods)<br>MGM 1013 (51.0 cm/ 38 pods) | PLM 694 (48 pods/ 5 br.)<br>LM 84 (38 pods/ 4.6 br.)<br>M 186 (32.2 pods/4.3 br.) |
| Seed per pod (>13)<br>LGG 498, P 269-1, PLM 694                                                                      | LGG 498<br>(60 days/ 13.3 seeds)                                                                                 | P269-1 (28.3 pods/ 13 seeds)<br>LGG 498 (20.8 pods/ 13.3 seeds)                                                        | P 269-1(47.8 cm/13.0 seeds)<br>V2276 (42.3 cm/12.1 seeds)                               | LM 629 (4 br./12.2 seeds)                                                         |
| 100 seed weight (> 4.5 gm)<br>ET 52194, ET 52195, PLM 759, LGG 488, 137-1, HUM 4                                     | EC 52195 (66 days/5.9 gm)<br>EC 52194 (60 days/5.0 gm)<br>PLM 759 (65 days/ 4.8 gm)<br>LGG 488 (66 days/ 4.8 gm) | LGG 4579 (23.3 pods/ 4.6 gm)                                                                                           | EC 52195( 54 cm/ 5.9 gm)<br>LGG 488(60.3 cm/4.8 gm)                                     |                                                                                   |
| Seed yield per Plant (>15 gm)<br>ML 337, 76-6, EC 146286 B, VC2719-29-1-B-12-1-B, 2184B, EC 146333, LGG 490, LGG 463 | LM 331(60 days/12.1 gm)<br>1356** (60 days/ 12.3 gm)<br>LGG 503(60 days/12.4 gm)                                 | PLM 694 (48 pods/ 11.5 gm)<br>LGG 503 (32 pods/ 12.4 gm)<br>2184 (32.8 pods/ 16.8 gm)<br>VC2719-29-1(32 pods/ 16.7 gm) | 2184B (28.7 cm/16.8 gm)<br>LM 389(31.3 cm/13.2 gm)<br>13-56++(31.7 cm/12.3 gm)          | PLM 694 (5 br. /14.4 gm)                                                          |

Abbreviation used: cl. = no. of pod bearing clusters / plant, gm= grams, br. = no. of branches / plant, cm= centimeter

Wide variation was recorded for 100 seed weight from 1.6 to 5.9 gms. the maximum seed weight being of accession EC 52195. Medium bold and bold seeded varieties with 100 seed weight above 4 gms are preferred by farmers and consumers both. Bold seeded varieties have lesser hard seeds, cook well and produce better sprouts. The promising germplasm lines identified for bold seed size are EC 52195, EC 52194, PLM 759 and LGG 488. Seven genotypes viz. ML 337, 76-6, EC 146286B, VC 2719-29-1B-12-1-B, EC 146333, LGG 490 and LGG 463 exhibited 15 to 25 gm seed yield per plant. It ranged from 0.4 to 25.1 gm in the studied germplasm lines.

Nine germplasm lines viz. P312, VC2777-21-B-B-3-B, EC 146298, EC146323A, EC 146323B, EC 146328 B, ML 610, Ganga-2 and TARM-1 expressed mungbean yellow mosaic resistance on the basis of field observations during both the years of study. Selection 224, IC 1627, Sel.A, EC 146323, EC 146323 B, AKM 9310 and AKM 9602 expressed pre-harvest sprouting resistance. These lines had pods without any pubescence (rain water does not stick to such surfaces) and had thicker pod walls with a well developed inner parchment membranes, which does not allow rain water to seep into the pods easily. These lines possibly may also have a higher wax content in the pod walls, which however needs to be worked out. Resistance to pre-harvest seed sprouting in the field due to untimely long spells of rains in *kharif* season is becoming a very important character. The seed damage is basically due to the zero dormancy of the seeds in this crop and many a time farmers loose the entire produce, as the resource poor farmers are not able to harvest the crop in time. So realizing the importance of this character, it may be transferred from these lines to the good agronomic bases. Table 4 denotes the various selections made that combine two or more useful traits. These selections may be used by the breeders as donors

of more than one useful character. The more useful traits may be pyramided into the same agronomical bases.

The promising germplasm lines identified from this investigation, can be used by pulse breeders in hybridization programmes for generation of breeding materials and commercial varieties with broad genetic base.

## References

- Anonymous (2004) *Agricultural Statistics at a Glance*. Directorate of Economics and Statistics, MOA, GOI, New Delhi.
- Anonymous (2000) *Expert Committee Report on Pulses*. Directorate of Information and Publications of Agriculture, ICAR, Krishi Anusandhan Bhavan, Pusa, New Delhi, pp 51-55.
- Chen S, C Chen, MJ Fan and SCS Tsou (1998) Geographical distribution and genetic diversity for morphological characters in world germplasm collection of mungbean (*Vigna radiata* (L.) Wilczek). *J. Agric. Res. China* 47: 108-124.
- Fedrer WT and DR Rao (1975) On Augmented block design. *Biometrics* 31: 29-35.
- Kawalkar TG, IS Bisht, RK Mahajan, DP Patel, PN Gupta and KPS Chandel (1996) *Catalogue on Mungbean Germplasm*. NBPGR, New Delhi.
- Kumar S, S Gupta, S Chandra and BB Singh (2004) How wide is the genetic base of pulse crops? In: Masood Ali, B.B. Singh, Shiv Kumar and Vishwa Dhar (eds) *Pulses in New Perspective*. Indian Society of Pulses Research and Development, Indian Institute of Pulses, Kanpur, pp 211-221.
- Malik BPS and VP Singh (1991) Phenotypic stability and variability in mungbean. *Ind. J. Pulses Res.* 4: 9-14.
- Paterson RG (1985) Augmented design for preliminary yield traits. *Arachis, Barley and Triticale. Newsletter (ICARDA)* 4: 27-32.
- Reddy TD, RK Mishra and RK Yadav (1991) Genetic variability and correlation coefficients related to yield and quantitative characters and use of path coefficients in mungbean (*Vigna radiata*). *Ind. J. Pulses Res.* 4: 100-104.
- Sadaphal MN (1988) Agronomy of pulses. In: B. Badev, S. Ramanujam and H.K. Jain (eds) *Pulse Crops*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, pp 456-512.
- Sharma BL, DP Singh and HH Ram (1997) Variation for yield components and yellow mosaic virus resistance in mungbean: *Ind. J. Pulses Res.* 10: 143-146.

## Promising Desi Cotton (*G. arboreum* L.) Germplasm for Fibre Quality Traits and Locule Retentivity

**RA Meena, D Monga, Rajiv Kumar and Hamid Hassan**

Central Institute for Cotton Research, Regional Station, Sirsa-125 055, Haryana

The current interest in desi cotton (*Gossypium arboreum*) has stimulated research on several aspects of improvement for its fibre properties and locule retentivity. Five hundred and forty geographically and phenotypically diverse lines of *G. arboreum* L. were screened during 2001-2002 to 2003-2004. A wide range of variability for each parameter was observed. Eight lines PA 255, CISA 196, CISA 290, CISA 334, CISA 338, CISA 342, 6637 and AC 3088 were completely resistant to shattering. The cultivar CISA 290 also showed higher boll number and good yield potential. Five superior genotypes for 2.5 % span length (above 25.6 mm) were CISA 12 (27.5), DLSA 8 (26.8), PA 255 (26.5), 1789 (26.4) and AK 580 (25.6); for fibre fineness CISA 12 (5.0), 1789 (4.9) AK 60-2 (4.8), AKH 607 (4.6), AK 580 (4.6) and 6629 (4.5); for fibre strength AC 3370-1 (24.8), KWAN 3 (24.5), CISA 245 (24.1), 6629 (23.2) AND PA 255 (22.7); for ginning outturn AKH 592 (37.3), DLSA 8 (35.5), AK 580 (35.0), 6571 (35.0) and KWAN 3 (34.5); for lint index AK 580 (4.8), AKH 592 (4.3), 6612 (4.2), 6619 (4.1) and 7038 (4.0) and for yield potential AC 1374 (128.8), DLSA 8 (103.4), KWAN 3 (99.9), 7173 WL NLL (98.6) and 6586 (97.5). The genotypes exhibiting >0.9 strength length ratios were CISA 245 (1.05), KWAN 3 (1.02), 6629 (0.92), 6644 (0.91) and CISA 329 (0.90). In addition to superiority for strength-length ratio some genotypes were also noticed superior for other quality traits such as culture 6629 for fineness, strength and GOT; KWAN 3 for GOT and yield and CISA 245 for fibre strength and GOT. These levels can be used further in crop improvement programmes for desired traits.

**Key words:** Cotton, Crop improvement, Fibre properties, Germplasm, Locule retentivity

Cotton, the most important commercial crop of the country, is grown in 15,00,000 ha in North zone out of which desi cotton (*G. arboreum*) constitutes around 25% area. The desi cottons have very high yield potential along with resistance to biotic and abiotic stresses. The yield potential of some desi cotton varieties is noticed up to 40 q/ ha, which is even higher than *G. hirsutum* in certain cases. However, inferior fibre properties and poor locule retentivity are the major drawbacks in desi cotton. The seed cotton immediately after opening of boll falls down on the ground and as a result several types of impurities combine with lint, which deteriorate the lint quality. In addition several pickings are to be done in such cases which involves huge labour requirement. The problem is further aggravated due to adverse weather like high wind, rain and hail storm. Inferior fibre properties are also due to its coarse nature (micronnair around 7-8), short fibre length (around 16-18 mm) and low strength (16-18 g/tex) and thus the demand for desi fibre in textile industry is very less. Its demand is only limited to surgical industry and in rough cloth making sector. In all the varieties/hybrids released for cultivation under north zone these are the major problems which need immediate attention and solution. To bring the improvement in desi cotton for this zone, it is necessary to generate information on genetic variability in germplasm for its fibre quality

and boll retentivity. In present investigation, 540 germplasm lines were evaluated for three years and superior genotypes are identified for each parameter based on their performance.

### Material and Methods

Five hundred forty geographically and phenotypically diverse lines from gene pool of *G. arboreum* cotton maintained at Central Institute for Cotton Research (CIRCOT), Regional Station, Sirsa were evaluated for locule retentivity and fibre quality traits for three years from 2001-2002 to 2003-2004. Each cultivar was sown in 20 dibbles at 60 cm x 30 cm spacing adopting all recommended practices. Observations on percent locule retentivity by counting the retained bolls on plant at picking and 2.5% span length, uniformity ratio, fibre strength and fibre fineness were recorded through CIRCOT unit Sirsa. In addition to these the yield/plant, boll weight, bolls/plant, ginning outturn, seed index and lint index were also recorded. The data is pooled after testing the homogeneity of variance.

### Results and Discussion

A wide range of variability for locule retentivity and fibre property traits was observed. Strength/ fibre length ratio is most important parameter to decide the fibre quality. Twenty-eight superior lines for this trait were selected

and are given in Table 1 along with data on 2.5 % span length, uniformity ratio, fibre fineness, fibre strength, ginning outturn, lint index and yield potential. Out of these twenty eight lines, five superior genotypes for 2.5 % span length (above 25.6 mm) were CISA 12 (27.5), DLSA 8 (26.8), PA 255 (26.5), 1789 (26.4) and AK 580 (25.6); for fibre fineness (below 5) CISA 12 (5.0), 1789 (4.9) AK 60-2 (4.8), AKH 607 (4.6), AK 580 (4.6) and 6629 (4.5); for fibre strength (above 22) AC 3370-1 (24.8), KWAN 3 (24.5), CISA 245 (24.1), 6629 (23.2) AND PA 255 (22.7); for ginning outturn (above 34) AKH 592 (37.3), DLSA 8 (35.5), AK 580 (35.0), 6571 (35.0) and KWAN 3 (34.5); for lint index (above 4) AK 580 (4.8), AKH 592 (4.3), 6612 (4.2), 6619 (4.1) and 7038 (4.0); for yield potential (above 97 g per plant) AC 1374 (128.8), DLSA 8 (103.4), KWAN 3 (99.9), 7173 WL NLL (98.6) and 6586 (97.5) identified. Similarly variability among genotypes were recorded earlier by several workers (Singh 1984; Singh and Singh 1984, Siwach *et al.*, 1988, CICR, 1989; Balakrishna *et al.*, 1992, Meena *et al.*, 1992) for different parameters in the different cultivars used by them in their study in different climates.

The fibre strength-length ratio is an important fibre quality indicator in addition to fibre length alone and a ratio of >0.8 is considered as good. Fibre strength-length ratio has been stressed as an important parameter by the textile industry for modern spinning mills. Out of twenty-eight genotypes given in table number 1, the five superior genotypes were CISA 245 (1.05), KWAN 3 (1.02), 6629 (0.92), 6644 (0.91) and CISA 329 (0.90). In addition to high fibre strength-length ratio, some genotypes also showed superiority for other fibre traits and yield these were 6629 (0.92) showing superiority in fineness (4.5), strength (23.2) and GOT (31.3); KWAN 3 (1.02) for fibre strength (24.5 g/tex) and GOT (34.5) and CISA 245 (1.05) for fibre strength (24.1g/tex) and GOT (32.1). Based on this study the genotypes with desired strength-length ratio and having superior quality parameters with higher GOT are available, which can be successfully used for replacement of existing *G. arboreum* cultivars as well as their utilization in the crop improvement programs.

The locule retentivity is a serious problem in desi cotton. The *G. arboreum* genotypes grown at present in northern zone are of inferior quality and their lint cannot

Table 1. Superior genotypes for fibre property traits

| Sr.No. | Accession  | 2.5% span length (mm) | Strength-length ratio | Uniformity ratio | Fineness micronair | Fibre strength g/tex | Yield per plant (g) | Lint index | Ginning outturn % |
|--------|------------|-----------------------|-----------------------|------------------|--------------------|----------------------|---------------------|------------|-------------------|
| 1.     | AKA 60-2   | 26.0                  | 0.87                  | 52               | 4.8                | 22.6                 | 67.00               | 2.6        | 30.4              |
| 2.     | AKA580     | 25.5                  | 0.84                  | 51               | 5.7                | 21.4                 | 96.00               | 4.3        | 35.0              |
| 3.     | AKH592     | 24.0                  | 0.86                  | 50               | 5.5                | 20.6                 | 95.70               | 3.0        | 37.3              |
| 4.     | AKH607     | 25.5                  | 0.83                  | 45               | 4.6                | 21.2                 | 47.25               | 3.3        | 31.2              |
| 5.     | AK580      | 25.8                  | 0.76                  | 50               | 4.6                | 19.7                 | 73.50               | 4.8        | 32.7              |
| 6.     | AC3174     | 24.6                  | 0.85                  | 51               | 5.5                | 21.0                 | 128.80              | 3.0        | 33.4              |
| 7.     | AC3637     | 22.5                  | 0.88                  | 50               | 5.3                | 19.9                 | 85.10               | 3.4        | 33.1              |
| 8.     | CISA245    | 22.9                  | 1.05                  | 49               | 5.5                | 24.1                 | 79.65               | 4.1        | 32.1              |
| 9.     | 7173WR NLL | 25.1                  | 0.88                  | 45               | 5.8                | 22.0                 | 98.55               | 3.8        | 32.4              |
| 10.    | 7038       | 23.3                  | 0.82                  | 47               | 5.4                | 19.2                 | 50.35               | 4.0        | 31.9              |
| 11.    | 6576       | 23.7                  | 0.89                  | 52               | 5.1                | 21.1                 | 93.75               | 3.2        | 32.5              |
| 12.    | 6612       | 23.6                  | 0.85                  | 49               | 5.6                | 20.0                 | 44.10               | 4.2        | 34                |
| 13.    | 6619       | 24.0                  | 0.85                  | 47               | 5.3                | 20.3                 | 70.35               | 4.1        | 32.9              |
| 14.    | 6629       | 25.3                  | 0.92                  | 46               | 4.5                | 23.2                 | 64.00               | 2.9        | 31.3              |
| 15.    | 6644       | 21.8                  | 0.91                  | 49               | 5.4                | 19.8                 | 74.25               | 3.2        | 30.8              |
| 16.    | 6676       | 22.6                  | 0.86                  | 49               | 5.8                | 19.4                 | 79.80               | 3.9        | 31.9              |
| 17.    | 6678       | 25.9                  | 0.82                  | 53               | 5.3                | 21.2                 | 92.30               | 3.1        | 33.2              |
| 18.    | CISA329    | 21.8                  | 0.90                  | 51               | 5.1                | 19.7                 | 85.05               | 3.0        | 32.5              |
| 19.    | 6571       | 22.8                  | 0.86                  | 47               | 5.8                | 19.7                 | 71.40               | 3.7        | 35                |
| 20.    | DLSA-8     | 26.8                  | 0.82                  | 50               | 5.9                | 22.1                 | 103.40              | 3.3        | 35.5              |
| 21.    | 7038       | 25.2                  | 0.88                  | 50               | 5.3                | 22.2                 | 63.80               | 3.7        | 31.9              |
| 22.    | AC3370-1   | 25.6                  | 0.97                  | 45               | 6.0                | 24.8                 | 59.40               | 3.2        | 31.3              |
| 23.    | PA255      | 26.5                  | 0.86                  | 45               | 5.4                | 22.7                 | 53.00               | 3.5        | 32.1              |
| 24.    | KWAN-3     | 24.0                  | 1.02                  | 47               | 4.6                | 24.5                 | 99.90               | 3.5        | 34.5              |
| 25.    | 6586       | 22.2                  | 0.87                  | 51               | 6.4                | 19.3                 | 97.50               | 3.6        | 30.5              |
| 26.    | AC 3370-2  | 23.7                  | 0.87                  | 51               | 5.7                | 20.6                 | 75.40               | 2.8        | 32.3              |
| 27.    | CISA 12    | 27.5                  | 0.67                  | 46               | 5.0                | 18.4                 | 57.00               | 3.6        | 31.0              |
| 28.    | 1789       | 26.4                  | 0.76                  | 48               | 4.9                | 19.5                 | 63.70               | 3.1        | 31.5              |

Table 2. Superior lines for locule retentivity

| Sr. No | Name of Entries | Boll weight | Boll No. | Shattering percentage | Boll Retained | Total Yield |
|--------|-----------------|-------------|----------|-----------------------|---------------|-------------|
| 1.     | PA255           | 2.1         | 37.0     | 0                     | 37.0          | 77.7        |
| 2.     | CISA196         | 2.3         | 39.5     | 0                     | 39.5          | 90.9        |
| 3.     | CISA290         | 2.5         | 45.5     | 0                     | 45.5          | 113.8       |
| 4.     | CISA334         | 2.0         | 23.5     | 0                     | 23.5          | 47.0        |
| 5.     | CISA338         | 2.3         | 33.0     | 0                     | 33.0          | 75.9        |
| 6.     | CISA342         | 2.4         | 35.5     | 0                     | 35.5          | 85.2        |
| 7.     | 6637            | 2.1         | 34.5     | 0                     | 34.5          | 72.5        |
| 8.     | AC3088          | 2.3         | 24.5     | 0                     | 24.5          | 56.4        |

be used for spinning purpose. Seed cotton from such genotypes fetches much lower price in the market (Rs 1600 to 1800/- per quintal as compared to Rs 2300 to 2500/- in *G. hirsutum*). Availability of varieties with superior quality and good locule retentivity can make *G. arboreum* even more popular than *G. hirsutum* because of their inherent strengths like tolerance to biotic and abiotic stresses. Genetics of locule retention and introgression of locule retention into bengalenses using cernum races in crosses have been reported by Singh *et al.* (1987) and Singh and Naranayan (1987).

The present study indicates a wide range of variability for locule retentivity in germplasm lines. Initially, sixty-nine genotypes with more than 80 % boll retention capacity were identified in the field. Out of which eight lines PA 255, CISA 196, CISA 290, CISA 334, CISA 338, CISA 342, 6637 and AC 3088 were observed completely resistant to shattering (Table 2). In addition to good locule retention capacity, the cultivar CISA 290 also showed higher boll number (45.5) and good yield potential (113.8 gm/plant) followed by cultivar CISA 196 (boll number 39.5, yield 90.9 gm/plant) and CISA 342 (boll number 35.5, yield 85.6gm) (Table 2). These

lines can be utilized for incorporating better locule retentivity through breeding programs in desi cotton.

## References

- Anonymous (1989) *A Catalogue of Cotton Genetic Resources of India*. Central Institute for Cotton Research, Nagpur.
- Balakrishna P, BM Khadi, MR Eshanna, BS Janagourdar and RB Naik (1992) Genetic Variability for Seed Characters in Cotton (*Gossypium herbaceum* L.). *Seed Res.* 20: 78-80.
- Dhaliwal GS and R Arora (1996) *Principles of Insect Pest Management*. NATIC Ludhiana, 59p.
- Meena RA, P Singh and RK Deshmukh (1992) Seed character in *Desi* and *Egyptian* cottons. *J. Cotton Res. Dev.* 6: 58-60.
- Singh P and SS Narayanan (1987) Interracial introgression for some economic characters in *Gossypium arboreum* Linn. *Indian J. Agri. Sci.* 57: 628-630.
- Singh P and Singh J (1984) Variability for some economic characters in the genetic stocks of *Gossypium arboreum* L. germplasm. *J. Cotton Dev.* 14: 15-17.
- Singh VV (1984) Range of variability in *Gossypium herbaceum* L. germplasm. *J. Cotton Dev.* 14: 45.
- Singh VV and AK Singh (1984) Studies on genetic diversity in upland cotton. *J. Indian Soc. Cotton Improv.* 9: 41-45.
- Siwach SS, DP Singh and IP Singh (1988) Studies for some characters in germplasm of *Gossypium arboreum*. *J. Cotton Dev.* 2: 70-72.

## Variability Studies in Sunflower Lines Derived through Interspecific Hybridization

GS Mohan<sup>1</sup> and A Seetharam<sup>2\*</sup>

<sup>1</sup> Department of Genetics and Plant Breeding, University of Agricultural Sciences, GKVK, Bangalore-560 065, Karnataka

<sup>2</sup> All India Coordinated Crop Improvement Project (Small Millets), University of Agricultural Sciences, GKVK, Bangalore-560 065, Karnataka

Variability and *per se* performance of 137 interspecific derived sunflower lines along with seven known cultivated sunflower accessions was assessed during the study. Considerable variation for several important agronomic attributes was seen in the interspecific derived lines. High values of phenotypic and genotypic coefficient of variability, and high heritability with high genetic advance were observed for seed yield/plant, oil yield/plant, plant height, head diameter, oil content and test weight indicating the scope for utilization in crop improvement. The study could identify a few superior seed and oil yielding lines with comparable *Alternaria* leaf spot tolerance to the best check.

**Key Words:** Coefficient of variability, Interspecific hybridization, *Per se* performance

Utilization of related wild species is one of the effective means of introducing new variability to cultivated sunflower. The genus *Helianthus* consists of a large number of wild relatives with 49 species and 19 subspecies. The species show wide variability to many agronomic characters, insect and disease resistance and seed quality factors (Seiler, 1992). Many successful attempts harnessing the variability in wild sunflowers have been recorded. For instance, they have been exploited for obtaining the male sterility and restorer genes into cultivated sunflower. (Leclercq, 1969; Kinman, 1970). More than 55 CMS lines including the extensively utilized male sterile source (introgressed from *Helianthus petiolaris*) in commercial breeding programmes are obtained through interspecific hybridization (Serieys, 1999).

The contribution of wild species in disease and pest resistance breeding has been enormous. Resistant lines to important diseases such as downy mildew, charcoal rot, rust, broomrape, sclerotinia wilt, *Alternaria* leaf spot and pests such as sunflower moth have been developed through interspecific hybridization. Moreover, interspecific hybridization is also employed for transferring the abiotic stress resistance (drought tolerance from *H. argophyllus*; Seiler 1999), yield and oil quality attributes. In the context of their importance, it is imperative that the interspecific derived lines be evaluated for the variability and *per se* performance in order to utilize them in the ongoing breeding programs. This exercise would also help in assessing the efficiency of current methods employed (prebreeding

efforts) to derive the interspecific lines and modifications in prebreeding efforts that needs to be explored.

### Material and Methods

The experiment was conducted at the University of Agricultural Sciences, Bangalore and the material comprised 144 accessions that included 137 advanced lines derived from interspecific crosses involving 5 wild species and seven other known sunflower lines as checks for comparison (Table 1). The interspecific lines were either derived by crossing the wild species as females to the cultivated sunflower variety or using available cytoplasmic male sterile lines crossed to a male wild species. The interspecific hybrid was subsequently backcrossed to the cultivated sunflower for four generations. In each backcross generation, the plants with desirable phenotypes were selected within the family rows, discarding branched and pigmented plants. From BC<sub>4</sub>F<sub>1</sub> generation, the desirable phenotypes were sibbed and the seeds were bulked. This is continued till BC<sub>4</sub>F<sub>4</sub> and the plants were further maintained by sib pollination. In each wild species, only one representative accession of the species was utilized for crossing program.

