Vol. 27 No.1 2014

ISSN 0971-8184

Indian Journal of Plant Genetic Resources

An International Journal for Conservation and Use of Plant Diversity

Indian Society of Plant Genetic Resources
New Delhi, India

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(Registration No. S/18336)

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ISSN 0971-8184

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Vol. 27 No. 1 2014

INDIAN SOCIETY OF PLANT GENETIC RESOURCES
NBPGR CAMPUS, NEW DELHI-110012, INDIA

CONTENTS

Determination of Physical Properties of Chickpea Seeds and their Relevance in Germplasm Collections

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(Received: 07 August 2013; Revised: 17 October 2013; Accepted: 28 November 2013)

The physical properties of seeds are important for processing and storage as well for assessing seed quality. Seed shape is an important qualitative character that determines the seed appearance and uniformity. Fifty chickpea germplasm accessions representing *desi*, *kabuli* and intermediate types were examined for various morphological and physical properties. High diversity for different seed traits was observed among the chickpea accessions. The extent of variation was wide for seed related traits especially in the pea-shaped chickpea accessions. These results are useful in refining the descriptor states of qualitative traits of chickpea seed and effectively utilizing germplasm in further crop improvement programmes.

Key Words: Chickpea, Diversity, Germplasm, Seed Colour, Seed Shape

Introduction

Chickpea (*Cicer arietinum* L.) is an annual grain legume cultivated in over 50 countries across all continents. During 2011, the global chickpea area was about 13.20 million ha, with a production of 11.62 million metric tons (FAOSTAT 2013). Two main types of chickpea are well recognized – small seeded, with coloured seed coat, angular shaped *desi* type and the beige coloured, large seeded, owl's head shape *kabuli* type. There is an intermediate type that is – dark or light coloured, small or medium sized and round (pea) shaped seeds (IBPGR/ICRISAT/ICARDA, 1993). Chickpea seeds are consumed in a variety of ways with or without seed coat. Agbola *et al*. (2002) described seed quality traits (colour, size and 'dhal' recovery rate) and common uses of chickpea varieties in India. Along with dietary value, chickpea quality is also judged by physiochemical and cooking traits (Patane, 2006). The physical properties of seeds are important in designing equipment and structures for handling, transporting, processing and storage, and also for assessing seed quality (Nikobin *et al*., 2009; Ayman *et al*., 2010). Mechanical resistance of seeds is a physical property that effects/gets affected by the technological process. Limited studies have been made to classify chickpea seeds on the basis of shape. Methods for measuring the seed shapes that are reliable, cost effective and have potential for wide acceptance are highly desirable (Meena *et al*., 2004).

Germplasm collections offer the much needed diversity for important morpho-agronomic traits for utilization in crop improvement research. The ICRISAT Genebank, Patancheru, India, conserves 20,267 accessions of chickpea from 60 countries. The collection represents wide diversity for important morpho-agronomic traits including seed characters. The physical properties of seeds are important for processing germplasm samples and some of the traits are important attributes of seed quality, consumer demands and market premiums. In chickpea, seed coat colour has overriding importance in determining market quality and acceptance of improved cultivars and hence breeders need access to diverse genetic resources. Information on the physical properties of chickpea seed especially the pea shaped intermediate types, and their use in crop improvement, is limited. Better knowledge on extent of variation for physical properties of seeds adds value to the genebank collections, especially when they are related to the useful seed quality parameters. Results from a study on the morphological and physical properties of 50 chickpea germplasm accessions representing *desi*, *kabuli* and the intermediate (pea) types from the chickpea collection conserved at the ICRISAT genebank are reported in this paper.

Materials and Methods

The 50 chickpea germplasm accessions selected for this study represent landrace/traditional cultivars (41), breeding lines (6) and advanced cultivars (3). These accessions were grown in Vertisols (black soils) during 2011 post-rainy season at ICRISAT, Patancheru, India. Each accession was planted in two rows of four meter

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length, with a row to row spacing of 60 cm and plant to plant spacing of 10 cm. Freshly harvested seed samples were hand-threshed and cleaned samples were stored in short-term storage conditions (25ºC and 40% RH) for two weeks to attain equilibrium moisture content (emc). During this period, the moisture content of the samples was estimated at two-day intervals and the emc was ascertained when the seed samples in all accessions showed stable moisture levels.

Observations were recorded on 17 important seed related traits. These include – seed moisture content, 100-seed weight, seed colour, shape, surface texture, seed coat content; and principal dimensions of seed size such as length, width and thickness, geometric mean diameter (GMD), surface area, sphericity/roundness index, shape aspect, volume, bulk density, true density and porosity.

Seed Moisture Content

The equilibrium moisture content (emc) of equilibrated seed samples under controlled environment was estimated on wet weight basis (w.b.) following oven-dry method (ISTA, 1993).

100-Seed Weight

100-seed weight of the chickpea accessions was measured on randomly selected 100 seeds and weighing them using a sensitive balance and weight was recorded in grams.

Seed Colour, Shape and Surface Texture

Observations on seed colour, shape and surface texture were recorded on bulk sample of 200 g following the descriptors for chickpea (IBPGR/ICRISAT/ICARDA, 1993).

Seed Coat Content

An accurately weighed sample of 10 seeds in each accession was soaked in distilled water for 16 hours at room temperature. After the water was drained, the soaked seeds were dried on blotting paper and the seed coat was completely removed with tweezers. The seed coats were dried in an oven at 60ºC for 24 hours, followed by cooling in a desiccator (Tizazu and Emire, 2010). The seed coats were weighed and the percent seed coat content was calculated.

Seed Size

Seed size was measured in millimeters on principal dimensions such as length, width and thickness. Twenty randomly selected seeds from each accession were used to measure length, width and thickness using electronic digital caliper and mean values were calculated.

The Geometric Mean Diameter (GMD)

The three mutually perpendicular diametrical dimensions of length, width and thicknesses of seed of chickpea were determined and used for calculating the geometric mean diameter in mm (Sreenarayanaa *et al*., 1988).

Surface Area, Sphericity and Shape Aspect

Sphericity is the state or form of being spherical. It is the ratio of the surface area of a given object to the surface area of a sphere with the same volume. The sphericity and shape aspect of chickpea seeds were determined as percentages using the procedures suggested by Mohsenin (1986) and Omobuwajo *et al*. (1999), respectively.

Seed Volume, Bulk Density, True Density and Porosity

Seed physical parameters such as volume, bulk density, true density and porosity (%) are dependent on morphological seed traits and the moisture content. Hence these were estimated on seed samples at equilibrium moisture contents. For determining the bulk density, true density and the porosity of seed a sample size of 100 g was used. Bulk density of the seed was calculated by dividing the weight of each sample on its volume (cc), measured by using a graduated cylinder (Ayman *et al*., 2010). True density and volume were determined by toluene solution displacement method (Mohsenin, 1986). Bulk density and true density were expressed as g/cc at given seed moisture conditions. The porosity was determined as the percentage of densities of bulk seeds (Jha, 1999).

Mean standard deviation and correlations were determined using Genstat 14th Edition.

Results

Based on the observations recorded, the tested accessions were classified into 14 seed colours following the descriptors for chickpea. Orange (11 accessions), beige (10) and light orange (10) were the major seed colours followed by light brown (6). Seed shapes were represented by pea (42 accessions – intermediate type), angular (4 – *desi* type) and owl's head (4 – *kabuli* type); and seed surface texture as smooth (32 accessions) and rough (18 accessions). On the basis of morphological traits and seed characteristics, the 50 accessions represented *desi*

(4), *kabuli* (4) and intermediate type (42) of chickpea. Diversity among accessions for seed colour, shape and surface texture is depicted in Fig. 1 and 2.

The physical properties of seeds of chickpea germplasm accessions used in the study are presented in Table 1. Significant differences were observed among accessions for these traits and the test accessions were classified into 4-6 classes (Table 2) considering the range of variation and the users of germplasm. Correlations among physical properties of seed are presented in Table 3. Seed moisture content is an important measure of seed quality influencing the physical parameters, seed handling procedures and storage behavior of seeds in the genebanks. The mean emc was 8.5% and accessions representing the smallest and largest *desi* type had maximum and minimum emc, respectively. Forty five intermediate and *kabuli* type accessions had similar emc (8.0-9.0%). The seed moisture content was negatively correlated to various seed size parameters and positively related to the sphericity and seed shape aspect and based on the observations the accessions were classified in to four emc groups. Likewise, 100-seed weight ranged from 9.2 to 58.5 g with a mean of 23.8 g. The small size (<15 g)

Fig. 1. Diversity for seed colour in chickpea germplasm accessions used in the study

Table 1. Mean, range and standard deviation of seed physical properties of chickpea germplasm accessions

Observation	Mean	Minimum	Maximum	SD (±)
Moisture content (%)	8.5	7.1	9.2	0.37
100-seed weight (g)	23.8	9.2	58.5	10.08
Seed coat content (%)	9.6	4.0	16.2	2.74
Length (mm)	8.5	6.9	12.3	1.02
Width (mm)	6.9	4.8	9.2	0.94
Thickness (mm)	6.8	4.8	9.0	0.89
Volume (mm^3)	419.0	166.0	1000.0	162.2
Geographic mean diameter (mm)	7.4	5.5	10.0	0.91
Surface area (mm^2)	173.0	95.0	314.0	43.60
Sphericity (%)	86.6	70.7	95.5	4.18
Seed shape aspect (%)	81.6	58.0	96.1	6.28
Bulk density (g/cc)	0.68	0.59	0.73	0.028
True density (g/cc)	1.37	1.25	1.46	0.047
Porosity (%)	49.6	44.7	54.5	2.55

Table 2. Frequency distribution for seed physical properties of chickpea germplasm.

Seed emc (%)	Frequency	GMD (mm)	Frequency
<8.0	4	<6.0	3
8.0-8.5	25	6.0-7.5	24
8.6-9.0	20	7.6-9.0	20
>9.0	1	>9.0	3
100-Seed weight (g)	Frequency	Surface area (mm^2)	Frequency
<15.0	7	<100	1
15.0-25.0	25	100-150	15
25.1-40.0	14	151-200	23
>40.0	4	201-250	7
Seed coat content (%)	Frequency	251-300	3
<5.0	5	>300	1
5.0-10.0	21	Sphericity (%)	Frequency
10.1-15.0	22	<80.0	4
>15.0	2	80.0-85.0	9
Length (mm)	Frequency	85.1-90.0	28
<7.0	2	90.1-95.0	8
7.0-8.0	14	>95.0	1
8.1-9.0	23	Seed shapeaspect (%)	Frequency
9.1-10.0	8	<80.0	17
>10.0	3	80.0-85.0	22
Width (mm)	Frequency	85.1-90.0	9
<5.0	1	90.1-95.0	1
5.0-6.0	7	>95.0	1
6.1-7.0	18	Bulk Density (g/cc)	Frequency
7.1-8.0	19	<0.60	1
8.1-9.0	4	0.60-0.65	8
>9.0	1	0.66-0.70	33
Thickness (mm)	Frequency	>0.70	8
<5.0	1	True Density (g/cc)	Frequency
5.0-6.0	7	<1.30	4
6.1-7.0	19	1.30-1.35	18
7.1-8.0	19	1.36-1.40	18
>8.0	4	>1.40	10
Volume (mm^3)	Frequency	Porosity (%)	Frequency
<200	2	<45.0	2
200-400	23	45.0-48.0	10
401-600	20	48.1-51.0	25
601-800	3	51.1-54.0	10
>800	2	>54.0	3

is represented by seven accessions and the extra-large (>40 g) by four accessions (ICC 15744, 15428, 15574 and 11745). Seed size is significantly correlated to all physical dimensions of seed and positively contributed to the sphericity and seed shape aspect and negatively to the bulk density and porosity. Significant differences were observed in the seed coat content of the tested accessions. The seed coats of *desi* are thicker than *kabuli* chickpeas. Five accessions had seed coat content <5%. The test accessions were classified into four groups based on the seed coat content and the variation is depicted in Fig. 3.

Observations on physical dimensions showed significant differences among accessions (Table 1 and 2). Seed length of the accessions ranged from 6.9 to12.3 mm with a mean of 8.5 mm. Eleven accessions had a seed length >9.0 mm including three accessions with >10.0 mm length. Similarly the seed width ranged from 4.8 to 9.2 mm. Five accessions had a seed width >8.0 mm. Seed thickness value ranged from 4.8 to 9.0 mm with a mean of 6.9 mm. Four accessions had a seed thickness >8.0 mm. The seed volume of tested accessions ranged from 166 to 1000 mm^3 with a mean of 419 mm^3. Forty-six accessions had seed volume between 200 and 800 mm^3. Based on the seed size dimensions the accessions were classified into four groups for geographic mean diameter (GMD), five groups for length, thickness and volume and six groups for width. The mean GMD of tested accessions was 7.4 mm and ICC 4948 had the lowest and ICC 11745 had the highest GMD. Four

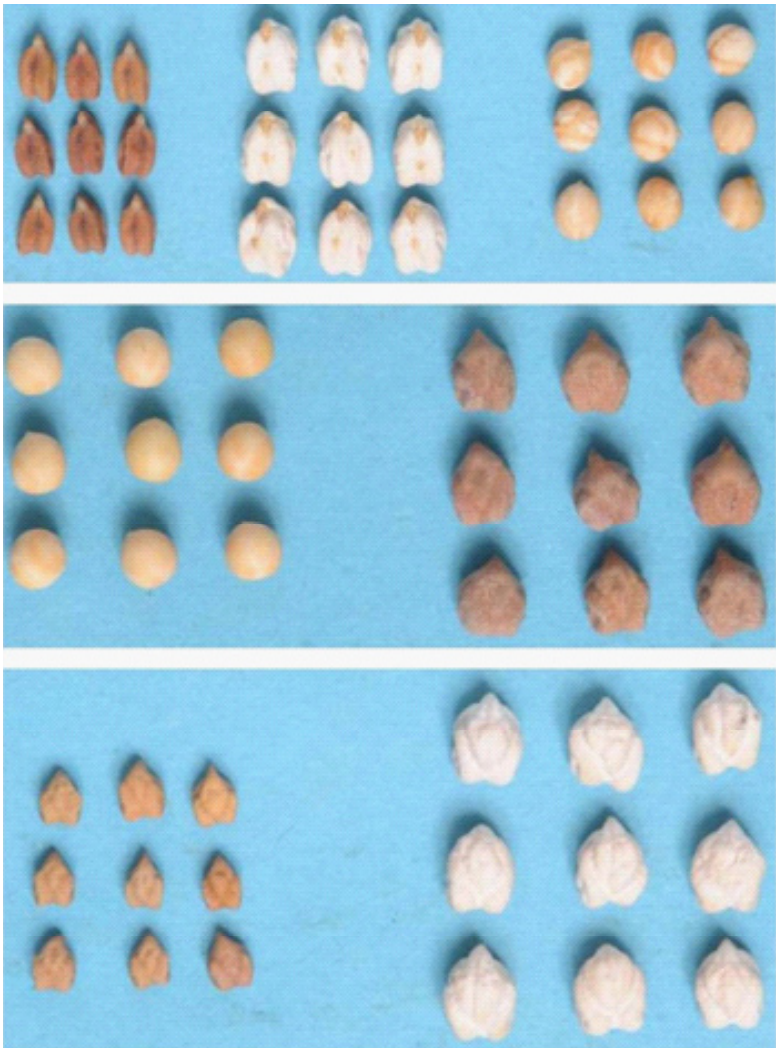

Fig. 2. Chickpea accessions differing in seed shape – angular, owl's head and pea (top), surface texture – smooth and rough (middle) and seed size/weight – small and large (bottom)

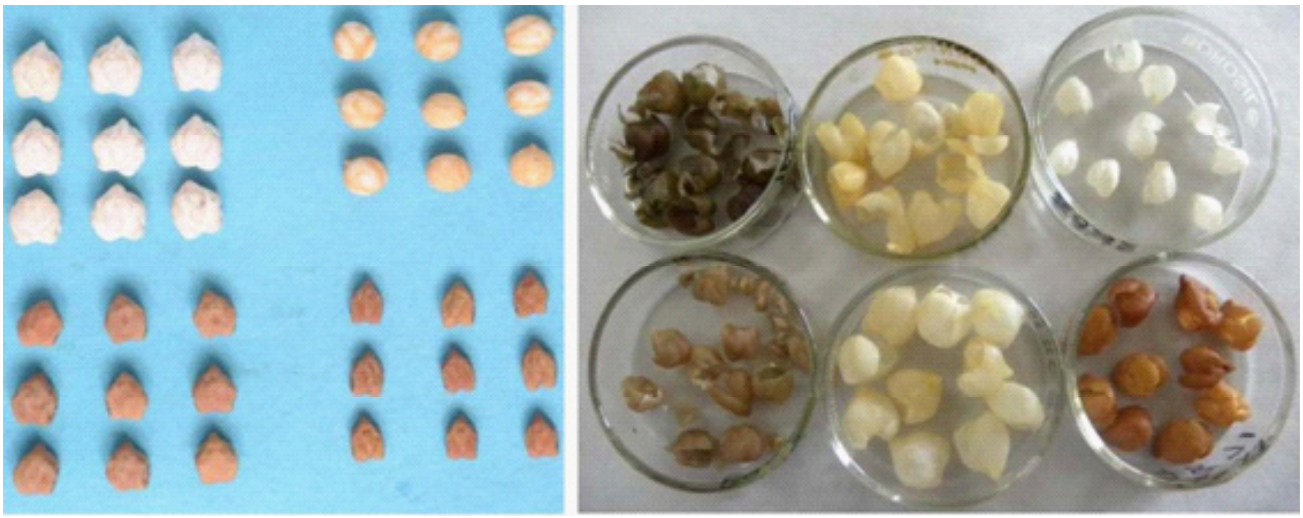

Fig. 3. Chickpea accessions differing in seed coat content – low and medium (top left) and high and very high (bottom left) and seed coats removed (right)

accessions (ICC 2296, 4948 16220 and 16960) were grouped as the smallest and four accessions (ICC 11745, 15428, 15574 and 15744) as largest for various seed size measurements.