The lines were sown with the spacing of 60 cm between rows and 30 cm within a row in 12 x 12 Simple Lattice design in two replications. Each replication consisted of 12 blocks and within each block 12 lines were sown. The replications, blocks and the lines within a block were randomized. Each line having 12 plants was grown in a row of 3.6 meters. Two seeds were dibbled in each hill

\* Correspondence: Dr. A Seetharam, Emeritus Professor, AICRP (Small Millets), University of Agricultural Sciences, GKVK, Bangalore-560 065, Karnataka. Telefax: 091 80 23332387 Email: annadanasram@rediffmail.com

Table 1. Details of pedigree of interspecific derived lines and checks

| Pedigree                                                                       | Generation                                                                                                                                                             | No. of cultures | Line no.                |
|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-------------------------|
| <b>Interspecific derived lines</b>                                             |                                                                                                                                                                        |                 |                         |
| <i>H. argophyllus</i> X <i>H. annuus</i> cv. Morden                            | BC <sub>4</sub> F <sub>4</sub>                                                                                                                                         | 36              | 1 to 35,127             |
| <i>H.petiolaris</i> X <i>H. annuus</i> cv. Morden                              | BC <sub>4</sub> F <sub>4</sub>                                                                                                                                         | 34              | 36 to 65,128 to 130,137 |
| <i>H.annuus</i> (wild) X <i>H. annuus</i> cv. Morden                           | BC <sub>3</sub> F <sub>5</sub>                                                                                                                                         | 18              | 66 to 80,131 to 132,136 |
| ( <i>H.argophyllus</i> X <i>H.annuus</i> (wild)) X <i>H. annuus</i> cv. Morden | BC <sub>3</sub> F <sub>4</sub>                                                                                                                                         | 30              | 81 to 107,133 to 135    |
| <i>H. annuus</i> cv. CMS234A X <i>H.debilis</i>                                | BC <sub>4</sub> F <sub>4</sub>                                                                                                                                         | 19              | 108 to 126              |
| <b>Checks</b>                                                                  | <b>Description</b>                                                                                                                                                     |                 |                         |
| Morden                                                                         | Open pollinated variety                                                                                                                                                |                 |                         |
| PAC1091                                                                        | Three way cross hybrid                                                                                                                                                 |                 |                         |
| KBSH-1                                                                         | Single cross hybrid                                                                                                                                                    |                 |                         |
| HA 6D-1                                                                        | Promising restorer line                                                                                                                                                |                 |                         |
| HA 265                                                                         | Restorer line                                                                                                                                                          |                 |                         |
| HA 234                                                                         | Promising inbred                                                                                                                                                       |                 |                         |
| HA 336                                                                         | Promising inbred                                                                                                                                                       |                 |                         |
| <b>Wild Speices</b>                                                            | <b>Source of Important Tratis</b>                                                                                                                                      |                 |                         |
| <i>H. argophyllus</i>                                                          | Resistance to Downy mildew, Rust, <i>Sclerotinia</i> wilt<br>CMS and fertility restoration, drought tolerance, self compatibility, oil content, Fatty acid composition |                 |                         |
| <i>H. petiolaris</i>                                                           | Resistance to rust, CMS source                                                                                                                                         |                 |                         |
| <i>H. annus</i> ( wild)                                                        | Resistance to Downy mildew, rust, <i>Verticillium</i> wilt, CMS source, Fertility restoration, Fatty acid composition                                                  |                 |                         |
| <i>H. debilis</i>                                                              | Salt tolerance and Fatty acid composition, Ornamental value                                                                                                            |                 |                         |

to facilitate better emergence and to provide uniform plant stand. The recommended manurial dosage was applied. Thinning was attended on 15<sup>th</sup> day after sowing to retain one plant per hill. The plants were grown under protective irrigation. All the recommended agronomic practices were followed to facilitate good growth and to raise a successful crop. From each line in each replication 5 competitive plants were tagged at random. Except days to 50 percent flowering, all other observations on quantitative characters were recorded at maturity. Variability and *per se* performance assessment were carried out utilizing these observations. Characterization of accessions based on limited qualitative characters was also attempted.

## Results and Discussion

### 1. Variability

The analysis of variance for 17 characters indicated highly significant differences among the lines. Considerable variation for each character was evident from the wide range thus providing large scope in selecting superior material for use in breeding programs (Table 2). High values (>20%) of Phenotypic and Genotypic Coefficient of Variability (PCV and GCV) were observed for percent autogamy, seed yield/plant, oil yield /plant, plant height, head diameter, number of leaves/plant, number of leaves in upper 1/3<sup>rd</sup> plant, oil content and test weight. Low GCV and moderate PCV was observed for days to 50 per cent

flowering, Percent Disease Index (*Alternaria*), hull content and both low GCV and PCV for days to maturity. Low GCV for *Alternaria* leaf spot was obvious as the lines employed in the study are derived from diploid annual species that are generally susceptible to *Alternaria*. Low GCV for days to 50 per cent flowering and days to maturity indicated limited variability in the material evaluated. However, many interspecific lines showed distinct earliness compared to checks and could form useful material.

High heritability estimates (>60%) were obtained for all characters except percent autogamy, *Alternaria* severity, number of leaves/plant, hull content and seed width. High heritability with high genetic advance (>20%) was observed for characters such as seed yield/plant, oil yield/plant, plant height, stem girth, head diameter, mean number of leaves in upper 1/3<sup>rd</sup> plant, volume weight, oil content and test weight. None of the characters showed high heritability with low genetic advance.

### 2. Per se Performance of Interspecific Lines

Comparative performance of interspecific derived lines and checks evaluated in the study is given in the Table 3. Lines 10 and 106 showed superiority even over the hybrid check PAC 1091 for many characters and could be useful genetic stocks. The lines 77, 88 and 5 possessed early maturity. It was observed that the upper limit for oil content in interspecific derived lines was generally less

Table 2. Descriptive statistics of different characters in 144 lines of sunflower

| Characters                                          | Min   | Max    | Mean  | SEm(±) | GCV   | PCV   | h <sup>2</sup> (BS) | GA (Percent of mean ) |
|-----------------------------------------------------|-------|--------|-------|--------|-------|-------|---------------------|-----------------------|
| Days to 50 percent flowering                        | 47.80 | 79.82  | 57.14 | 0.44   | 8.90  | 9.66  | 84.78               | 16.88                 |
| Plant height (cm)                                   | 52.36 | 204.88 | 97.53 | 2.05   | 24.44 | 25.89 | 89.17               | 47.55                 |
| Stem girth (cm)                                     | 0.86  | 2.77   | 1.56  | 0.03   | 18.13 | 22.21 | 66.67               | 30.50                 |
| Head diameter (cm)                                  | 4.79  | 20.54  | 11.53 | 0.24   | 24.20 | 26.67 | 82.34               | 45.23                 |
| Days to maturity                                    | 67.66 | 106.48 | 83.71 | 0.52   | 7.21  | 7.69  | 87.87               | 13.92                 |
| <i>Alternaria</i> incidence (Percent Disease Index) | 48.28 | 86.50  | 69.33 | 0.54   | 7.67  | 10.65 | 51.82               | 11.37                 |
| Mean number of leaves/plant                         | 2.90  | 25.50  | 10.79 | 0.30   | 27.81 | 37.19 | 55.91               | 42.84                 |
| Number of leaves in upper 1/3 <sup>rd</sup> plant   | 2.73  | 11.87  | 5.48  | 0.12   | 23.58 | 29.93 | 62.08               | 38.28                 |
| Volume weight(g)                                    | 16.36 | 42.69  | 27.86 | 0.38   | 15.43 | 17.36 | 79.00               | 28.25                 |
| Hull content (%)                                    | 21.30 | 56.19  | 33.32 | 0.43   | 8.90  | 19.98 | 19.85               | 8.16                  |
| Seed length(cm)                                     | 0.60  | 1.25   | 0.90  | 0.01   | 10.24 | 11.92 | 73.91               | 18.14                 |
| Seed width(cm)                                      | 0.35  | 0.65   | 0.46  | 0.01   | 11.91 | 15.37 | 60.00               | 19.00                 |
| Oil content (%)                                     | 11.40 | 46.20  | 24.84 | 0.55   | 25.43 | 28.02 | 82.40               | 45.41                 |
| Test weight (g)                                     | 1.57  | 7.22   | 3.50  | 0.09   | 28.90 | 32.54 | 78.87               | 52.87                 |
| Percent autogamy                                    | 0.12  | 93.11  | 14.72 | 0.04   | 38.63 | 50.99 | 58.82               | 3.51                  |
| Seed yield /plant(g)                                | 0.16  | 55.09  | 10.92 | 0.78   | 79.97 | 90.68 | 77.77               | 145.28                |
| Oil yield/plant (g)                                 | 0.03  | 24.83  | 3.08  | 0.31   | 81.58 | 92.60 | 81.89               | 211.88                |

though range was considerably large. Only two lines (line 10 and 106) were found to be superior to the best check. There was not much improvement for oil content in the interspecific derived lines due to higher number of backcrosses and relatively low oil content of the recurrent parent Morden (23.40 %) which might have restricted the improvement that would otherwise be possible. So it would be prudent to use recurrent parent with high oil content in interspecific hybridization studies.

The lines were also screened for two important diseases of sunflower namely *Alternaria* leaf spot and rust, and the major pest *Heliothis*. However, none of the lines showed less severity of *Alternaria* compared to best check PAC 1091 or KBSH-1. On the other hand, all the interspecific derived lines showed higher tolerance to rust disease. As far as *Heliothis* incidence was concerned, two lines 86 and 87 were having high mean larval load/plant and seemed relatively more susceptible to *Heliothis*.

The interspecific derived lines were scored for six distinguishable qualitative characters such as head inclination, head shape, leaf size, pigmentation, plant type and seed color following IPGRI sunflower descriptor (Table 4). For head inclination, majority of the lines (90) had the most desirable 135° angle and for head shape, majority of the lines (94) had the desirable convex shape head. Intense purple plant pigmentation is not a preferred

character in sunflower and with regard to plant type, erect types are preferred over druping ones. The absence of pigmentation was observed in 131 lines and 100 lines with erect plant type were observed in the study.

### Conclusions

The magnitude of heritability and genetic advance would influence the effectiveness of selection in breeding programs. It was evident that the two most important characters viz., seed yield and oil yield along with oil content showed high heritability and genetic advance indicating that selection would be effective and the improvement is possible in the interspecific derived lines. Further there is ample scope for selection, as exemplified by high phenotypic and genotypic coefficient of variation. Though many superior lines were identified in the study, for economic traits such as seed yield, oil yield and oil content only one or two lines were superior and few other lines were on par with the best checks. Manjula and Seetharam (2000) evaluated 32 lines (BC<sub>3</sub>F<sub>2</sub>) derived from the interspecific cross *Helianthus annuus* var. Morden x *Helianthus argophyllus* and observed low to moderate performance for agronomic traits.

While attempting introgression of genes from wild gene pool, one has to resort to backcrossing with the recurrent parent (cultivated species) in order to retrieve the desirable agronomic background. While doing so, one may fail to optimize the blending of genes from wild and

Table 3. Interspecific derived lines identified superior to best checks in hybrids and population / inbreds

| Character                         | Best check       |                    | Superior Lines |             |             |             |             |
|-----------------------------------|------------------|--------------------|----------------|-------------|-------------|-------------|-------------|
|                                   | Hybrid           | Population/ inbred |                |             |             |             |             |
| Percent autogamy (+)              | PAC1091<br>60.2  | R265<br>91.9       | 70<br>91.9     | 98<br>85.6  | 34<br>83.6  | 127<br>81.5 |             |
| Days to maturity (-)              | KBSH-1<br>92     | Morden<br>78       | 77<br>68       | 88<br>69    | 5<br>70     | 105<br>71   | 2<br>71     |
| Days to 50 per cent flowering (-) | KBSH-1<br>62     | Morden<br>49       | 88<br>48       | 77<br>48    |             |             |             |
| Plant height (cm) (-)             | KBSH-1<br>160.4  | Morden<br>76.8     | 77<br>52.4     | 85<br>57.5  | 84<br>58.1  | 88<br>61.2  | 89<br>62.0  |
| Volume weight (g) (+)             | KBSH-1<br>37.8   | 336B<br>37.5       | 106<br>42.7    | 10<br>42.3  |             |             |             |
| Percent hull content (-)          | PAC 1091<br>27.5 | 6D-1<br>22.50      | 24<br>21.3     |             |             |             |             |
| Test weight (g) (+)               | PAC1091<br>5.4   | Morden<br>5.2      | 10<br>7.2      | 45<br>6.3   | 106<br>6.2  | 79<br>6.1   |             |
| Percent oil content (+)           | PAC1091<br>41.4  | 336B<br>41.1       | 10<br>46.2     | 106<br>42.1 |             |             |             |
| Oil yield/plant (g) (+)           | PAC1091<br>22.7  | Morden<br>4.8      | 10<br>24.8     | 106<br>17.7 | 130<br>15.7 |             |             |
| Seed Yield/plant (g) (+)          | PAC1091<br>55.1  | Morden<br>18.9     | 10<br>53.3     | 130<br>43.0 | 106<br>42.6 | 40<br>31.5  | 128<br>27.2 |

Values in italics are the actual figures for that character ; + and - indicate the desirable direction of the character

Table 4. Qualitative grouping of 144 lines

| Character               | Category                            | # of lines |
|-------------------------|-------------------------------------|------------|
| Head inclination        | 90°                                 | 20         |
|                         | 135°                                | 92         |
|                         | 180°                                | 32         |
| Head shape.(Grain side) | Concave                             | 4          |
|                         | Flat                                | 52         |
|                         | Convex                              | 85         |
|                         | Highly convex                       | 3          |
| Leaf size               | Small                               | 2          |
|                         | Medium                              | 139        |
|                         | Large                               | 3          |
| Pigmentation            | Stem, petiole and disc pigmentation | 4          |
|                         | Petiole pigmented                   | 9          |
|                         | Green                               | 131        |
| Plant type              | Errect                              | 100        |
|                         | Non errect                          | 44         |
| Seed colour             | Grey                                | 12         |
|                         | Brown                               | 10         |
|                         | Black                               | 122        |

cultivated groups leading to greater tilt towards cultivated forms. As a result, the value of interspecific derived lines by way of providing additional advantages in breeding

research is reduced. Restricting to BC<sub>1</sub> generation for selecting the superior introgressions and intercrossing amongst them would result in lines with higher heterogeneity and *per se* performance.

#### Acknowledgements

This work was supported through a fellowship provided by the Council of Scientific and Industrial Research, New Delhi, India for the Ph.D. research of the first author.

#### References

- Kinman ML (1970) New developments in the USDA and State Experiment Station sunflower breeding programs. In: *Proc. 4<sup>th</sup> Int. Sunflower Conf.*, Memphis, TN, Int. Sunflower Assoc., Toowoomba, Australia, pp. 215-218.
- Leclercq P (1969) Line sterile cytoplasmique chez le tournesol. *Ann. Amelior. Plant* **12**: 99-106.
- Manjula T and Seetharam A (2000) Use of wild species *Helianthus argophyllus* in sunflower improvement. *Karnataka J. Agric. Sci.*, **13**: 557-563.
- Seiler GJ (1992) Utilization of wild sunflower for the improvement of cultivated sunflower. *Field Crops Res.*, **30**: 195-230.
- Seiler GJ (1999) The report of the workgroup: evaluation of wild *Helianthus* species Part I. *Helia*, **22**: 29-35.
- Serieys H (1999) The report of the working group: identification, study and utilization in breeding programs of new CMS sources. Part I. *Helia* **22**: 35.

## Genetic Divergence in Pea (*Pisum sativum* L.)

RS Rath<sup>i</sup>\* and RPS Dhaka

Department of Agriculture Botany, KPG Simbhaoli, Ghaziabad, Meerut University (U.P) India

\*National Bureau of Plant Genetic Resources, Pusa, New Delhi-110 012

Genetic divergence of 35 genotypes of pea (*Pisum sativum* L.) was assessed using Mahalanobis's  $D^2$  statistics. These genotypes could be grouped in seven clusters. Grouping of genotypes in different clusters was not related to their geographic origin. Estimates of *intra*-cluster distance ranged from 0.0-8.49. It was maximum in cluster III and minimum in cluster IV. The maximum *inter*-cluster values 7.26 and 24.14 were obtained between cluster VI and VII. The maximum diversity was observed between cluster II and VI which suggested that the genotypes of these two clusters are genetically very close. The over all picture indicated that the cluster I, II, III, IV and VI were quite divergent from the rest of the clusters also from one another. Selecting genotypes from such divergent groups for breeding programme/hybridization is likely to yield high heterotic response and release better segregants in subsequent generations.

**Key Words:** Exotic, Genetic divergence, Indigenous, *Pisum sativum*

Pea (*Pisum sativum* L.) is a very important crop for multipurpose use and can be grown very well in semi-arid to temperate regions. Considering the importance of this crop, the knowledge of the nature and degree of divergence at *inter*- and *intra*- allelic level is very useful in characterization of genotypes and selecting desirable parents for breeding programme. The present research work was conducted on indigenous and exotic genotypes, including some released varieties, to determine the genetic divergence.

### Materials and Methods

The experimental material consisted with 35 diverse genotypes comprising indigenous and exotic material of pea. Two rows of 3m length in a replication were planted for each genotype. The experiments were laid out in randomized block design with three replications during 1996-98 season. The plants were spaced at 45-15 cm. Research trial was conducted at research Farm of Kisan Post Graduate College, Simbhaoli, Ghaziabad, Uttar Pradesh. Observations were recorded for five randomly selected plants in each genotype per replication. Eight environments were created by manipulating the dates of sowing and fertilizer doses as 10-15 November (20:40, 10:40) and 25-30 December (20:40, 10:40) respectively. The Mahalanobis's  $D^2$  statistics was used to measure the genetic divergence as suggested by Rao (1952). Using V statistics which in turn utilizes Wilk's Criteria, a simultaneous test of differences between mean value of a number of correlated variables is done (Rao, 1948).

### Results and Discussions

The analysis of variance revealed significant difference

among 35 genotypes for all the 13 characters studies during both the years. Based on  $D^2$  value, the 35 genotypes could be grouped in to seven clusters. The cluster pattern of these genotypes is depicted in Table 2. Cluster V included maximum of 12 genotype followed by cluster II that included 11 genotypes. The cluster VII has only one genotype (IC-11191) while cluster II included two genotypes. Cluster IV and VI included three genotypes each while cluster II had only two genotypes.

Cluster mean are presented in Table 3 for all 13 characteristics. The highest seed yield per plant (11.48) was recorded in cluster III while lowest seed yield was recorded for cluster VI that included only one genotype (IC-11191). Highest test weight (17.81) was observed in cluster VI followed by (16.74) with cluster V. The cluster III consisted of early flowering with 69.71 day where as cluster VII with early maturity 91.17, the maximum (12.69) cluster mean for number of pods per plant was calculated in cluster V, but the maximum pod length (6.92) was noted in cluster III which includes only two genotypes viz. Boneville and Arkel. The highest dry matter yield (34.82) was recorded in cluster V that consisted maximum number of 12 genotypes. The cluster VI that included only one genotype (IC-11191) showed the lowest values except days to flower, plant height and number of seeds per pod (Table 1).

The *intra*- and *inter* cluster divergence ( $D^2$ ) values are presented in Table 2. The maximum cluster distance was observed between cluster VI and VII ( $D^2=24.14$ ) followed by cluster IV and VI ( $D^2=20.21$ ) and lowest distance was noted between cluster II and IV ( $D^2=7.26$ ). The *intra*- cluster values ranged from 0.00-8.49 (cluster

Table 1. Cluster means and grouping patterns based on D<sup>2</sup> analysis for 13 characteristics in 35 genotypes of pea

| Cluster No. | Name of the genotype                                                                                                  | No. of genotypes | S. No. of genotype                       | Characters     |                              |                  |                   |                          |                    |                 |                   |                             |                    |                   |               |                     |
|-------------|-----------------------------------------------------------------------------------------------------------------------|------------------|------------------------------------------|----------------|------------------------------|------------------|-------------------|--------------------------|--------------------|-----------------|-------------------|-----------------------------|--------------------|-------------------|---------------|---------------------|
|             |                                                                                                                       |                  |                                          | 1              | 2                            | 3                | 4                 | 5                        | 6                  | 7               | 8                 | 9                           | 10                 | 11                | 12            | 13                  |
|             |                                                                                                                       |                  |                                          | Days to flower | Days to green pod harvesting | Days to maturity | Plant height (cm) | No. of branch- es/ plant | No. of pods/ plant | Pod length (cm) | No. of pods/ node | Dry matter yield/ plant (g) | No. of grains/ pod | Seed yield/ plant | Harvest index | 100 seed weight (g) |
| I           | EC 341766, EC 27168, NIC 18727                                                                                        | 3                | 23,24,34                                 | 72.05          | 95.80                        | 114.54           | 95.24             | 2.75                     | 12.06              | 4.77            | 1.24              | 22.87                       | 4.60               | 7.99              | 31.62         | 13.52               |
| II          | DDR 13, KPF 103, HUDP-6, Arka Ajeet, DDR-12, HUDP-8, J M-1, EC 381864, EC 381865, EC 341995, KNM-4                    | 11               | 1,2,3,4,6, 11,12,18, 22,25,27            | 74.93          | 99.88                        | 117.79           | 72.91             | 2.58                     | 10.53              | 5.93            | 1.73              | 27.35                       | 4.76               | 8.85              | 33.48         | 16.59               |
| III         | Boneville and Arkel                                                                                                   | 2                | 7, 13                                    | 69.71          | 94.06                        | 113.14           | 70.53             | 2.365                    | 12.28              | 6.925           | 1.94              | 23.385                      | 5.895              | 11.48             | 40.92         | 14.86               |
| IV          | KJPD-59, LFP-96, HFP-4                                                                                                | 3                | 8,14,16                                  | 82.84          | 105.06                       | 122.00           | 67.01             | 2.74                     | 9.88               | 5.66            | 1.82              | 24.99                       | 4.35               | 7.72              | 28.48         | 15.89               |
| V           | DMR-1, Rachna, NIC 23636, DMR-11, BDJ 42-174, PLP-359, EC 341787, NIC 23625, NIC 12860, NIC 11181, NIC 18735, EC 8495 | 12               | 5,9,10, 15, 19, 21, 26, 28, 29,30, 33,35 | 76.70          | 100.76                       | 119.66           | 120.42            | 3.01                     | 12.695             | 5.51            | 1.50              | 34.82                       | 4.52               | 10.03             | 29.00         | 16.74               |
| VI          | KPMR-144-1, NIC 11249, EC 381856                                                                                      | 3                | 17,20,31                                 | 76.48          | 100.76                       | 119.15           | 60.69             | 2.48                     | 11.98              | 5.34            | 1.87              | 25.57                       | 3.72               | 8.77              | 33.36         | 17.81               |
| VII         | NIC 11191                                                                                                             | 1                | 32                                       | 74.50          | 91.17                        | 111.71           | 66.75             | 3.11                     | 9.11               | 3.73            | 1.19              | 14.18                       | 4.51               | 3.18              | 23.94         | 6.59                |

Table 2. Intra and Inter cluster divergence D<sup>2</sup> values among seven clusters.

| Clusters | No. of genotypes per cluster |             |             |             |             |             |       |
|----------|------------------------------|-------------|-------------|-------------|-------------|-------------|-------|
|          | (3)                          | (11)        | (2)         | (3)         | (123)       | (3)         | (1)   |
|          | I                            | II          | III         | IV          | V           | VI          | VII   |
| I        | <u>7.76</u>                  | 13.18       | 11.88       | 14.76       | 12.40       | 17.55       | 13.02 |
| II       |                              | <u>5.73</u> | 8.63        | 7.26        | 8.07        | 8.06        | 19.87 |
| III      |                              |             | <u>8.49</u> | 11.75       | 11.14       | 13.29       | 18.10 |
| IV       |                              |             |             | <u>5.74</u> | 10.12       | 7.45        | 20.21 |
| V        |                              |             |             |             | <u>5.79</u> | 10.04       | 19.47 |
| VI       |                              |             |             |             |             | <u>4.87</u> | 24.14 |
| VII      |                              |             |             |             |             |             | 0.00  |

\* Underlined figures denote *Intra*-cluster divergence values

VI and III). The minimum *intra*-cluster D<sup>2</sup> value of 0.00 was recorded in cluster VII followed by 4.87 in cluster

VI. Maximum *intra*-cluster D<sup>2</sup> value of 8.49 was recorded in cluster III (Table 2).

The over all analysis showed that the cluster I, II, III, IV, VI and VII were quite divergent from the others and also from one another. Among these types of cluster, the selecting genotypes for breeding programme/hybridization produce high heterotic response and release better segregant/lines in subsequent generation. However, caution may be exercised in selecting very divergent genotypes because such crosses may not yield proportionate heterotic response since a cross between extremely divergent parents create a situation where the harmonious functioning of alleles is rather distributed and consequently the physiological function are not so efficient (Dobhal *et al*, 1985). This is further substantiated by the fact that if 'm' is the mean and 's' is the standard deviation of divergence value ( $D^2$ ) among parents whose genetic divergence fall between (m-s) and (m+s) then crosses will have better chance of producing higher frequency and magnitude of heterosis as compared to cross whose parental divergence falls outside the limits, (m-s and m+s) Arunachalam and Bandhopadhyay (1984).

Hence the clustering of genotypes, has no relationship between geographic and genetic diversity could be established. The elite lines identified on the basis of  $D^2$  and *per se* performance may be crossed and handled as per diallel selective matting system, Jensen (1970), so as to utilize both additive and non-additive components that are known to exist to concentrate maximum number of

desirable genes in a few lines to isolate higher yielding lines (Rana, 1989).

Testing significance of  $D^2$  against V Statistics (3838.81) where V statistics is distributed as  $\chi^2$  with 442 degree of freedom indicated highly significance of  $D^2$  value.

On the bases of  $D^2$ , the promising genotypes/varieties namely DDR-12, Arkel, DMR-I, NIC 11249 and KPFD-59 belonging to different clusters could be crossed in a diallel fashion in order to achieve the genetic improvement.

## References

- Arunachalam V and A Bandhopadhyay (1984) Limits to genetic divergence for occurrence of heterosis-experimental evidence from crop plants. *Indian J. Genet.* **44**: 548-54.
- Dobhal VK and HH Ram (1985) Genetic Divergent in pea (*Pisum sativum* L.). *Indian J. Agri. Sci.* **55**: 67-71.
- Jensen NF (1970) A diallel selective matting system for cereal breeding. *Crop. Sci.* **10**: 629-635.
- Rana JC (1989) Studies on gene action and response to selection in early generation in pea (*Pisum sativum* L.). *Ph. D Thesis* HPKVV, Palampur, H.P., India.
- Mahalanobis PC (1936) On the generalized distance in statistics. *Proc. Nat. Sci. India.* **2**: 49-55.
- Rao CR (1948) The utilization of multiple measurement in problems of biological classification. *J. Roy. Stat. Soc.*, **10-B**: 159-2003.
- Rao CR (1952) *Advanced Statistical Methods in Biometrical Research*. Johan Wiley and Sons, Inc., New York.

## Exploration, Collection and Characterization of Citrus Genetic Diversity from Manipur and Tripura

IP Singh

National Research Centre for Citrus, P.B. 464, Shankarnagar P.O., Amravati Road, Nagpur-440 010, Maharashtra

To collect citrus genetic diversity the National Research Centre for Citrus, Nagpur led 2 exploration missions during the year 2003, specially for North-east hill region of India. Total 40 accessions of *Citrus* belonging to different citrus species *C. jambhiri*, *C. macroptera*, *C. grandis*, *C. medica*, *C. sinensis*, *C. limon*, *C. reticulata*, *C. aurantifolia* were collected from different districts of Manipur and Tripura. Passport data were documented. A wide range of variability was observed in collected material, especially fruit weight which ranged from 35.2 g to 1342 g. One dwarf genotype (plant height 2-3 m) known as *Elaichi Nimbu* was located in Teliamura area of West Tripura and another high yielding (yield potential 72-80 tonnes per ha) landrace locally known as *Kachai lemon* was identified in Ukhrul district of Manipur. Shifting cultivation and farmers choice for commercial types only, are identified as potential threat to diversity of *Citrus* occurring in these areas.