Surface area of chickpea accessions ranged from 95 to 314 mm² with a mean of 173 mm². The smallest seed surface area was recorded in ICC 4849 followed by ICC 2296, 16220 and 16960 while ICC 11745 had highest seed surface area followed by ICC 15574, 15428 and 15744. Seed sphericity and shape aspect are related traits and are useful in defining the roundness of chickpea seeds. Observations on sphericity of chickpea seeds showed significant differences among tested accessions (Fig. 4). The sphericity ranged from 70.7 to 95.5%. The sphericity was lowest in ICC 16868 followed by ICC 4948 and ICC 13766 with angular seed shape (*desi* type) and ICC 16220 having owl's head shape (*Kabuli* type). The seed shape aspect ranged from 58.0 to 96.1% with a mean of 81.6%. The seed shape aspect was lowest in ICC 16868 followed by ICC 4948 and 13766 with angular seed shape and 16220 having owl's head shape. Based on the measurements the accessions were classified in to six groups for seed surface area and five groups for sphericity and shape aspect.

Bulk density, true density and porosity of chickpea seeds showed significant differences among accessions. The bulk density ranged from 0.59 to 0.73 g/cc with a mean of 0.68 g/cc. The lowest bulk density was observed in ICC 4973 (a *kabuli* type accession), followed by ICC 2296 an intermediate type with smooth surface texture. The highest bulk density was observed in ICC 5905 (rough surface) followed by ICC 5674 (smooth surface intermediate type). The true density ranged from 1.25 to 1.46 g/cc with a mean of 1.37 g/cc. The lowest true density of chickpea seeds was observed in angular shaped *desi* type (ICC 16868) which had highest seed coat content. Porosity of chickpea accessions ranged from 44.7 to 54.5%. The lowest porosity was observed in ICC 10338 and highest in ICC 16960, both representing intermediate type accessions with pea shape and smooth seed surface. Porosity of seeds has influence on packaging and storage behavior of germplasm accessions. The test accessions were classified into four groups for bulk density and true density and five groups for porosity.

Discussion

Seed shape directly affects the seed appearance and uniformity of chickpea and is often used as a quality indicator for importers and consumers. There is increasing demand on lighter seed coat colour and pea-shaped seed and pink colour *desi* types and the white or beige seed coat colour and extra-large *kabuli* (>55 g/100 seed) chickpea command very high premium price in the markets (Yadav *et al*., 2007). The pea shaped chickpea is popular in central India. Consumers in North and South America, Europe, the Middle East and Africa prefer the *kabuli* type. Hence, techniques to precisely measure specific seed shapes and to discriminate the possible shape variants are required to meet specific market demands. Several methods are used to measure seed shape characteristics. Of these, the low cost traditional visual assessments of

Table 3. Correlations among physical properties of chickpea germplasm seeds

Trait	SWT*	SCC	SL	SW	ST	SV	GMD	SSP	SSa	SSA	SBD	STD	SP
EMC	-0.301	-0.332	-0.421	-0.208	-0.199	-0.273	-0.278	0.268	0.237	-0.276	0.071	0.127	-0.027
SWT		-0.229	0.913	0.927	0.942	0.988	0.966	0.254	0.252	0.981	-0.240	0.116	-0.273
SCC			-0.071	-0.273	-0.262	-0.223	-0.219	-0.380	-0.373	-0.221	0.348	-0.104	0.356
SL				0.799	0.842	0.923	0.910	-0.068	-0.073	0.920	-0.230	-0.035	-0.163
SW					0.986	0.948	0.974	0.538	0.538	0.965	-0.200	0.322	-0.380
ST						0.960	0.988	0.472	0.454	0.977	-0.208	0.290	-0.365
SV							0.984	0.279	0.277	0.996	-0.216	0.158	-0.282
GMD								0.349	0.340	0.996	-0.219	0.213	-0.322
SSP									0.993	0.315	-0.020	0.605	-0.425
SSa										0.310	-0.027	0.592	-0.421
SSA											-0.218	0.186	-0.303
SBD												0.098	0.740
STD													-0.596

Significance levels : <0.05% = 0.288 and <0.01% = 0.372
* SWT = 100-seed weight; EMC = Equilibrium moisture content; SCC = Seed coat content; SL = Seed length; SW = Seed width; ST = Seed thickness; SV = Seed volume; GMD = Geographic mean diameter; SSP = Seed sphericity; SSa = Seed shape aspect; SSA = Seed surface area; SBD = Bulk density; and STD = True density; SP = Seed porosity

seed appearance have mainly been used to determine the segregation for seed shape among chickpea populations (Meena *et al*., 2004). The seed moisture content is an important measure for handling the germplasm collections in the genebanks. The range of variation in the emc of the observed chickpea accessions was significant even under controlled environment conditions. The mean emc was 8.5% and accessions representing the smallest and largest *desi* type had maximum and minimum emc, respectively. Forty-five intermediate and *kabuli* type accessions had similar emc (8.0-9.0%). The seed sizes are expressed at given moisture contents of the seeds. The seed size is an important trait of *kabuli* type chickpea and a 100-seed weight of >40 g garner higher market price as they are preferred by consumers (Gowda *et al*., 2011). The market price of chickpea is primarily decided by the appearance (size, shape and colour) of the seed. However, the consumer preferences for chickpea seed traits may change over times. Consumers prefer the large-seeded types for whole seed consumption, confectionary products, salads, and savory meals (Regan *et al*., 2006). The extra-large (>50 g/100 seed) *kabuli* cultivars are sold at three times the price of *desi* and twice the price of medium-size *kabuli* types with a 100-seed weight from 25 to 40 g in India (Gaur *et al*., 2006). Four accessions (ICC 11745, 15428, 15574 and 15744) were observed with test weight >40 g in this study and considering other quality parameters, these accessions could be of value for further utilization in research.

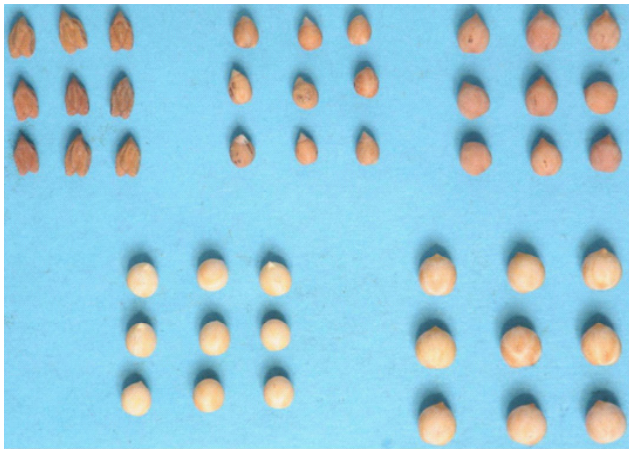

Fig. 4. Chickpea accessions differing in sphericity – lowest (top left) and highest (bottom right)

The seed coats of *desi* are thicker than *kabuli* type chickpea in tested accessions. The lowest seed coat content (4.0%) was observed in ICC 11745, a *kabuli* type accession with smooth seed surface and having highest 100-seed weight and other physical dimensions. Six accessions had seed coat content <5%. The seed coat content was highest (16.2%) in ICC 16868, a small seeded *desi* accession with angular shape, rough seed surface and having lowest sphericity and seed shape aspect. Singh *et al*. (1980) have also reported higher seed coat contents in *desi* types (14.2%) than in *kabuli* types (4.9%). Seed coats of *desi* types were 2.72 times thicker than *kabulis* with normal testa and 3-25 times thicker

than *kabulis* with cracked testa (Yadav and Sharma, 2000). Wood *et al*. (2011) reported differences in the processing of *desi* and *kabuli* chickpea seed types on the basis of morphology and composition of seed coats.

Certain factors such as seed hardness, small seed size, absence of anti-nutritional factors, and presence of toxic substances, may affect bruchid damage to legume seeds (Southgate, 1979), and rough (wrinkled) and thick seed coat might be responsible for resistance to bruchids. He recommended ICC 4969 (a chickpea germplasm accession with thick green coloured seed coat) for use in future breeding programs for bruchid resistance. ICC 4969 deserves further studies as it is also reported to be free from damage by the seed beetle (Erle *et al*., 2009). There is growing evidence of seed coat characteristics to specific seed problems like susceptibility to mechanical damage, seed longevity and tolerance to field weathering (Shahid *et al*., 2011). The seed coat performs a vital function in protecting the seed prior to germination and allows the seed to remain dormant or withstand mechanical damage (Dave *et al*., 2010). Seed coat thickness exhibits monogenic inheritance, with the thin *kabuli* seed coat being the recessive character. No relationship was found between seed coat thickness and seed size (Gil and Cubero, 1993).

Observations on physical dimensions of chickpea seeds showed significant differences among accessions. Four accessions (ICC 2296, 4948 16220 and 16960) were smallest and four accessions (ICC 11745, 15428, 15574 and 15744) were the largest for various seed size measurements. Seed volume and GMD are relative measures of length, width and thickness and among the tested accessions ICC 4948 and ICC 2296 had seed volume less than 200 mm^3 and ICC 11745 and ICC 15574 had volume more than 800 mm^3. The GMD of seeds ranged between 5.5 and 10 mm and 23 accessions had a GMD more than 7.5 mm. The trade recognizes three groups in chickpea based on seed diameter in Europe and Australia: large seeded (>9 mm), medium seeded (8-9 mm), and small seeded (7-8 mm). *Kabuli* type chickpea seeds more than 7 mm receive a premium of US $50 per ton for each additional mm of diameter (Biçer, 2009) and the seed lot must contain a large proportion of such seeds to get the extra price (Barker, 2007).

Seed surface area, sphericity and seed shape aspect are important physical parameters contributing to the seed shape of chickpea. The smallest seed surface area was recorded in ICC 4849 followed by ICC 2296, 16220 and 16960 while ICC 11745 had highest seed surface area followed by ICC 15574, 15428 and 15744. It is important to evaluate the sphericity of the germplasm accessions especially for the pea shaped accessions. Such accessions are of interest to breeders attempting to satisfy diverse marketing needs. Nelson and Wang (1989) proposed a visual scoring system to describe a broad variation of seed shape. Based on the measurements the accessions were classified into six groups for seed surface area and five groups for sphericity and shape aspect.

The sphericity among tested accessions ranged from 70.7 to 95.5%. The sphericity was highest in ICC 15428 followed by ICC 15744, 16395 and 15833 with pea shaped intermediate types. Nine accessions had sphericity between 90 to 95% having a perfect pea shape followed by 28 accessions with sphericity between 85 to 90%. Dutta *et al*. (2004) reported a sphericity (74%) and roundness (70%) at 10•9% moisture content in chickpea. Higher sphericity of chickpea seeds allows more sliding and rolling during seed processing (Konak *et al*., 2002). Ghadge *et al*., (2008) studied the physical properties of chickpea split ('dhal') and identified the importance of sphericity and aspect ratio of the seeds in determining the shape of the splits ('dhal'). The seed shape aspect of chickpea accessions ranged from 58.0 to 96.1% with a mean of 81.6%. Ten accessions had seed shape aspect between 85 and 90% including one accession (ICC 15428) with seed shape aspect >95%. Sphericity and seed shape aspect of chickpea seeds were significantly correlated ($r = 0.993$). The 100-seed weight, emc and other physical dimensions significantly contributed to the sphericity and seed shape aspect of chickpea. However, these traits were negatively correlated to the seed coat content. The basic seed shapes of chickpea germplasm such as angular, owl's head and pea were recorded following the Descriptors for Chickpea (IBPGR/ICRISAT/ICARDA, 1993). However, further classification/grading these shapes of large germplasm collections offers much needed diversity for seed shape trait for utilization in research.

True seed density in chickpea is related to physical seed dimensions, the sphericity and seed shape aspect. The intermediate types have greater true seed densities compared to *desi* and *kabuli* types. Seed density is a component of grain yield that is positively correlated with seed protein concentration and selection for increased density could provide an efficient way to improve protein concentration without affecting seed yield. Also, the

measurement of seed density and seed weight is relatively inexpensive hence a low-cost way to identify promising accessions (Hongxia and Joseph, 2002).

Along with dietary value, importance of chickpea is also judged by physiochemical and cooking quality traits (Patane, 2006). New varieties are accepted as fully valuable raw material for the production of foodstuffs based on evaluation of their physical, chemical and nutritive properties. Efforts are needed to identify variation for these traits for use in breeding programmes. Lopez and Fuentes (1990) and Badshah *et al*. (2003) observed relationships among water absorption and seed coat contents which depend on cultivar, size and rugosity of the seed affecting the cooking quality. Ozer *et al*. (2010) emphasized the importance of physical, physiochemical and cooking properties of chickpea in identification of chickpea landraces for developing high quality chickpea cultivars.

Seed weight and volume are important attributes determining the consumer preference and cooking quality of chickpea cultivars. *Kabuli* type chickpea genotypes had high values of seed weight, hydration and swelling capacity than *desi* types, indicating seed coat differences affecting the seed quality traits. Mehla *et al*. (2001) identified seed weight, seed volume, swelling capacity and hydration capacity as important quality traits in chickpea. Agbola *et al*. (2002) and Shahid *et al*., (2011) emphasized the need to improve the physical quality characteristics and selections based on these traits for improvement of quality traits in chickpea. Singh *et al*. (2003) and Lokare *et al*. (2007) observed little influence of environment on seed physiochemical traits in chickpea. Hossain *et al*. (2010) observed low genotype x environment interaction and high magnitude of heritability suggesting the environmental stability of the chickpea seed shape trait (roundness index). Selection for variation in the physical seed characters of chickpea will enable breeding of varieties with the potential to attract premium prices.

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Variability Studies in *Jatropha curcas* L. Germplasm Collected from Different Agro-climatic Zones of India

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(Received: 21 August 2012; Revised: 26 October 2013; Accepted: 11 December 2013)

Jatropha curcas L. commonly known as 'Ratanjyot' or 'Physic nut' is an important source of biofuel, which has the ability to grow in a wide range of agro-climatic regions. In the present communication, efforts have been made to undertake variability studies in genetic resources of *J. curcas* assembled from seven agro-climatic zones of the country. These zones are considered to be as potential sites for identification of suitable genotypes with desired attributes pertaining to growth and yield parameters as discussed in the present communication.

Key Words: Agro-ecological zones, Intra-zonal variation, *Jatropha curcas*, Provenances, Variability studies

Introduction

Jatropha curcas L. (family Euphorbiaceae) commonly known as 'Ratanjyot' or 'Physic nut' is believed to be a native of Mexico and Central America. It is a drought tolerant large shrub or small tree that occurs throughout the arid and semi-arid tropical regions of the world (Dehgan and Webster, 1979). It has emerged recently as one of the most promising tree borne oilseed species due to its adaptability to a wide range of edaphic and climatic conditions. Of late, energy conservation and its alternative production as biodiesel fuel has gained significant importance in the wake of world energy crisis (Ginwal *et al.,* 2005). *Jatropha curcas* seed oil can be replaced with petroleum based biodiesel fuel which is comparatively more efficient than any other known source of biofuel (Forson, 2004). Thus, a large scale plantation of *J. curcas* genotypes with promising attributes to save the energy, wasteland development, countering greenhouse gas, accumulation and enhancing the income of marginal farmers would be of great importance (Keith, 2000; Gubiz *et al.,* 1999).

Jatropha curcas has adapted and acclimatized itself well in diverse agro-ecological niches in India and simultaneously developed considerable variations. Various geographical and environmental factors (latitude and longitude, elevation, soil moisture, soil nutrients, temperature, type of habitat, site disturbance, etc.) have played important role in creation of variation in seed germination behaviour of *J. curcas*, as also reported by Ginwal *et al.* (2004). Documentation of such variations is necessary to tap the available diversity for utilization in its genetic improvement. Genetic variation in growth and seed traits at the provenance, variety or progeny levels has also been reported in several other multi-purpose tree species such as *Albizia, Acacia* and *Prosopis* (Costa *et al.,* 2005; Wanyancha *et al.,* 1994; El Amin and Luukkanen, 2006; Goel and Behl, 2001). Studies pertaining to genetic variation would help in selection of genetically improved better quality seed for plantation (Burley and Nikles, 1973; Lacaze, 1978). Variations in seed morphology, seedling characteristics, reproductive phenology and yield of *J. curcas* germplasm collected from specific location have also been reported (Ginwal *et al.,* 2005; Rao *et al.,* 2008). Though studies pertaining to different aspects of *J. curcas* have so far been carried out, however variability and adaptability aspects with respect to different agro-climatic zones of India and their interrelationship are still lacking. Thus, it is imperative to determine the variability in germplasm assembled from different provenances in terms of plant growth parameters and morphological traits of seeds mainly to identify the quality germplasm.