**Key Words:** Citrus, Exploration, Germplasm, Rootstock, Threat

The North-eastern region of India is considered as one of the main centre of diversity for *Citrus* spp. A large number of citrus species are reported from this region (Bhattacharya and Dutta, 1951 & 56, Dutta, 1958; Hodgson *et al.*, 1963; Kaul, 1981; Sarkar, 1994; Sheo Govind and Yadav, 1999; Singh, 1981; Singh and Singh, 1967; Singh and Singh, 1968; Singh and Chadha, 1993; Singh and Singh, 2001; Singh, 1977; Tanaka, 1937 and 1958). Many citrus species were observed growing wild and semi-wild in different pockets of the region (Borthakur, 1993; Hore, *et al.*, 1997; Singh *et al.*, 2001; Ghosh, 1977; Sheo Govind and Singh 2002; Singh and Singh, 2003). Vavilov (1940) reported this region to be the primary as well as secondary centre of origin of a large number of plants. However, a large genetic diversity in the region is under threat due to several factors. It warrants urgent steps for collection and conservation of the diverse flora. Therefore, extensive survey were conducted by National Research Centre for Citrus (NRCC), Nagpur, Maharashtra to collect available citrus genetic diversity for utilization and their conservation.

### Materials and Methods

#### Grid Points of Exploration

To collect the genetic diversity, explorations were carried out during December 6-13, 2003 in different districts of Manipur (Bishnupur, Tamenglong, Imphal East, Imphal West and Ukhrul) and from November 4-11, 2003 in different areas of Tripura. The areas explored in Tripura were Lembucherra, Kamalghat, Mohanpur, Agartala, Bishalgarh, Bishramganj, Melaghar, Sopnamura,

Teliamura, Zirania and Khowi (West Tripura), Udaipur, Birchndramanu, Shantirbazar and Subrum (South Tripura), Ambasa, Manu, Nalkata and Kumarghat (Dhalai District), Kanchanpur and Jampui Hills (North Tripura). Fruit samples collected were brought to NRCC, Nagpur and observations were recorded for fruit weight, fruit size, number of segments per fruit, seed number, peel thickness, total soluble solids (TSS) and acidity.

#### Route Map of Exploration

The route map followed for exploring the area showing various grid points is shown in Fig. 1

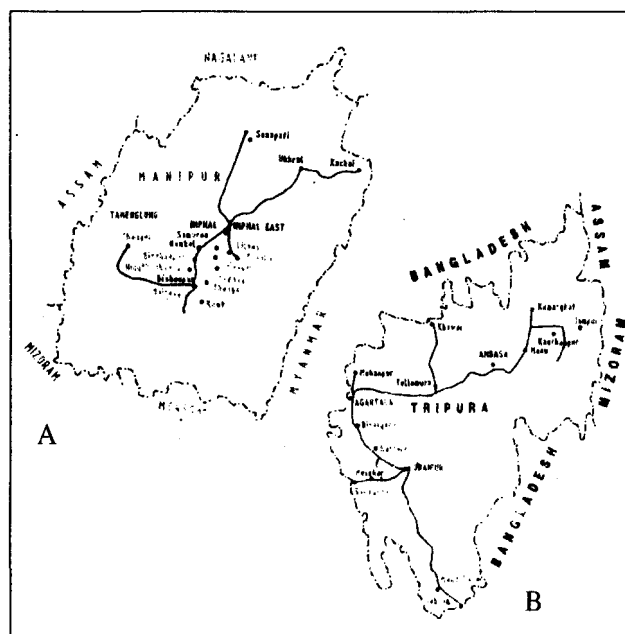


Fig. 1: Route map of Manipur (A) and Tripura (B) for collecting citrus diversity

E-mail: citrus9\_ngp@sancharnet.in

### Soil and Climatic Conditions

The climate of Manipur is sub-tropical humid. The soil types range from black, sandy loam, alluvial and very shallow to deep ones. Most of the Imphal east and Imphal west area comes under valley whereas other are hill slopes. On hill slope, soil erosion is very common. The rainfall pattern varied from 2000 mm to 2500 mm per year. Temperature ranged from 4°C to 35°C. The terrain of Tripura is hilly and due to this it was earlier known as hill Tripura. The topographic feature of the state is its close association of undulating lands locally known as *tillas* interspaced with nearby valleys locally known as *lungas*. The soil is very deep, well drained and usually very fertile. The texture varies from sandy to loamy sand and is generally acidic with pH values varying from 4.85 to 5.80. It has tropical, moist climate with fairly distributed rainfall of 2200 mm/annum between April to October. The humidity ranges between 42% in April to about 100% in June. The maximum and minimum temperature ranges between 7°C to 35 °C without any frost formation. The habitat from where samples were collected covered physiographic locations like plain, farmer's field, hilly area, home gardens, valley and forest area representing altitude ranging from 16 to 900 m above mean sea level.

### Results and Discussion

#### *Citrus Genetic Diversity in Manipur*

Manipur comes under the North eastern region of India and it has bounded on the North, West, South with Nagaland, Assam and Mizoram respectively and North-east and East by the international boundary of Myanmar (Burma). This is one of the potential State for collecting citrus genetic diversity since it is adjoining to Myanmar where maximum diversity is reported. A total of 23 accessions of citrus belonging to different species were collected from Manipur (Table 1). Various available statistics estimate that out of total tonnage of citrus produced in the state, maximum emerge from Tamenglong and Ukhrul districts, besides Tipaimukh and Tinsung of Churachandpur district, Chandel and Jiribam of Imphal East. In Manipur, mandarin, different strains of rough lemon and semi-wild type of Heiribob (*C. macroptera*) are grown on commercial scale. Among all citrus fruits available in Manipur, Heiribob fruits are most costly owing to greater demand. It is sold in Imphal market at Rs 15 per fruit as compared to Mandarin fruit (Rs 2 per fruit). Its cultivation is restricted near Burma border in Khoibu village, Chandel District. One landrace was collected from Kachai village in Ukhrul district. Perhaps this would be first village in the historical calendar

of citrus cultivation that one single variety is grown on such a large scale with very high production. The preliminary report says that the combination of soil and micro-climate is largely attributed to quality development of Kachai lemon in this area as such a quality of Kachai lemon is not found even in nearby villages. Although Kachai lemon is not a true lemon, it gives very high yield and two crops are obtained in a season. One matures in November-December whereas the other matures in the months of May and June. Fruit of Kachai lemon is very popular among the locals and therefore very remunerative for the farmers. The village has established one community orchard of Kachai lemon. In contrast mandarin orchards have more than 2,000 fruits with beautiful colour but without optimum fruit size coupled with a medium taste. This is due to poor soil fertility (deficiency of nutrients like Mg, N, P, Zn and B in Tamenglong and Kachai areas), conditioned by comparatively difficult to amend sub-soil acidity. It is difficult to find any orchard practicing the standard cultural practices. Due to the absence of any analysis to unravel the soil fertility and plant nutritional factors contributing to fruit quality development and subsequently the development of soil and climate specific agro-techniques.

Mandarin, Heribob and Kachai lemon germplasm are mostly maintained in farmers, field whereas others are maintained in home garden. Manipur valley has abundant pummelo and large variability in pummelo germplasm was observed. However, farmers are not getting any price in the market since there is no demand of pummelo fruits. This resulted in reduction of farmers maintaining pummelo germplasm. Rich genetic diversity was observed in rough lemon and citron. Different shape, size and colour were collected from different areas. The majority of citrus plantation exists on steep slopes having slope of 70-80% without any protection against soil erosion. When these orchards are raised on untterraced land, over the years (25-30 years, which is an as the average orchard life) the top fertile soil is nearly lost, leading to exposure of unfertile sub-soil with very high acidity. However, orchards of 45-50 years can also be easily located (e.g. Thangal village) indicating that there is a potential of longer orchard life. The plants remaining consistently under moisture stress apart from poor soil fertility, especially in untterraced citrus orchards are bound to produce under-sized fruits.

#### *Citrus Genetic Diversity in Tripura*

Citrus belonging to 5 different species were observed to grow in Tripura. Total 17 accessions belonging *C. grandis*,

*C. medica*, *C. aurantifolia*, *C. limon* and *C. reticulata* were collected from all districts of Tripura (Table 1). Rich diversity in pummelo germplasm was observed near Bangladesh border and maximum concentration was observed in Agartala city where large number of plants were maintained in home garden. Hore *et al.* (1997) also reported rich diversity of citrus in Tripura. Before 1949, Tripura was under separate kingdom. Tripura is culturally very rich and this is the main reason that most of the pummelo plants are maintained in home garden, as it is mostly utilized for religious purpose. Great demand of this fruits was observed during the Hindu festival namely *Vishwakarma puja*, *Durga puja*, *Kali puja* and other tribals festival. Therefore, farmers are getting good price in the market unlike other states where less demand of

pummelo creates marketing problem. However, due to modernization, tribal people of Tripura are removing pummelo plants for construction of concrete houses. Before 1950 every house in Tripura usually had one small pond and on the border of pond they used to plant pummelo and other fruits. But now they are converting pond for house construction and therefore removing pummelo plants too. In rural area these materials are well protected since more than 60% area of Tripura is under forest. When author visited Tripura in 1986 and 1993, Agartala city bordering Bangladesh was full of pummelo. This time it was observed that most of the plants were uprooted and we could not find any young plantation of pummelo. This indicates serious threat to pummelo variability in Agartala which was collected by tribals through many generations.

Table 1. List of citrus germplasm collected during exploration from Manipur and Tripura

| S. No. | Collector (s) no. | Species                | Common name    | Local name                     | Area of collection (District) | Status<br>Wild, cultivated, semi-cultivated |
|--------|-------------------|------------------------|----------------|--------------------------------|-------------------------------|---------------------------------------------|
| 1      | IPS-433           | <i>C. medica</i>       | Citron         | Citron                         | Bishnupur, Manipur            | Semi-cultivated                             |
| 2      | IPS-434           | <i>C. jambhiri</i>     | Rough lemon    | Rough lemon                    | Bishnupur, Manipur            | Semi-cultivated                             |
| 3      | IPS-435           | <i>C. jambhiri</i>     | Rough lemon    | <i>Gole nimbu</i>              | Bishnupur, Manipur            | Semi-cultivated                             |
| 4      | IPS-436           | <i>C. medica</i>       | Citron         | <i>Heijerang var. Gandhraj</i> | Bishnupur, Manipur            | Semi-cultivated                             |
| 5      | IPS-437           | <i>C. macroptera</i>   | Satkara        | <i>Heiribob</i>                | Bishnupur, Manipur            | Semi-wild                                   |
| 6      | IPS-438           | <i>C. medica</i>       | Citron         | Citron                         | Bishnupur, Manipur            | Semi-cultivated                             |
| 7      | IPS-439           | <i>C. jambhiri</i>     | Rough lemon    | <i>Sindhuritenga</i>           | Bishnupur, Manipur            | Semi-cultivated                             |
| 8      | IPS-440           | <i>C. jambhiri</i>     | Rough lemon    | <i>Gol nimbu</i>               | Bishnupur, Manipur            | Semi-cultivated                             |
| 9      | IPS-441           | <i>C. medica</i>       | Citron         | Citron                         | Tamenglong, Manipur           | Semi-cultivated                             |
| 10     | IPS-442           | <i>C. jambhiri</i>     | Rough lemon    | <i>Gol nimbu</i>               | Tamenglong, Manipur           | Semi-cultivated                             |
| 11     | IPS-443           | <i>C. jambhiri</i>     | Rough lemon    | Rough lemon                    | Tamenglong, Manipur           | Semi-cultivated                             |
| 12     | IPS-444           | <i>C. jambhiri</i>     | Rough lemon    | Rough lemon                    | Tamenglong, Manipur           | Semi-cultivated                             |
| 13     | IPS-445           | <i>C. reticulata</i>   | Khasi mandarin | Khasi mandarin                 | Tamenglong, Manipur           | Cultivated                                  |
| 14     | IPS-446           | <i>C. medica</i>       | Citron         | Citron                         | Ukhrul, Manipur               | Semi-cultivated                             |
| 15     | IPS-447           | <i>C. sinensis</i>     | Sweet orange   | <i>Haithumb</i>                | Imphal East, Manipur          | Semi-cultivated                             |
| 16     | IPS-448           | <i>C. medica</i>       | Citron         | <i>Heijrang</i>                | Imphal East, Manipur          | Semi-cultivated                             |
| 17     | IPS-449           | <i>C. medica</i>       | Citron         | Citron                         | Imphal East, Manipur          | Semi-cultivated                             |
| 18     | IPS-450           | <i>C. jambhiri</i>     | Rough lemon    | Rough lemon                    | Imphal East, Manipur          | Semi-cultivated                             |
| 19     | IPS-451           | <i>C. jambhiri</i>     | Rough lemon    | <i>Kata jamir</i>              | Imphal East, Manipur          | Semi-cultivated                             |
| 20     | IPS-452           | <i>C. jambhiri</i>     | Kachai lemon   | <i>Kachai lemon</i>            | Ukhrul, Manipur               | Cultivated                                  |
| 21     | IPS-453           | <i>C. jambhiri</i>     | Rough lemon    | Rough lemon                    | Ukhrul, Manipur               | Semi-cultivated                             |
| 22     | IPS-454           | <i>C. reticulata</i>   | Khasi mandarin | Khasi mandarin                 | Ukhrul, Manipur               | Cultivated                                  |
| 23     | IPS-455           | <i>C. grandis</i>      | Pummelo        | Pummelo                        | Ukhrul, Manipur               | Semi-cultivated                             |
| 24     | IPS-416           | <i>C. grandis</i>      | Pummelo        | Pummelo                        | West Tripura                  | Semi-cultivated                             |
| 25     | IPS-417           | <i>C. grandis</i>      | Pummelo        | Pummelo                        | West Tripura                  | Semi-cultivated                             |
| 26     | IPS-418           | <i>C. aurantifolia</i> | Kagzi lime     | <i>Nimboo</i>                  | West Tripura                  | Cultivated                                  |
| 27     | IPS-419           | <i>C. grandis</i>      | Pummelo        | Pummelo                        | South Tripura                 | Semi-cultivated                             |
| 28     | IPS-420           | <i>C. limn</i>         | Lemon          | <i>Elaichi Nimboo</i>          | South Tripura                 | Cultivated                                  |
| 29     | IPS-421           | <i>C. medica</i>       | Citron         | <i>Pati Nimboo</i>             | South Tripura                 | Cultivated                                  |
| 30     | IPS-422           | <i>C. grandis</i>      | Pummelo        | Pummelo                        | West Tripura                  | Semi-cultivated                             |
| 31     | IPS-423           | <i>C. medica</i>       | Citron         | Citron                         | Dhalai, Tripura               | Semi-cultivated                             |
| 32     | IPS-424           | <i>C. medica</i>       | Citron         | Citron                         | Dhalai, Tripura               | Semi-cultivated                             |
| 33     | IPS-425           | <i>C. reticulata</i>   | Khasi mandarin | <i>Kamala</i>                  | North Tripura                 | Cultivated                                  |
| 34     | IPS-426           | <i>C. limon</i>        | Lemon          | <i>Elaichi Nimboo</i>          | Dhalai (Tripura)              | Cultivated                                  |
| 35     | IPS-427           | <i>C. grandis</i>      | Pummelo        | Pummelo                        | West Tripura                  | Semi-cultivated                             |
| 36     | IPS-428           | <i>C. limon</i>        | Lemon          | <i>Elaichi Nimboo</i>          | West Tripura                  | Cultivated                                  |
| 37     | IPS-429           | <i>C. limon</i>        | Lemon          | <i>Elaichi Nimboo</i>          | West Tripura                  | Cultivated                                  |
| 38     | IPS-430           | <i>C. limon</i>        | Lemon          | <i>Elaichi Nimboo</i>          | West Tripura                  | Cultivated                                  |
| 39     | IPS-431           | <i>C. limon</i>        | Lemon          | <i>Elaichi Nimboo</i>          | West Tripura                  | Cultivated                                  |
| 40     | IPS-432           | <i>C. grandis</i>      | Pummelo        | Pummelo                        | West Tripura                  | Semi-cultivated                             |

Except mandarin and lemon, most of citrus germplasm are maintained in home garden. Mandarin is commercially grown only in North Tripura at Jampui hills bordering Mizoram. These hills were once famous for quality mandarin fruit but now these are facing serious decline mainly due to powdery mildew disease which results in poor quality production of mandarin in Jampui hills of Tripura. Fruits available in market were bitter in taste as also reported by state department of horticulture. The main reason for poor quality is attributed to decline of orchards, where force ripening is experienced due to early colour development in infected plants. Farmers sell their produce in market before ripening. During survey we tested mandarin fruits in all major market which indicated that fruits are harvested before ripening. In Jampui hills farmers also agreed that they harvest mandarin before ripening, or else fruits will drop and not fetch any price. Therefore, utmost priority should be given to save Jampui mandarin which is facing severe decline problem mainly due to powdery mildew disease. Even water is not available for spraying to control the diseases. After mandarin in Jampui hills another citrus crop which is getting popularity in state is *Elaichi Nimboo*. This is now commercially grown in Teliamura area in West Tripura. Its plants are bushy type and dwarf (height 2-3 m). This genotype is very good for high density plantation (2 x 2 m). Farmers are getting good price, Rs 250 to 500 per plant at spacing of 2x2 m. Besides these, many citron types were observed growing mainly in home garden throughout Tripura. Shifting cultivation was found to be serious threat to genetic diversity in both the areas.

#### Characterization of Collected Materials

A wide range of variability was observed for physico-chemical characters in fruits of collected germplasm (Table 2). Maximum fruit weight (1342.0g) was recorded in accession IPS-422 (pummelo) followed by IPS-441 (oblong type citron) and lowest (35.2 g) in IPS-418 accession. Maximum variability was observed in fruit length. Highest fruit length (200 mm) was recorded in citron (IPS-441) followed by IPS-448 (177 mm). Number of segment per fruit varied from 8 to 17. Variability was also observed in peel thickness (1.43 mm to 46 mm). Acidity ranged from 0.55 % to 7.0 %. It was observed that accession (IPS-430) *Elaichi Nimbu* has highest percentage of juice (56.0%) followed by Kachai lemon 55% (IPS-452). Accession IPS-427 has highest seeds/fruit (85.0) and accession IPS-420 has lowest value for seed (3.0 seeds/fruit). These finding are in agreement with the finding of other workers (Hore

*et al.*, 1997; Singh and Sheo Govind, 1999; Sheo Govind and Singh, 2002; Singh *et al.*, 2001; Singh and Singh 2003) where they also reported wide range of variability in physico-chemical characters in fruits of different citrus species found in NEH region. The mission indicated that Manipur has maximum diversity of rough lemon, citron, *Satkara* and one wild type sweet orange. Therefore, in future collection there should be focus in bordering areas of Myanmar. In case of Tripura, maximum diversity was observed for pummelo and lemon. Therefore, in future collections in North and West Tripura only should be targeted.

#### Acknowledgements

This study was carried out under the National Agricultural Technology Project (Plant Biodiversity) of ICAR, New Delhi. Author is thankful to Dr. BS Dhillon, Director and Mission Leader, Dr. SK Pareek, Principal Investigator of the project, NBPGR, New Delhi, for their help and encouragement during the period of study.

#### References

- Bhattacharya SC and S. Dutta (1951) Citrus varieties of Assam, *Indian J. Genet.* **11**: 57-62.
- Bhattacharya SC and S Dutta (1956) *Classification of Citrus Fruits of Assam*. Sci. Monog. No. **20**, 110 p.
- Borthakur DN (1993) Plant genetic resources of the North-east. *Indian J. Hill Farmg.* **6**: 1-18.
- Dutta S (1958) Origin and history of citrus fruits of Assam. *Indian J. Hort.* **15**: 146-153.
- Ghosh SP (1977) Citrus industry of North-east India. *Punjab Hort. J.* **1 & 2**: 13-21.
- Hodgson RW, R Singh and D Singh (1963) Some little known Indian citrus species. *California Citrograph.* **48**: 188, 211-214, 228.
- Hore DK, S Govind and IP Singh (1997) Collecting of citrus germplasm from the Mizoram and Tripura hills of India. *Pl. Genet. Resour. Newsl.* **110**: 57-59.
- Kaul GL (1981) Development of horticulture in Northeastern region - A case study of North Cachar District. NEC Secretariat, Shilling, Meghalaya.
- Sarkar AN (1994) Resource potential and biodiversity of North eastern region. *J. Hill Farmg.* **7(1)**: 11-21.
- Sheo Govind and IP Singh (2002) Evaluation of citrus germplasm in North Eastern Hill region. *Indian J. Pl. Genet. Resour.* **15**: 19-22.
- Sheo Govind and DS Yadav (1999) Genetic resources of citrus in North eastern hill region of India. In: *Hi-Tech Citrus Management*, Shyam Singh and S.P. Ghosh (eds), Indian Society of Citriculture, NRC for Citrus, Nagpur, pp 38-46.
- Singh B (1981) *Establishment of First Gene Sanctuary for Citrus in Garo Hills*. Concept Pub. Co., New Delhi, 182 p.
- Singh D and R Singh (1967) Taxonomic status of Indian Citrus rootstock. *Proc. Int. Symp. Subtrop. Trop. Hort.* 424.

Table 2. Characterization of citrus germplasm based on physico-chemical characteristics of fruits

| S.No. | Collector Number | Cultivars/Species                               | Fruit wt (g) | Fruit length (mm) | Fruit breadth (mm) | Peel thickness (mm) | Juice (%) | No. of segment | Seeds/ Fruit | TSS  | Acidity (%) |
|-------|------------------|-------------------------------------------------|--------------|-------------------|--------------------|---------------------|-----------|----------------|--------------|------|-------------|
| 1     | IPS-433          | Citron ( <i>C. medica</i> )                     | 348.0        | 118.0             | 77.0               | 5.0                 | 23.0      | 10.0           | 29.0         | 6.0  | 4.5         |
| 2     | IPS-436          | Heijerang ( <i>C. medica</i> )<br>var. Gandhraj | 746.0        | 200.0             | 86.0               | 7.0                 | 8.2       | 10.0           | 37.0         | 7.0  | 3.10        |
| 3     | IPS-438          | Citron ( <i>C. medica</i> )                     | 139.0        | 88.0              | 55.0               | 4.0                 | 10.0      | 9.0            | 36.0         | 8.0  | 4.2         |
| 4     | IPS-441          | Citron ( <i>C. medica</i> )                     | 1076.0       | 200.0             | 112.0              | 46.0                | 6.2       | 10.0           | 43.0         | 7.0  | 1.20        |
| 5     | IPS-446          | Citron ( <i>C. medica</i> )                     | 343.0        | 137.0             | 70.0               | 18.0                | 4.0       | 12.0           | 19.0         | 8.0  | 2.40        |
| 6     | IPS-448          | Heijrang ( <i>C. medica</i> )                   | 622.0        | 177.0             | 88.0               | 23.0                | 4.6       | 9.0            | 66.0         | 8.0  | 2.4         |
| 7     | IPS-449          | Citron ( <i>C. medica</i> )                     | 616.0        | 122.0             | 99.0               | 15.0                | 22.0      | 11.0           | 9.0          | 7.0  | 8.8         |
| 8     | IPS-423          | Citron ( <i>C. medica</i> )                     | 177.0        | 88.0              | 67.0               | 5.4                 | 41.0      | 10.0           | 48.0         | 6.0  | 4.44        |
| 9     | IPS-424          | Citron ( <i>C. medica</i> )                     | 79.0         | 56.0              | 50.0               | 3.8                 | 31.0      | 11.0           | 8.0          | 7.0  | 5.10        |
| 10    | IPS-421          | Pati Nimboo ( <i>C. medica</i> )                | 197.0        | 89.0              | 70.4               | 7.2                 | 29.0      | 10.0           | 13           | 5.2  | 3.2         |
| 11    | IPS-437          | Heiribob ( <i>C. macroptera</i> )               | 398.0        | 84.0              | 101.0              | 7.0                 | 41.0      | 14.0           | 16.0         | 8.8  | 6.4         |
| 12    | IPS-434          | Rough lemon ( <i>C. jambhiri</i> )              | 218.0        | 80.0              | 80.0               | 4.0                 | 37.0      | 10.0           | 25.0         | 8.0  | 3.73        |
| 13    | IPS-435          | Gole nimbu ( <i>C. jambhiri</i> )               | 36.0         | 39.0              | 41.0               | 1.7                 | 32.0      | 8.0            | 7.0          | 8.0  | 2.88        |
| 14    | IPS-439          | Sindhuritenga ( <i>C. jambhiri</i> )            | 180.0        | 70.0              | 71.0               | 5.0                 | 21.0      | 10.0           | 19.0         | 8.0  | 3.90        |
| 15    | IPS-440          | Gol nimbu ( <i>C. jambhiri</i> )                | 40.0         | 41.0              | 40.0               | 3.0                 | 32.0      | 9.0            | 5.0          | 9.0  | 3.30        |
| 16    | IPS-442          | Gol nimbu ( <i>C. jambhiri</i> )                | 42.0         | 44.0              | 41.0               | 2.5                 | 25.0      | 8.0            | 14.0         | 7.0  | 4.5         |
| 17    | IPS-443          | Rough lemon ( <i>C. jambhiri</i> )              | 86.0         | 55.0              | 54.0               | 2.3                 | 44.0      | 9.0            | 15.0         | 9.0  | 4.8         |
| 18    | IPS-444          | Rough lemon ( <i>C. jambhiri</i> )              | 103.0        | 57.0              | 56.0               | 2.0                 | 40.0      | 9.0            | 7.0          | 8.5  | 5.6         |
| 19    | IPS-450          | Rough lemon ( <i>C. jambhiri</i> )              | 123.0        | 64.0              | 61.0               | 3.0                 | 50.0      | 8.0            | 18.0         | 7.0  | 4.13        |
| 20    | IPS-451          | Kata jamir ( <i>C. jambhiri</i> )               | 39.0         | 42.0              | 41.0               | 3.0                 | 26.0      | 9.0            | 10.0         | 6.0  | 4.1         |
| 21    | IPS-452          | Kachai lemon ( <i>C. jambhiri</i> )             | 98.0         | 53.0              | 57.0               | 2.0                 | 55.0      | 9.0            | 17.0         | 7.4  | 4.4         |
| 22    | IPS-453          | Rough lemon ( <i>C. jambhiri</i> )              | 67.0         | 52.0              | 48.0               | 3.5                 | 21.0      | 10.0           | 21.0         | 7.0  | 4.4         |
| 23    | IPS-445          | Khasi mandarin ( <i>C. reticulata</i> )         | 97.0         | 52.0              | 59.0               | 2.0                 | 44.5      | 9.0            | 14.0         | 10.0 | 0.8         |
| 24    | IPS-454          | Khasi mandarin ( <i>C. reticulata</i> )         | 91.0         | 57.0              | 62.0               | 3.0                 | 43.0      | 10.0           | 11.0         | 9.0  | 0.72        |
| 25    | IPS-425          | Khasi mandarin ( <i>C. reticulata</i> )         | 176.0        | 59.0              | 73.0               | 2.0                 | 46.0      | 12.0           | 23.0         | 10.0 | 0.89        |
| 26    | IPS-447          | Haithumb ( <i>C. sinensis</i> )                 | 389.0        | 64.0              | 74.0               | 3.0                 | 53.0      | 11.0           | 20.0         | 9.0  | 1.68        |
| 27    | IPS-418          | Kagzi lime ( <i>C. aurantifolia</i> )           | 35.2         | 42.0              | 35.0               | 1.43                | 37.8      | 12.0           | 11.0         | 6.8  | 5.12        |
| 28    | IPS-422          | Pummelo ( <i>C. grandis</i> )                   | 1342.0       | 130.0             | 155.0              | 23.0                | 21.0      | 13.0           | 35.0         | 8.0  | 0.96        |
| 29    | IPS-455          | Pummelo ( <i>C. grandis</i> )                   | 1074.0       | 126.0             | 134.0              | 18.0                | 12.0      | 17.0           | 68.0         | 9.0  | 1.7         |
| 30    | IPS-416          | Pummelo ( <i>C. grandis</i> )                   | 927.4        | 60.2              | 64.0               | 13.0                | 29.5      | 14.0           | 23.0         | 9.75 | 1.10        |
| 31    | IPS-417          | Pummelo ( <i>C. grandis</i> )                   | 1060.0       | 148.0             | 153.0              | 20.0                | 16.0      | 13.0           | 32           | 8.5  | 0.64        |
| 32    | IPS-427          | Pummelo ( <i>C. grandis</i> )                   | 878.0        | 123.0             | 122.0              | 10.0                | 27.0      | 14.0           | 85.0         | 7.8  | 1.1         |
| 33    | IPS-419          | Pummelo ( <i>C. grandis</i> )                   | 720.4        | 113.0             | 109.5              | 9.0                 | 40.0      | 12.0           | 16.0         | 8.1  | 0.96        |
| 34    | IPS-432          | Pummelo ( <i>C. grandis</i> )                   | 700.0        | 99.0              | 111.0              | 8.0                 | 41.0      | 15.0           | 43.0         | 10.0 | 0.55        |
| 35    | IPS-420          | Elaichi Nimboo ( <i>C. limon</i> )              | 264.0        | 89.0              | 71.0               | 6.3                 | 44.0      | 11.0           | 3.0          | 6.5  | 4.10        |
| 36    | IPS-426          | Elaichi Nimboo ( <i>C. limon</i> )              | 226.0        | 73.0              | 73.0               | 4.0                 | 52.0      | 13.0           | 42.0         | 6.0  | 7.0         |
| 37    | IPS-428          | Elaichi Nimboo ( <i>C. limon</i> )              | 288.0        | 112.0             | 68.0               | 3.8                 | 50.0      | 10.0           | 23.0         | 6.0  | 5.1         |
| 38    | IPS-429          | Elaichi Nimboo ( <i>C. limon</i> )              | 142.0        | 68.0              | 63.0               | 5.7                 | 26.0      | 13.0           | 4.0          | 5.3  | 4.1         |
| 39    | IPS-430          | Elaichi Nimboo ( <i>C. limon</i> )              | 135.0        | 64.0              | 64.0               | 5.6                 | 56.0      | 12.0           | 4.0          | 5.4  | 2.6         |
| 40    | IPS-431          | Elaichi Nimboo ( <i>C. limon</i> )              | 151.0        | 84.0              | 59.0               | 4.1                 | 24.0      | 12.0           | 45.0         | 5.8  | 5.1         |