The objective of the present study was to observe the morphological variation in seed characteristics and their growth performances in the germplasm collected from different agro-ecological zones of India for exploiting the better adaptability, high seed yield and oil content as well as to understand the interrelationship between seed characteristics and growth phenology.

Material and Methods

A total of 160 accessions of *J. curcas* were collected from seven agro-climatic zones of the country during 2005

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and 2006 (Table 1). The germplasm was collected in the form of cuttings from the identified tree/ shrub having good growth habit, high number of branches and fruit yield during field survey. Rooted cuttings of assembled germplasm along with two genotypes (Chhatrapati and Urlikanchan) as checks were planted in the Experimental Farm, Issapur, NBPGR, New Delhi during 2006-07. The experimental site is located in semi-arid tropical climatic zone which experienced an average temperature between 2^{o}C to 45^{o}C and average rainfall approximately 440 mm during the cropping season. The soil of the site is sandy loam to loamy sandy with 8.0 pH. The experiment was conducted in completely Randomized Block Design and each accession was grown in two rows of 6 m length plot with a row to row spacing of 3m and plant to plant spacing of 2m. A basal dose (5 kg FYM/plant, 50 g urea/plant, 15 g MOP/plant and 60 g SSP/plant) of fertilizer, life saving irrigation and hand weeding operations whenever required were performed. For statistical analysis, 21 representative accessions (IC545440, IC559378, IC565694, IC 566065, IC574433, IC566088, IC559385, IC565695, IC566057, IC565687, IC566080, IC566075, IC566041, IC566044, IC574421, IC574455, IC566040, IC545452, IC566052, IC559381, IC565691), one from each provenance on the basis of their overall performance, were selected.

After establishment, the observations were recorded periodically at different stages of plant growth for each accession using 12 selective descriptors *viz.* plant height (cm), branches/plant, collar diameter, crown cover, fruits/ plant, seed length (mm), seed width (mm), seed thickness (mm), 100 seed weight (g), kernel to seed coat ratio, seed yield/plant (g), and oil content (%). For recording seed characteristics, ten randomly selected seeds stored at ambient conditions in medium-term storage (MTS) facility of NBPGR were used for the purpose. Seed length, width and thickness were measured using a digital Vernier Calliper while oil content (per cent) was estimated using Soxhlet method. Seed coat and seed kernel weight were recorded separately to compute seed coat to kernel ratio.

Differences between means were analyzed using unpaired t-test for zones with two provenances only while for other provenances, one-way ANOVA (for all the descriptors) with SPSS 13 statistical software package was used for analysis. Correlation was calculated to determine the interrelationship between seed characteristics and growth phenology parameters.

Results and Discussion

In the present study, intra-zonal variation among seed traits and growth parameters (seed length, seed width

Table 1. Number of accessions collected from provenances of different agro-climatic zones

Zone. No.	Agro-climatic zones	Provenances	Accessions (nos)
1.	Humid western Himalayan region	Uttarakhand	10
		Himachal Pradesh	7
2.	Humid Bengal Assam region	Assam	6
		West Bengal	5
3.	Humid eastern Himalaya region	Arunachal Pradesh	3
		Tripura	3
		Manipur	1
		Meghalaya	1
4.	Sub-humid Sutlej Ganga alluvial plains	Uttar Pradesh	15
		Jharkhand	13
		Bihar	10
		Punjab	3
5.	Sub-humid to humid eastern and south eastern uplands	Madhya Pradesh	10
		Chhattisgarh	10
		Andhra Pradesh	10
		Odisha	7
6.	Arid western plains	Rajasthan	10
		Gujarat	10
		Haryana	7
7.	Humid to semi-arid Western Ghats	Tamil Nadu	10
		Kerala	10

and seed thickness) was recorded maximum for zone 1 followed by zone 4 and zone 3 (Fig.1a, b, c); highest 100-seed weight was recorded for zone 6 and minimum for zone 5 (Fig. 1d); highest kernel/ seed coat ratio was recorded for zone 6 and minimum for zone 7 (Fig. 1e); maximum plant height was recorded for Zone1 and minimum for zone 5 (Fig.1f); highest number of primary branches were recorded for zone 7 and lowest for zone 6 (Fig. 1g); highest oil content was recorded for zone 1 followed by zone 3 and zone 2 (Fig.1h); and highest seed yield was recorded for zone 1 and minimum for zone 7 (Fig.1i). In contrast, maximum fruit yield was recorded for zone 7 and minimum for zone 4 (Fig.1j).

Variability at Provenances Level

Variation in Growth Characteristics

Various growth attributes exhibited considerable variation among them as shown in Table 2. Maximum plant height (375 cm) was recorded for Meghalaya provenance (IC565695), while Chhattisgarh (IC574421) exhibited lowest height (223 cm); maximum number of primary branches (10) was recorded for Kerala provenance (IC574433) and lowest (4.67) for Jharkhand provenance; highest collar diameter (48.67 cm) and crown cover (331.7 cm) were recorded for Tamil Nadu provenance, while lowest collar diameter was recorded for Jharkhand (13.33 cm) and lowest crown cover (149.2 cm) for Andhra Pradesh provenances, respectively.

Variation in Yield Characteristics

Highest seed yield (630 g/plant) was recorded for Assam provenance (IC565694) and closely followed by Tamil Nadu (599.5 g/plant) and Bihar (594 g/plant) while lowest yield (99 g/plant) was recorded for West Bengal provenance. Tamil Nadu provenance (IC559381) showed highest (1974 g /plant) and West Bengal lowest (210 g/ plant) fruit yield.

Variation in Seed Characteristics

While comparing the mean values of different seed characteristics, either significant or insignificant variations were observed among all provenances of different zones. Maximum seed length (18.95 mm) was recorded for Uttarakhand provenance (zone 1) and minimum (15.68 mm) for Odisha (zone 5) (Table 3); maximum seed width was observed for Uttarakhand provenance (11.51 mm) while with the same magnitude also observed for Himachal Pradesh, Assam, Bihar, Andhra Pradesh and Haryana provenances; maximum seed thickness (8.89 cm) was observed for Uttarakhand provenance (zone 1) and minimum (7.56 cm) for Kerala (zone 8); highest 100-seed weight was recorded for Andhra Pradesh provenance (67.32 g) and lowest (42.24 g) for Odisha (both the provenances belong to zone 5); highest kernel/ seed coat ratio was recorded for Haryana provenance; highest oil content (36.2%) was recorded for Uttarakhand provenance followed by Arunachal Pradesh provenance (33.5%), while lowest oil content was recorded for Bihar (28.6%) and West Bengal (28.3%) provenances. Seed viability test indicated that most of the provenances within the zones showed more than 85% viability.

Studies was also conducted for determining the inter-zonal variations for different seed characters. Most of the seed characters showed significant variability among provenances of different zones (Table 3). All zones showed significant variation for seed length (except zone 4), seed width (except zone 4 and zone 6), seed thickness (except zone 1), while 100-seed weight also showed significant variation among provenances within different zones (except zone 1 and zone 6).

Phenotypic Association among Different Traits

The phenotypic correlation among the 12 traits showed interrelationship among all characters (Table 4). The seed length exhibited high significant positive correlation with seed width, seed thickness and 100-seed weight. Both seed width and seed thickness showed high correlation with each other. Seed weight also showed significant correlation with oil per cent. Plant height exhibited significant positive association with collar girth, crown cover, seed yield/plant and fruit yield/plant. Primary branches were significantly correlated with plant height, crown cover and fruit yield/plant. Collar girth also showed positive correlation with crown cover, seed yield/plant and fruit yield/plant. High significant positive correlation between seed yield/plant and fruit yield/plant was also recorded.

Thus, *J. curcas* germplasm collected from different agro-ecological zones in the present study has considerable amount of variation in morphological traits pertaining to seed, growth and yield parameters within the zones as well as among the provenances. Since the germplasm was collected from approximately same age group of trees (as per passport data record) growing in different geographical locations, hence the variation in

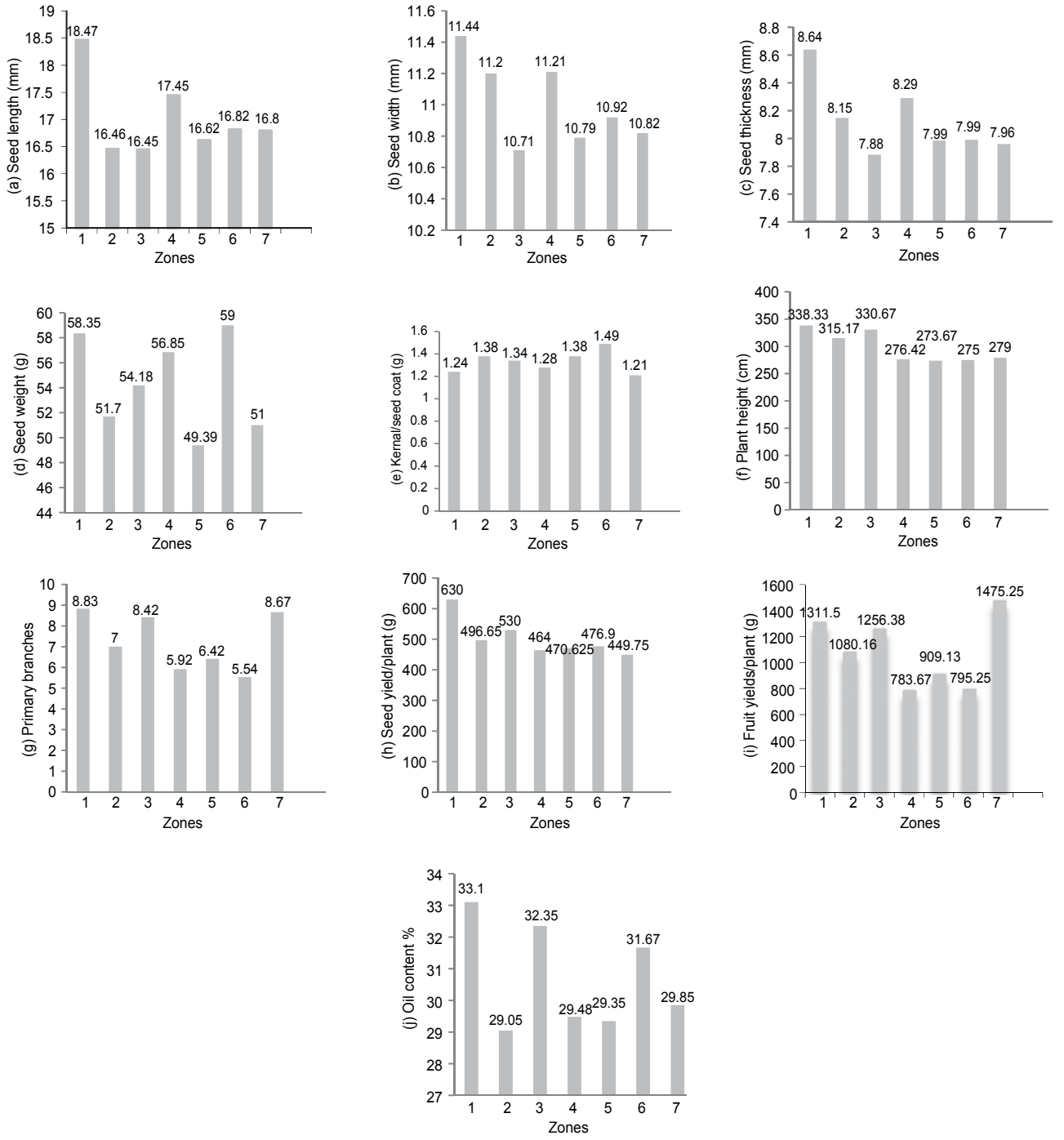

Fig. 1. Zonal variation for (a) seed length , (b) seed width, (c) seed thickness, , (d) seed weight, (e) kernel/seed coat, (f) plant height, (g) primary branches, (h) seed yield/plant, (i) fruit yield/plant, and (j) oil % (Zone 1: Humid western Himalayan region, Zone 2: Humid Bengal Assam Region, Zone 3: Humid eastern Himalaya region, Zone 4: Sub-humid Sutlej Ganga alluvial plains, Zone 5: Sub-humid to humid eastern and south eastern uplands, Zone 6: Arid western plains, Zone 7: Humid to semi-arid western)

morphological parameters is obvious. These variations may be attributed to genetic nature of the *J. curcas* as it is adapted to diverse environmental conditions (Ginwal, 2005). Germplasm assembled from different geographical regions has acclimatized itself with the local climatic conditions (dry semi-arid condition) of Delhi and thus, showed variation accordingly. Such variations have also been reported in *Azadirachta indica* (Kaura *et al.,* 1998), *Acacia nilotica* (Gera *et al.,* 1976), and *A. catechu* (Kumar *et al.,* 2004) when grown in different situations.

Table 2. Provenances variations in plant attributes of *Jatropha curcas* collected from different zones (Mean) in field trial

Agro-climatic zones	Provenances	Plant height (cm)	Primary branches	Collar diameter (cm)	Crown cover (cm)	Seed yield/ plant (g)	Fruit yield/ plant (g)
Humid western Himalayan region	Uttarakhand	336.7	8.67	32.33	259.2	540.0	1177.00
	Himachal Pradesh	340.0	9.00	26.33	285.8	453.3	983.00
Humid Bengal Assam region	Assam	308.3	7.33	26.00	249.2	630.0	1311.00
	West Bengal	322.0	6.67	22.33	304.2	99.0	210.00
Humid eastern Himalaya region	Arunachal Pradesh	348.7	9.67	34.67	309.2	574.5	1414.00
	Manipur	320.0	9.00	27.67	274.2	533.0	1261.00
	Tripura	279.0	6.67	28.06	233.3	451.0	912.00
	Meghalaya	375.0	8.33	30.33	327.5	561.5	1438.00
Sub-humid Sutlej Ganga alluvial plains	Uttar Pradesh	325.0	7.33	40.67	236.7	548.0	1233.00
	Punjab	270.7	5.67	25.67	228.3	391.0	617.00
	Bihar	263.3	6.00	19.00	234.2	594.0	820.00
	Jharkhand	246.7	4.67	13.33	229.2	323.0	463.00
Sub-humid to humid eastern and south eastern uplands	Odisha	265.0	7.67	40.00	268.4	410.0	912.00
	Madhya Pradesh	318.3	6.67	24.67	206.7	407.5	830.00
	Chhattisgarh	223.0	5.33	19.00	198.3	592.5	1220.00
	Andhra Pradesh	288.3	6.00	22.33	149.2	472.5	674.00
Arid western plains	Haryana	284.0	7.67	27.33	223.3	405.0	927.00
	Rajasthan	253.3	5.67	35.67	297.5	439.0	571.00
	Gujarat	286.7	3.00	27.00	272.5	386.7	888.33
Humid to semi-arid Western Ghats	Tamil Nadu	324.0	7.33	48.67	331.7	599.5	1974.00
	Kerala	234.0	10.00	25.00	278.3	300.0	976.50
LSD		19.5	0.72	3.15	24.7	–	–

In the present study, plants in zone 1 (humid western Himalayan region) showed excellent and stable performance with respect to almost all traits of seed morphology, growth and yield parameters as topographically this zone is characterized with moderate rainfall, temperature and better soil quality; perhaps this might have lead to better growth of plant and seed characters. Plants in zone 6 (arid western plains) showed poorest performance with regard to seed traits because of low rainfall, high temperature and harsh environmental conditions. Plants in zone 3 (humid eastern Himalayan region) also did not show good performance for seed morphology due to high humidity, frost and flood conditions.

Variation in traits pertaining to seed morphology of *J. curcas* among various provenances as observed in the present study have also been reported by Kausik *et al.* (2003) and Ginwal *et al.* (2005) in their studies. Multiple factors may be responsible to induce and maintain variations in seed size. Provenances within, the zones also showed differences in seed size due to location specific variations in climate, soil fertility and topographic conditions. Seed morphological study is important because the performance of seed immediately after germination is governed by the seed size (Willan, 1985). Hence, recording observations on seed size was important because of availability of more food reserve to produce large seedling with better survival chance whereas small seeds may have a selection advantage due to wider and more effective dispersal mechanism. Manga and Sen (1995) have also observed that germination in *Prosopis* can be improved by selecting large and heavy seeds. In our study, plants in Uttarakhand provenance showed heavy and large sized seeds (65.4 g) and highest oil content (36.2%). During field survey to Uttarakhand, it was observed that the vegetative growth was high as compared to seed yield, may be due to low temperature and short day length. But when the same germplasm was grown in Delhi condition (having high temperature and long day length), the seed yield, oil content and fruit yield were recorded high. Armstrong and Westoby (1943) and Uniyal *et al.* (2002) reported that seed size and seed weight are considered important parameters for improving seedling productivity and reducing nursery cost through selection of quality seeds. Wide variation in seed oil content was reported in various tree-borne oilseed species (Johansson *et al.,* 1997; O'Neil *et al.,* 2003; Vollmann *et al.,* 2007 and Rao *et al.,* 2008). A significant variation in range of oil content (28.3-36.2%) of *J. curcas* seed obtained from different habitats in present study provides a viable selection alternative to use in improvement programmes.