Singh D and R Singh (1968) Taxonomy of Indian rough lemon. *Indian J. Agric. Sci.* 38: 25-37.

Singh HP and KL Chadha (1993) Genetic resources of citrus. In *Advances in Horticulture Vol. 1- Fruit crops Part I*, KL Chadha and OP Pareek (eds) Malhotra Publishing House, New Delhi, pp.95-121.

Singh IP and Sheo Govind (1999) Variability in physico-chemical characteristics of indigenous citrus species/landraces of NEH region of India. In: Shyam Singh and SP Ghosh (eds), *Hi-Tech Citrus Management*, Indian Society of Citriculture, NRC for Citrus, Nagpur, pp. 91-96.

Singh IP and Awtar Singh (2001) Citrus germplasm and its utility. In: Shyam Singh and SAMH Naqvi (eds) Citrus, International Book Distributing Co. Lucknow, India, pp. 45-66.

Singh IP and Shyam Singh (2003) *Exploration collection and mapping of citrus genetic diversity in India*. Technical Bulletin No.7, NRC for Citrus, Nagpur, 230 p.

Singh IP, Shyam Singh, K Singh and R Srivastava (2001) Exploration and collection of citrus germplasm from NEH region (Meghalaya) of India. *Indian J. Pl. Genet. Resour.* 14: 70-73.

Singh R (1977) Indigenous citrus germplasm in India. In: GS Nijjar (ed.) *Fruit Breeding in India* Oxford IBH Publ. Co., New Delhi, pp. 39-49.

Tanaka T (1937) Further revision of *Rutaceae auranitoidae* of India and Ceylon. *J. Bot. Soc.*

Tanaka T (1958) The origin and dispersal of citrus fruits having their centre of origin in India. *Indian J. Hort.* 15: 101-115.

Vavilov NI (1940) Origin of cultivated plant. *Chron. Botanical*

## Genetic Variability in *Chenopodium*

Atul Bhargava, Sudhir Shukla and Deepak Ohri

Division of Genetics and Plant Breeding, National Botanical Research Institute, Lucknow-226 001, Uttar Pradesh

Coefficient of variability and genetic gain for seed yield and its 10 contributing traits was worked out in 44 germplasm lines of *Chenopodium* spp. in the year 2000-2001 at National Botanical Research Institute, Lucknow. Seed yield/plant ranged from 2.17-97.97 g with an average yield of  $34.99 \pm 1.18$  while leaf size ranged from 1.42-178.77 cm<sup>2</sup> indicating great diversity among the strains involved in the present study for these traits. Phenotypic coefficient of variation and genotypic coefficient of variation was maximum for leaf size, followed by dry weight of plant and 100 seed weight. The heritability estimates were high for all the traits, which also confirmed a great amount of variation in the lines under study. Genetic gain was high for all the traits except days to flowering and days to maturity, which indicated that all the traits were mainly governed by additive gene effects. A breeding plan was discussed to enhance the yield potential.

**Key Words:** Additive Gene, *Chenopodium*, Coefficient of Variability, Genetic gain, Heritability.

### Introduction

*Chenopodium* spp. are being cultivated since centuries as a subsidiary crop, especially as leafy vegetable (*C. album*) (Singh, 1961) as well as for grain (*C. quinoa*). It can be grown under various agroclimatic situations ranging from tropical to temperate zones. The potherb is a cheap and rich source of carotenoids (78-190 mg/kg) (Prakash *et al.*, 1993). *Chenopodium quinoa* is native to the Andean region and is adapted to problems of stoniness, poor or excessively free drainage and can be cultivated in soils having a pH of 4.8 to 8.5 (Tapia, 1979). The nutritional value of quinoa seeds has been known for a long time to be superior to traditional cereals. The seeds have a protein content of 10-18%, fat content of 4.1-8.8% and traces of starch, ash and crude fibre (DeBruin, 1964). Calcium and iron are significantly higher in quinoa than in rice, maize, wheat or oats (White *et al.*, 1955; DeBruin, 1964). The seed proteins have a balanced amino acid spectrum with high lysine (5.1-6.4%) and methionine (0.4-1.00%) contents (Prakash and Pal, 1998). In spite of its great potential, no systematic studies on various genetical aspects have been conducted. Hence an attempt has been made to initiate a crop-breeding programme on *Chenopodium* spp. The knowledge of the magnitude of variation in the available germplasm, interdependence of quantitative characters, extent of environmental influence on these factors, heritability and genetic gain in the genotypes are the prerequisite aspects for any crop-breeding programme. The present investigation was carried out to study different selection parameters in the available germplasm lines belonging to different species of *Chenopodium*.

### Materials and Methods

The present investigation consisted of 44 germplasm lines of *Chenopodium* spp. of exotic and indigenous origin which included one entry each of seven spp. of *Chenopodium* namely *C. bushianum*, *C. amaranticolor*, *C. murale*, *C. opulifolium*, *C. strictum*, *C. berlandieri*, *C. ugandae* and 2 entries of *C. giganteum*, 10 lines of *C. quinoa*, 23 lines of *C. album* and two selections from 2 separate cross progenies (Table 1). The germplasm lines were selected to ensure adequate representation of germplasm lines of different ploidy levels as well as the whole distributional range of the genus. The seeds were sown in randomized block design with 3 replications in the year 2000-2001 at the experimental field of National Botanical Research Institute, Lucknow. Two rows of each entry were sown with crop geometry of 45 x 15 cm<sup>2</sup> row-to-row and plant-to-plant distance respectively. Five plants from each replication were randomly selected and data for 11 characters viz. days to flowering, days to maturity, plant height (cm), leaf size (cm<sup>2</sup>), stem diameter (cm), number of primary branches/plant, inflorescence length (cm), 100 seed weight (g), dry weight of plant (g), number of inflorescence/plant and seed yield/plant (g) were recorded. Analysis of variance for each trait was done according to Panse and Sukhatme (1978) and phenotypic and genotypic coefficient of variation (PCV and GCV), heritability in broad sense and genetic advance were computed following Singh and Chaudhary (1985) and Johnson *et al.* (1955).

### Results and Discussion

The analysis of variance exhibited significant differences among the strains for all the traits (Table 2) indicating

Table 1: Germplasm lines, their source, chromosome number and ploidy level

| S. No. | Name of germplasm line                           | Source               | Chromosome number | Ploidy |
|--------|--------------------------------------------------|----------------------|-------------------|--------|
| 1.     | <i>C. album</i> PRC 9801                         | India                | -                 | -      |
| 2.     | <i>C. album</i> PRC 9803                         | India                | -                 | -      |
| 3.     | <i>C. album</i> PRC 9804                         | India                | -                 | -      |
| 4.     | <i>C. album</i> PRC 9802                         | India                | -                 | -      |
| 5.     | <i>C. album</i> IC 107295                        | India                | -                 | -      |
| 6.     | <i>C. album</i> IC 107297                        | India                | -                 | -      |
| 7.     | <i>C. album</i> IC 107299                        | India                | -                 | -      |
| 8.     | <i>C. album</i> IC 107296                        | India                | -                 | -      |
| 9.     | <i>C. quinoa</i> 587173                          | USDA                 | 36                | 4x     |
| 10.    | <i>C. album</i> local 2x Red                     | India                | 18                | 2x     |
| 11.    | <i>C. bushianum</i> 22376                        | USDA                 | 36                | 4x     |
| 12.    | <i>C. album</i> IOWA                             | IOWA, USA            | 54                | 6x     |
| 13.    | <i>C. album</i> H.P                              | India                | 54                | 6x     |
| 14.    | <i>C. quinoa</i> 510537                          | USDA                 | 36                | 4x     |
| 15.    | <i>C. quinoa</i> CHEN 92/91                      | Gatersleben, Germany | 36                | 4x     |
| 16.    | Progenitor of quinoa                             | Mexico               | 36                | 4x     |
| 17.    | <i>C. quinoa</i> 478414                          | USDA                 | 36                | 4x     |
| 18.    | <i>C. album</i> (local) x <i>C. quinoa</i>       | Hybrid               | 54                | 6x     |
| 19.    | <i>C. quinoa</i> 584524                          | USDA                 | 36                | 4x     |
| 20.    | <i>C. amaranticolor</i>                          | India                | 54                | 6x     |
| 21.    | <i>C. album</i> Mexico                           | Mexico               | 36                | 4x     |
| 22.    | <i>C. album</i> x <i>C. album</i> Siliguri       | Hybrid               | 18                | 2x     |
| 23.    | <i>C. album</i> 'Siliguri'                       | India                | 18                | 2x     |
| 24.    | <i>C. quinoa</i> 596498                          | USDA                 | 36                | 4x     |
| 25.    | <i>C. quinoa</i> 22158                           | USDA                 | 36                | 4x     |
| 26.    | <i>C. album</i> 'chandanbathua'                  | India                | 18                | 2x     |
| 27.    | <i>C. quinoa</i> CHEN 67/78                      | Gatersleben, Germany | 36                | 4x     |
| 28.    | <i>C. album amaranticolor</i>                    | India                | 54                | 6x     |
| 29.    | <i>C. quinoa</i> CHEN 71/78                      | Gatersleben, Germany | 36                | 4x     |
| 30.    | <i>C. album</i> CHEN 60/76                       | Gatersleben, Germany | 54                | 6x     |
| 31.    | <i>C. album</i> CHEN 85/82                       | Gatersleben, Germany | 54                | 6x     |
| 32.    | <i>C. album</i> Czech                            | Czech Republic       | 54                | 6x     |
| 33.    | <i>C. album</i> x <i>C. quinoa</i> (colchipsoid) | Hybrid               | 54                | 6x     |
| 34.    | <i>C. murale</i> local                           | India                | 18                | 2x     |
| 35.    | <i>C. opulifolium</i>                            | Gatersleben, Germany | 36                | 4x     |
| 36.    | <i>C. album</i> PI 605700                        | USDA                 | 54                | 6x     |
| 37.    | <i>C. album</i> local 6x                         | India                | 54                | 6x     |
| 38.    | <i>C. giganteum</i> 596371                       | USDA                 | 54                | 6x     |
| 39.    | <i>C. giganteum</i> 596372                       | USDA                 | 54                | 6x     |
| 40.    | <i>C. album</i> local                            | India                | 18                | 2x     |
| 41.    | <i>C. strictum</i> 47/79                         | Gatersleben, Germany | 54                | 6x     |
| 42.    | <i>C. berlandieri</i> 568156                     | USDA                 | 36                | 4x     |
| 43.    | <i>C. album</i> CHEN 63/80                       | Gatersleben, Germany | 54                | 6x     |
| 44.    | <i>C. ugandae</i> 77/78                          | Gatersleben, Germany | 36                | 4x     |

a wide range of variability exists in the strains. The seed yield/plant was variable between 2.17-97.97 g with an arithmetic mean of  $34.99 \pm 1.18$ . The character leaf size showed large variation among the strains ranging from 1.42-178.77 cm<sup>2</sup>, with the arithmetic mean  $29.48 \pm 1.02$ , which suggests that strains were very diverse for this trait. However, the characters dry weight of plant and number of inflorescence/plant also had large variation in the strains and varied from 3.65-289.87 g and 39.63-742.89 with an average of  $65.36 \pm 2.56$  and  $264.12 \pm 4.80$  respectively. The inflorescence length varied from 1.47-38.16 cm with an arithmetic mean of  $17.98 \pm 0.49$ . The 100 seed weight ranged from 0.03-0.30 g with an average  $0.102 \pm 0.004$ .

The plant height and number of primary branches/plant varied from 20.55-305.00 cm and 4.20-55.33 with arithmetic mean  $150.54 \pm 2.52$  and  $28.33 \pm 0.88$  respectively. The days to flower varied from 86.00-154.67 with an average of  $109.55 \pm 1.00$ . Days to maturity ranged from 110.10-194.33 with a mean of  $143.02 \pm 1.12$ . The stem diameter varied from 0.37-2.30 cm with an average  $1.37 \pm 0.06$ .

The PCV and GCV was maximum for leaf size followed by dry weight of plant and 100 seed weight (Table 2). The PCV had marginally higher estimate than corresponding GCV for all the traits, which indicates that the variability was primarily due to genotypic component.

Table 2: Genetic variability, heritability and genetic advance for different traits in *Chenopodium* spp.

| Characters                    | F Value<br>± SE   | Mean             | Range             | s <sup>2</sup> g | s <sup>2</sup> p | s <sup>2</sup> e | GCV    | PCV    | Heritability<br>(%) | Genetic<br>advance | Genetic<br>advance (%) |
|-------------------------------|-------------------|------------------|-------------------|------------------|------------------|------------------|--------|--------|---------------------|--------------------|------------------------|
| Days to<br>flowering          | 663.77            | 109.55<br>± 1.00 | 86.00-<br>154.67  | 336.11           | 337.64           | 1.52             | 16.73  | 16.77  | 99.5                | 37.68              | 34.40                  |
| Days to<br>maturity           | 835.45            | 143.02<br>± 1.12 | 110.10-<br>194.33 | 527.48           | 529.38           | 1.90             | 16.06  | 16.09  | 99.6                | 47.23              | 33.02                  |
| Plant height<br>(cm)          | 2635.50           | 150.54<br>± 2.52 | 20.55-<br>305.00  | 8355.18          | 8364.70          | 9.51             | 60.72  | 60.75  | 99.9                | 188.19             | 125.01                 |
| Leaf size (cm <sup>2</sup> )  | 2356.75<br>± 1.02 | 29.48<br>178.77  | 1.42-             | 1217.94          | 1219.49          | 1.55             | 118.39 | 118.47 | 99.9                | 71.85              | 243.73                 |
| Stem diameter<br>(cm)         | 145.74            | 1.37<br>± 0.06   | 0.37-<br>2.30     | 0.26             | 0.27             | 0.005            | 37.29  | 37.67  | 98.0                | 1.04               | 76.03                  |
| Number of<br>primary branches | 372.98            | 28.33<br>± 0.88  | 4.20-<br>55.33    | 146.74           | 147.93           | 1.18             | 42.76  | 42.93  | 99.2                | 24.85              | 87.73                  |
| Inflorescence<br>length (cm)  | 1152.30           | 17.98<br>± 0.49  | 1.47-<br>38.16    | 135.94           | 136.29           | 0.35             | 64.85  | 64.93  | 99.7                | 23.99              | 133.41                 |
| 100 Seed<br>weight (g)        | 951.92            | 0.102<br>± 0.004 | 0.03-<br>0.30     | 0.006            | 0.006            | 0.00             | 77.31  | 77.44  | 99.7                | 0.16               | 159.02                 |
| Dry weight<br>of plant (g)    | 1301.10           | 65.36<br>± 2.56  | 3.65-<br>289.87   | 4257.49          | 4267.32          | 9.82             | 99.83  | 99.95  | 99.8                | 134.26             | 205.42                 |
| Number of<br>inflorescence    | 3203.30           | 264.12<br>± 4.80 | 39.63-<br>742.89  | 36892.41         | 36926.97         | 34.56            | 72.72  | 72.76  | 99.9                | 395.49             | 149.74                 |
| Seed yield (g)                | 949.36<br>± 1.18  | 34.99<br>97.97   | 2.17-             | 656.11           | 658.19           | 2.07             | 73.19  | 73.31  | 99.7                | 52.68              | 150.53                 |

s<sup>2</sup>g = Genotypic variance, s<sup>2</sup>p = Phenotypic variance, s<sup>2</sup>e = Environmental variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation

The characters days to flower and days to maturity showed low estimates for PCV and GCV indicating that these traits had less scope towards improvement of yield through selection. To determine the heritable portion of variation, consideration of heritability estimates are necessary. The heritability estimates in broad sense were very high for all the characters and ranged from 99.20-99.90% (Table 2) suggesting that substantial improvement can be made using standard selection techniques. High heritability alone does not guarantee large gain through selection unless sufficient genetic advance attributable to additive gene action is present. Hence, heritability in conjunction with the estimates of genetic advance is more useful in isolating superior genotypes. The values of genetic gain were highest for leaf size (243.73%), followed by dry weight of plant (205.42%) and 100 seed weight (159.02%) (Table 2). The values of genetic advance above 100% obtained in some of the characters are due to the extreme variations present among the genotypes as evident since the genotypes belong to distinct species and are of different geographical origin. High heritability coupled with high values of genetic advance and genotypic coefficient of variation for most of the traits suggest that additive gene action played an important role for these traits. This study concludes that selection based on phenotypic performance (mass selection) for the traits namely leaf size, dry weight of plant and seed weight would be more rewarding for achieving desired

gain in grain yield. Besides this, it is pertinent to discuss the crossability and the breeding potential both within and among the species. In the present study, the lines belonging to *C. quinoa*, *C. album*, and most of the species are cross compatible among themselves. Also the diploid cytotype of *C. album* found in North India is intercrossable with *C. quinoa* and the hexaploid obtained through colchicine treatment of the resultant triploid is fully fertile (Wilson 1980; Personal Communication by Dr. M Pal).

#### Acknowledgements

The authors are thankful to the Director NBRI, Lucknow for providing the facilities and constant encouragement to carry out the present investigation. CSIR, New Delhi is duly acknowledged for providing financial assistance.

#### References

- DeBruin A (1964) Investigation of the food value of quinoa and canihua seed. *J. Food Sci.* **29**: 872-876.
- Johnson HW, HF Robinson and RE Comstock (1955) Genotypic and phenotypic correlation in soybean and their implication in selection. *Agronomy J.* **47**: 477-485.
- Panse VG and PV Sukhatme (1978) *Statistical Methods for Agricultural Workers*. ICAR, New Delhi.
- Prakash D, P Nath and M Pal (1993) Composition, variation of nutritional contents in leaves, seed protein, fat and fatty acid profile of *Chenopodium* species. *Intern. J. Food Sci. Agric.* **62**: 203-205.
- Prakash D and M Pal (1998) *Chenopodium*: seed protein, fractionation and amino acid composition. *Intern. J. Food Sci. Nutrition* **49**: 271-275.

- Singh H (1961) *Grain Amaranthus, Buckwheat and Chenopods*, Res. Cereal Crop. Ser. No. 1. Indian Council of Agriculture, New Delhi, India.
- Singh RK and BD Chaudhary (1985) *Biometrical Methods in Quantitative Genetic Analysis*. 3rd Edn., Kalyani publishers, New Delhi.
- Tapia ME (1979) Historia y Distribucion geographica. In ME Tapia (ed.) *Quinoa y Kaniwa*. Cultivos Andinos, Serie Libros y Materiales Educativos No. 49, pp. 11-15. Instituto Interamericano de Ciencias Agricolas, 'Bogota', Colombia.
- White PL, E Alvistur, C Dias, E Vinas, HS White and C Collazos (1955) Nutrient content and protein quality of quinoa and canihua, edible seed products of the Andes mountains. *J. Agr. Food Chem.* **3**: 531-534.
- Wilson HD (1980) Artificial hybridization among species of *Chenopodium* sect. *Chenopodium*. *Syst. Bot.* **5**: 253-263.

## Important Information Systems for Plant Genetic Resources in the World

**RC Agrawal**

*National Bureau of Plant Genetic Resources, New Delhi-110 012*

One of the major challenges for food security in the next generation is the effective management of plant genetic resources worldwide. Thus, documentation of plant genetic resources becomes very important at the national, regional and global levels for effective conservation of rapidly disappearing genetic stocks for possible future use and also for immediate utilization of already conserved and evaluated/characterized germplasm in the on going crop improvement programmes. In the present article, an attempt has been made to compile the list of some of the most important web sites related to issues, databases, availability and information systems of plant genetic resources.

**Key Words:** Databases, Information System, Plant Genetic Resources, Taxonomic databases, Web sites

Plant genetic resources (PGR) for food and agriculture consists of the diversity of genetic material contained in traditional varieties and modern cultivars grown by farmers as well as wild relatives of crops and other wild plant species that can be used for food, feed fiber, clothing, shelter, wood/timber, energy, etc. One of the major challenges for food security in the next generation is the effective management of PGR worldwide. Thus, documentation of PGR becomes very important at the national, regional and global levels to effective conservation of rapidly disappearing genetic stocks for possible future use and also for immediate utilization of already conserved and evaluated/characterized germplasm in the ongoing crop improvement programmes. The recent advancement in information technology especially two activities namely development of databases and the internet has led to an explosion in the compilation and collation of information in all fields, including PGR. This wealth of information available in the world wide web through the internet is searchable using various search engines such as *www.google.com*, *www.altavista.com*, *www.yahoo.com*, etc. However, when specific information is required by scientists, policy makers, teachers etc. for a specific topic such as PGR management, it would be helpful to have a ready reference to the varied information sources on the internet, rather than the cumbersome search through a search engine.

Thus information on the important institutes, organizations, working groups dealing with PGR has been compiled along with their exact web addresses, important objectives and the type of information available on each of these sites. It is hoped that this compilation would serve as a ready reckoner for all PGR workers.

### A. International/Regional Databases and Information Sites

#### 1. *World Information and Early Warning System (WIEWS) on PGR* (<http://apps3.fao.org/wiews/wiews.jsp>)

The WIEWS website is hosted by FAO World Agricultural Information Centre (WAICENT) presently consists of a number of relational databases, resulting from direct contributions from Member Countries and from routinely (e.g. World Seed Review; data gathering from publications; etc.) and event-related data collating activities (e.g. Country reports for the IV International Technical Conference on PGR; Regional Meetings; etc.) carried out by AGPS staff; a Global Network of Country Correspondents on PGRFA Information Exchange, officially nominated by the Governments (for India it is the author); a repository directory of documents and proceedings related to: the activities of the Global Network on PGRFA Information Exchange; the Early Warning System on Genetic Erosion; and the Global Plan of Action for the conservation and sustainable utilisation of PGRFA (GPA).

Among WIEWS and SIS relational databases, there are:

- the Country Profiles database, including the structure of 190 national PGR programmes and activities;
- the *Ex-situ* Collection database, containing summary records of PGR holdings (more than 5 million accessions belonging to more than 18,000 species) reported by more than 1,500 national, regional or international genebanks;
- the PGRFA and Seed Laws and Regulations database (70 countries);

- the World List of Seed Sources database (approx. 8,000 entries from 150 countries); and
- The List of Crop Varieties database (about 65,000 varieties from 1,249 cultivated crops).

2. **CGIAR System-wide Information Network for Genetic Resources (SINGER)** (<http://singer.grinfo.net/>)

The CGIAR System-wide Information Network for Genetic Resources (SINGER) is the genetic resources information exchange network of the Centres of the Consultative Group on International Agricultural Research (CGIAR). It provides access to information on the collections of genetic resources held by the CGIAR Centres. Together, these collections comprise over half a million samples of crop, forage and tree germplasm of major importance for food and agriculture.