Table 3. Provenances variation in seed characters of *Jatropha curcas* collected from different zones (Mean)

Agro-climatic zones	Provenances	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	100-seed weight (g)	Germination (%)	Oil (%)	Kernel/ seed coat
Humid Western	Uttarakhand	18.95	11.51	8.89	65.4	9.67	36.2	1.17
Himalayan region	Himachal Pradesh	17.99	11.38	8.39	51.3	9.00	30.0	1.30
t-value		3.12	7.01	NS	NS	NS	–	–
Humid Bengal Assam	Assam	17.84	11.38	8.29	58.90	9.33	29.8	1.35
region	West Bengal	16.46	11.03	8.01	44.50	10.00	28.3	1.39
t-value		5.52	3.25	2.29	9.71	2.00	–	–
Humid Eastern Himalayan	Meghalaya	16.93	10.82	7.90	56.26	10.00	31.5	1.47
region	Tripura	15.79	10.38	7.75	50.38	8.67	32.2	1.31
	Arunachal Pradesh	16.84	11.11	8.08	64.68	10.00	33.5	1.31
	Manipur	16.25	10.53	7.80	45.40	8.67	32.2	1.27
LSD		1.04	0.53	NS	4.56	1.05	–	–
Sub-humid Sutlej Ganga	Punjab	17.33	11.17	8.27	57.50	9.67	28.7	1.42
alluvial plains	Uttar Pradesh	17.61	11.20	8.40	53.00	9.33	30.6	1.13
	Bihar	17.43	11.38	8.49	59.62	10.00	28.6	1.22
	Jharkhand	17.43	11.08	8.01	57.28	9.67	30.0	1.35
LSD		NS	NS	0.49	3.04	NS	–	–
Sub humid to humid eastern and	Madhya Pradesh	16.87	11.00	7.99	44.09	8.67	28.8	1.28
south eastern uplands	Andhra Pradesh	17.20	11.29	8.37	67.32	9.67	31.2	1.40
	Chhattisgarh	16.74	10.70	7.98	43.90	9.33	30.1	1.30
	Odisha	15.68	10.38	8.29	42.24	9.67	29.3	1.20
LSD		1.02	0.54	0.51	1.37	NS	–	–
Arid western plains	Haryana	16.64	11.29	8.13	57.73	8.33	31.8	1.80
	Rajasthan	16.65	10.55	7.86	61.28	10.00	32.4	1.43
	Gujarat	17.16	10.92	7.99	57.60	10.00	30.8	1.22
LSD		1.25	NS	0.72	NS	NS	–	–
Humid to semi-arid	Tamil Nadu	17.37	11.12	8.37	57.69	10.00	29.1	1.29
Western Ghats	Kerala	16.22	10.52	7.56	45.13	10.00	30.6	1.14
t-value		5.21	2.68	9.36	6.97	–	–	–
Pooled LSD		0.39	0.24	0.22	1.64	0.38	–	–

Literature indicates that plant attributes of *J. curcas* have exhibited considerable amount of variations in different progeny trials (Ginwal *et al.,* 2005). Similarly in our experimental trial, the growth parameters of germplasm from Arunachal Pradesh provenances have shown good performance while seed yield traits of Tamil Nadu provenances showed better performance as compared to others. Plant height and number of branches are considered important characters (as major selection indices) when the objective is to select *J. curcas* for agro-forestry system while high yield is one of the important traits to utilize in crop improvement programmes (Rao *et al.,* 2008). The purpose of provenances testing under the present study was mainly to understand the variation pattern as well as to aid in selection of well-adapted and highly productive seed source for silvicultural practices.

Correlation coefficient has revealed interesting inter-relationship in both seed characters and growth parameters studied. Significant correlation of seed weight was there with oil content, seed width and seed thickness; hence seed weight and seed size can be considered most important traits for selection of early types from a seed lot of any seed source. Similar findings have also been reported by Rao *et al.* (2008) and Kausik *et al.* (2007).

Significant correlation of plant height with number of branches, collar girth, crown cover, seed yield and fruit yield also indicates that selection from early plantation can be made on the basis of such parameters. This is further supported by significant association of primary branches with fruit yield and seed yield. The correlation between these parameters can be explained by the fact that during the phenological succession of appearance of physiological and morphological determinants of yield, the number of branches contributed to higher number of flowers which in turn to higher yield. Similar results have also been reported in other crops as well (Bhargava *et al.,* 2007; van Osteroma *et al.,* 2006). In case of *J. curcas*, selection of plant types not only depend upon seed yield but also depend on the morphological and

Table 4. Phenotypic correlation among different seed characters and plant attributes

Trait	Seed length	Seed width	Seed thickness	Seed weight	Kernel/ seed coat	Oil%	Branches	Height	Collar girth	Crown cover	Seed yield/plant	Fruit yield/plant
Seed length		0.845**	0.897**	0.586**	-0.35	0.209	-0.04	0.169	0.11	0.055	0.228	0.144
Seed width			0.895**	0.644**	-0.32	0.037	-0.17	0.079	0.13	0.091	0.024	-0.10
Seed thickness				0.64**	-0.36	0.2	-0.07	0.223	0.189	0.038	0.172	0.106
Seed wt.					-0.03	0.459*	-0.14	0.128	0.147	-0.03	0.363	0.111
Kernel/ seed coat						-0.11	0.064	0.107	0.112	-0.2	-0.04	-0.13
Oil %							0.241	0.205	0.067	0.09	0.338	0.166
Branches								0.468*	0.341	0.394*	0.11	0.43
Height									0.395*	0.458*	0.401*	0.392
Collar girth										0.525*	0.417*	0.585**
Crown cover											0.093	0.32
Seed yield/plant												0.777**

* Significance at 5% level.
** Significance at 1% level.

growth parameters because yield trait stabilized only when plant attained 4-5 years of growth cycle (Barua, 2011). This plant did not express any interrelationship between seed phenology and growth parameters perhaps because the growth of plant is regulated by availability of nutrients, water and other biotic factors and seed size depends upon the food storage capacity of seed.

The overall findings from the present study revealed that the considerable genetic variability exists among the germplasm assembled from provenances of different agro-ecological zones. The significant zonal difference indicates that various environmental factors also play a major role in creation of variability and adaptation of *J. curcas* to a wide range of climatic conditions. This experimental study also indicates that for selecting good genotypes, some important characteristics such as large and heavy seeds, high oil content, good plant height and branching pattern with high seed yield may be important traits for genetic improvement of *J. curcas*. In the present study, zone 1 (humid western Himalayan region) showed high value for number of branches, seed yield, 100-seed weight and oil content followed by zone 6 (arid western plain) and zone 3 (humid eastern Himalayan region). Therefore, selecting best genotypes from above mentioned zones will improve agro-forestry system and energy plantation in the wastelands, besides boosting the economic status of farming communities with marginal holdings.

Acknowledgement

The authors are thankful to the funding agency Council for Scientific and Idustrial Research (CSIR), New Delhi, for providing funds to conduct the study under the New Millennium Indian Technology Leadership (NMITLI) project on "Genetic Improvement of *J. curcas* for Adaptability and Oil Yield". Thanks are also due to the ex-Directors and present Director, NBPGR, New Delhi for support and to use field and farm facilities during the study. The help rendered by Dr. RK Mahajan, Principal Scientist (Retired) in sparing his valuable time for statistical analysis is greatly acknowledged.

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Exploration, Collection, Ethnobotany and Morpho-taxonomic Characterization of *Musa* Germplasm from Belgaum, Dharwad and Uttara Kannada Regions of Karnataka

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(Received: 06 May 2013; Revised: 27 August 2013; Accepted: 07 December 2013)

Parts of Belgaum, Dharwad and Uttara Kannada districts of Karnataka were surveyed for studying *Musa* diversity. A total of 36 accessions were collected and 14 distinct types were identified after characterization using minimum descriptor. Ethnobotanical observations were recorded on some wild *Musa* types in the region. The 14 accessions were planted in field gene bank and characterized for morpho-taxonomic and biometric traits. Results indicated that the 14 accessions belonged to nine distinct groups and subgroups. Their names, synonyms and genomic status have been identified and reported. Biometric data suggested that there is a lot of variability for all the traits studied. Survey for disease occurrence revealed that *banana bunchy top virus* (BBTV), *Banana streak virus* (BSV) and Sigatoka Leaf Spot are the major diseases, while nematodes and pseudostem weevil are important insect-pests occurring on *Musa* accessions collected from the three districts.

Key Words: Characterization, Dharwad, Genetic diversity, *Musa,* Pests, Uttara Kannada

Introduction

India is well-recognized as one of the centers of origin and domestication for the genus *Musa*, comprising banana and plantains (Simmonds 1962; Jacob 1952). Domestication and long periods of cultivation in India have led to the vast diversity in *Musa*. The diversity ranges from delicate edible diploid *acuminata* (AA) types to hardy hybrid triploid (ABB) types. Furthermore, the prevalence of varied agro-climatic conditions has encouraged the development and sustenance of numerous varieties catering to the local needs.

The practice of conferring local names in regional dialects has resulted in a plethora of synonyms, which is the major cause of confusion in the collection and maintenance of large germplasm. Proper characterization helps in unambiguous discrimination among accessions and detecting redundancies. Referring a single cultivar in different names and different names to a single cultivar poses severe problems not only to researchers, but also to the farming community (Uma and Sathiamoorthy, 2002). For example the famous local cultivar of Munavalli region (Belgaum district) – 'Rajapuri' is referred by local farmers in different names such as 'Jawari Bale', 'Wallah', 'Munoli Bale', 'Kullan', 'Gujarathi' etc. (Uma and Sathiamoorthy, 2002).Thus, an exploration programme was executed in Dharwad and Uttara Kannada districts of Karnataka located in the Western Ghats region, which have rich diversity for *Musa*, but not properly documented. The objective was exploration, collection and characterization of *Musa* genetic diversity and to resolve the taxonomic status of the locally named cultivars.

Materials and Methods

In the present study, two different regions of Karnataka were surveyed for *Musa* genetic diversity – North-western region, which is comparatively dry plains, and Uttar Kannada district with moist evergreen forests. Munavalli of Belgaum district which is 60 km (towards north) from Dharwad, is the main banana growing belt of North-western region of Karnataka. This region enjoys rains during June-July and has extremely high temperature during summer. The predominant soil type is black clay while some part has red soil too. The other banana growing belt of North-western Karnataka is Thimmapur region (Dharwad district), where the soil is black clay. This region receives about 1,500 mm rainfall annually.

The second region explored for *Musa* variability (especially for wild banana and *Ensete* spp.) was the moist evergreen hilly area of Uttar Kannada (Karwar district). This region is part of Western Ghats and is a

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high rainfall zone. Among the different places explored, the highest altitude is 1,500 m at Ambikanagar dam site where *Ensete superbum* was found to occur. Areas of exploration are indicated in Fig. 1.

Explorations were conducted during the year 2000 and also in 2009 in the Belgaum, Dharwad and Uttara Kannada districts of Karnataka. The places of exploration lie between 74º–75º East longitude and 14.5º–16º North latitude. A total of 36 accessions were collected. Passport data was collected on-site. Each accession was assigned an accession number.

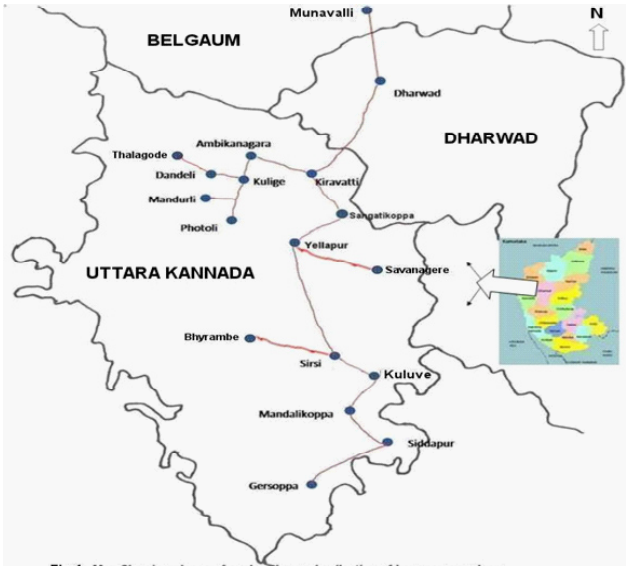

Fig. 1. Map showing places of exploration and collection of banana germplasm

Minimum Crop Descriptor for Banana (http://tag.inibap.org/) was applied to study the nearest grouping of the collected accessions (for the cultivated varieties), while all wild accessions were retained for further studies using molecular characterization. All distinct varieties and wild types (14 nos.) were taken to field gene bank at National Research Centre for Banana (NRCB), Tiruchirapalli, and a duplicate set was supplied to local All India Coordinated Research Project – Tropical Fruits (AICRP - TF) center, Kittur Rani Chennamma College, Arabhavi. Details about accessions collected are given in Table 1. The 15th accession, *Ensete* do not produce suckers and are propagated through fertile seeds. Hence, it could not be taken to field gene bank. During the exploration traditional banana cultivation of the popular cultivar, 'Jawari Bale' was also studied.

The collected accessions were initially planted in the active collection block of NRCB field gene bank and evaluated for morpho-taxonomic and biometric traits. MUSAIDwin software developed by INIBAP/CIRAD (1996) was used to calculate the percent similarity values. Six replicates of each of the 14 accessions were planted in the field gene bank. They were raised under wetland conditions with normal package of practices used for banana cultivation. Morpho-taxonomic characterization of the accessions was carried out using standard banana descriptor (INIBAP/CIRAD 1996). After characterization, they were grouped into standard genomic and sub-genomic categories, along with their probable synonyms grown elsewhere in the country. Data presented is the average of six plants and repeated for two seasons.

Table 1. Accessions collected during the exploration

S.No.	NRCB Accession No.	Name	Location (Latitude/longitude)	Biological status	Genomic group and subgroup
1.	1160	Local Mitli	Kirawatti	domesticated	AB
2.	1156	Shan Bale	Kirawatti	landrace	ABB
3.	1149	Kari Bale	Sangatikoppa	landrace	AAB
4.	1146	Bargi Bale	Sirsi	landrace	AAB
5.	1152	Mitli	Bhyrambe	domesticated	AB
6.	1147	Kaadu Bale-Kuluve	Kuluve	wild	BB
7.	1161	Chandra Bale	Kuluve	domesticated	AAA
8.	1148	Bhoodhi Mitiga	Kuluve	domesticated	ABB
9.	1150	Kaadu Bale-Manjukeri	Manjukeri	wild	BB
10.	1151	Kaadu Bale-Gundha	Gundha	wild	BB
11.	1153	Sakkare Bale	Mandolikoppa	domesticated	ABB
12.	1157	Boodhi Bale	Siddhapura	domesticated	ABB
13.	1158	Rajapuri	Munavali	domesticated	AAB
14.	1159	Mysore Mitli	Haliyal	domesticated	AAB

Results and Discussion

Traditional Way of Banana Cultivation in Munavalli Region of Karnataka

In Munavalli region, the sole banana cultivar under commercial cultivation is 'Rajapuri' (AAB-Pome group), also known as 'Jawari Bale'. 'Rajapuri' is cultivated as a perennial crop; annual replanting of suckers is not practiced in this region. Usually the side suckers are not removed which has resulted in increased incidence of Sigatoka leaf spot and nematode problems. The increased incidence of leaf spot is due to closer spacing between the mats under perennial system of cultivation. Hence, the farming community is now shifting towards Robusta (AAA). Initially, the severely infected clumps of 'Rajapuri' banana is replaced by Robusta suckers which will be maintained for another two years (one main crop plus one ratoon crop) and again fresh planting of 'Rajapuri' banana is being taken up. Though Robusta has been recently introduced, farmers prefer 'Rajapuri' as it fetches premium price in the market and the locals favour 'Rajapuri' for its sweet-acid taste. One of the current startling problem is wide spread occurrence of banana bunchy top disease. The incidence is about 20-25%, which is expected to rise due to ignorance and perennial system of cultivation.

'Rajapuri' banana is maintained under constant perennial system for about 8-12 years. During the first year intercropping is practiced with tomato, chilly and coriander. 'Rajapuri' banana is a hardy cultivar and hence it does perform better under North Karnataka districts. It bears a bunch of 15-18 kg with 6-8 hands. This local cultivar is cultivated organically in this region. About 25-50 kg of well decomposed FYM and sheep manure is dumped around the base of each clump without any organic fertilizers. The local preharvest traders visit the orchard at bunching stage to fix the price of the bunch. The traders prefer organic bananas since they fetch better price because organically grown bananas are said to have extended shelf life after harvest. Non-removal of side suckers and continual system of cultivation results in weekly harvest and marketing of bunches in weekly 'Shandys'. This system fulfils the concept of Subsistence Farming. The other variety, which was noticed in the Munoli/ Munavalli market, is 'Suganthi' (AAB-Mysore), which is not grown commonly in this area but arrives at the local market from other parts of Belgaum district.