SINGER links the genetic resources databases of the CGIAR Centres and allows simultaneous searches for information concerning the identity, source, characteristics and transfer of the genetic resources in the individual Centre collections.

3. **Commission on Genetic Resources for Food and Agriculture (CGRFA)** (<http://www.fao.org/WAICENT/FAOINFO/AGRICULT/cgrfa/>)

The FAO Commission on Genetic Resources for Food and Agriculture (CGRFA) is a permanent forum for governments to discuss and negotiate these matters. Its main objectives are to ensure the conservation and sustainable and fair utilization of genetic resources in food and agriculture. Membership is open to all FAO members and associate members, on request. The site has information about the aims and activities of the CGRFA, documents published by the commission, (in PDF, requiring Adobe Acrobat Reader), and specific information on global strategies for animal and plant genetic resources. The site is available in English, French and Spanish, but some documents are available only in English.

4. **Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture** (<http://www.fao.org/WAICENT/FaoInfo/Agricult/AGP/AGPS/GpaEN/gpatoc.htm>)

The Global Plan of Action for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture, as adopted by 150 countries at the International Technical Conference. It contains 20 priority activities grouped in four theme areas:

- *In situ* conservation and development

- *Ex situ* conservation
- Use of Plant Genetic Resources
- Institution and capacity building

The following information is categorized in this site-

- Global Plan of Action
- State of the World
- Global system
- International Technical Conference

5. **International Undertaking on Plant Genetic Resources for Food and Agriculture** (<http://www.fao.org/ag/cgrfa/IU.htm>)

The International Undertaking was the first comprehensive international agreement dealing with plant genetic resources for food and agriculture. It was adopted by the FAO Conference in 1983 (Resolution 8/83), as an instrument to promote international harmony in matters regarding access to plant genetic resources for food and agriculture. This complete text of the 1983 undertaking and the information about the negotiations for the revision of the international undertaking is also available on this site.

6. **International Plant Genetic Resources Institute** (<http://www.ipgri.cgiar.org/>)

The International Plant Genetic Resources Institute (IPGRI) was established in 1975 and is one of the 16 research centres which come under the Consultative Group on International Agricultural Research (CGIAR). Details are provided about IPGRI, its aims and activities. Information on the research programmes currently undertaken by IPGRI is available. A collection of online information resources is provided and include germplasm databases, training materials and publications. Many training materials and IPGRI publications are in PDF format and can be downloaded and viewed online. All IPGRI online materials are available in English but some can also be viewed in French and Spanish. Press releases and topical news articles and reports are also provided on this site.

7. **The International Treaty on Plant Genetic Resources for Food and Agriculture** (<http://www.fao.org/ag/cgrfa/itpgr.htm>)

This site gives the details in the following categories.

- Official versions of the Treaty
- Video on the Treaty
- Signatures and ratifications
- Comments on compliance
- Funding Strategy

- Questionnaire
- Background Study
- Paper on Compliance

8. ***The International Union for the Protection of New Varieties of Plants (UPOV)*** ([www.upov.int](http://www.upov.int))

The UPOV is an intergovernmental organization with headquarters in Geneva. This site has provision to download all the documents related to various meetings and technical committees of UPOV. It gives a comprehensive coverage of all the news, calendar of events, archives, list of publication etc.

9. ***IPGRI Directory of Germplasm Collections*** (<http://web.ipgri.cgiar.org/germplasm/default.asp>)

IPGRI maintains a number of databases with summary information on *ex situ* germplasm collections worldwide. The data include address information on organizations holding germplasm and summary information on the type of germplasm that is maintained, such as: species names, number of accessions per species, type of accessions, etc. Currently, summary information on more than 5 million accessions worldwide is available. IPGRI attempts to keep these databases up to date by continuously incorporating new information. The updating and collation of *ex situ* germplasm holding data is done in close collaboration with FAO which provides a similar type of data as part of its World Information and Early Warning System (WIEWS). Synchronization of common data types is achieved through bi-monthly data exchange.

10. ***CIAT database on plant genetic resources*** (<http://www.ciat.cgiar.org/pgri/>)

The Genetic Resources Unit (GRU) contains 60,000 accessions (samples of seeds and other reproductive plant materials), mostly unimproved landraces. Representing 720 species, this germplasm is documented in bean, cassava, and forage databases, from which users can generate reports on selected accessions in the collections.

11. ***International and Regional Crop-related Networks Supported By FAO*** (<http://www.fao.org/WAICENT/FaoInfo/Agricult/AGP/AGPS/cnet.htm>)

The International Agreement on Genebanks for the network of *ex situ* collections and the links to individual crop-related networks under the auspices of FAO can be found on this site.

12. ***International neem network*** (<http://www.fao.org/forestry/foris/webview/forestry2/index.jsp?siteId=2021&langId=1>)

The International neem network is made up of national institutions from 23 countries under the overall coordination of FAO's Forestry Department. It focuses its work on exploring and evaluating the genetic diversity of the neem (*Azadirachta indica*) tree. The Web site gives details of the organization and activities of the network, including workshops, and publications by the network (most of which are available online) and others.

13. ***Seed and Plant Genetic Resources Service: AGPS*** (<http://www.fao.org/waicent/faoinfo/agricult/AGP/AGPS/>)

A Service of the FAO's Plant Production and Protection Division, the AGPS provides technical and policy advice on plant genetic resources conservation and use, seed and planting materials improvement, and production, including seed security. This site provides information about the Service, its aims and activities. Access is provided to several online databases, namely World Seed Review, World List of Seed Sources, and Olive Germplasm, Cultivars and World-Wide Collections. Information about AGPS publications is available. Information, and in some cases links, to crop-related networks supported by the FAO is provided. News and events of relevance to the AGPS is available as is a collection of links to useful Web sites.

14. ***Genetic Resources Action International (GRAIN)*** (<http://www.grain.org>)

It is a comprehensive and very rich web site providing information and views on issues related to PGR, biodiversity, environment and other issues related to the subjects.

15. ***The Convention on Biological Diversity*** (<http://www.biodiv.org>)

- The information about the Convention, the Biosafety Protocol, Programmes and Issues,
- Clearing-House Mechanism, CBD Information Centre, Public Participation, Press Room
- Discussion Forums, Secretariat, Divisions, Opportunities, Quarterly Reports and the information about the latest notification is available on this CBD Site.

16. ***Plant Genetic Resources Abstracts*** (<http://www.cabi-publishing.org/AbstractDatabases.asp?SubjectArea=&PID=46>)

Plant Genetic Resources Abstracts is a fully searchable abstracts database of internationally published research. Derived from the CAB Abstracts database, PGRA provides

the latest information on the genetic resources of all plant species of economic value and their wild relatives. This includes their taxonomy and evolution, biotechnology, genetic diversity, conservation, ethnobotany, gene banks, characterization and utilization. Information is also included on quarantine issues related to germplasm exchange.

Each week Plant Genetic Resources Abstracts delivers all the new highly-targeted, searchable summaries comprehensively covering key English and non-English language journal articles, reports, conferences and books on plant genetic resources. Over 2,500 records are added to the database annually.

Plant Genetic Resources Abstracts Online includes a fully searchable 10-year backfile of nearly 34,000 records and brings a wealth of current and seminal research in this subject area.

The search is divided in following main categories-

- Genetic resources, general aspects
- Taxonomy, evolution and origin
- Genetic diversity
- Conservation
- Local and traditional uses of genetic resources
- Biotechnology
- Gene banks, documentation and information management
- Germplasm characterization and evaluation
- Germplasm enhancement and utilization
- Plant health, quarantine and safe movement of germplasm

Plant Genetic Resources Abstracts is updated weekly online, it is also available quarterly in print.

## B. National Databases

### 1. *Federal Information System on Genetic Resources (BIG)* ([http://www.big-flora.de/index\\_e.html](http://www.big-flora.de/index_e.html))

The Federal Information System Genetic Resources (BIG) integrates relevant data on genetic resources for cultivated and wild flora in Germany by establishing a set of related internet databases. Four partner institutions with extensive databases on wild and cultivated plants are jointly developing the Bundes Informations system Genetische Ressourcen (Federal Information System on Genetic Resources – BIG) as an on-line system for the internet.

- (i) The Federal Office for Nature Conservation (Bundesamt für Naturschutz - BfN) in Bonn collects

databases on variety inventories (*in situ*), distributions, populations and the ecology of native wild plants as well as information on the conservation and trade of varieties protected by national and international law (<http://www.bfn.de/>).

It provides the following database-

- Information Network Plants and Vegetation (FloraWeb)
- Distribution data and situation of the population (FLORKART)
- Information on endangerment: federal and state Red Lists
- Taxonomy und systematics
- Information on distribution (spatial) Database WISIA (Scientific Information System in Species Protection)
- Protection status of species appearing in trade according to international and national agreements and laws
- Distribution based on countries of origin

- (ii) Plant collections of botanical gardens in Germany (*ex situ*) are registered and documented by the Botanical Garden of the Ruhr-Universität Bochum (RUB) (<http://www.boga.ruhr-uni-bochum.de/>) for the Association of Botanical Gardens (Verband Botanischer Gärten) (<http://www.biologie.uni-ulm.de/verband/index.html>).

It provides the following database-

- SysTax - Botanical Garden Information System
- Data on living material from until now 18 botanical gardens
- Information from reference collections (herbaria)
- Taxonomic data (systematics/taxonomy/naming)
- Pictures
- Distributions
- Literature references

- (iii) The Institute for Plant Genetics and Crop Plant Research (Institut für Pflanzengenetik und Kulturpflanzenforschung – IPK) (<http://www.ipk-gatersleben.de/englisch>) in Gatersleben holds the database of nearly 100,000 cultivated plant accessions of the gene bank (*ex situ*) and is creating a database on “Mansfeld’s World Manual of Agricultural and Horticultural Crops” as well as working on basic questions of cultivated plants taxonomy.

It provides the following database-

- Mansfeld’s World Database of Agricultural and Horticultural Crops (Hanelt, P. and Institute of Plant

Genetics and Crop Plant Research (Eds.) 2001: Mansfeld's Encyclopedia of Agricultural and Horticultural Crops. 1-6: 3716 pp.)

- Information about taxonomy, names, synonyms, folk or common names, distribution, uses, literature on more than 6,000 cultivated plants world-wide
- Gene Bank – Search for Accessions
- Data on about 85,000 samples from the Gatersleben gene bank collection on taxonomy and origins.

(iv) The Information Centre for Biological Diversity (Informationszentrum Biologische Vielfalt - IBV) (<http://www.zadi.de/ibv/en>) of the German Centre for Documentation and Information in Agriculture (Zentralstelle für Agrardokumentation und -information - ZADI) (<http://www.zadi.de/en/index-en.htm>) in Bonn has many years of experience on Internet-based information systems and provides in addition to a number of variety-specific databases the main database on German plant genetic resources on the Internet.

It provides the following database-

- PGRDEU – Collections of Plant Genetic Resources in Germany
- Sample-related and taxonomic information on about 130,000 samples in 40 German *ex situ* collections
- FGRDEU – Forest Genetic Resources in Germany
- Information on *in situ* – and *ex situ* – conservation of forest genetic resources in Germany (more than 100 important forest trees and woody shrub species)

2. **Centre for Genetic Resources (CGN)** (<http://www.plant.wageningen-ur.nl/about/Biodiversity/Cgn/default.htm>)

The CGN maintains the Dutch genebank for plant genetic resources for food and agriculture and this site provides information on the CGN, its organisation, aims and activities. Information is provided on CGN research projects and project leader contact details are available. There is a wealth of documentation on the CGN approach to genetic resource management, covering seed handling procedures, material acquisition, seed storage facility, regeneration protocols, and information systems. The CGN holds collections of several agricultural and horticultural crops, the passport data of which can be searched online or downloaded per crop. Evaluation data is also available but can only be downloaded per trait. All downloadable datasets are provided in zipped Excel format.

3. **Danida Forest Tree Seed Centre (DFSC)** (<http://www.dfsc.dk/>)

Danida Forest Seed Centre (DFSC) is an institution under the Danish International Development Administration, providing “technical support to developing countries in the fields of procurement and handling of seed of tropical and subtropical tree species, basic tree improvement and conservation of forest gene resources.” Information is provided on their publications, research, training, seed supply services and staff.

4. **EUFORGEN Bibliography** (<http://www.ipgri.cgiar.org/networks/euforgen/biblio/select.asp>)

This online bibliography from EUFORGEN (European Forest Genetic Resources Programme) contains 1674 references, mainly to grey literature on conservation and use of forest genetic resources in Europe, but a number of articles from refereed journals are also included. It can be searched free-text or by initial letter of the title. Reference materials are held in the IPGRI (International Plant Genetic Resources Institute) library in Italy.

5. **European Vitis Database** (<http://www.dainet.de/eccdb/vitis/>)

Published on the Web by the German Centre for Documentation and Information in Agriculture (ZADI), the European Vitis Database was established as one of the objectives of the GENRES#081 project, and provides free access to European grapevine genetic resources information. The database provides access to grape “passport” information, covering grape species, holding institute, country of origin, accession name, accession number, use, and pedigree. In addition, a collection of grape images is available to view online, and photographs are organised by either plant part or accession name.

6. **GENRES #081 Vitis** (<http://www.genres.de/vitis/index.htm>)

This is the homepage for the European Network for Grapevine Genetic Resources Conservation and Characterization. Established in 1997, this is a collaborative project which aims to establish a free online database of genetic grapevine resources thereby enhancing the utilization of relevant and valuable germplasm in breeding. There are 15 partners involved in the project, all of whom are European National research institutes with a strong interest in viticulture. The site hosts 2 searchable databases which contain a range of information relating to grape

cultivars including; plant images, country of origin, holding institute, species, colour of berry and accession name. The project terminates in 2002 and provides useful information for scientists and researchers working in the field of viticulture.

**7. Greek vitis database (<http://www.biology.ucl.ac.uk/gvd/>)**

Published on the Web by the Department of Biology, University of Crete, the Greek Vitis Database aims to "present all the possible information about Greek cultivars including genetic data and ampelographic data." The Greek Vitis Database comprises 6 separate databases: Information Database, which records exhaustively all possible information about Greek cultivars; Nuclear Microsatellite Database, which provides nSSR profiles of Greek cultivars; Chloroplast Microsatellite Database, which provides cpSSR profiles of Greek cultivars; nSSR – cpSSR Database, a combined database of the two previous databases; Ampelographic Database, a descriptive database of the ampelographic characteristics of 270 cultivars; and the Rootstocks Database, which provides nSSR profiles of Vitis species and hybrids used as rootstocks. Each database can be searched separately using an individually designed search page. In addition, the site provides access to an email discussion forum, links to related sites, and a full bibliography. The database was authored by Francois Lefort and Kalliopi A. Roubelakis-Angelakis who both work at the Laboratory of Plant Physiology and Biotechnology, University of Crete.

**8. Information System on Genetic Resources: GENRES (<http://www.genres.de/genres-e.htm>)**

GENRES is an information service of the Information Centre Genetic Resources (IGR), which in turn is a Department of the German Centre for Documentation and Information in Agriculture (ZADI). Information is provided on the IGR, its aims, projects and activities. IGR databases can be accessed online and include, central crop databases, AGRDEU Living Aquatic Resources in Germany, and PGRDEU - Ex situ - Collections of Plant Genetic Resources for Food and Agriculture. GENRES provides information on German, European and International activities on conservation and the sustainable use of genetic resources, for food, agriculture and forestry. The information available relates to cultivated and wild plants, forest plants, domestic animals, aquatic resources, microorganisms, and the policy framework. The site can be searched by keyword and is available in English and German.

**9. Nordic gene bank: a plant genetics resources centre (<http://www.ngb.se/>)**

Situated in Sweden, the Nordic Gene Bank (NGB) operates as a centre for the conservation and utilization of plant genetic resources within Scandinavia. The NGB preserves species used in Nordic agriculture and horticulture and include their wild relatives. Materials are preserved in one of three ways; frozen as seed in the seedstore, held in clonal archives or preserved as mini plants in test-tubes. This site provides access to the three main NGB databases: the Taxon database which describes taxa within the mandate of the NGB; the Culton database which is an inventory of commercial and primitive cultivars of taxa within the mandate; and the Accessions database which contains information about the accessions in the NGB seedstore. In addition, access to other NGB databases which cover seed accessions of crops stored in European gene banks, and data collection on perennial plants and cultivars in Nordic botanical gardens, is provided. Summaries of NGB project reports are available online via the "Library" section of the site, which also provides access to some full-text NGB documents. Details of genebanks set up through NGB aid work in the Baltic region and Africa is available.

**10. Czech Information System on Plant Genetic Resources (EVIGEZ) (<http://genbank.vurv.cz/genetic/resources/asp2/default.htm>)**

Information system EVIGEZ has been developed since 1984 in the Research Institute of Crop Production, Prague as a special user programme for documentation of plant genetic resources in former Czechoslovakia. Since 1992 it has been used by all institutions dealing with plant genetic resources in the Czech Republic (11 institutions located in 14 places). Presently the programme runs under FoxPro environment. Documentation system EVIGEZ consists of three main data sets:

- (a) Passport data
- (b) Characterization and evaluation data (values in scale 1 - 9, estimated on the base of national descriptor lists, which are presently available for 27 crops)
- (c) Documentation of seed store in the Gene Bank

Centrally is the information held in the Gene Bank of RICP Prague and partial information is stored in crop specialized institutions, which co-operate within the "National Programme for Plant Genetic Resources Conservation and Utilisation". On-line availability is for passport data only.

11. **Information System on Plant Genetic Resources in Egypt** (<http://apps3.fao.org/wiews/Morocco/Paper3.htm>)

Most of the data on plant genetic resources are manually recorded. The National Plant Genetic Resources Unit is developing a computerized data system using "ACCESS" version 7.

The information within the database is divided into following main subjects:

- Scientific name of species (in English and Arabic).
- Morphology and general characteristic features
- Ecosystem of each species and the habitat
- Geographical distribution
- Economic importance
- Publications on each species which include information about the author, title of the paper, pages no. etc.
- Collaborators (Family Name, position, title, Institute contact, address, Tel., Fax etc.)
- Status of each species and measures has been taken for its protection
- Species within the protectorate and the name of each one
- Various protectorates and their distribution in the country, type of ecosystem and environmental conditions, people and their activities, etc.
- Other information under "Notes"

12. **BioCASE - A Biodiversity Collection Access Service for Europe** ([http://www.zadi.de/ibv/en/igr\\_projekte\\_biocase\\_en.htm](http://www.zadi.de/ibv/en/igr_projekte_biocase_en.htm))

The aim of the European project BioCASE is the development of an advanced electronic access system for biological collections. A network out of national and thematic nodes will provide integrated access to heterogeneous, distributed base data of varying completeness, quality and depth.

13. **Establishment of European Plant Genetic Resources Information Infra-Structure (EPGRIS)** (<http://www.ecpgr.cgiar.org/EPGRIS/>)

The main objective of the project (a concerted action) is to develop national inventories of passport data for *ex situ* collections of plant genetic resources and to establish an European Search Catalogue, called EURISCO to make the national inventories jointly searchable via the internet. The EU-financed project is coordinated by the Plant Research International, Centre for Genetic Resources

(CGN), Wageningen.

14. **National Plant Germplasm System of United States Department of Agriculture** (<http://www.ars-grin.gov/npgs/>)

In 1990, the U.S. Congress authorized establishment of a National Genetic Resources Program (NGRP). It is the NGRP's responsibility to: acquire, characterize, preserve, document, and distribute to scientist users germplasm of all life forms important for food and agricultural production. The Germplasm Resources Information Network (GRIN) web server provides germplasm information about plants, animals, microbes and invertebrates. This program is within the U.S. Department of Agriculture's Agricultural Research Service.

This site proves the user with a very good search facility for the germplasm and also the on line request for the germplasm can be registered. The following types of queries can be executed from this website-

- Accession Area Queries
- Multi-Database Query (test)
- Crop Science Registration
- Plant Variety Protection
- Taxonomic Queries
- Research Crops and
- Descriptor/Evaluation
- Data Queries

15. **NIAR database** (<http://www.gene.affrc.go.jp/plant/image/gbsys.html>)

National Institute of Agrobiological Resources (NIAR) a MAFE (Ministry of Agriculture, Forestry and Fisheries Genebank) of Japan has divided its Illustrated Plant Genetic Resources Database in 4 plant groups-

- Legume (<http://www.gene.affrc.go.jp/plant/image/legume.html>)
- Vegetables (<http://www.gene.affrc.go.jp/plant/image/vegetable.html>)
- Flower&Ornamental Plants (<http://www.gene.affrc.go.jp/plant/image/flower.html>)
- Millet and Forage Crops (<http://www.gene.affrc.go.jp/plant/image/millet.html>)

Japan has also developed a new system to integrate plant genetic resources database with image data. This system has a consistency of image data and an ease of data manipulation.

**16. Resource Identification for a Biological Collection Information Service in Europe (<http://www.bgbm.fu-berlin.de/biocise/DataBase/default.htm>)**

BioCISE address information on more than 2500 European biological collections available in the Collection Catalogue (<http://www.bgbm.fu-berlin.de/biocise/DataBase/default.htm>). Collaboration: BioCISE initiated the Portuguese Biological Collection Data Resource (<http://central.igc.gulbenkian.pt/BioCISE/drpbcb.html>). Collection information held by the Belgian BIODIV (<http://www.bgbm.fu-berlin.de/BioCISE/TheProject/IntroCollab.htm>) programme, the Institute of Botany, Polish Academy of Sciences, Cracow (<http://www.ib-pan.krakow.pl/>) for Polish herbaria, the CABRI Project (<http://www.cabri.org/>) for biotechnological resources and information, NatureWeb (<http://www.natureweb.at/>) for Austrian collections and the IPGRI Directory of Germplasm Collections (<http://www.ipgri.cgiar.org/germplasm/dbintro.htm>) is directly accessible through the BioCISE collection catalogue; this serves as an example for the kind of cooperation agreement we envision for the next phase of BioCISE. BioCISE is followed up by a new project called BioCASE (<http://www.biocase.org/>)

**17. N.I. Vavilov All-Russian Scientific Research Institute of Plant Industry (VIR) database (<http://www.vir.nw.ru/data/dbf.htm>)**

The N.I. Vavilov Institute of Plant Industry (VIR) is the only research institution in Russia whose activities include plant genetics resources (PGR) collection, conservation and study. There are 3 types of search available on this page. Passport data:

- Index Search Form
- Passport Search Form
- Passport Descriptors

**18. Database of Plant Gene Resources of Canada ([http://pgrc3.agr.gc.ca/search\\_grinca-recherche\\_rirgc\\_e.html](http://pgrc3.agr.gc.ca/search_grinca-recherche_rirgc_e.html))**

This database searches for germplasm through the Germplasm Resources Information Network (Canadian version). It has three types of searches-

- Accession Queries ([http://pgrc3.agr.gc.ca/acc/search-recherche\\_e.html](http://pgrc3.agr.gc.ca/acc/search-recherche_e.html))
- Taxonomic Queries ([http://pgrc3.agr.gc.ca/tax/index\\_e.html](http://pgrc3.agr.gc.ca/tax/index_e.html))
- Research Crops Descriptor/Evaluation Data Queries (<http://pgrc3.agr.gc.ca/cgi-bin/npgs/html/croplist.pl>)

The details of the major holdings and distribution details can be also found from the link ([http://pgrc3.agr.gc.ca/holdings-stocks\\_e.html](http://pgrc3.agr.gc.ca/holdings-stocks_e.html)) available on this site.

**19. SHIGEN database (<http://www.shigen.nig.ac.jp/>)**

SHIGEN stands for SHared Information of GENetic resources.

The objectives of the SHIGEN project are to

1. provide a portal site for science researchers to find where they can get resource information, ( WGR )
2. provide a useful database for researchers to find as much resource-related information available in Japan as possible,
3. provide the latest information about the Genetic Resource Committee's activities in Japan, ( GRC )
4. support the database construction of resources on demand by researchers who maintain genetic resources.

**20. National Plant Genetic Resources Center – Taiwan database (<http://192.192.196.3/npgrc/apec010e.htm>)**

National Plant Genetic Resources Center (NPGRC) provides four types of queries from the germplasm database.

- Query from crop lists and their descriptors
- Query from taxonomy
- Query from passport data
- Query for germplasm image data

**21. National Inventories under EPGRIS - European Plant Genetic Resources Information Infra-Structure (<http://www.ecpgr.cgiar.org/epgris/Partners/NatInvent.htm>)**

A number of European countries have established national PGR inventories and are available on the web. The national inventories and can be consulted here:

- Austria ([http://www.ecpgr.cgiar.org/epgris/National\\_Inventory/Austria.htm](http://www.ecpgr.cgiar.org/epgris/National_Inventory/Austria.htm))
- Netherlands ([http://www.ecpgr.cgiar.org/epgris/National\\_Inventory/Netherlands.htm](http://www.ecpgr.cgiar.org/epgris/National_Inventory/Netherlands.htm))
- Bulgaria ([http://www.ecpgr.cgiar.org/epgris/National\\_Inventory/Bulgaria.htm](http://www.ecpgr.cgiar.org/epgris/National_Inventory/Bulgaria.htm))
- Nordic Countries ([http://www.ecpgr.cgiar.org/epgris/National\\_Inventory/NordicCountries.htm](http://www.ecpgr.cgiar.org/epgris/National_Inventory/NordicCountries.htm))
- Czech Republic ([http://www.ecpgr.cgiar.org/epgris/National\\_Inventory/CzechRepublic.htm](http://www.ecpgr.cgiar.org/epgris/National_Inventory/CzechRepublic.htm))
- Poland ([http://www.ecpgr.cgiar.org/epgris/National\\_Inventory/Poland.htm](http://www.ecpgr.cgiar.org/epgris/National_Inventory/Poland.htm))

- Estonia ([http://www.ecpgr.cgiar.org/epgris/National\\_Inventory/Estonia.htm](http://www.ecpgr.cgiar.org/epgris/National_Inventory/Estonia.htm))
- Russian Federation ([http://www.ecpgr.cgiar.org/epgris/National\\_Inventory/Russia.htm](http://www.ecpgr.cgiar.org/epgris/National_Inventory/Russia.htm))
- France ([http://www.ecpgr.cgiar.org/epgris/National\\_Inventory/France.htm](http://www.ecpgr.cgiar.org/epgris/National_Inventory/France.htm))
- Slovenia ([http://www.ecpgr.cgiar.org/epgris/National\\_Inventory/Slovenia.htm](http://www.ecpgr.cgiar.org/epgris/National_Inventory/Slovenia.htm))
- Germany ([http://www.ecpgr.cgiar.org/epgris/National\\_Inventory/Germany.htm](http://www.ecpgr.cgiar.org/epgris/National_Inventory/Germany.htm))
- Spain ([http://www.ecpgr.cgiar.org/epgris/National\\_Inventory/Spain.htm](http://www.ecpgr.cgiar.org/epgris/National_Inventory/Spain.htm))
- Lithuania ([http://www.ecpgr.cgiar.org/epgris/National\\_Inventory/Lithuania.htm](http://www.ecpgr.cgiar.org/epgris/National_Inventory/Lithuania.htm))

**22. National Centre for plant genetic resources, Poland**  
([http://www.ihar.edu.pl/gene\\_bank/](http://www.ihar.edu.pl/gene_bank/))

The collections maintain their own computerized documentation. All data available are sent to the documentation centre at the Centre for Plant Genetic Resources. The documentation there is updated once a year. Additional data concerning the condition of the samples (viability, water content), and the evaluation data are also collected. Databases stored at the Centre for Plant Genetic Resources provide a safety duplication of the collection data. The data are stored in duplicate and updated once a week. The information is available in a local computer network.