Status and Cultivation of Wild Bananas

Rain forest ranges of Western Ghats harbours both wild *Musa* and *Ensete*. Wild banana *Musa balbisiana* was observed under semi-wild conditions which were raised for its leaf and hence it is known as 'Ele Bale' ('Ele' means leaf and 'Bale' means banana, in Kannada) or 'Kaadu Bale'. *Ensete superbum*, the close member of the genus *Musa* was observed in rocky cracks and crevices. It is locally known as 'Kallu Bale'('Kallu' means stony in Kannada, probably denoting its habitat or stony seeds).

Fig. 2. *Musa balbisiana* ('Kaadu Bale')

Musa balbisiana, 'Kaadu Bale' is a seeded, diploid, wild type grown in all rural households of Western Ghats of Karnataka. Banana, both wild and cultivated, is an integral part of backyard gardens. They are also cultivated in *Areca* plantations under multi-storied cropping systems. During the initial years banana serves as shade plant for *Areca*. In due course of time *Areca* becomes the main

crop and banana is maintained to enhance microclimate in the plantations. *Musa balbisiana* with natural tolerance to diseases and pests is preferred by the farmers as it requires minimum care. They also form a perennial source of dining plates due to high phyllochron rate.

Conservation and Perpetuation

Many families have family graves in a corner of their backyard and considered sacred. Suckers of wild types of *Musa*, like 'Kaadu Bale' are usually planted in such vicinities where surroundings are kept clean. Some 10-20 clumps of 'Kaadu Bale' are maintained in each household by the elderly women, taking care of fertilizing, crop production (if necessary) and irrigation etc. Few suckers are carried along while visiting relatives, as a gift along with banana fruits, flowers, betel leaves and sweets (Uma, 2006).

Ensete superbum 'Kallu Bale'

Ensete is the only other important genus in Musaceae. Though there are about 26 species identified by different authors, only nine main species in *Ensete* have been recognized based on their commercial importance and morphological features. They are *E. ventricosum* (Welw.) Cheesman, *E. livingstoniana, E. proboscidea, E. gilletti* (De Wild) Cheesman, *E. buchanani, E. homblei* (Bequaert) Cheesman, *E. perrieri* (Claverie) Cheesman which are prevalent in Africa (Nelson *et al.,* 2006). Current studies have shown that they are not different species, but they are the synonyms for the main 6 species of *Ensete.* India has only two species, *E. superbum* and *E. glaucum*. Unlike *Musa, Ensete* do not produce suckers and are propagated through fertile seeds.

Morpho-taxonomic Characterization of Collected Accessions

A total of 36 accessions were collected. Using minimum descriptors, a total of 15 distinct accessions were identified and 14 of them were taken for characterization and field evaluation. The morpho-taxonomic data for collected 14 accessions (131 traits) revealed distinct nine groups based on genomic (AAA, AB, AAB and ABB) and sub-genomic groups (Ney Poovan, Monthan, Pome etc.) and ploidy levels (2x and 3x). Details are given in Table 2. 'Mitli' and 'Local Mitli' were found synonyms (100%) so also were the three 'Kaadu Bale' (accessions collected from different areas, Kuluve, Gundha and Manjukeri). All were *M. balbisiana* with 99% similarities. 'Bhoodi Bale', 'Kari Bale' and 'Shan Bale' belonged to same group with more than 95% similarities. The 5% of differences probably attributed to ashy fruit nature of 'Boodhi Bale' while 'Kari Bale' and 'Shan Bale' were green 'Monthan' types. 'Chandra Bale' is equivalent of Red Banana. 'Sakkare Bale' and 'Boodhi Mitiga' were similar belonging to Pisang Awak group with ABB genome. 'Bargi Bale' and 'Jawari Bale' grouped together as they belong to Pome subgroup of AAB genome. 'Bargi Bale' is similar to 'Ladan' and 'Pachaladan' of Pome bananas of Tamilnadu. 'Jawari Bale' is an unique landrace with dwarf stature and persistent male bracts and flowers. Most of the growth and other characteristics in comparison with other accessions in respective group is also discussed in previous literature (Uma *et al.*, 2005; Uma and Sathiamoorthy, 2002).

Banana diversity recorded with respect to morphological and biometric traits revealed presence of good diversity among bananas of Western Ghats in Karnataka (Table 3). Data on *Ensete superbum* was not recorded in the present work as it takes more than three years to flower and fruit. Variability with respect to height was found to be varying from 185 cm to 625 cm with lowest being recorded in cultivar 'Rajapuri' (185 cm) and highest being in 'Kadu Bale' (625 cm). Variability with respect to duration indicated a wide range from 326 days ('Bargi Bale') to 585 days ('Kadubale') indicating the suitability of short duration cultivars into the annual cropping system in that area. 'Chandra Bale' followed by 'Rajapuri' and 'Bargi Bale' were found to be poor yielding with lower bunch weight compared to 'Mysore Mitli' and 'Sakkare Bale'. 'Sakkare Bale', 'Boodhi Bale' and 'Boodhi Mitiga' recorded high total soluble sugar (TSS) with good sugar-acid blend compared to other cultivars.

Status of Pests and Diseases on Local Cultivars

Banana attracts a number of pests and diseases, which is aggravated due to perennial cultivation in some traditional banana growing areas (Singh, 2009). Backyard cultivation and polyclonal system is in vogue in the areas surveyed. Backyard cultivation with perennial system has led to spread of several diseases prevalent in the region. None of the commercial cultivars were found to be free of Sigatoka leaf spot disease. Fusarium wilt and *Banana bunchy top virus* (BBTV) infection were noticed in Red banana and 'Karpooravalli' (Table 4). In 'Suganthi' (Mysore-AAB), infestation of pseudostem borer was noticed, while in 'Rajapuri' cultivar in Munavali region, heavy incidence of BBTV was observed.

Table 2. Evaluation and identification of accessions collected and assignment of genomic group and subgroup status

S.No.	Varieties	Genome group	Assignment of subgroup status	National synonyms	International synonyms (Uma and Sathiamoorthy, 2002)
1.	Mitli	AB	Ney Poovan	Elakki Bale, Elarasi	Ney Poovan, Sukali Dizi
2.	Local Mitli	AB	Ney Poovan	Mittuga	–
3.	Boodhi Bale	ABB	Monthan	Ash Monthan, Emmae Bale, Embale, Kachkol	Ash Monthan
4.	Sakkare Bale	ABB	Pisang Awak	Bhoodhi Bale	Pisang Awak, Namwa Khom
5.	Bhoodhi Mitiga	ABB	Pisang Awak	Karpura, Bhoodi Bale, Karpuravalli	Pisang Awak, Namwa Khom
6.	Rajapuri	AAB	Pome	Jawari Bale, Wazha, Munoli Bale, Gujarathi, Kullan	Nil
7.	Mysore Mitli	AAB	Mysore	Poovan, Suganthi, Mysore Poovan, Mittuga	Mysore, Pisang Ceylan
8.	Bargi Bale	AAB	Pome	–	–
9.	Kari Bale	ABB	Bluggoe	–	Bluggoe
10.	Kaadu Bale- Manjukeri	BB	*M. balbisiana*	Ele Bale, Elavazhai	Nil
11.	Kaadu Bale- Gundha	BB	*M. balbisiana*	Ele Bale, Elavazhai	Nil
12.	Kaadu Bale- Kuluve	BB	*M. balbisiana*	Ele Bale, Elavazhai	Nil
13.	Chandra Bale	AAA	Red Banana	Aanbale, Sevvazhai, Agniswar, Agnisagar	Red Dacca
14.	Shan Bale	ABB	Bluggoe	–	Bluggoe

Table 3. Evaluation data on growth, yield and selected fruit parameters

Varieties	Genome group	Plant height (cm)	Pseudo-stem girth	Days to flower	Days to harvest	Bunch weight (kg)	No. of hands	Total no. of fruits	Sugar content (% Brix)	Flesh weight* (g)	Peel weight (g)	Flesh texture	Edible portion (%)
Mitli	AB	340	70	300	410	11	11	160	26	42	68	firm	38
Local Mitli	AB	360	69	295	410	15	12	195	27	56	59	firm	49
Boodhi Bale	ABB	420	76	308	418	16	10	154	30	76	34	firm	69
Sakkare Bale	ABB	384	82	269	388	17	12	172	31	77	42	firm	65
Bhoodhi Mitiga	ABB	399	82	315	430	14	10	146	30	65	50	Medium	57
Rajapuri	AAB	185	80	215	345	9	7	98	22	33	98	Soft	25
Mysore Mitli	AAB	275	74	235	345	18	13	198	25	55	55	firm	50
Bargi Bale	AAB	320	80	194	326	9	8	106	23	46	86	Soft	35
Kari Bale	ABB	390	72	224	344	10	7	108	22	48	72	Firm	40
Kaadu Bale-Manjukeri	BB	620	115	475	520	22	13	160	29	87*	58	Mucilaginous	10
Kaadu Bale-Gundha	BB	625	116	478	520	22	13	160	28	102*	41	Mucilaginous	12
Kaadu Bale-Kuluve	BB	590	120	462	585	24	15	164	28	114*	48	Mucilaginous	10
Chandra Bale	AB	240	56	275	400	8	8	116	26	31	94	Medium	65
Shan Bale	ABB	340	63	200	330	12	5	86	24	52	85	Medium	45

* Mucilaginous flesh with seed weight
Data has been rounded off to next highest value without decimals

Table 4. Major pests recorded in the regions surveyed

S.No.	Area	Varieties	Diseases	Pests
1.	Kirawatti	Ney Poovan, Ash Monthan, Mysore, Shan Bale	BBTV, Sigatoka Leaf Spot	–
2.	Sangatikoppa	Kari Bale	BBTV*	Nematodes
3.	Yallapura	Mundagod Bale (Kari Bale)	BBTV	–
4.	Savanagere	*Musa balbisiana*	BBTV	Nematodes
5.	Sirsi	Ney Poovan, Red banana, Bhoodhi Bale (Pisang Awak), Bargi Bale, Kari Bale, Monthan *Ensete superbum*	BBTV Fusarium wilt, BBTV	Pseudostem borer
6.	Bhyrambe	Bhoodhi Bale (Pisang Awak), Bargi Bale, Mitli (Ney Poovan), Poovan	BBTV, Sigatoka Leaf Spot	Severe incidence of pseudostem borer
7.	Kuluve	Red Banana, Green red, Mysore, Ney Poovan, Bargi Bale, Kari Bale, Bhoodhi mitiga, *Ensete superbum*	BBTV (Severe), Fusarium wilt, BBMV	Pseudostem borer
8.	Mandalikoppa	Karpooravalli, Mitli, (Ney Poovan,), *Musa balbisiana*	BBTV, Fusarium wilt –	
9.	Siddhapura	*Musa balbisiana,* Mysore, Ney Poovan, ed banana, Pachakappa, Bhoodhi Bale (Pisang Awak), Bargi Bale, Kari Bale	BBTV, –	Sigatoka Leaf Spot
10.	Thalagode	*Musa balbisiana*	BBTV	–
11.	Haliyal	Mitli, Mysore Mitli	BBTV, BSV*	–
12.	Kulige	Kari Bale, Ney Poovan, Mysore	Sigatoka Leaf Spot	–
13.	Dandeli	Ney Poovan, Monthan, Mysore	BBTV, Sigatoka Leaf Spot	Nematodes
14.	Ambikanagar Sykes point	Ney Poovan, *Ensete superbum, Musa balbisiana*	–	Nematodes
15.	Gundha	*Musa balbisiana,* Mysore, Ney Poovan	BSV	–

*BBTV – Banana Bunchy Top Virus, *BSV – Banana Streak Virus

Acknowledgements

This work was supported by the ICAR/World Bank funded NATP project on Sustainable Management of Plant Biodiversity.

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Morphological Characterization of *Allium* spp. Using Multivariate Analysis

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(Received: 11 June 2013; Revised: 26 September 2013; Accepted: 11 December 2013)

Thirty-five accessions of *Allium* species were characterized for foliage colour, density of leaves, foliage attitude, cross-section of leaf, degree of leaf waxiness, storage organ, bulb skin colour, shape of mature dry bulbs, ability to flower, seed coat colour, leaf length, leaf girth, number of leaves/plant and plant height. High level of variability was observed for bulb colour and shape of mature dry bulbs as they were distributed into maximum of six classes and least variability was observed for ability to flower. The significant differences were observed for all the measureable characters. In principal component analysis, first five components explained 74.53% of the total variation, where first component explained 22.92% and second accounted for 16.66% of total variation. In, PC-1 storage organ has highest positive contribution and shape of mature dry bulbs in PC-2. The different *Allium* species show extensive overlapping in PCA plot draw based on the morphological characters.

Key Words: *Allium*, Eigen value, PCA, species

Introduction

Allium is a large genus which is widely distributed in the Central Asia, North America and Indian Himalayan regions (Stearn, 1992; Negi and Pant, 1992). Several *Allium* species are grown by local tribes in wild or semi-domesticated forms in India. These species are utilized as vegetables, condiments and medicinal plants to fulfill their daily needs (Negi, 2006; Pandey *et al*., 2008).

About 40 *Allium* species are available in wild or semi-domesticated form in Himalayan region but not much attention was paid on their collection and characterization. To realize the full potential of available germplasm, explorations were made in Himalayan region and a number of *Allium* species was collected (Negi, 2006). Prior to utilization, the detailed knowledge of genetic, cytogenetic and agro-morphological characteristics of wild species is a pre-requisite. Among them, morphological characterization of germplasm is very useful for botanist, breeder and geneticist to assess genetic erosion, germplasm exploration, conservation and utilization strategies. In order to optimize better utilization of *Allium* germplasm this work was planned with objective of characterizing *Allium* germplasm based on morphological characters to identify major components of variation and grouping of various *Allium* species based on them. The goal was to identify the differences among the accessions and major variables which leads to the identification of possible groups and relationships among accessions.

Materials and Methods

Thirty-five accessions of different *Allium* species (Negi, 2006) were grown on the beds of 3' x 3' size during 2010-11 and 2011-12 in Randomized Block Design at Bhowali, Nainital, India (Table 1). The data were recorded following IBPGR descriptors (IBPGR, 2001) for foliage colour, density of leaves, foliage attitude, cross-section of leaf, degree of leaf waxiness, storage organ, bulb skin colour, shape of mature dry bulbs, ability to flower, seed coat colour, leaf length, leaf girth, number of leaves/plant and plant height. The data was analyzed to calculate mean and range values to estimate degree of variability for quantitative descriptors. Distribution analysis was performed to identify various classes to measure the extent of variability in qualitative descriptors. Principal component analysis (PCA) was performed to identify major variables by aggregation of variables. First and second principal component axes scores were plotted to aid visualization grouping pattern of *Allium* germplasm using SAS software package (NC, USA, 2008).

Results

Distribution Analysis

The distribution analysis for qualitative characters showed maximum number of classes for bulb skin colour and shape of mature dry bulbs (6) followed by cross-section of leaf (4) and storage organ (4). All accessions fall in one class for ability to flower, two for seed coat colour and three for foliage colour, density of leaves, foliage

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Table 1. *Allium* species used for morphological characterization

S. No.	Species	S. No.	Species
1.	*A. fistulosum*-EC321643	19.	*A. albidium*-EC328484
2.	*A. schoenoprasum*- EC328499	20.	*A. fistulosum*-NIC23426
3.	*A. altaicum* EC-328485	21.	*A. auriculatum*-IC353529
4.	*A. scorodoprasum*- EC328450	22.	*A. auriculatum*-IC353531
5.	*A. ledebouranum*-EC328491	23.	*A. carolinianum*-IC353527
6.	*A. oreoprasum*-EC328494	24.	*A. ascalonicum*-IC353531
7.	*A. oschaninii*-EC328495	25.	*A. proliferum*-NIRP/SSM 2799
8.	*A. tuberosum*-IC353524	26.	*A. proliferum*-NIRP/SSM 2801
9.	*A. pskemence*-EC328497	27.	*A. roylei*-IC353540
10.	*A. cernuum*-IC353525	28.	*A. hookeri*-HN 2800
11.	*A. scorodoprasum*-EC328501	29.	*A. griffithianum*-NIC94272
12.	*A. fistulosum*-NIC20231	30.	*A. angulosum*-EC328486
13.	*A. ramosum*-EC328498	31.	*A. carolinianum*-IC326228
14.	*A. obliqum*-EC328493	32.	*A. cernuum*-IC142272
15.	*A. ameloprasum*-IC353526	33.	*A. clarkei*-IC383446
16.	*A. fistulosum*-IC353541	34.	*A. chinense*-NAF 89/61
17.	*A. consanguineum*-IC212783	35.	*A. cepa*
18.	*A. senescens*- EC328503		

attitude and degree of leaf waxiness. In bulb colour, dark brown was predominant with 29.00% share and 37.00% of total accessions fall in broad elliptic bulb shape. The green foliage colour was observed in 42.00, medium density of leaves in 63.00, erect leaf habit in 71.00, flat cross-section in 46.00, medium degree of leaf waxiness in 71.00, bulb (single) as a storage organ in 54.00 and black seed coat colour in 80.00% of total accessions.

Variability

The leaf length ranged from 16.50 cm (*A. senescens,* EC328503) to 50.00 cm (*A. schoenoprasum,* EC328499) with mean of 31.79 cm, while, plant height varied from 19.00 cm (*A. senescens,* EC328503) to 56.93cm (*A. ledebouranum,* EC328491) with average of 38.94 cm. The leaf girth among different accession of *Allium* species varied between 0.27 cm (*A. roylei,* IC353540) to 2.20 cm (*A. carolinianum,* IC353527) with mean of 0.86 cm and number of leaves/plant from 3.80 (*A. fistulosum,* EC321643) to 10.00 (*Allium tuberosum,* EC353524) with average of 6.52 (data not given).

Principal Component Analysis

The first five components were identified as major based upon their eigen values and explained 74.53% of the total variation. The first component has 22.92% share in the total variation, where, storage organ (0.47229), seed coat colour (0.34583), number of leaves/plant (0.32225) and density of leaves (0.27640) contributed positively. While, plant height (-0.35551), leaf length (-0.34863), degree of leaf waxiness (-0.25985) and foliage colour (-0.25769) have negative effects. The second PC accounted for 16.66% of the total variation have positive contribution from foliage colour (0.37942), density of leaves (0.35470), cross-section of leaf (0.46021), bulb skin colour (32.824), shape of mature dry bulbs (0.48114) and number of leaves/plant (0.32161), while none of

Table 2. Contribution of each character towards principal components for various characters

Eigen Vectors	Prin1	Prin2	Prin3	Prin4	Prin5
Foliage colour	-0.25769	0.37942	-0.25744	0.18933	-0.16067
Density of leaves	0.27640	0.35470	0.31162	0.10971	-0.32072
Foliage attitude	-0.17924	0.01264	0.01285	0.67016	0.26520
Cross-section of leaf	0.11127	0.46021	-0.05836	-0.02237	0.33948
Degree of leaf waxiness	-0.25985	0.02794	-0.30364	0.07814	0.08503
Storage organ	0.47229	-0.17203	-0.02297	-0.05724	0.23898
Bulb skin colour	0.12957	0.32824	-0.09926	-0.15444	0.48774
Shape of mature dry bulbs	-0.06618	0.48114	-0.05419	-0.22129	0.16842
Ability to flower	-0.00000	0.00000	-0.00000	-0.00000	0.00000
Seed coat colour	0.34583	-0.20472	0.21541	0.11867	0.42194
Leaf length (cm)	-0.34863	0.03017	0.44897	-0.31748	0.13881
Leaf girth (cm)	-0.17139	0.03501	0.36096	0.48507	0.17542
Number of leaves/plant	0.32255	0.32161	0.34629	0.14120	-0.33193
Plant height (cm)	-0.35551	-0.03430	0.47890	-0.22403	0.12998
Eigen value	2.9803	2.1658	2.0937	1.2547	1.1948
% Variation explained	22.92	16.66	16.10	9.65	9.19
% Cumulative variance	22.92	39.58	55.69	65.34	74.53

Pl Note: Fig 1 and Table 2 refered

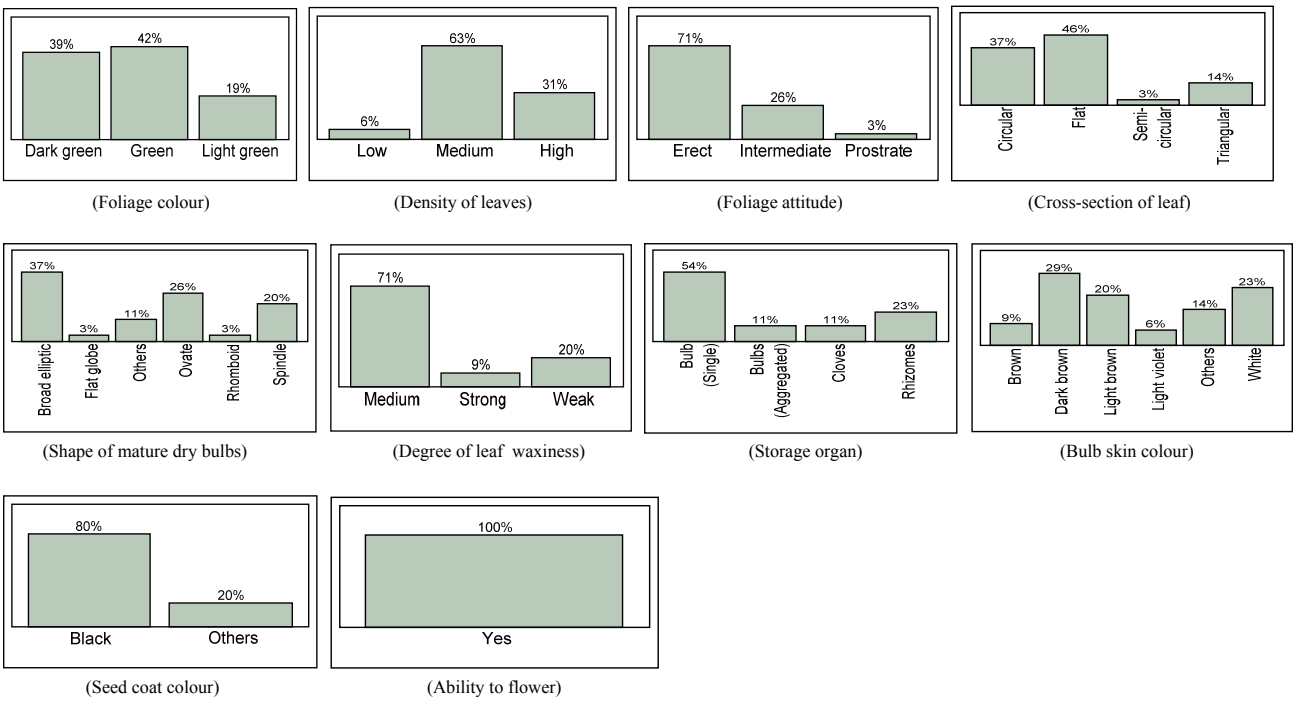

Fig. 1. Distribution analysis for different morphological characters in various *Allium* species

the characters gave significant negative effect. In PC 3, density of leaves (0.31162), leaf length (0.44897), leaf girth (0.36096), number of leaves/plant (0.34629) and plant height (0.47980) contribute positively with 16.10% of total variation. Whereas, PC 4 has foliage attitude (0.67016) and leaf girth (0.48507), while, PC 5 includes foliage attitude (0.26520), cross-section of leaf (0.33948), bulb skin colour (0.48774) and seed coat colour (0.42194) with 9.65 and 9.19% share of total variation, respectively.

Principal Component Analysis shows extensive overlapping of accessions of different *Allium* species in PCA plot (Fig. 2). The exotic accession *A. fistulosum*, EC 321643 (1) was quite different from *A. fistulosum*, IC 353541 (16) and *A. fistulosum*, NIC 23426 (20). Both accessions of *A. auriculatum* (21, 22) and *A. proliferum* (25,26) group together but differences existed within accessions. The genetic variability was also observed between *A. cernuum*, IC 353525 (10) and *A. cernuum*, IC 142272 (32). Four accessions *viz. A. fistulosum*, EC 321643 (1) *A. schoenoprasum*, EC 328499 (2) *A. scorodoprasum*, EC 328450 (4) and *A. chinense*, NAF 89/61 (34) are quite different from other *Allium* germplasm as they group apart in PCA plot (Fig. 2).

Discussion

Genetic variability was observed within and between various accessions of different *Allium* species. High level of variability was observed for bulb skin colour and shape of mature dry bulbs, whereas, differences were moderate for other traits, except ability to flower in different *Allium* species. These results were consistent with previous findings (Negi and Pant, 1992; Negi 2006; Verma *et al.*, 2008). It indicates that all qualitative characters are also crucial for the characterization of various alliums. The wide differences for all the quantitative characters were recorded in present investigation which was also supported by earlier observations (Verma *et al*., 2008). In, PCA first five major components explained 74.53% of total variability, where storage organ and shape of mature dry bulbs were the major contributors in PC-1 and PC-2. Nearly similar results were reported in garlic where first four components explained about 80.00% of total variation and bulb related characters contributed significantly towards the total variability (Panthee *et al*., 2006). The multiple accessions of *Allium* species show genetic variability within species and grouped together which indicates that selection can be followed for the improvement of other alliums used by local tribes in

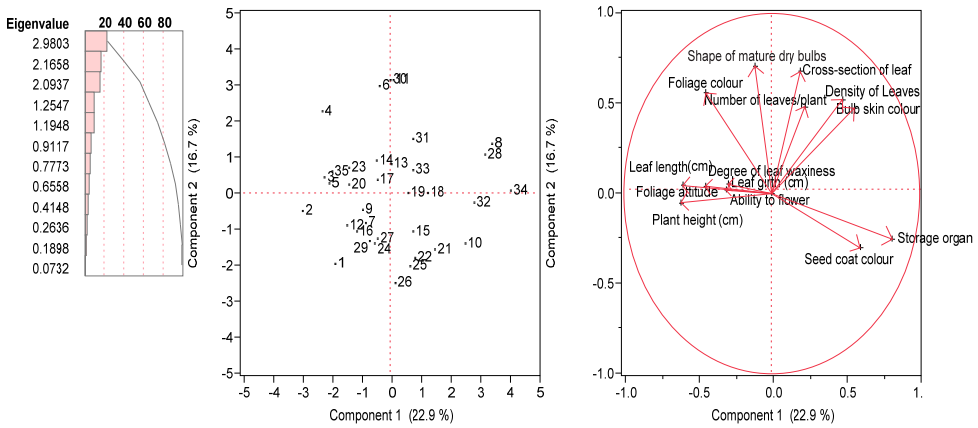

Fig. 2. Principal component analysis for different morphological characters in various *Allium* species (numbers indicate *Allium* species as mentioned in table in serial order)

India. The exotic bunching onion accessions are quite different from indigenous which was also detected at molecular level (Khosa, 2012).The overlapping of accessions based on morphological characters indicates that there is urgent need to use molecular markers to establish phylogenetic relationships.

From present investigation it was concluded that *Allium* species show complex morphological variability which must be conserved. At present *A. roylei is* regarded as endangered species in the red data list of IUCN even in its native habitat (Walter and Gillet, 1997). In coming years some more species might come under endangered list due to global warming, increase in habitat area and extensive use by local tribes. So, there is urgent need for the management of different *Allium* species in India. It seems necessary the accomplishment of new collections of botanical material of the wild species seeking the enlargement of the conserved variability as well as definition of preservation strategies to avoid losses of genetic variability. In nutshell, collaborative and multidisciplinary strategies for efficient management and utilization of *Allium* germplasm should be followed.

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Evaluation of Okra [*Abelmoschus esculentus* (L.) Moench] Germplasm for Yield and Quality of Fruits

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(Received: 14 June 2013; Revised: 17 January 2014; Accepted: 25 January 2014)

One hundred and one accessions of okra [*Abelmoschus esculentus* (L.) Moench], collected from various parts of India were evaluated for yield and 11 yield attributes under field conditions at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala. The experiment was laid out in randomised block design with three replications and 10 plants/plot. The traits analysed were fruit yield [fruit weight/plant (g)] and yield attributes *viz*., fruits/plant, average fruit weight (g), fruit length (cm), fruit girth (cm), ridges/fruit, seeds/fruit, fruit colour, fruit pubescence, crude fibre content (%), protein content (g), mucilage content (%). ANOVA revealed remarkable variation for all the traits studied. Varsha Uphar, Parbhani Kranti and NBPGR/TCR-985 were the most promising genotypes identified during the investigation.

Key Words: *Abelmoschus esculentus*, Fruit yield, Okra, Variability, Yield components

Introduction

Vegetables, the important protective foods, are excellent sources of protein, vitamins, carbohydrate and minerals. Okra [*Abelmoschus esculentus* (L.) Moench] is an important vegetable of the world being produced in the tropical and sub-tropical low land regions of Asia, Africa, America and warmer parts of Mediterranean regions. As per Indian Horticulture database-2011, in India, okra is grown in an area of 4,98,000 ha and total production is 57,84,000 tons with a productivity of 11.6 t/ha. At global level, okra occupies an area of 11,47,950 ha and total production of 78,96,260 tons with 6.90 t/ha productivity. Thus, India contributes 73.25% of total world production of okra.

Okra, a highly adaptable crop, is grown throughout the country for its tender green fruits which are cooked and consumed in various forms and also used for canning. Besides being rich in protein, vitamins, minerals (especially iron) and dietary fibre, the high iodine content makes it unique among vegetables and helps it to play a vital role in controlling goitre disease especially for vegetarians. Seeds form a nutritious ingredient of cattle feed whereas mucilage finds its use in the manufacture of gums. The juice of over-ripe fruits is an ideal substitute for shampoo. Also, the plant as a whole serves as a source of fibre. Owing to these myriad uses, okra remains in high demand in inland market along with great export potential. While formulating suitable breeding methodology for the improvement in this crop, attention must be paid for the improvement of visual appearance as well as the biochemical qualitative aspects too, besides the productivity. Hence, development of high yielding varieties with improved fruit parameters is an important need in the field of improvement of okra. Focusing on this objective, an attempt has been made to evaluate the fruit parameters in the available germplasm of okra.

Materials and Methods

The 101 okra genotypes, collected from various parts of India (Table 1) were laid out in randomised block design with two replications at a spacing of 60 x 45 cm and 10 plants/treatment/replication during summer 2001 to evaluate for yield and its attributes. Cultural and manurial practices were followed as per package of practices [Recommendations of KAU 1996]. Observations on fruit yield, yield attributes and fruit quality parameters *viz*., fruit number, average fruit weight (g), fruit yield [fruit weight/plant (g)], fruit length (cm), fruit girth (cm), fruit colour, fruit pubescence, ridges/fruit, seeds/fruit including biochemical traits *viz*., crude fibre content (%), protein content (g) and mucilage content (%) were recorded. Fruit colour and fruit pubescence were scored as per the NBPGR descriptors as detailed below:

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a) Fruit colour	Score
Green	1
Dark green	2
Yellowish green	3
Red	4
Dark red	5
Light green	6
Straited (green with purple)	7
Beige pink	8
Green with purple blend	9
Red purple	10
Watery green	11
b) Fruit pubescence	Score
Downy	1
Slightly rough	2
Prickly	3

Regarding the biochemical traits, crude fibre content was assessed from three fruits from each observational plant at the marketable stage by the method proposed by Chopra and Kanwar (1976) and expressed as percentage