**23. Indian Plant Genetic Resources Information System**

National Bureau of Plant Genetic Resources is maintaining database containing information about the passport data, evaluation and characterization data, genebank information data, and the details about the import and export of the data. The databases have not been made on line but the databases can be queried by making a request to the Director, NBPGR ([director@nbpgr.ernet.in](mailto:director@nbpgr.ernet.in)).

**C. Taxonomic, Herbarium, Botanical Gardens Databases**

**1. The Royal Botanic Gardens, Kew**  
(<http://www.rbgekew.org.uk/>)

The information about the scientific research and horticultural activities, collection (including herbarium and reference), conservation and wild life, education and data is available on for download and search. The other botanic garden and museum links are also linked ion this site (<http://www.rbgekew.org.uk/aboutus/links.html>).

**2. International Legume Database & Information Service**  
(<http://www.ildis.org>)

The International Legume Database & Information Service (ILDIS) is an international project which aims to document and catalogue the world's legume species diversity in a readily accessible form. Research groups in many countries are participating on a co-operative basis to pool information in the ILDIS World Database of Legumes. This database is in searchable form.

**3. TDWG (Taxonomic Databases Working Group)**  
**Subgroup on Biological Collection Data**  
(<http://www.bgbm.org/TDWG/acc/Software.htm>)

Links for various herbarium, taxonomic databases and botanical gardens etc. are available on this site.

**(a) Multiple Collection Types**

BIOLINK. <http://www.ento.csiro.au/biolink/software.html>

BioOffice - Datenbank und geographisches Informations system. <http://www.biooffice.at/>

BIOTICA - Systema de Información. <http://www.conabio.gob.mx> [Look under "Sistema de Información BIOTICA".]

BIOTA - The Biodiversity Database Manager. <http://viceroy.eeb.uconn.edu/Biot>

DEMUS - museum collection system (currently only in Czech). <http://www.mzm.cz/engmzm/demus/demus.html>

KE EMu - Electronic Museum. <http://www.ke.com.au/ke/products/emu/emu.html>

FieldNote - Mobile computing in a fieldwork environment. <http://www.cs.ukc.ac.uk/projects/mobicomp/Fieldwork/Software/index.html>

Multi MIMSY 2000. <http://www.willoughby.info/mimsy/>

MUSE - The KUNHM MUSE Project software for curation of natural history collections. <http://www.biodiversity.uno.edu/muse/>

SAMPADA - Natural History Collection Database Software. <http://www.ncbi.org/in/sampada/index.html>

SPECIFY. <http://usobi.org/specify/>

SysTax <http://www.biologie.uni-ulm.de/systax/index.html>

TAXIS - Taxonomic Information System: <http://bio-tools.tcn.ru/products/taxis/index.htm>

VERNON - Collection Management System: [www.vernonsystems.com](http://www.vernonsystems.com)

**(b) Botanical Gardens**

BG-BASE Collections Management Software.

<http://rbg-web2.rbge.org.uk/BG-BASE/>

BG-MAP Botanical Garden Mapping System/GIS [for BG-Base]. <http://www.bg-map.com/>

Calypso for Windows [3.11 to 98]. [English version:] [http://hortus.karelia.ru/com/soft\\_e.htm](http://hortus.karelia.ru/com/soft_e.htm) [Russian:] <http://hortus.karelia.ru/com/soft.htm>

**(c) Herbarium collections**

BibMaster – A database application for nomenclature, literature and specimen management. <http://www.rjb.csic.es/bibmaster/bibcaract.htm>

BRAHMS – Botanical Research And Herbarium Management System. <http://www.brahms.co.uk>

FLORIN Information System. <http://www.florin.ru/florin/>

HERBAR – una aplicación en MS-Access para la gestión de herbarios. <http://www.rjb.csic.es/herbario/herbar.htm>

The PANDORA taxonomic database system. <http://www.ibiblio.org/pub/academic/biology/ecology+evolution/software/pandora/>

PLabel: Herbarium Label Program. <http://www.flmnh.ufl.edu/natsci/herbarium/pl/>

TRACY – A Herbarium Management System. <http://www.csdl.tamu.edu/FLORA/input/inputsys.html>

University of California Davis Herbarium Management System. <http://herbarium.ucdavis.edu/database.html>

Virtual Herbarium Express. <http://www.nybg.org/bsci/vh/>

**(d) Entomological collections**

Mantis – A Manager of Taxonomic Information and Specimens. <http://140.247.119.145/Mantis/>

Mandala. <http://pherocera.inhs.uiuc.edu/index.htm>

**(e) Surveys/ Observations**

AditSite Wildlife Recording System <http://www.adit.co.uk/html/aditsite.html>

AvianStore Birdwatcher Database <http://sparc.airtime.co.uk/users/cygnus/avianstr.htm>

AviSys Birding Database Software <http://www.avisys.net/>

BIRDBASE and BIRDAREA Birding Software <http://members.aol.com/sbsp/bbba.htm>

Birder's Diary by Thayer Birding Software <http://www.thayerbirding.com/>

Bird Info for Windows – Birding Software <http://netspeed.com.au/birds/birdinfo/>

Bird Recorder 32 <http://www.wildlife.co.uk/>

Faunist <http://home.hccnet.nl/mp.van.veen/>

LANIUS Bird Sighting Database <http://www.onmymountain.com/>

LANIUS Excalibur 2.0 - The Ornithological Database for the Natural World <http://www.laniussoftware.com/excalibur.htm>

LEPILIST Lepidoptera Listing Software <http://members.aol.com/sbsp/lepilist-info1.htm>

RECORDER 2000. <http://www.dorsetsoftware.com/recorder/>

**(f) Palaeontological collections**

PaleoTax – Information System for Palaeontologists. [www.paleotax.de](http://www.paleotax.de)

**(g) Other software sites**

Digital Taxonomy, Database Software <http://www.geocities.com/RainForest/Vines/8695/software.html#Databases>

**(h) Data quality control (here: distribution mapping and modelling)**

Jones P.G. and Gladkov, A. (2001). *Floramap Version 1.01*. Cali, Colombia: CIAT. <http://www.floramap-ciat.org/ing/floramap101.htm>

Hijmans, R.J., Guarino, L., Bussink, C., Barrentes, I. and Rojas, E. (2003) *DIVA-GIS Version 3. A geographic information system for the analysis of biodiversity data*. <http://www.diva-gis.org>

**4. Taxonomic Nomenclature Checker**

(<http://pgrdoc.ipgri.cgiar.org/taxcheck/grin/>)

It allows for quick and convenient checking of large numbers of scientific names against other standardized databases. The Taxonomic Nomenclature Checker currently checks lists of scientific names against weekly downloaded data from the Germplasm Resources Information Network (GRIN) (<http://www.ars-grin.gov/npgs/tax>) of the United States Department of Agriculture, Agricultural Research Service. GRIN TAXONOMY currently contains over 18,000 generic and 65,000 specific or infraspecific records of vascular plants from throughout the world, with a focus on plants important to agriculture or other commerce.

Following is a list of links to other taxonomic databases for additional checking of individual names:

- VAST Missouri Botanical Garden (nomenclature and taxonomic usage) (<http://mobot.mobot.org/W3T/Search/vast.html>)

- IPNI International Plant Names Index (bibliographic details of names) ([http://www.ipni.org/ipni/query\\_ipni.html](http://www.ipni.org/ipni/query_ipni.html))
- IOPI Global Plant Checklist (currently provisional) (<http://bgbm3.bgbm.fu-berlin.de/IOPI/GPC/query.htm>).

#### **D. Indian Acts**

1. ***The Biological Diversity Act, 2002 of India***  
([http://www.envfor.nic.in/divisions/biodiv/act/bio\\_div\\_act.htm](http://www.envfor.nic.in/divisions/biodiv/act/bio_div_act.htm))

The complete information about this Biological Diversity Act is hosted on this Ministry of Environment and Forest

web site. All the details related to the Act can be downloaded in html, PDF and Word format.

2. ***The Protection of Plant Varieties of Farmers Rights Rules, 2003***  
(<http://agricoop.nic.in/seeds/farmersact2001.htm>)

Information related to notification, different schedules, plant variety registration forms and plant variety forms can be downloaded from this site. This site is hosted by Department of Agricultural and Co-operation, Ministry of Agriculture, Govt. of India.

## Inter-relationships in Morphotypes of Greater Yam (*Dioscorea alata* L.)

Asha KI and Maya C Nair\*

National Bureau of Plant Genetic Resources Regional Station, Vellanikkara-680 654, Thrissur (Kerala)

The germplasm holding in greater yam (*Dioscorea alata* L.) consisting of 182 accessions belonging to 19 morphotypes collected from different agro-ecological situations of peninsular India were subjected to a detailed investigation on characterization of both above ground and below ground vegetative parts with respect to 49 qualitative and 22 quantitative traits. Seventy-six descriptor states were analyzed for pair-wise similarity coefficients by un-weighted pair-group method analysis (UPGMA) and also for single and complete linkage. The study revealed existence of 9 major arbitrary clusters indicating close resemblances between many of the morphotypes. Clustering pattern did not show any strict relationship between geographical distribution and morphotypes as the accessions from different geographic regions and of different morphotypes were grouped in most of the clusters. Based on these observations, an attempt is being made here to interpret the extent of similarity within and between the earlier described morphotypes.

**Key Words:** Clustering, *Dioscorea alata*, Morphotypes.

Greater yam (*Dioscorea alata* L.) belonging to the family Dioscoreaceae is an ancient crop with considerable importance under the subsistence farming system in the tropics. Earlier reports indicated the occurrence of considerable variability in the crop using both morphological and biometrical techniques (Burkill, 1917; Gooding, 1960; Rhodes and Martin, 1972; Muralidharan and Velayudhan, 1985; Velayudhan *et al.*, 1991). Studies on genetic relationship between greater yam cultivars revealed a narrow genetic base as demonstrated by isozyme patterns (Lebot *et al.*, 1998). This study also revealed the occurrence of identical zymotypes in different geographical areas and different zymotypes in same geographic zone. Velayudhan *et al.* (1991) have reported a classification of this plant in which the germplasm has been grouped into 19 morphotypes on the basis of subjective morphology. Even though these morphotypes differed in many qualitative and quantitative characteristics, a critical observation on them showed some differences within certain morphotypes and similarities between different morphotypes. Hence, in order to revalidate the morphotypes in *Dioscorea alata* and to study the interrelationship between various accessions, these were subjected to detailed morphological studies.

### Materials and Methods

Germplasm of 182 accessions of *D. alata*, belonging to 19 morphotypes (M1 to M19) (Velayudhan *et al.*, 1991), collected from different localities of peninsular India were selected. These were grown at the experimental farm of NBPGR Regional Station, Thrissur, at 10.5° N latitude and 76.5° E longitude in two main cropping seasons between

1999-2001. The experimental plants were raised in augmented design with three controls following the recommended package of practices (Anon, 1996).

Observation on 49 qualitative and 22 quantitative traits was made on 3 plants per accession. Data on above ground vegetative characters such as leaves, bulbils and flowers were recorded at the maximum growth period during September to October and that on below ground tubers at the time of harvest during January.

The qualitative characters contained 76 different descriptor states and each state was scored as present (1) or absent (0) across all the accessions. The two-way data matrix of accessions x traits was used to calculate pair-wise similarity coefficients following Jaccard (1908). Similarity coefficients were subjected to unweighted pair-group method analysis (UPGMA) to generate a dendrogram using average linkage procedure. In addition to this, the same was subjected to single-linkage and complete-linkage method of analysis and consensus of these two were worked out to find ball-clusters in the germplasm. The entire analysis was carried out using the computer programme, NTSYS-PC, Version 1.80 (Exeter Software, New York). Based on this grouping, the range of various quantitative traits was also worked out. The re-evaluation of the diversity patterns was done using these 76 different descriptor states.

### Results and Discussion

In the present study of the morphotypes and collections of 182 accessions, 9 major groups having 30 different ball clusters were identified. The ball clusters were identified by single link and complete link methods and their

\* Post-graduate Department of Botany, Government Victoria College, Palakkad, Kerala

consensus. The resulting dendrogram obtained for different clusters are summarized in Figures 1-5 and this depicts the detailed clustering for all the 182 accessions.

The similarity coefficients ranged from 0.046512 to 1.000 for all accessions. The minimum morphologic similarity was between IC 87393 and EC 391129 and the greatest similarity between IC 87401 and IC 136849. A detailed account of this grouping is summarized below.

#### Cluster 1

Morphotype 1 ('Chorakachil') of earlier classification is a complex group having close linkage of more than 80% with some accessions in M2 (IC 87331), M3 (IC 87353, IC 87354, IC 87359), M4 (IC 87338) and M9 (IC 87361). Two accessions (IC 136853 and IC 266651), earlier grouped in M1, showed clustering with M12 ('Kulambukachil'), but as a distinct ball cluster. In this cluster, 7 different

ball clusters were found, each with two accessions having more than 80% similarity. Hence a total of 31 accessions clustered together with more than 60% linkage. In this cluster, all the accessions earlier grouped as M1, clustered together except IC 136853 and IC 266651 but with close similarity to some accessions grouped in M2, M3, M4 and M9. The characteristics of the plants grouped in this cluster include the presence of erect, non-spiny greenish purple stem; oblong/digitate bulbils with brown outer skin, purple inner skin and light yellow flesh. Flowering was observed in October. An average of 5-8 tubers were produced per plant with smooth outer skin, purple cortex and white flesh. Crop duration is about 151 days. Tuber starch is grainy with very good taste. The typical types on the basis of the characters of this cluster for easy scoring are IC 44207 and IC 44208 of the morphotype M1.

#### Cluster 2

In this cluster, morphotype 6 ('Thonielayankachil') in earlier grouping was the major representative showing close resemblance with M3 (IC 87352 and IC 87412), M5 (IC 87358) and M6 (IC 87372) with 15 accessions. This

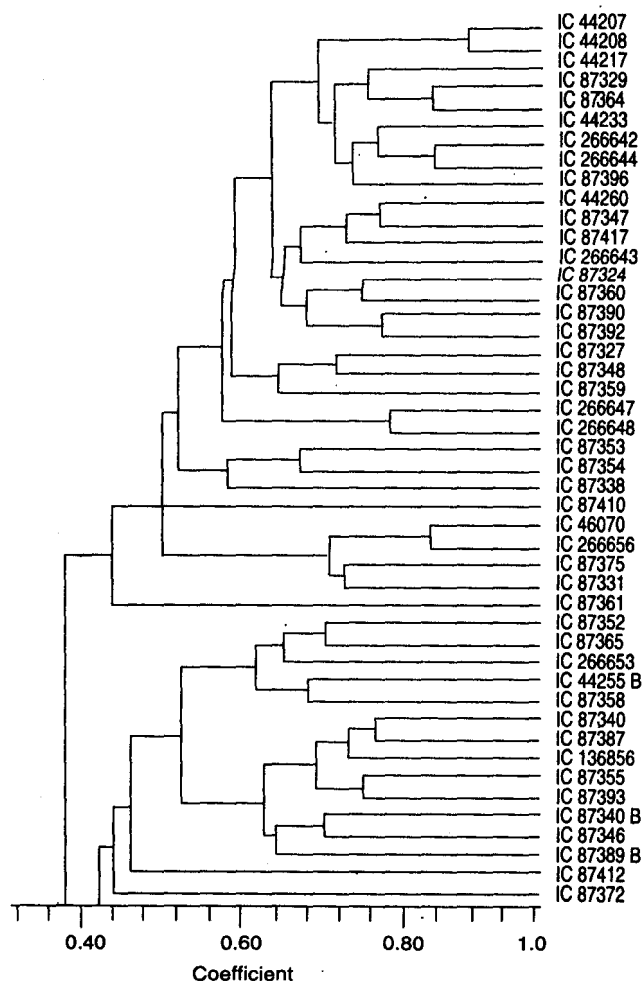


Fig. 1: Accessions grouped under Cluster 1 and 2

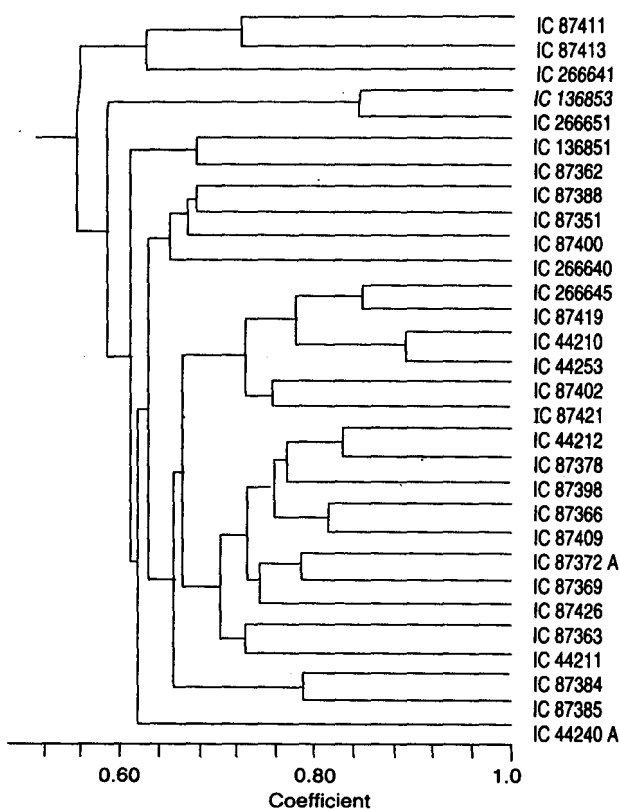


Fig. 2: Accessions forming Cluster 3

Dendrogram based on morphological traits

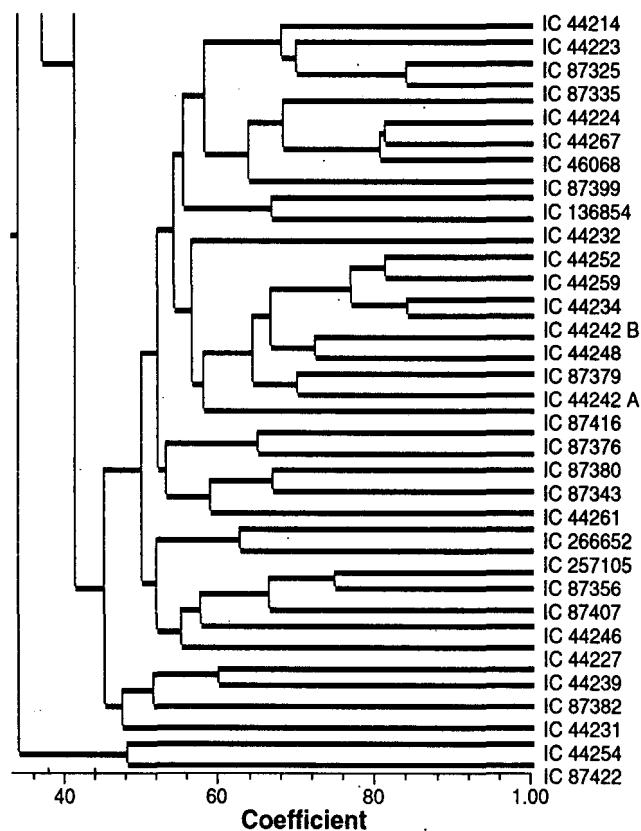


Fig. 3. Accessions forming Cluster 4

cluster showed the presence of two ball clusters one with 5 accessions, one each from M3 (IC 87352) and M5 (IC 87358) and three from M6 (IC 44255 B, IC 87365 and IC 266653) and the other with 8 accessions, all from M6 (IC 87340, IC 87340 B, IC 87346, IC 87355, IC 87387, IC 87389 B, IC 87393 and IC 136856). The prostrate, non-spiny purple stem characterizes this cluster with medium sized digitate/oblong bulbils having gray outer skin, purple inner skin and yellow flesh colour. Non-flowering is reported in these plants. 2-3 irregular tubers per plant having warty skin, dark purple cortex colour, white flesh with purple centre and orange yellow outer part. Highly grainy starch without much taste is the major character. Distinctive types of this cluster are IC 87340 and IC 87387 of M6. The highest values for bulbil thickness (2.34-6.83 cm) and individual tuber weight (0.88-2.52 kg) were recorded in this cluster (Table 1).

### Cluster 3

Majority of the representatives in this cluster were from M12 ('Kulambukachil') with 30 different accessions. Many accessions in M12 of this cluster showed close linkage with accessions in M1 (IC 136853, IC 266651), M8 (IC 87413), M11 (IC 44212, IC 136851, IC 266641), M13

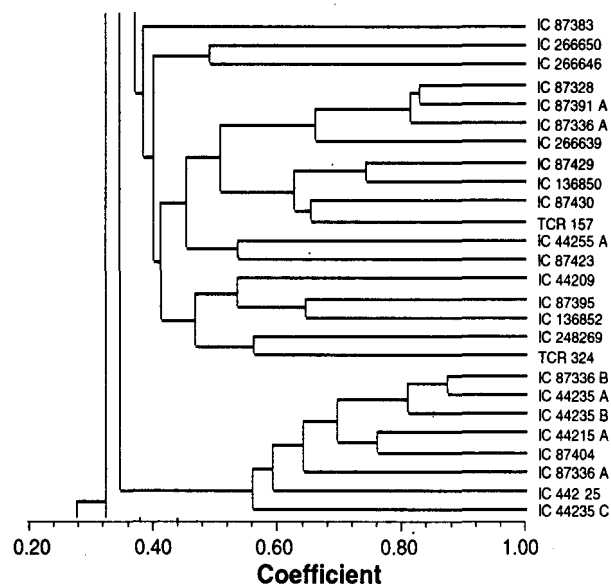


Fig. 4. Accessions forming Cluster 5 and 6

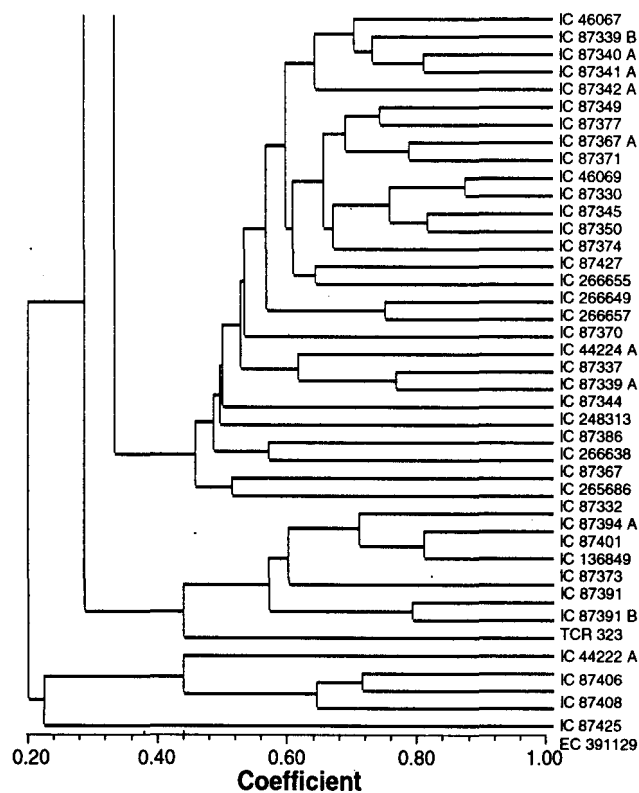


Fig. 5. Accessions forming Cluster 7, 8 and 9

(IC 87351, IC 44240 A), M6 (IC 266640, IC 266645) and M7 (IC 44210, IC 44253, IC 87411). There were 5 ball clusters, 4 with two accessions each and other one with 4 accessions, viz., M6 (IC 266645), M12 (IC 87419) and M7 (IC 44210, IC 44253). The characteristic features that