Table 1. Germplasm of okra collected from various parts of India

S. No.	Variety/Genotype	National ID	Source
1.	NBPGR/TCR-128-A	IC45792 A	NBPGR Regional Station, Vellanikkara, Thrissur, Kerala
2.	NBPGR/TCR-760	IC85595	-do-
3.	NBPGR/TCR-776	IC113904	-do-
4.	NBPGR/TCR-808	IC218879	-do-
5.	NBPGR/TCR-874	IC282257	-do-
6.	NBPGR/TCR-893	IC282259	-do-
7.	NBPGR/TCR-985	IC282293	-do-
8.	NBPGR/TCR-1185	IC128072	-do-
9.	NBPGR/TCR-1471	EC169329A	-do-
10.	NBPGR/TCR-1479	EC169340	-do-
11.	NBPGR/TCR-1498	EC169363	-do-
12.	NBPGR/TCR-1507	EC169375	-do-
13.	NBPGR/TCR-1508	EC169378	-do-
14.	NBPGR/TCR-1524	EC169400	-do-
15.	NBPGR/TCR-1533	EC169414	-do-
16.	NBPGR/TCR-1552	EC169447	-do-
17.	NBPGR/TCR-1569	EC169485	-do-
18.	NBPGR/TCR-1581	EC169522	-do-
19.	NBPGR/TCR-1674	IC15435	-do-
20.	NBPGR/TCR-1676	IC15537	-do-
21.	NBPGR/TCR-1722	IC27898	-do-
22.	NBPGR/TCR-1728	IC29119A	-do-
23.	NBPGR/TCR-1753	IC31398A	-do-
24.	NBPGR/TCR-1777	IC34190	-do-
25.	NBPGR/TCR-1783	IC39132A	-do-
26.	NBPGR/TCR-1828	IC45728	-do-
27.	NBPGR/TCR-1871	IC52322	-do-
28.	NBPGR/TCR-1883	IC89712	-do-
29.	NBPGR/TCR-1899	IC90073	-do-
30.	NBPGR/TCR-1904	IC90082	-do-
31.	NBPGR/TCR-1929	IC90187	-do-
32.	NBPGR/TCR-1934	IC90200	-do-
33.	NBPGR/TCR-1943	IC90212	-do-
34.	NBPGR/TCR-1948	IC90222	-do-
35.	NBPGR/TCR-1955	IC90230	-do-
36.	NBPGR/TCR-1956	IC90231	-do-
37.	NBPGR/TCR-1957	IC90233	-do-
38.	NBPGR/TCR-1963	IC90246	-do-
39.	NBPGR/TCR-1966	IC90251	-do-
40.	NBPGR/TCR-1968	IC90253	-do-
41.	NBPGR/TCR-1975	IC90269	-do-
42.	NBPGR/TCR-1981	IC90289	-do-
43.	NBPGR/TCR-1982	IC90291	-do-
44.	NBPGR/TCR-1988	IC93777	-do-
45.	NBPGR/TCR-1998	IC93777	-do-
46.	NBPGR/TCR-1999	IC99724	-do-
47.	NBPGR/TCR-2001	IC99726	-do-
48.	NBPGR/TCR-2019	IC108235	-do-
49.	NBPGR/TCR-2020	IC111014	-do-
50.	NBPGR/TCR-2040	IC111478	-do-
51.	NBPGR/TCR-2042	IC111480	-do-
52.	NBPGR/TCR-2048	IC111488	-do-
53.	NBPGR/TCR-2050	IC111490	-do-
54.	NBPGR/TCR-2055	IC111500	-do-
55.	NBPGR/TCR-2060	IC111507	-do-
56.	NBPGR/TCR-2061	IC111508	-do-
57.	NBPGR/TCR-2137	IC117134	-do-
58.	NBPGR/TCR-2145	IC117202	-do-
59.	NBPGR/TCR-2146	IC117202	-do-
60.	NBPGR/TCR-2168	IC117226	-do-
61.	NBPGR/TCR-2173	IC117229	-do-
62.	NBPGR/TCR-2177	IC117234	-do-
63.	NBPGR/TCR-2187	IC117244	-do-
64.	NBPGR/TCR-2192	IC117251	-do-
65.	NBPGR/TCR-2228	IC117300	-do-
66.	NBPGR/TCR-2235	IC117308	-do-
67.	NBPGR/TCR-2237	IC117310	-do-
68.	Anakkomban-I	…..	Palappoor, Thiruvananthapuram, Kerala
69.	Anakkomban-II	…..	Kalliyoor, Thiruvananthapuram, Kerala
70.	Arka Abhay	…..	IIHR, Bangalore, Karnataka
71.	Arka Anamika	…..	-do-
72.	Aruna	…..	College of Horticulture, Vellanikkara, Thrissur, Kerala
73.	Balussery Local	…..	Balussery, Kozhikode, Kerala
74.	Chittarikkal Local	…..	Chittarikkal, Kasaragod, Kerala
75.	Eranakulam Local	…..	Eranakulam, Kerala
76.	Goureesapattom Local	…..	Goureesapattom, Thiruvananthapuram, Kerala
77.	Kakkamoola Local	…..	Kakkamoola, Thiruvananthapuram, Kerala
78.	Kalavoor Local	…..	Kalavoor, Alappuzha, Kerala

S. No.	Variety/Genotype	National ID	Source
79.	Kanhangad Local	…..	Kanhangad, Kasaragod, Kerala
80.	Kannur Local Red	…..	Kannur, Kerala
81.	Kattayikkonam Local	…..	Kattayikkonam, Thiruvananthapuram, Kerala
82.	Kazhakkoottam Local	…..	Kazhakkoottam, Thiruvananthapuram, Kerala
83.	Kilikolloor Local	…..	Kilikolloor, Kollam, Kerala
84.	Kiran	…..	Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, Kerala
85.	Kollam Local-1	…..	Kollam, Kerala
86.	Kollam Local-2	…..	-do-
87.	Koyilandy Local	…..	Koyilandy, Kozhikode, Kerala
88.	Mananthavady Local	…..	Mananthavady, Wayanad, Kerala
89.	Mavungal Local	…..	Mavungal, Kasaragod, Kerala
90.	MDU-1	…..	TNAU, Coimbatore, Tamil Nadu
91.	Nedumangad Local	…..	Nedumangad, Thiruvananthapuram, Kerala
92.	Nileshwaram Local	…..	Nileshwaram, Kasaragod, Kerala
93.	Pananchery Local	…..	Pananchery, Thrissur, Kerala
94.	Parbhani Kranti	…..	Marathwada Agricultural University, Parbhani
95.	Payyannur Local	…..	Payyannur, Kannur, Kerala
96.	Peechi Local	…..	Peechi, Thrissur, Kerala
97.	Pudukad Local	…..	Pudukad, Thrissur, Kerala
98.	Salkeerthi	…..	College of Horticulture, Vellanikkara, Thrissur, Kerala
99.	Selection-13	…..	Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, Kerala
100.	Selection-46	…..	-do-
101.	Varsha Uphar	…..	Haryana Agricultural University, Hisar, Haryana

of fresh weight. Protein content of the fruits harvested at marketable stage was estimated as per the method adopted by Bradford (1976). The fruits harvested at the marketable stage formed the sample fruits for estimation of mucilage content. The mucilage content was estimated by following the method suggested by Hirst and Jones (1955). All other traits were recorded as per standard procedure routinely followed. The biometric observations recorded were subjected to ANOVA (Panse and Sukhatme, 1985) for comparison for yield and yield parameters among various treatments and to estimate variance components.

Results and Discussion

An insight into the extent of variability available in the genetic stock is of prime importance which provides the best picture of genetic gain achievable through selection. Critical assessment of nature and magnitude of variation is the first and the foremost step in formulating an effective breeding programme. In quantitative characters, phenotype is an unreliable indicator of genotype and hence it is desirable to test the genotypic value of individuals prior to selection. Since the observed variability in a population is the sum total of variation arising due to genotypic and environmental effects, knowledge on the nature and magnitude of genetic variation contributing to gain under selection is essential (Allard, 1960). Analysis of variance helps in partitioning the total phenotypic variation into components such as genotypic and environmental (error) variances, thereby providing information regarding the breeding value of genotypes involved and also the nature and magnitude of variability in the expression of a particular trait.

ANOVA revealed remarkable variation in all the traits under investigation (Table 2). Several research findings are available dealing with the varietal variation in okra with respect to many characters (Ariyo, 1990; Kumbhani *et al*., 1993; Gondane and Lal, 1994; Bindu *et al*., 1997).Significant works among them include those of Murthy and Bavaji (1980) for number, length and yield of fruits, Vashistha *et al*. (1982) for yield, Jeyapandi and Balakrishnan (1992) for seeds/fruit, Rajani and Manju (1997) for number, length, girth, weight and yield of fruits, Hazra and Basu (2000) for seeds/fruit and number, weight and yield of fruits, Philip *et al*. (2000) for number, weight, yield and crude fibre content of fruits, and Gandhi *et al*. (2001) for number, length, girth and seeds of fruits.

Table 2. ANOVA for fruit parameters in okra germplasm

S. No.	Character	Genotypic mean square (df = 100)
1.	Fruits/plant	9.82**
2.	Average fruit weight (g)	48.88**
3.	Fruit weight/plant (g)	9374.69**
4.	Fruit length (cm)	23.41**
5.	Fruit girth (cm)	1.55**
6.	Ridges/fruit	1.15**
7.	Seeds/fruit	195.72**
8.	Crude fibre content (%)	0.56**
9.	Protein content (g)	0.50**
10.	Mucilage content (%)	0.48**

The mean performance of the accessions for various fruit parameters are shown in Table 3. Fruit number varied significantly among the genotypes and it ranged from 2.50 (NBPGR/TCR-1981) to 13.67 (NBPGR/TCR-2020). NBPGR/TCR-1981 was at par with other four genotypes *viz*., NBPGR/TCR-1676, NBPGR/TCR-1674, NBPGR/TCR-1581 and NBPGR/TCR-2235 whereas NBPGR/TCR-2020 was at par with Parbhani Kranti, Varsha Uphar, and MDU-1.

Average fruit weight showed wide range of variation among the genotypes from 12.18 (NBPGR/TCR-1533) to 34.47 (Kollam Local-1). Forty six genotypes were homogeneous with NBPGR/TCR-1533 while Kollam Local-1 was on par with NBPGR/TCR-1999, Goureesapattom Local, NBPGR/TCR-985, Parbhani Kranti, Varsha Uphar, Selection-13, Selection-46, Anakkomban-I, Anakkomban-II, Kannur Local Red and Payyannur Local.

Parbhani Kranti was the best yielder, with a fruit yield of 373.25 g/plant whereas the lowest fruit yielder was NBPGR/TCR-1981 with 34.52 g/plant. However, only two genotypes *viz*., Varsha Uphar and NBPGR/TCR-985 were on par with Parbhani Kranti whereas several genotypes were low yielders similar to NBPGR /TCR-1981.

The length of fruit exhibited wide range of variation among the various genotypes (Fig. 1). The longest (27.18 cm) and the shortest (8.99 cm) fruits were produced by Anakkomban-II and NBPGR/TCR-1507 respectively. The length of fruits of Anakkomban-I and Payyannur Local was on par with that of Anakkomban-II.

The fruits with maximum girth (10.08 cm) were produced by Kilikolloor Local and Kollam Local-1. Fruit girth was minimum (4.20 cm) in NBPGR/TCR-1999, which exhibited similarity with thirty other genotypes.

The maximum score of 9 (green with purple blend) for fruit colour was observed for NBPGR/TCR-2020 and Kollam Local-1 whereas Peechi Local, Kattayikkonam Local, Nedumangad Local, Pananchery Local and Balussery Local secured the minimum score 1 (green).

The highest value of fruit pubescence was observed for NBPGR/TCR-1533 (3-prickly) and two accessions (NBPGR/TCR-1508 and NBPGR/TCR-1957) possessed medium value (2-slightly rough) while all the others exhibited minimum value (1-downy) for this trait.

Ridges/fruit among the various genotypes ranged from 5.00 to 8.17 (Fig. 2). Highest number of ridges per fruit was observed in Kazhakkoottam Local (8.17). As pointed out by Hazra and Basu (2000), variation was low for ridges on fruits and moderate for fruit length.

Seventy genotypes had fruits with five ridges whereas other accessions including Kollam Local-1, Anakkomban-II, NBPGR/TCR-2020, Kilikolloor Local, Payyannur Local, Anakkomban-I, NBPGR/TCR-776, NBPGR/TCR-1728, NBPGR/TCR-893 and NBPGR /TCR-808 etc. possessed fruits with more than five ridges.

Seeds/fruit varied from 26.50 in NBPGR/TCR-2168 to 85.17 in Kazhakkoottam Local (Fig. 3). NBPGR/TCR-2020 and Anakkomban-II were found to be at par with Kazhakkoottam Local with respect to this character.

Fig. 1. Variability in length and colour of okra fruits

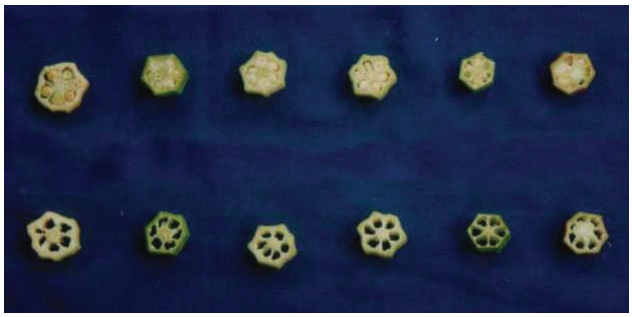

Fig. 2. Variability in ridges and locules of okra fruits

Table 3. Mean performance of 101 okra genotypes for fruit characters

S. No.	Genotype	Fruit number	Average weight (g)	Fruit yield/ plant (g)	Fruit length (cm)	Fruit girth (cm)	Fruit colour	Fruit pube-scence	No. of fruit ridges	No. of seeds/ fruit	Crude fibre content (%)	Protein content (g)	Mucilage content (%)
		1	2	3	4	5	6	7	8	9	10	11	12
1.	NBPGR/TCR-128-A	5.75	24.29	140.36	20.12	5.95	2	1	5.00	56.84	2.20	0.74	1.40
2.	NBPGR/TCR-760	5.25	22.43	117.73	17.99	5.85	2	1	5.00	48.17	2.55	1.09	1.10
3.	NBPGR/TCR-776	5.80	18.40	123.90	15.53	4.85	6	1	6.90	53.50	2.55	1.03	1.40
4.	NBPGR/TCR-808	5.75	19.26	110.32	12.99	7.69	2	1	6.92	47.17	2.35	0.66	1.30
5.	NBPGR/TCR-874	6.98	26.51	184.69	16.09	5.70	3	1	6.00	59.34	1.10	0.40	2.00
6.	NBPGR/TCR-893	7.75	20.71	160.72	14.96	6.65	2	1	6.25	42.84	2.15	0.40	1.10
7.	NBPGR/TCR-985	11.90	27.62	327.46	21.26	5.73	7	1	5.17	55.84	1.40	2.50	1.30
8.	NBPGR/TCR-1185	5.38	19.69	105.94	13.95	5.40	3	1	5.00	44.75	1.55	0.19	1.80
9.	NBPGR/TCR-1471	5.09	20.45	103.22	17.00	5.83	6	1	5.00	32.75	2.55	0.24	1.10
10.	NBPGR/TCR-1479	6.09	16.10	100.48	10.70	4.73	2	1	5.00	39.25	2.00	0.77	1.50
11.	NBPGR/TCR-1498	10.97	24.85	272.26	17.65	5.80	2	1	5.13	58.05	1.45	0.92	1.49
12.	NBPGR/TCR-1507	5.00	20.75	103.75	8.99	5.94	2	1	5.00	58.67	2.90	0.07	1.50
13.	NBPGR/TCR-1508	6.15	20.80	129.71	13.60	4.95	2	2	5.00	48.25	2.45	0.44	1.44
14.	NBPGR/TCR-1524	7.40	18.71	137.70	14.12	5.69	2	1	5.53	63.92	1.05	0.34	2.04
15.	NBPGR/TCR-1533	4.47	12.18	54.30	11.24	5.47	2	3	5.00	34.04	3.65	1.49	1.00
16.	NBPGR/TCR-1552	5.50	15.55	86.14	12.60	5.00	3	1	5.00	55.00	0.75	0.20	3.07
17.	NBPGR/TCR-1569	6.25	21.69	135.38	15.55	5.40	2	1	5.00	46.59	0.70	0.30	3.07
18.	NBPGR/TCR-1581	4.10	14.25	58.32	12.38	5.13	2	1	5.00	44.00	1.55	0.30	1.80
19.	NBPGR/TCR-1674	4.00	16.46	64.85	12.04	4.57	2	1	5.00	41.34	1.85	0.46	1.30
20.	NBPGR/TCR-1676	3.90	14.75	57.61	11.29	4.84	6	1	5.00	45.75	1.05	0.11	2.00
21.	NBPGR/TCR-1722	5.09	16.46	83.51	15.05	5.14	6	1	5.00	48.25	1.40	0.31	2.06
22.	NBPGR/TCR-1728	4.30	16.41	70.60	12.91	5.54	2	1	6.25	38.17	2.15	0.29	1.50
23.	NBPGR/TCR-1753	6.00	15.39	91.47	10.93	5.40	3	1	5.00	39.75	2.15	0.76	1.40
24.	NBPGR/TCR-1777	7.13	22.15	157.85	19.65	4.93	3	1	5.00	44.17	1.80	0.33	1.40
25.	NBPGR/TCR-1783	6.50	20.40	132.57	14.63	4.95	3	1	5.00	40.50	2.15	0.62	1.10
26.	NBPGR/TCR-1828	5.50	25.91	144.96	16.78	5.56	6	1	5.00	45.38	2.20	1.50	1.30
27.	NBPGR/TCR-1871	7.70	20.71	160.31	16.52	5.02	6	1	5.00	40.50	2.30	0.10	1.30
28.	NBPGR/TCR-1883	5.00	14.84	74.18	10.82	4.44	3	1	5.00	38.17	1.65	0.20	1.55
29.	NBPGR/TCR-1899	8.75	20.73	182.29	15.19	5.70	6	1	5.00	55.34	1.90	0.59	1.45
30.	NBPGR/TCR-1904	5.70	25.22	144.03	11.35	6.45	6	1	5.00	42.67	2.50	0.49	1.30
31.	NBPGR/TCR-1929	6.67	17.72	118.59	13.45	5.48	6	1	5.00	41.00	1.70	0.56	1.20
32.	NBPGR/TCR-1934	9.43	20.18	190.87	14.92	5.29	3	1	5.00	41.17	1.50	0.57	1.10
33.	NBPGR/TCR-1943	4.75	19.93	93.43	14.88	5.46	3	1	5.33	40.25	1.95	0.20	1.50
34.	NBPGR/TCR-1948	5.50	14.35	78.48	11.73	5.17	6	1	5.00	48.17	1.75	1.77	1.50
35.	NBPGR/TCR-1955	5.30	18.88	99.45	15.34	5.54	7	1	5.00	37.50	2.30	0.17	1.50
36.	NBPGR/TCR-1956	11.50	23.50	269.91	15.37	5.92	2	1	5.63	44.84	1.60	0.84	1.00
37.	NBPGR/TCR-1957	6.00	20.04	120.24	12.93	5.80	6	2	5.00	42.25	2.30	0.24	1.10
38.	NBPGR/TCR-1963	5.54	17.66	97.99	15.05	5.06	2	1	5.00	30.92	1.85	0.51	1.40
39.	NBPGR/TCR-1966	5.92	17.82	103.96	15.65	4.92	6	1	5.00	47.67	1.20	0.60	1.80
40.	NBPGR/TCR-1968	5.35	13.40	71.58	11.83	4.30	3	1	5.00	45.50	2.30	0.54	1.20
41.	NBPGR/TCR-1975	6.00	15.12	92.28	11.65	4.68	3	1	5.00	37.25	1.80	0.55	1.40
42.	NBPGR/TCR-1981	2.50	13.89	34.52	11.65	4.45	3	1	5.67	46.00	1.90	0.20	1.90
43.	NBPGR/TCR-1982	5.50	17.04	93.27	11.93	4.25	6	1	5.75	52.50	1.55	0.37	1.30
44.	NBPGR/TCR-1988	5.85	15.78	92.21	14.17	5.70	6	1	5.00	45.75	1.90	0.49	1.18
45.	NBPGR/TCR-1998	5.45	17.02	92.78	14.23	5.04	6	1	5.00	32.17	2.00	0.72	1.35
46.	NBPGR/TCR-1999	5.34	17.10	90.44	13.78	4.20	3	1	5.00	38.00	2.15	0.09	0.90
47.	NBPGR/TCR-2001	8.00	27.77	222.97	16.95	6.02	2	1	5.50	51.00	2.10	0.21	1.30
48.	NBPGR/TCR-2019	10.53	24.79	258.36	16.58	5.87	2	1	5.00	50.73	2.30	0.89	1.05