Table 1. Variability in quantitative traits of different clusters

| S.No. | Traits                       | Cluster 1   | Cluster 2   | Cluster 3   | Cluster 4   | Cluster 5   | Cluster 6  | Cluster 7   | Cluster8    | Cluster 9   |
|-------|------------------------------|-------------|-------------|-------------|-------------|-------------|------------|-------------|-------------|-------------|
| 1     | Leaf length (cm)             | 14.17-21.23 | 11.67-23.83 | 12.07-21.4  | 14.43-22.37 | 10.6-21.67  | 9.77-19.0  | 13.37-17.5  | 13.53-19.53 | 16.27-19.5  |
| 2     | Leaf breadth (cm)            | 8.43-13.3   | 9.53-15.17  | 7.13-14.93  | 10.17-16.27 | 7.33-16.5   | 6.87-12.9  | 11.23-16.93 | 9.13-14.63  | 12-14.97    |
| 3     | Petiole length (cm)          | 6.5-10.87   | 8.57-14.83  | 7.03-13.17  | 8.17-15.4   | 6.67-15.73  | 5.43-12.13 | 9.8-20      | 8.6-13.17   | 10.5-13.07  |
| 4     | Basal wing length (cm)       | 4.13-7.23   | 5.23-8.47   | 3.17-7.8    | 5.3-9.57    | 3.9-9.07    | 3.5-6.87   | 5.1-8.3     | 5.0-7.67    | 6.57-8      |
| 5     | Basal wing distance (cm)     | 1.63-6.13   | 0.87-4.00   | 0.27-3.07   | 0.33-2.73   | 0.4-3.7     | 0.43-1.83  | 0.43-2.13   | 0.7-2.63    | 0.4-4.83    |
| 6     | Sinus depth (cm)             | 2.03-4.23   | 2.4-5.93    | 2.87-6.67   | 3-6.23      | 1-5.77      | 1.87-4.23  | 3.07-6.67   | 2.37-6.13   | 1.27-4.17   |
| 7     | Initiation of bulbils (days) | 0-154       | 101-148     | 79-159      | 91-151      | 0-116       | 0-121      | 0-135       | 0-114       | -           |
| 8     | Flower initiation (days)     | 0-159       | 0-159       | 0-160       | 0-154       | 0-169       | 0-147      | 0-159       | 0-147       | -           |
| 9     | Bulbil length (cm)           | 0-4.92      | 2.82-7.47   | 2.82-10.31  | 1.44-9.94   | 0-11.95     | 0-8.63     | 0-11.08     | 0-4.58      | -           |
| 10    | Bulbil thickness (cm)        | 0-5.89      | 2.34-6.83   | 1.45-5.9    | 1.68-6.03   | 0-6.77      | 0-2.96     | 0-4.47      | 0-2.49      | -           |
| 11    | Individual Bulb weight (g)   | 0-61.33     | 5.33-95.33  | 3.83-100.5  | 2.83-124    | 0-85.5      | 0-27.67    | 0-56.33     | 0-15.33     | -           |
| 12    | No. of bulbils               | 0-164       | 25-353      | 8.0-590     | 5.0-805     | 0-460       | 0-65       | 0-555       | 0-95        | -           |
| 13    | Bulbils /Plant               | 0-33.33     | 8.33-117.66 | 2.66-196.66 | 1.6-268.33  | 0-186.66    | 0-21.66    | 0-185       | 0-31.66     | -           |
| 14    | Bulbil Yield (Kg)            | 0-0.924     | 0.064-2.382 | 0.018-3.497 | 0.011-3.593 | 0-3.685     | 0-0.394    | 0-3.793     | 0-0.258     | -           |
| 15    | Bulb. Harvest (days)         | 0-186       | 171-181     | 167-186     | 0-185       | 0-186       | 0-184      | 0-177       | 0-180       | -           |
| 16    | Individual Tuber wt. (Kg)    | 0.360-1.34  | 0.88-2.52   | 0.410-2.42  | 0.30-1.92   | 0.37-2.05   | 0.7-2.12   | 0.63-2.63   | 0.78-2.10   | 0.58-2.27   |
| 17    | Tuber length (cm)            | 11.33-24    | 16.33-31.33 | 10.33-27    | 11-23.67    | 12-38.33    | 16.33-34   | 21.33-45    | 17.67-22.5  | 12-22.67    |
| 18    | Tuber perimeter (cm)         | 25.33-49.33 | 31.67-55.67 | 29-49.67    | 25.33-54.67 | 26.67-55.67 | 22.67-46.5 | 23.33-55.67 | 39-54.33    | 33.33-48.67 |
| 19    | No. of Tuber Bran.           | 2-6.67      | 3.5-10      | 0-6.33      | 0-5         | 0-5.33      | 1-8        | 0-6.0       | 2.33-5.5    | 2-4         |
| 20    | Neck length (cm)             | 0-9         | 2.67-10     | 0-7.5       | 0-6         | 0-5.33      | 2-5.5      | 0-6.0       | 0-6         | 2-3         |
| 21    | Yield/Plant (Kg)             | 0.58-2.25   | 0.25-3.7    | 0.63-2.53   | 0.33-2.78   | 0.42-2.83   | 1.23-3.33  | 1-4.4       | 1.17-2.5    | 1.07-2.9    |
| 22    | Total Yield (Kg)             | 1.75-6.75   | 3.5-11.1    | 1.9-7.6     | 1-8.35      | 1.25-8.5    | 3.7-10     | 3-13.5      | 3.5-7.5     | 3.2-8.7     |

distinguish the plants belonging to this cluster are purple coloured, non-spiny, erect stem. Bulbil initiation in 146 days in October having brown outer skin, greenish purple inner skin and white flesh. Flowering in November. Two tubers per plant are recorded with highly warty brown skin and light purple cortex with white flesh is a common feature in this cluster. The starch is grainy and flowering is recorded in 159 days. IC 44212 and IC 87378 of M12 were the representative types.

#### Cluster 4

This cluster proved to be a distinct one with most of the accessions from M13 ('Thalavannankachil') of earlier grouping. Of the 39 accessions in this cluster, 36 were of earlier M13 and others are from M6 (IC 266654), M11 (IC 44254) and M15 (IC 87422). This cluster showed the presence of 4 distinct ball clusters each with two, three and four (2 clusters) accessions. This group included plants with prostrate, non-spiny, purple stem. Bulbils were

initiated in 108 days and are large, oblong, with brown outer skin, purple inner skin and purplish white flesh. Flowering is recorded in October. The plants bear 1-3 spherical tubers with dark brown skin, dark purple cortex and purplish cream flesh were having grainy starch with good flesh taste. The types identified are IC 44248 and 87379 of M13.

#### Cluster 5

This group was also found to be a complex one with all the accessions from earlier M18 ('Karimpachamullankachil') and a few from M16 (IC 87429, IC 87430), M17 (IC 136850), M15 (IC 44255 A, IC 87423), M10 (IC 44209, IC 87395, IC 136852, IC 266650) and one ungrouped accession (IC 248269). This showed 3 distinct ball clusters, one with accessions from M18 (IC 266689, IC 87328, IC 87336 A, 87391 A), second one with M16 (IC 87429) and M17 (IC 136850) and the third with two accessions from M10 (IC 87395, IC 136852). This cluster has types with erect spiny purple stem and bulbil initiation in 91-94 days. The bulbils are large, digitate with brown outer skin, light green inner skin and yellow flesh. Flowering was absent. 1-2 digitate tubers with warty brown outer skin, light yellow cortex and white/cream tuber flesh is a characteristic feature of this cluster. Flesh is slightly grainy and starchy with not much taste. IC 87328 and IC 87391 A of M18 are the typical types of this cluster.

#### Cluster 6

This group was a distinct ball cluster with 8 accessions of which 5 are from M11 ('Kaiyyankachil'), 2 from M12 (IC 44235 C, IC 87336 A) and the other from M7 (IC 87336 B). Plants are prostrate, non-spiny, with purple stem and purple wings. Bulbils as well as flowering are absent. Six cylindrical highly warty tubers with brown outer skin, light purple cortex and white flesh is produced per plant. Crop duration is about 146 days. Starch is grainy with good taste. Representative types of this cluster include IC 87336 B of M7 and IC 44235 A of M11

#### Cluster 7

Of the 28 collections in this cluster, most of them (23) are from M16 (Vattayilakachil) of earlier classification. These accessions were found grouped with one accession from M4 (IC 87367), one from M13 (IC 44224 A) and three accessions from ungrouped category. This group showed the presence of 5 distinct clusters, 4 of them with 2 accessions each and the other with 4 accessions. Early stem prostrate, non-spiny and purple. Bulbil initiation was

recorded in 133 days and the bulbils are oblong, medium sized with outer brown skin, light green inner skin and yellow flesh. 4-5 cylindrical, highly warty brown skinned tubers having light yellow cortex and very light yellow tuber flesh which is grainy is a common feature in this cluster. Crop duration is about 141 days. Tuber yield in this cluster is the highest, which ranges from 3.0 to 13.5 kg/plant (Table 1). Representative types identified are IC 46069 and IC 87330 of M16.

#### Cluster 8

This cluster was found to be a group of two different morphotypes, M2 (Parakkachil-5 accessions) and M19 (Thalikayilakachil-2 accessions), but each of these morphotypes appeared as distinct ball clusters. Moreover, one ungrouped accession (IC 259824) was also found clustered in this forming 8 accessions in this cluster. As these morphotypes occur as distinct ball clusters in this group, they can be treated as separate entities. Here the green early stem is erect and spiny with dark purple wings. Bulbil formation and flowering are absent. Single digitate tuber per plant with smooth dark brown outer skin, purple cortex and very light yellow flesh is the characteristic tuber type of this cluster. The tuber flesh is grainy with very good taste. Crop duration is about 141 days. Tuber perimeter is the highest in this group ranging from 39.0 to 54.33 cm (Table 1). Typical type identified is IC 87391 of M19.

#### Cluster 9

This is a distinct group of 4 accessions in earlier M14 (Aanikachil) and an ungrouped exotic accession (EC 391129). Moreover 3 accessions in M14 (IC 87406, IC 87408, IC 87425) appeared as a ball cluster. Erect green stem with purple wings and light green petiole top and bottom is a general feature in this group. Bulbils and flowers are absent. 1-2 oblong tubers having highly warty dark brown outer skin, light yellow cortex and white flesh were produced per plant. Crop duration is about 146 days. Grainy flesh with very good taste is the distinctive feature of this cluster. Characteristic types identified are IC 87406 and IC 87408 of M14.

As the qualitative characters grouped the germplasm into 9 different clusters, the quantitative traits also showed distinct variation between the clusters.

A critical observation of these clusters showed that only 10 morphotypes retained the integrity as morphologic groups, even though most of them showed relationships with accessions from other morphotypes. As far as the morphotypic diversity and geographical distribution are

concerned, the clustering pattern did not show any strict relation as the accessions from different geographic regions are grouped in all the clusters.

According to this, the status of the morphotypes 3,4,5,7,8,9,10,15 and 17 as separate entities are not concrete and are grouped in the 9 basic clusters in which many accessions retained the integrity with earlier morphotypic grouping. Hence, cluster-1 with majority of accessions from earlier M1, cluster-2 with M6, cluster-3 with M12, cluster-4 with M13, cluster-5 with M18, cluster-6 with M11, cluster-7 with M16, cluster-8 with M2 and cluster-9 with M14 can be grouped as distinct morphologic entities. Even though the accessions earlier grouped as morphotypes differ in certain morphometric parameters, the distinctiveness of such traits may not be sufficient to group them as distinct morphotypes. In effect, it can be concluded that the germplasm holds distinct variability with respect to vegetative and tuber characteristics and there exists 9 different morphologic groups in the germplasm.

#### Acknowledgements

The authors are grateful to the Director, NBPGR, New Delhi for the facilities provided. They are also thankful to Dr. Mahender Singh, Head, Evaluation Division, NBPGR, New Delhi and Dr. Z Abraham, Officer-in-Charge, NBPGR Regional Station, Thrissur for the

encouragement. Further they are grateful to Sri KC Velayudhan, Senior Scientist of the station, for his critical suggestions. The authors are also grateful to USDA, for funding the project No. USIF-IN-ARS- 862 under which the work was carried out.

#### References

- Anonymous (1996) *Package of Practices Recommendations 'Crops'*; Kerala Agricultural University, Directorate of Extension, Mannuthy, Thrissur, Kerala.
- Burkill IH (1917) A report on the races of Greater Yam or 10 months yam *Dioscorea alata* cultivated in the Botanic Gardens, Singapore. *Gard. Bull. Straits settle* **1**: 371-396.
- Gooding HJ (1960) West Indian *Dioscorea alata* cultivars. *Trop. Agric. (Trinidad)* **50**: 183-192.
- Jaccard P (1908) Nouvelles recherches sur la distribution florale. *Bull. Soc. Vaud. Sci. Nat.* **44**: 223-270.
- Lebot V, B Trilles, JL Noyer and J Modesto (1998) Genetic relationships between *Dioscorea alata* L. cultivars. *Gen. Resour. Crop Evol.* **45**: 99-509.
- Muralidharan VK and KC Velayudhan (1985) Performance of promising collections of *Dioscorea alata* L. from Kerala. *Nat. Symp. Tropical Tuber Crop* 63-64.
- Rhodes AM and FW Martin (1972) Multivariate studies of variation in yams (*Dioscorea alata* L.). *J. Am. Soc. Hort. Sci.* **97**: 685-688.
- Velayudhan KC, VK Muralidharan VA Amalraj and TA Thomas (1991) *Genetic Resources of Dioscorea alata* L. Sci. Monograph No.1. National Bureau of Plant Genetic Resources, New Delhi.

## SHORT COMMUNICATION

## Collection of Crop Germplasm from Sikkim and Adjacent Darjeeling District of North Bengal

**RS Rathi, NS Panwar and BS Phogat**

National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi-110 012

The agro-climatic condition of Sikkim and North Bengal provides favourable environment for different types of land use. The cultivated area of Sikkim state is approximately 11% of total geographical area (Patiram *et al.*, 1999). In India rice bean distribution is mainly confined to the tribal region of North-Eastern Hills, Western Ghats and Eastern Ghats in Peninsular India and often in hilly tracts (Arora *et al.*, 1980) of India. The adzuki bean probably originated in Asia and the wild types are found in China and also in this surveyed area. However, the exact site of origin is not clear (Chomchalow *et al.*, 1990). Considering the availability of diverse types in respect of grain size, grain colour, pod size, number of pods and yield attributes of rice bean and adzuki bean in this area the collection programme was undertaken.

### Areas of Collection

The Sikkim state and north Bengal regions are located in Eastern Himalayas situated between latitude 28°-30°N to 27°-30°N and longitude 88°-57°E to 89°-11°E. The altitude range lies between 600-2400m. The Sikkim state is divided into four major districts namely, Eastern (Gangtok), Northern (Mangan), Southern (Namachi) and Western (Geyzing). Darjeeling and Kalimpong area comes under North Bengal. The route map followed during the collection programme is depicted in Fig. 1. Soils of these areas are mostly under developed, mixed with sandy to clay loams. However, in the valleys where terrace farming is practiced, soils are fertile with developed profile.

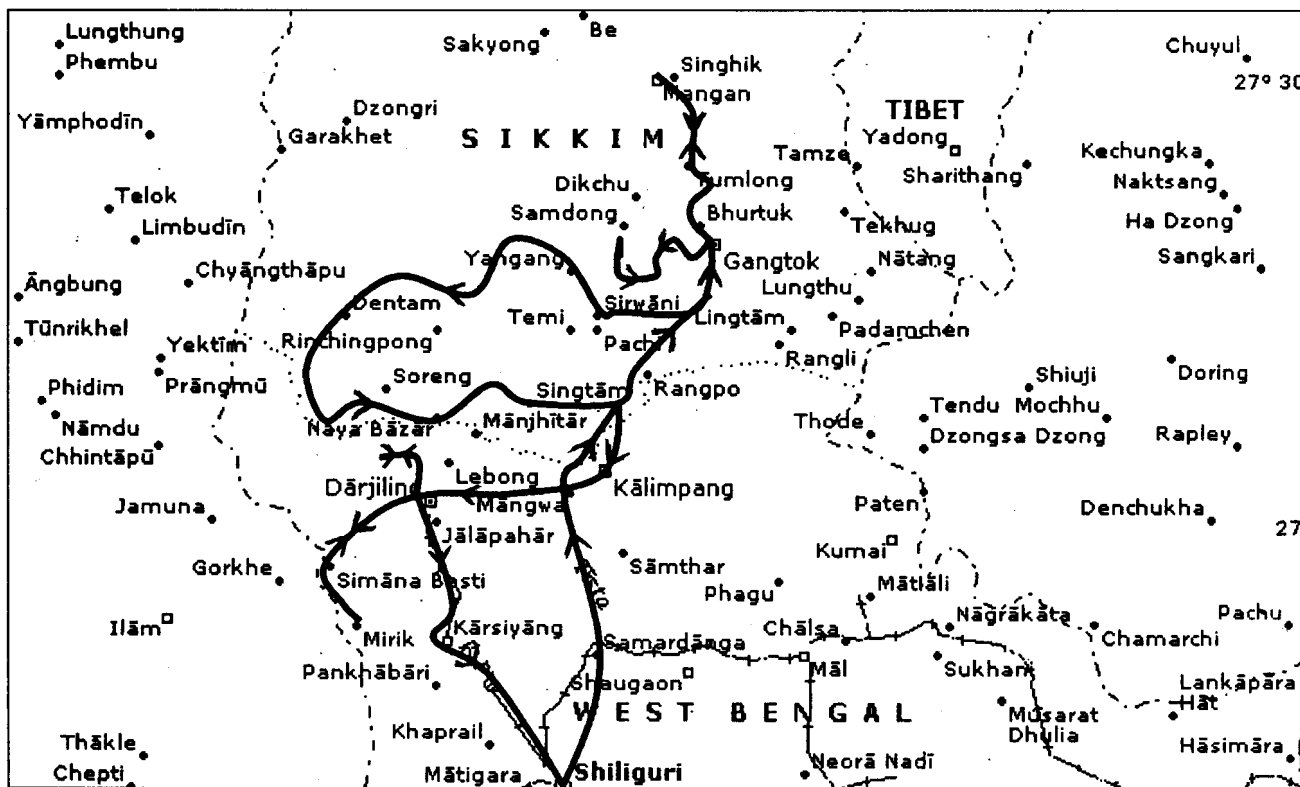


Fig. 1: Route followed during exploration and collection of crop germplasm in Sikkim and Darjeeling district of West Bengal

### Agricultural Practices and Uses of Crops

Most of the explored area is occupied by Lepchas and Gorkhas. The food habits of both communities was almost same. They use rice with meat and pulses. The rice bean is a very common pulse crop in the region, particularly in Sikkim and other beans like French bean, cowpea, sword bean are also consumed with rice.

Terrace cultivation on slopes is a common practice under rainfed condition and diverse crops comprising of adzuki bean, french bean, lablab bean, moong bean, rice bean, soybean, uridbean, barley, buckwheat, minor millets, maize, wheat, brinjal, chillies, cucurbits, tomato and banana, cardamom, Coix, Perilla are grown. It was noted that Coix lacryma-jobi is grown as fodder crop only. However, Arora *et al.* (1977) reported that Coix is grown for dual purposes as minor food and fodder. Rice bean locally known as *Masam* is generally grown with rice (on bunds) or as mixed cropping with maize/vegetable crops and sometimes as a sole crop. In hill slopes, the bold seeded type rice bean is grown whereas the small seeded are grown with rice crop. Fresh pods of bold seeded type are used as green vegetable and mature seeds are used as pulse. Rice bean is used as fodder crop also. French bean is cultivated as vegetable and pulse crop. Lablab bean and sword bean are used as green vegetable and cooked with rice and other vegetables too. A mixed farming (Jhoom) of different crops like adzuki bean, brinjal, chillies, french bean, maize, Perilla and rice bean were also observed which showed a wide maturity duration. In all parts of Sikkim and Darjeeling, crop sowing is done by broadcasting method or in line sowing, manually after the first monsoon. Buckwheat (*F. tataricum*), known as Phaphar teeta, is also used as leafy vegetable. Tree tomato (*Cyphomandra betacea*) fruit is used to prepare Chatni or used as substitute of tomato in preparation of vegetables. Perilla is grown all over subtropical Himalayas and in North Eastern Hill region. This is consumed in the form of Chatni, edible oil and spices. This crop has also medicinal properties. The seed and fruit of Indrayan (*Citrullus colocynthis*) are eaten by tribal people after roasting.

### Germplasm Diversity Collected

A total fifty-two samples were collected. These include rice bean (12); adzuki bean (5); soybean (1); french bean (4); moong bean (1); lablab bean (1); sword bean (2) in pulses/grain legumes; barley (3); wheat (1); buckwheat (5); maize (2) in cereals/pseudocereals; brinjal (2); chilli (4); pumpkin (2); tree tomato (2) in vegetables; banana (1); white indrayan (1); *Perilla* (2) and ornamental chilli

(*Capsicum* species) (1) were the miscellaneous collections among. The number of collected material along with indigenous collector number, collection sites, districts and states is given in Table 1. The extent of crop variability observed and collected in different crops is discussed as under:

### Pulses/Grain Legumes

The rice bean plants had tall viny growth with heavy pod bearing and showed variability particularly in seed colour and seed size. Two types of rice bean plant habit i.e. viny (indeterminate) and bushy (determinate) were found. Considerable diversity was observed in the characteristics of pod size, seed shape, seed size and seed colour. The pod length varied from 8.00 cm to 15.00 cm. The seeds with different colours such as dark red, creamy/pale white, greenish black and brownish were collected. Collections made in Adzuki bean did not show much variability in respect of pod length and seed colour. Seed colour variability was seen and collected in French bean. Variations were observed in lablab bean and sword bean. The pod length of sword bean was observed upto 13-18 cm.

### Cereals/Pseudocereals

One landrace of wheat with red seed colour having cold and drought resistance was collected from Western Sikkim area. Huskless barley accessions were collected from Eastern Sikkim (2) and South Sikkim (1), respectively.

### Vegetables

Every household grows different local vegetables in the area in their backyard/kitchen garden and in irrigated fields/fertile patches for domestic as well as commercial purposes. Diversity was collected in pumpkin, chilli, brinjal and tree tomato (*Cyphomandra betacea* Cav.). The tree tomato bears heavily with 3-4 fruits in one cluster (Fig 2). Two distinct types was noted in tree tomato one with red fruit while other is violet at their ripening stage. Two distinct brinjal accessions (one with white round medium fruit and another with small red fruits) at ripening, looking like tomato, were also collected from Korphector village Namachi of Southern Sikkim.

### Miscellaneous

Four sample viz. bhanjira (*Perilla frutescens*) (2), banana (*Musa paradisiaca*) (1), Indrayan (*Citrullus colocynthis*) and ornamental chilli (*Capsicum* species) were collected. Indrayan was collected from jungle of Sukhia in Darjeeling district. The fruit weight ranged from 800 to 1200 g with thick and hard skin. One unique sample of Ornamental

Table 1. List of crop germplasm collections from parts of Sikkim, Darjeeling district of Bengal

| S. No. | Coll. No. | IC. No.   | Conman Name       | Scientific Name              | Site of collection | District   | State     |
|--------|-----------|-----------|-------------------|------------------------------|--------------------|------------|-----------|
| 1.     | RPD-1     | IC-364039 | Rice bean         | <i>Vigna umbellata</i>       | Tirkutam busty     | E. Sikkim  | Sikkim    |
| 2.     | RPD-2     | IC-364040 | Barley            | <i>Hordeum vulgare</i>       | Martam khadi       | E. Sikkim  | Sikkim    |
| 3.     | RPD-3     | IC-364041 | Rice bean         | <i>Vigna umbellata</i>       | Rawtay rumtek      | E. Sikkim  | Sikkim    |
| 4.     | RPD-4     | IC-364042 | Barley            | <i>Hordeum vulgare</i>       | Rawtay rumtek      | E. Sikkim  | Sikkim    |
| 5.     | RPD-5     | IC-364043 | Buck wheat        | <i>Fagopyrum tataricum</i>   | Rawtay rumtek      | E. Sikkim  | Sikkim    |
| 6.     | RPD-6     | IC-364044 | Buck wheat        | <i>Fagopyrum esculentum</i>  | Rawtay rumtek      | E. Sikkim  | Sikkim    |
| 7.     | RPD-7     | IC-364045 | Soybean           | <i>Glycine max</i>           | Sazong             | E. Sikkim  | Sikkim    |
| 8.     | RPD-8     | IC-364046 | Pumpkin           | <i>Cucurbita moschata</i>    | Sazong             | E. Sikkim  | Sikkim    |
| 9.     | RPD-51    | IC-364089 | Ornamental chilli | <i>Capsicum species</i>      | Nazitam            | Gangtaok   | Sikkim    |
| 10.    | RPD-9     | IC-364047 | Rice bean         | <i>Vigna umbellata</i>       | Tumlang            | Mungum     | Sikkim    |
| 11.    | RPD-10    | IC-364048 | Barley            | <i>Hordeum vulgare</i>       | Tumlang            | Mungum     | Sikkim    |
| 12.    | RPD-11    | IC-364049 | Buck wheat        | <i>Fagopyrum tataricum</i>   | Phondong           | Mungum     | Sikkim    |
| 13.    | RPD-12    | IC-364050 | Mung bean         | <i>Vigna radiata</i>         | Dahan goan         | Namchi     | Sikkim    |
| 14.    | RPD-13    | IC-364051 | Buck wheat        | <i>Fagopyrum esculentum</i>  | Dahan goan         | Namchi     | Sikkim    |
| 15.    | RPD-14    | IC-364052 | Rice bean         | <i>Vigna umbellata</i>       | Uttarey            | Geyzing    | Sikkim    |
| 16.    | RPD-15    | IC-364053 | Beans             | <i>Vigna sp.</i>             | Legship            | Geyzing    | Sikkim    |
| 17.    | RPD-16    | IC-364054 | Rice bean         | <i>Vigna umbellata</i>       | Uttarey            | Geyzing    | Sikkim    |
| 18.    | RPD-52    | IC-364090 | Banana            | <i>Musa paradisiacal</i>     | Bormik             | Geyzing    | Sikkim    |
| 19.    | RPD-17    | IC-364055 | Wheat             | <i>Triticum aestivum</i>     | Martam upper       | Geyzing    | Sikkim    |
| 20.    | RPD-18    | IC-364056 | Buck wheat        | <i>Fagopyrum tataricum</i>   | Lower budang       | Geyzing    | Sikkim    |
| 21.    | RPD-19    | IC-364057 | Chilli            | <i>Capsicum annuum</i>       | Korohector         | Namchi     | Sikkim    |
| 22.    | RPD-20    | IC-364058 | Chilli            | <i>Capsicum annuum</i>       | Korphector         | Namchi     | Sikkim    |
| 23.    | RPD-21    | IC-364059 | Brinjal           | <i>Solanum melongena</i>     | Korphector         | Namchi     | Sikkim    |
| 24.    | RPD-22    | IC-364060 | French bean       | <i>Phaseolus vulgaris</i>    | Nandugaoan         | Namchi     | Sikkim    |
| 25.    | RPD-23    | IC-364061 | Rice bean         | <i>Vigna umbellata</i>       | Nandugaoan         | Namchi     | Sikkim    |
| 26.    | RPD-24    | IC-364062 | Pumpkin           | <i>Cucurbita moschata</i>    | Nandugaoan         | Namchi     | Sikkim    |
| 27.    | RPD-25    | IC-364063 | Chilli            | <i>Capsicum annuum</i>       | Nandugaoan         | Namchi     | Sikkim    |
| 28.    | RPD-26    | IC-364064 | Rice bean         | <i>Vigna umbellata</i>       | Upper lameta       | Darjeeling | N. Bengal |
| 29.    | RPD-27    | IC-364065 | Bitter apple      | <i>Citrullus colocynthis</i> | Upper lameta       | Darjeeling | N. Bengal |
| 30.    | RPD-28    | IC-364066 | Rice bean         | <i>Vigna umbellata</i>       | Lepcha             | Darjeeling | N. Bengal |
| 31.    | RPD-29    | IC-364067 | Chilli            | <i>Capsicum annuum</i>       | Lepcha             | Darjeeling | N. Bengal |
| 32.    | RPD-30    | IC-364068 | Maize             | <i>Zea mays</i>              | Lepcha             | Darjeeling | N. Bengal |
| 33.    | RPD-31    | IC-364069 | Brinjal           | <i>Solanum melongena</i>     | Poyshore           | Darjeeling | N. Bengal |
| 34.    | RPD-32    | IC-364070 | Tree tomato       | <i>Cyphomandra betacea</i>   | Poyshore           | Darjeeling | N. Bengal |
| 35.    | RPD-33    | IC-364071 | Perilla           | <i>Perilla frutescens</i>    | Poyshore           | Darjeeling | N. Bengal |
| 36.    | RPD-34    | IC-364072 | Maize             | <i>Zea mays</i>              | Kalawal rangbay    | Darjeeling | N. Bengal |
| 37.    | RPD-35    | IC-364073 | Adzuki bean       | <i>Vigna angularis</i>       | Kalawal rangbay    | Darjeeling | N. Bengal |
| 38.    | RPD-36    | IC-364074 | Tree tomato       | <i>Cyphomandra betacea</i>   | Okyt 7 mile        | Darjeeling | N. Bengal |
| 39.    | RPD-37    | IC-364075 | Lablab bean       | <i>Lablab purpureus</i>      | Okyt 7 mile        | Darjeeling | N. Bengal |
| 40.    | RPD-38    | IC-364076 | French bean       | <i>Phaseolus vulgaris</i>    | Okyt 7 mile        | Darjeeling | N. Bengal |
| 41.    | RPD-39    | IC-364077 | Adzuki bean       | <i>Vigna angularis</i>       | Mirik              | Darjeeling | N. Bengal |
| 42.    | RPD-40    | IC-364078 | Adzuki bean       | <i>Vigna angularis</i>       | Mirik              | Darjeeling | N. Bengal |
| 43.    | RPD-41    | IC-364079 | Rice bean         | <i>Vigna umbellata</i>       | Mirik              | Darjeeling | N. Bengal |
| 44.    | RPD-42    | IC-364080 | Rice bean         | <i>Vigna umbellata</i>       | Rajbari            | Darjeeling | N. Bengal |
| 45.    | RPD-43    | IC-364081 | Rice bean         | <i>Vigna umbellata</i>       | Rajbari            | Darjeeling | N. Bengal |
| 46.    | RPD-44    | IC-364082 | French bean       | <i>Phaseolus vulgaris</i>    | Rajbangay          | Darjeeling | N. Bengal |
| 47.    | RPD-45    | IC-364083 | French bean       | <i>Phaseolus vulgaris</i>    | Dali               | Darjeeling | N. Bengal |
| 48.    | RPD-46    | IC-364084 | Perilla           | <i>Perilla frutescens</i>    | Neemka dada        | Darjeeling | N. Bengal |
| 49.    | RPD-47    | IC-364085 | Sword bean        | <i>Canavalia gladiata</i>    | Rangbul            | Darjeeling | N. Bengal |
| 50.    | RPD-48    | IC-364086 | Sword bean        | <i>Canavalia gladiata</i>    | Rangbul            | Darjeeling | N. Bengal |
| 51.    | RPD-49    | IC-364087 | Adzuki bean       | <i>Vigna angularis</i>       | Gorabari           | Darjeeling | N. Bengal |
| 52.    | RPD-50    | IC-364088 | Adzuki bean       | <i>Vigna angularis</i>       | Gorabari           | Darjeeling | N. Bengal |



Fig. 2: Tree tomato (*Cyphomandra betacea*) in cluster collected from Okyat near Darjeeling in North Bengal

chilli (*Capsicum* species) was collected from Nazitam, Near Rumtek, Gangtok (Fig. 3). The plant height is about 75 cm and bears 2-4 fruits per plant. The fruit is drooping and triangular in shape with long peduncle and becomes yellowish red at ripening.

#### Acknowledgements

The authors are thankful to Dr. BS Dhillon, Director and Dr. SS Malik, Head, Exploration Division, National Bureau of Plant Genetic Resources, New Delhi for providing valuable guidance and essential facilities.



Fig. 3: A unique ornamental chilli collected from Nazitam, Gangtok, Sikkim

#### References

- Arora RK, KPS Chandel, KC Pant and BD Joshi (1980) Rice bean—a tribal pulse of eastern India. *Econ. Bot.*, **34**: 260-263.
- Arora RK (1977) Job's tears (*Coix lacryma-jobi*) – a minor food and fodder crop of north eastern India. *Econ. Bot.* **31**: 358-366.
- Arora RK (1979-1982) Collecting in Sikkim Himalayas. *IBPGR Newsletters*, FAO, Rome.
- Patiram, RK Awasthi and SBS Bhaduria (1999) Sustainable land utilization for ecological balance in the Sikkim hills. *J. Hill Res.* **12**: 83-85.
- Chomchalow N, CLL Gowda and P Laosuwan (eds) (1990) *Proc. work Under-exploited and Potential Food Legumes in Asia*. Thailand, FAO/UNDP.

## SHORT COMMUNICATION

## Variability in Sunflower Inbreds for Physiological Characters

**Lakshmi Prayaga, A Vishnuvardhan Reddy and P Lakshamma**

Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500030, Andhra Pradesh

**Key Words:** Inbreds, Physiological characters, Sunflower, Variability

Sunflower has gained much popularity because of its short duration, wider adaptability to varied agro-climatic conditions, high yield potential and for its oil rich in PUFA content. In spite of its wide spread cultivation, the productivity of the crop in the country is low when compared to its yield potential. Development of good hybrids and varieties depend on the availability of variation in the germplasm for different characters. Therefore, in the present investigation, emphasis was given for characterization of the inbreds developed at Directorate of Oilseeds Research (DOR), Hyderabad for selecting physiologically efficient types for further use in breeding programmes.

Thirty elite inbreds developed at DOR along with two checks, KBSH 1 and Morden (Table 1) were sown in Randomized Block Design during *rabi* 2001 with three replications. Crop was sown at a spacing of 45 x 30 cm. Recommended dose of N-P-K (60-30-30 kg/ha) were applied. Irrigation and plant protection measures were given as and when required. Five rows or 4m length constituted one replication. In each replication observations were recorded on five plants.

The variation available and the promising inbreds for different characters have been represented in Table 2 and 3. It was observed that considerable amount of variability exists in the inbreds studied which offers scope for selection and utilization in further hybridization programme.

Though there is possibility to improve crop yield by reducing plant height via increasing HI, the decreased plant height causes reduction in internodal length thereby

causing shading of leaves. Therefore, medium plant height is preferred (Skoric, 1980). Plant height in different inbreds ranged from 77-165 cm with a mean of 116. There is only one genotype, DSI 78 which recorded <80 cm height other than Morden (77cm) and in GP 774 and Acc 226 it's more than 150 cm. Three inbreds DSI 41, DSI 57, DSI 55 recorded less than 100 cm height. Majority of the inbreds are in the range of 100-130 cm. This character has been found significantly correlated with seed yield (Punia and Gill, 1994) by influencing head diameter (Doddamani *et al.*, 1997).

Stem girth indicates strength of stem to withstand lodging. Therefore while selection, short and firm stems were preferred. Girth varied from 5.0-6.7 cm with a mean of 5.8 cm. Variation for stem girth is not much among genotypes. Both positive (Jayaram Gowda, 1994) and negative (Doddamani *et al.*, 1997) effects of stem girth on seed yield were reported.

Leaf number and area are important as they decide the size of assimilating area. The highest leaf of 32 was recorded in inbred DSI 103 and the lowest (20) in DSI 57. Leaf number varied between 20-32 whereas LAI ranged from 1.0 to 3.5. In only three genotypes viz., Acc 226, DSI 103, GP 774 the leaf number recorded was higher than KBSH 1(28). However, LAI crossed 2.5 only in DSI 38, DSI 45, DSI 36, and DSI 198. Other than the number and area, leaf orientation that results in least shading is the character to be considered while selection. Inbreds with < 25 leaves has lower LAI. As there was positive

**Table 1. List of inbreds studied**

| S.No. | Inbred | S.No. | Inbred | S.No. | Inbred | S.No. | Inbred    |
|-------|--------|-------|--------|-------|--------|-------|-----------|
| 1     | Acc226 | 9     | DSI 45 | 17    | DSI 60 | 25    | DSI 78    |
| 2     | DSI 16 | 10    | DSI 48 | 18    | DSI 63 | 26    | DSI 103   |
| 3     | DSI 36 | 11    | DSI 49 | 19    | DSI 65 | 27    | DSI 198   |
| 4     | DSI 37 | 12    | DSI 50 | 20    | DSI 67 | 28    | GP -774   |
| 5     | DSI 38 | 13    | DSI 51 | 21    | DSI 69 | 29    | GP -761   |
| 6     | DSI 41 | 14    | DSI 54 | 22    | DSI 70 | 30    | GP -771   |
| 7     | DSI 42 | 15    | DSI 55 | 23    | DSI 71 | 31    | KBSH-1(C) |
| 8     | DSI 44 | 16    | DSI 57 | 24    | DSI 73 | 32    | MORDEN(C) |

Table 2. Variation among inbreds for different characters

| S.No | Character                      | Mean $\pm$ S.E  | Range     | KBSH 1 | Morden | C.V (%) |
|------|--------------------------------|-----------------|-----------|--------|--------|---------|
| 1    | Plant height (cm)              | 116 $\pm$ 8.2   | 77-165    | 144    | 77     | 10      |
| 2    | Leaf number                    | 25 $\pm$ 1.18   | 20-32     | 28     | 21     | 7       |
| 3    | LAI at flowering               | 1.9 $\pm$ 0.26  | 1.0-3.5   | 2.8    | 2.5    | 19      |
| 4    | TDMat flowering(g/plant)       | 49 $\pm$ 6.5    | 19-85     | 56     | 53     | 19      |
| 5    | TDM at harvest (g/plant)       | 86 $\pm$ 7.2    | 53-115    | 115    | 100    | 14      |
| 6    | Head diameter (cm)             | 14.3 $\pm$ 0.78 | 11.6-17.3 | 15.2   | 14.9   | 9       |
| 7    | Diameter of unfilled area (cm) | 5.3 $\pm$ 0.67  | 1.0-7.1   | 5.0    | 5.7    | 22      |
| 8    | Stem girth (cm)                | 5.8 $\pm$ 0.32  | 5.0-6.7   | 6.2    | 6.0    | 10      |
| 9    | Days to flowering              | 61 $\pm$ 1.2    | 55-66     | 55     | 55     | 3       |
| 10   | Days to maturity               | 98 $\pm$ 1.3    | 92-102    | 102    | 95     | 4       |
| 11   | Seed yield (g/plant)           | 25 $\pm$ 3.11   | 16-45     | 45     | 44     | 21      |
| 12   | HI (%)                         | 29 $\pm$ 3.9    | 18-44     | 41     | 44     | 22      |

Table 3. Promising inbreds for various characters

| S.No | Character                       | Inbreds                                                                                                                 |
|------|---------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| 1    | Plant height (cm)               |                                                                                                                         |
|      | Short <100                      | DSI 41, DSI 55, DSI 57, DSI 78                                                                                          |
|      | Tall >120                       | Acc 226, DSI 16, DSI 38, DSI 45, DSI 63, DSI 73, DSI 103, GP 774                                                        |
| 2    | Leaf number >27                 | Acc 226, DSI 38, DSI 45, DSI 63, DSI 67, DSI 103, GP 774                                                                |
| 3    | LAI at flowering >2.5           | DSI 36, DSI 38, DSI 45, DSI 198                                                                                         |
| 4    | TDM at flowering > 60 g/plant   | Acc 226, DSI 36, GP 761, DSI 198                                                                                        |
| 5    | TDM at harvest >100 g/plant     | Acc 226, DSI 63, DSI 65, GP 761, DSI 198                                                                                |
| 6    | Head diameter (=15cm)           | DSI 37, DSI 38, DSI 44, DSI 45, DSI 63, DSI 67, DSI 69, GP 761, DSI 198                                                 |
| 7    | Diameter of unfilled area < 4cm | DSI 37, DSI 42, DSI 48, DSI 49, DSI 67                                                                                  |
| 8    | Stem girth > 6cm                | Acc 226, DSI 37, DSI 38, DSI 45, DSI 51, DSI 55, DSI 63, DSI 69, GP 774                                                 |
| 9    | Days to flowering < 60 days     | Acc 226, DSI 37, DSI 41, DSI 44, DSI 57, DSI 103, GP 761, GP 771                                                        |
| 10   | Days to harvesting < 95 days    | DSI 37, DSI 41, DSI 50, DSI 57, DSI 103, GP 761, GP 771                                                                 |
| 11   | Seed yield                      |                                                                                                                         |
|      | >30g/plant                      | DSI 50, DSI 63, DSI 67, GP 761                                                                                          |
|      | >25                             | DSI 65, DSI 70, DSI 103, GP 774, DSI 198                                                                                |
| 12   | HI >30%                         | DSI 16, DSI 37, DSI 41, DSI 49, DSI 50, DSI 54, DSI 63, DSI 65, DSI 67, DSI 70, DSI 71, DSI 103, GP 761, GP 771, GP 774 |

relationship between assimilating area and seed yield, LAI can be used as a selection parameter (Nanjareddy *et al.*, 1994). Another advantage in selection for LAI is that it is superdominantly heritable character (Skoric, 1985).

Days to flowering ranged from 55-66 days and to maturity from 92-102 days. However, these two characters did not show any significant association with seed yield (Doddamani *et al.*, 1997).

Direct relation between total dry matter (TDM) production and seed yield was reported (Nanjareddy *et al.*, 1994). High TDM at anthesis would lead to remobilization of stored carbohydrates from stem to seed which is more important during periods of stress. In this study, TDM ranged from 19-85 at flowering with a mean of 49 and 53-115 at harvest with a mean of 86g/plant. Inbreds that recorded >60 g weight at flowering are Acc 226, GP 761, DSI 36, DSI 198 and at harvest >100 g/plant are Acc 226, GP 761, DSI 63, DSI 198. Therefore, selection for high pre-anthesis storage drymatter coupled with active current assimilation during seed development contributes significantly towards improvement of

productivity (Nanjareddy *et al.*, 1996).

Head diameter and diameter of unfilled zone are important characters that have direct bearing on seed yield. Maximum head diameter of 17.3 cm was recorded in DSI 67 and lowest, 11.6 cm was recorded in DSI 78 with a mean of 14.3cm. Though variation for head diameter among inbreds was not much, considerable variation was observed for the central unfilled zone (from 1.0 to 7.1 cm). Seed yield was negatively and significantly associated with unfilled seed percentage (Punia and Gill, 1994). Therefore, yield can be improved by minimizing the area of this unfilled zone. This central unfilled area is > 4cm in 25 genotypes and in only 5 inbreds viz., DSI 67, DSI 37, DSI 42, DSI 48, DSI 49 it is < 4 cm.

Seed yield per plant ranged from 16-45 g with a mean of 25 g. Highest seed yield was recorded in inbred GP 761 and the lowest in DSI 78. In 9 inbreds, DSI 103, GP 761, GP 774, DSI 50, DSI 70, DSI 67, DSI 65, DSI 63 and DSI 198, the seed yield was >25g/plant. None of the inbreds tested were superior to KBSH 1 and Morden, which recorded > 40g/plant yield. Seed yield showed

significant positive correlation with plant height, number of filled seeds, head diameter, test weight and HI (Teklewold *et al* 2000).

HI ranged from 18-44% with a mean of 29%. Inbred GP 761 recorded highest HI of 37% and lowest 18% in DSI 78. Inbreds with HI  $\geq$  30% include DSI 41, DSI 103, GP 761, GP 771, GP 774, DSI 50, DSI 70, DSI 71, DSI 67, DSI 65, DSI 63, DSI 54, DSI 16, DSI 37 and DSI 49. Inbreds Acc 226, DSI 38, and DSI 45 though have high TDM and LAI, their seed yield and HI are low because of poor translocation from stem. Acc 226 is a tall type and 47% of total dry matter is found in stem only. Nanjareddy *et al.*, (1994), Tanimu and Ado (1988) and Teklewold *et al.*, (2000) and many others also reported similar ranges for the above characters.

Based on the overall performance, DSI 103, GP 774, GP 761, DSI 198, DSI 67 and DSI 63 were identified as physiologically efficient with high seed yield, HI coupled with high LAI. However, based on the requirement, inbreds with specific characters can be selected.

#### References

- Doddamani IK, SA Patil and RL Ravikumar (1997) Relationship of autogamy and self fertility with seed yield per plant and yield components in sunflower (*Helianthus annuus* L.). *Helia* 20: 95-102.
- Jayaram Gowda (1994) *Evaluation of sunflower for autogamy, yield and yield components*. M.Sc. (Ag) thesis, University of Agricultural Sciences, Bangalore.
- Nanjareddy YA, MS Sheshshayee, R Uma Shankar, K Virupakshappa and TG Prasad (1994) Selection for high canopy assimilation rate is a good strategy to increase productivity in sunflower. *Helia* 17: 45-52.
- Nanjareddy YA, R Uma Shankar and K Virupakshappa (1996) Relative contribution of pre and post anthesis dry matter to productivity: an analysis in sunflower. *Proc. 14<sup>th</sup> Int. Sunflower Con.* Beijing/Shenyang, China. pp. 628-634.
- Punia MS and HS Gill (1994) Correlation and path coefficient analysis for seed yield traits in sunflower (*Helianthus annuus* L.). *Helia* 17: 7-12.
- Skoric D (1980) Desired model of hybrid sunflower and the newly developed NS hybrids. *Helia* 3: 19-24.
- Skoric D (1985) Mode of inheritance of LAI in F1 generation of different sunflower inbreds. *Proc. 11<sup>th</sup> Int. Sunflower Conf.* Mar del Plata, Argentina. pp 683-689.
- Tanimu B and SC Ado (1988) Relationships between yield and yield components in forty populations of sunflower. *Helia* 11: 17-20.
- Teklewold A, H Jayaramaiah and Jayaram Gowda (2000) Genetic divergence study in sunflower. *Helia* 23: 93-104.

## SHORT COMMUNICATION

Genetic Variability in Exotic Lines of Tomato (*Lycopersicon esculentum* Mill)

Megha Upadhyay, JP Singh and Anita Singh

Department of Vegetable Science, Govind Ballabh Pant University for Agriculture and Technology, Pantnagar-263145, Uttarakhand

Key Words: Genetic advance, Heritability, Tomato, Variability

The assessment of variability type and magnitude of association among attributes is essential for evaluating the possibility of simultaneous improvement for many characters. Therefore, the present investigation was carried out to evaluate the exotic germplasm for improvement of tomato through studies on variability, heritability and genetic advance.

The present study was conducted at Z.A.R.S., Majhera, Nainital, during summer of 2003. The 26 materials were planted in 3.0x1.2 m plot size at a distance of 60x60 cm. The experiment was laid out in Randomized Block Design and replicated thrice. Five plants were selected at random in each replication and observation on number of flowers per clusters, flower clusters at first picking, number of fruits per cluster, weight per fruit, yield per plant (kg), total yield (q/ha), total soluble solids (TSS) (%) and juice content (%) were taken. Statistical analysis was done according to Snedecor and Cochran (1967). Genotypic and phenotypic coefficient of variation were computed according to Burton (1952). Heritability and genetic advance were estimated according to Allard (1960) and Johnson *et al.* (1955), respectively.

Data relating to various yield and quality contributing characters (Table 1) revealed that number of flowers per cluster was variable from 4.33 to 8.33 with an average of  $5.55 \pm 0.56$ . Regarding flower cluster at first picking,

genotype CLN 1466 P showed lowest number (9.66) and CL 11-31-0-38-4-0 showed the maximum clusters (58) among the germplasm lines. The average was  $20 \pm 0.47$ . GCV was high (44.26%) indicating the rich exploitable variability.

Among the yield contributing traits, yield per plant showed maximum GCV (46.44%) followed by weight per fruit (36.83%) and number of fruits per cluster (19.46%). The GCV is very high indicating the presence of exploitable variability for this character.

The total yield ranged from 90.81 to 835.10 q/ha with an average of  $385 \pm 47.79$ . CLN 2237 A had the highest yield (835.1 q/ha) followed by CLN 915-93 D<sub>4</sub>-1-0-3 (812.6 q/ha) and CL 11-31-0-38-4-0 (730.2 q/ha). The GCV for total yield (46.59%) was high indicating adequate variability among germplasm lines.

TSS varied from 3.23 to 7.46% with mean value of  $4.90 \pm 0.17$ . Juice percentage of the fruits ranged from 35.33 to 57.96 % with an average of  $46.98 \pm 1.22$ . Both the above characters exhibited poor variability. The coefficient of variation does not offer full scope to estimate the heritable variation. The relative proportion of heritable variation assessed with the help of heritability estimates and genetic advance expressed as percentage of mean are given in Table 1. In general, heritability was high for all the characters. Broad sense heritability was found to be

Table 1. Estimates of variability, heritability and genetic advance for some agro-morphological characters in tomato cultivars

| Characters                                 | Range of Variability | Mean   | Standard error | GCV   | PCV   | ECV   | Heritability (%) | Genetic advance (%) |
|--------------------------------------------|----------------------|--------|----------------|-------|-------|-------|------------------|---------------------|
| Number of flowers per cluster              | 4.33-8.33            | 5.50   | 0.56           | 12.22 | 21.47 | 17.65 | 32.41            | 78.87               |
| Flower clusters at 1 <sup>st</sup> picking | 9.66-58.00           | 20.61  | 1.47           | 44.26 | 45.97 | 12.41 | 92.70            | 18.10               |
| Number of fruits per cluster               | 2.66-6.00            | 3.69   | 0.45           | 19.46 | 28.72 | 21.13 | 45.89            | 10.02               |
| Weight per fruit (g)                       | 5.83-85.00           | 44.92  | 2.98           | 36.83 | 38.59 | 11.51 | 91.10            | 32.54               |
| Yield per plant (kg)                       | 0.36-3.00            | 1.38   | 0.16           | 46.44 | 50.45 | 20.96 | 83.07            | 12.08               |
| Yield (q/ha)                               | 90.81-835.10         | 385.60 | 47.79          | 46.59 | 59.30 | 21.46 | 82.49            | 33.62               |
| Total soluble solids (%)                   | 3.23-7.46            | 4.90   | 0.17           | 18.92 | 19.89 | 61.62 | 90.41            | 18.47               |
| Juice content (%)                          | 35.33-57.96          | 46.98  | 1.22           | 13.24 | 13.99 | 45.25 | 89.54            | 12.13               |

maximum for flower clusters at first picking (92.70%) followed by weight per fruit (91.10%) and total soluble solids (90.41%).

Genetic advance were high for number of flowers per cluster (78.87%), total yield (33.62%) and weight per fruit (32.54%). High heritability coupled with high genetic advance and coefficients of variability for weight per fruit and total yield indicate that most likely heritability for these characters is due to additive gene effects and hence direct selection may be highly effective. Characters showing high heritability with low genetic advance indicated that these characters were governed by non-additive gene action and presence of GxE interaction. The heritability

is being exhibited due to favourable effect of the environment rather than genotype and hence simple selection may not be effective.

#### References

- Allard RW (1960) *Principles of Plant Breeding*, John Wiley and Sons Inc., New York.
- Burton GW (1952) Quantitative inheritance in grasses. *Proc. 6<sup>th</sup> Int. Grassland Cong.* 11: 277-283.
- Johnson HW, HF Robinson and RE Comstock (1955) Estimation of genetic and environmental variability in soybean. *Agronomy J.* 47: 314-318.
- Snedecor GW and WG Cochran (1967) *Statistical Methods*. Oxford and IBH Publishing Co. Pvt. Ltd., Calcutta.

---

## CONTENTS

|                                                                                                                                                                 |     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Status of Horticultural Crop Genetic Resources in India<br>GUNJEET KUMAR, KK GANGOPADHYAY, VK DOBHAI, KC BHATT AND BS DHILLON ...                               | 89  |
| Introduction, Collection, Evaluation and Utilization of Fruit Germplasm<br>SN PANDEY AND AK SINGH ...                                                           | 105 |
| Evaluation of Wheat ( <i>T. aestivum</i> L.) Germplasm for Yield and Yield Attributes<br>RAVI KANT AND RAJENDRA PRASAD ...                                      | 110 |
| Evaluation of Genetic Variability in Mungbean ( <i>Vigna radiata</i> (L.) Wilczek) Germplasm<br>RAKESH KUMAR, JL TICKOO, N CHANDRA AND HK DIKSHIT ...           | 114 |
| Promising Desi Cotton ( <i>G. arboreum</i> L.) Germplasm for Fibre Quality Traits and Locule Retentivity<br>RA MEENA, D MONGA, RAJIV KUMAR AND HAMID HASSAN ... | 118 |
| Variability Studies in Sunflower Lines Derived through Interspecific Hybridization<br>GS MOHAN AND A SEETHARAM ...                                              | 121 |
| Genetic Divergence in Pea ( <i>Pisum sativum</i> L.)<br>RS RATHI AND RPS DHAKA ...                                                                              | 125 |
| Exploration, Collection and Characterization of Citrus Genetic Diversity from Manipur and Tripura<br>IP SINGH ...                                               | 128 |
| Genetic Variability in <i>Chenopodium</i><br>ATUL BHARGAVA, SUDHIR SHUKLA AND DEEPAK OHRI ...                                                                   | 133 |
| Important Information Systems for Plant Genetic Resources in the World<br>RC AGRAWAL ...                                                                        | 137 |
| Inter-relationships in Morphotypes of Greater Yam ( <i>Dioscorea alata</i> L.)<br>ASHA KI AND MAYA C NAIR ...                                                   | 148 |
| Collection of Crop Germplasm from Sikkim and Adjacent Darjeeling District of North Bengal<br>RS RATHI, NS PANWAR AND BS PHOGAT ...                              | 154 |
| Variability in Sunflower Inbreds for Physiological Characters<br>LAKSHMI PRAYAGA, A VISHNUVARDHAN REDDY AND P LAKSHMAMMA ...                                    | 158 |
| Genetic Variability in Exotic Lines of Tomato ( <i>Lycopersicon esculentum</i> Mill)<br>MEGHA UPADHYAY, JP SINGH AND ANITA SINGH ...                            | 161 |