S. No.	Genotype	Fruit number	Average weight (g)	Fruit yield/ plant (g)	Fruit Length (cm)	Fruit girth (cm)	Fruit colour	Fruit pube-scence	No. of fruit ridges	No. of seeds/ fruit	Crude fibre content (%)	Protein content (g)	Mucilage content (%)
		1	2	3	4	5	6	7	8	9	10	11	12
49.	NBPGR/TCR-2020	13.67	16.52	225.79	11.62	6.05	9	1	7.80	80.50	2.90	0.83	1.2
50.	NBPGR/TCR-2040	5.00	14.38	71.90	12.24	5.32	3	1	5.00	34.92	1.30	0.03	2.0
51.	NBPGR/TCR-2042	5.95	14.90	89.32	11.82	4.92	3	1	5.00	34.34	2.40	0.29	1.4
52.	NBPGR/TCR-2048	8.20	22.44	182.28	15.35	5.89	2	1	5.00	49.09	2.40	2.20	1.3
53.	NBPGR/TCR-2050	5.84	22.80	133.41	15.15	5.81	6	1	5.00	49.63	1.65	1.39	1.4
54.	NBPGR/TCR-2055	8.50	20.40	172.89	15.38	4.65	3	1	5.00	41.00	2.60	1.54	1.3
55.	NBPGR/TCR-2060	12.10	23.86	288.89	17.80	5.63	2	1	5.25	48.00	3.10	0.53	1.4
56.	NBPGR/TCR-2061	8.20	17.79	142.78	14.29	5.02	3	1	5.00	43.59	1.60	0.61	1.3
57.	NBPGR/TCR-2137	9.15	23.66	215.81	14.81	6.03	2	1	5.00	48.17	0.85	0.37	3.6
58.	NBPGR/TCR-2145	4.50	13.78	61.82	11.89	4.74	6	1	5.00	41.92	1.70	0.71	1.5
59.	NBPGR/TCR-2146	7.15	16.17	115.31	13.55	4.45	3	1	5.50	41.00	1.70	0.34	1.2
60.	NBPGR/TCR-2168	5.67	18.37	103.89	15.30	4.85	3	1	5.00	26.50	1.15	0.38	2.3
61.	NBPGR/TCR-2173	4.94	12.88	62.73	12.64	5.47	3	1	5.00	31.42	2.40	0.40	1.2
62.	NBPGR/TCR-2177	4.50	15.19	68.36	10.48	4.78	3	1	5.00	32.25	2.60	0.13	1.5
63.	NBPGR/TCR-2187	6.75	20.43	137.94	14.47	5.68	2	1	6.00	62.17	2.00	1.41	1.3
64.	NBPGR/TCR-2192	6.50	19.04	123.11	14.38	5.78	6	1	5.00	51.00	2.20	1.06	1.3
65.	NBPGR/TCR-2228	8.85	15.06	133.19	11.65	5.15	3	1	5.00	40.34	1.10	0.89	1.8
66.	NBPGR/TCR-2235	4.80	12.70	60.05	11.52	5.11	6	1	5.00	44.50	2.30	0.33	1.3
67.	NBPGR/TCR-2237	4.13	15.91	65.60	11.33	4.73	7	1	5.00	32.50	1.40	0.20	1.7
68.	Anakkomban-I	4.50	30.78	136.85	23.87	6.14	2	1	7.34	52.50	2.25	0.26	1.5
69.	Anakkomban-II	4.75	29.78	140.43	27.18	6.35	6	1	8.00	70.09	2.10	0.99	1.4
70.	Arka Abhay	5.50	23.80	130.88	17.05	5.84	2	1	5.00	50.17	2.20	1.00	1.5
71.	Arka Anamika	7.80	24.84	193.80	18.97	5.69	2	1	5.00	45.59	1.95	0.33	1.3
72.	Aruna	5.90	25.60	150.73	19.66	4.95	4	1	5.00	50.17	2.10	0.46	1.5
73.	Balussery Local	5.00	14.08	35.44	11.05	4.48	1	1	5.00	40.25	2.35	0.67	1.5
74.	Chittarikkal Local	5.75	25.85	156.10	11.46	4.84	2	1	5.00	41.34	2.10	0.94	1.2
75.	Eranakulam Local	4.67	20.71	97.00	16.53	5.50	6	1	5.00	54.50	1.65	0.40	1.8
76.	Goureesapattom Local	10.70	28.34	303.17	18.49	6.63	7	1	5.17	56.83	2.40	0.51	1.3
77.	Kakkamoola Local	7.80	22.97	179.87	16.65	5.82	6	1	5.00	34.84	2.10	1.66	1.2
78.	Kalavoor Local	6.00	15.43	94.74	12.63	5.38	6	1	5.00	47.25	0.75	1.21	4.0
79.	Kanhangad Local	5.67	22.19	125.73	16.14	4.94	6	1	5.25	43.25	2.65	0.65	1.1
80.	Kannur Local Red	5.80	29.92	172.38	22.25	5.57	4	1	6.00	56.25	1.80	0.25	2.0
81.	Kattayikkonam Local	4.65	18.56	86.19	15.38	5.13	1	1	5.25	38.67	1.05	0.81	2.2
82.	Kazhakkoottam Local	5.50	22.22	121.94	16.59	6.89	6	1	8.17	85.17	2.65	0.94	1.1
83.	Kilikolloor Local	5.25	19.67	103.38	13.53	10.08	7	1	7.75	62.00	2.35	0.88	1.4
84.	Kiran	5.80	24.94	144.65	17.57	5.13	6	1	5.00	52.00	1.70	0.62	1.4
85.	Kollam Local-1	6.10	34.47	210.23	15.49	9.91	9	1	8.00	68.09	2.25	1.33	1.5
86.	Kollam Local-2	5.25	18.44	97.08	12.59	5.14	7	1	5.00	33.00	2.45	1.11	1.1
87.	Koyilandy Local	4.60	15.63	71.59	12.18	4.63	6	1	5.00	49.75	2.25	0.92	1.4
88.	Mananthavady Local	5.38	27.26	146.83	20.62	6.09	2	1	5.00	46.42	2.10	0.35	1.6
89.	Mavungal Local	6.50	19.40	125.29	22.17	5.58	2	1	5.00	40.25	1.50	1.80	1.7
90.	MDU-1	12.40	23.70	293.28	19.14	5.96	2	1	5.00	58.50	1.55	1.20	1.0
91.	Nedumangad Local	6.75	15.71	106.26	12.55	6.30	1	1	5.00	52.17	2.05	1.14	1.5
92.	Nileshwaram Local	5.35	15.59	99.19	12.50	5.23	2	1	5.00	43.00	1.85	1.16	1.4
93.	Pananchery Local	5.09	18.78	94.53	13.25	5.38	1	1	5.00	50.00	1.85	0.46	1.4
94.	Parbhani Kranti	12.70	29.41	373.25	18.80	5.72	7	1	5.25	47.89	2.10	2.02	1.1
95.	Payyannur Local	4.44	28.37	125.41	22.75	6.03	2	1	7.50	50.50	2.15	0.26	1.5
96.	Peechi Local	9.40	24.65	231.99	16.67	6.08	1	1	5.00	44.50	1.35	0.20	1.8
97.	Pudukad Local	5.80	16.44	95.35	17.07	5.49	6	1	5.25	58.63	2.25	0.99	1.4

S. No.	Genotype	Fruit number	Average weight (g)	Fruit yield/ plant (g)	Fruit length (cm)	Fruit girth (cm)	Fruit colour	Fruit pube-scence	No. of fruit ridges	No. of seeds/ fruit	Crude fibre content (%)	Protein content (g)	Mucilage content (%)
		1	2	3	4	5	6	7	8	9	10	11	12
98.	Salkeerthi	5.17	24.56	125.97	21.16	5.62	6	1	5.00	38.13	1.90	0.58	1.80
99.	Selection-13	6.70	28.85	192.17	21.63	6.25	2	1	5.00	42.00	2.20	0.39	1.70
100.	Selection-46	5.90	30.28	178.53	19.10	5.62	2	1	5.50	42.25	1.30	0.38	2.20
101.	Varsha Uphar	12.65	27.58	348.44	19.31	5.54	2	1	5.34	52.90	2.00	0.48	1.30
	Mean	6.49	20.43	136.45	15.18	5.52	–	–	5.31	46.44	1.95	0.69	1.52
	SE	0.64	2.71	21.11	1.74	0.51	–	–	0.31	5.93	0.26	0.28	0.27
	CD	1.68	7.10	55.31	4.56	1.34	–	–	0.81	15.54	0.68	0.73	0.71

Fig. 3. Variability in seeds of okra fruits

Among the significantly varying genotypes, NBPGR/TCR-1533 had the highest fibre content (3.65 %) and NBPGR/TCR-2060 was at par with NBPGR/TCR-1533. Fibre content was the lowest in NBPGR/TCR-1569 (0.70 %). Crude fibre content (13.1 to 14.3 %) in okra fruits was earlier reported by Elangovan *et al*. (1983).

Protein content was the highest (2.50 g) in the fruits of NBPGR/TCR-985 and NBPGR/TCR-1948, NBPGR/TCR-2048, Mavungal Local and Parbhani Kranti was at par with NBPGR/TCR-985. NBPGR/TCR-2040 had the lowest protein content (0.03 g).

The highest mucilaginous type Kalavoor Local (4.0 %) was at par with NBPGR/TCR-2137. NBPGR/TCR-1999 (0.9 %) had the lowest mucilage content which was at par with 77 genotypes.

High yield was observed for Parbhani Kranti in this study is in accordance those of Singh *et al*. (1993) and Lal *et al*. (2001). Singh (2000) reported that Parbhani Kranti displayed high yield and fruit weight along with high resistance to YVM consistently for three years which corroborates with the present findings.

Screening of germplasm comprising 101 okra genotypes for yield and component traits revealed significant variation among the genotypes. Based on overall performance, eight superior genotypes *viz*., NBPGR/TCR-985, NBPGR/TCR-1498, NBPGR/TCR-2019, NBPGR/TCR-2020, NBPGR/TCR-2060, MDU-1, Parbhani Kranti and Varsha Uphar were selected for hybridization programme to develop F_1 hybrids.

Acknowledgement

The authors sincerely acknowledge NBPGR, New Delhi, and NBPGR Regional Station, Vellanikkara, for providing okra germplasm for the study.

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Genetic Variability and Interaction of Some Quantitative Traits in Chickpea (*Cicer arietinum* L.)

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(Received: 19 June 2013; Revised: 07 January 2014; Accepted: 13 January 2014)

A study was conducted during 2007-08 and 2008-09 to identify the stable genotypes of chickpea (*Cicer arietinum* L.) for grain yield under diverse agro-climatic conditions. Twenty nine genotypes were evaluated in four environments under irrigated and un-irrigated conditions for their agronomic performance. Data on 10 yield component traits (days to flowering, days to maturity, plant height, branches/plant, pods/plant, seeds/pod, 100-seed weight, biological yield, seed yield/plant and harvest index) were studied to investigate the effects of genotypes, environments and G x E interactions. Study indicated that evaluation of yield components must be taken for different environments. On partitioning of these components into liner and non-liner components, it was observed that both the components were responsible for the expression of traits. However, the liner component was found larger in magnitude than the non-liner component, suggesting that variation in the performance of different cultivars could be predicted. The genotypes Pusa 1105, BG 2050, DG 5003 DG 5008 and DG 5009 were found suitable for irrigated environments for grain yield. For moisture stress environment four genotypes – Pusa 1003, Pusa 1053, DG 5005 and DG 5055 were also found stable for grain yield. For the days to maturity, only two genotypes - Pusa 1105 and Pusa 1105 were found stable across environments. Thus, these genotypes could be used for commercial cultivation and production system. The stability measures are useful in characterizing cultivars by showing their relative performance in various environments. High phenotypic and genotypic coefficient of variation coupled with high heritability and genetic advance as per cent of mean were also reported for seed yield/plant, number seeds/pod and number of pods/plant indicating predominance of additive gene effects in controlling these characters.

Key Words: Chickpea, G x E interactions, Moisture stress, Yield components

Introduction

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops. India is the largest producer and consumer of this crop with area, production and productivity of 8.75 million ha, 8.25 million tons and 943 kg/ha, respectively (Anonymous, 2011). The crop has great significance in India particularly for meeting the protein demand of vegetarian population and restoring soil fertility. In Jammu & Kashmir, chickpea is grown in about 4300 ha with the production of about 2,550 tons and average yield of 667 kg/ha (Anonymous, 2011). Besides management practices, narrow genetic base and poor soil fertility has been reported to be one of the major causes of low productivity (Sharma and Sinha, 1989). A considerable area of about 43,435 ha remains unutilized during *rabi* season in most parts of the hills and foothills of the Shivalik and Pirpanjal mountain ranges in subtropical rain-fed area of Jammu region especially after the harvest of long duration rice and maize crops. Chickpea can be a good alternate crop under these conditions to encourage double cropping in otherwise mono-cropped area. Though, chickpea is a winter (*rabi*) crop, but its timely sowing greatly affects the productivity. The temperature during sowing time varies in different growing areas of Jammu province due to different mini agro-climatic zones. It is necessary to develop widely adapted elite varieties with stability in yield performance and having good response to high levels of management under diverse agro-ecological conditions. Lack of stability in production is perhaps the major limiting factor responsible for low material productivity rather than low potential of crops. Further, lack of stable varieties for diverse agro-ecological conditions has been the main bottleneck. Therefore, the objective of the present study was to supplement the earlier efforts on this for identifying stable genotypes with higher seed yield.

Materials and Methods

The experimental material comprised 29 genotypes of chickpea. All genotypes were evaluated during *rabi* season of 2007-08 and 2008-09 under diverse environments (irrigated and rainfed) at Regional Agricultural Research

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Station (RARS), Rajouri of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J), and Indian Agricultural Research Institute, New Delhi (irrigated and rainfed). In each experiment, genotypes were sown each in six rows of 4 m length in randomized complete block design (RCBD) with three replications. Under irrigated experiment, normal irrigations were applied, whereas under rainfed condition only pre-sowing irrigation was given to ensure good germination, thereafter crop was left to utilize natural precipitation. The row-to-row and plant-to-plant distance was kept 40 cm x 20 cm, respectively. Recommended agronomic and plant protection practices were followed for raising the crop. Observations were recorded on five randomly taken plants in each plot on ten characters (days to 50% flowering, days to 50% maturity, plant height (cm), number of branches/plant, number of pods/plants, number of seeds/pod, 100-seed weight (g), biological yield (kg), and seed yield/plant (g) and harvest index(%). Standard statistical methods were followed for estimating genetic constants *i.e.* phenotypic and genotypic coefficients of variation (Burton, 1952), heritability in broad sense (Hanson *et al.*, 1956) and expected genetic advance (Johnson *et al*., 1955). Genotypic and phenotypic correlation coefficients were calculated following Searle (1971) and path analysis following Dewey and Lu (1959). Stability analysis was done as per Eberhart and Russell (1966).

Results and Discussion

The estimates of both phenotypic (PCV) and genotypic coefficients of variation (GCV) for the 10 characters are presented in Table 1. The variability estimates, in general, revealed that the estimates of PCV were greater than those of GCV for all the traits; this suggested the role of environment in the expression of the characters. Highest GCV was obtained for seed yield/plant (23.63%) followed by harvest index (21.04%), number of seeds/pod (18.37%) and number of pods/plant (17.75%). The higher estimate of PCV (26.63%) in comparison to GCV (23.63%) for seed yield/plant suggested environmental influence on this character, which was confirmed by its low heritability. The least difference between PCV and GCV for plant height suggested that this character is less affected by environment. In such a situation, selection can be effective on the basis of phenotype alone with equal probability of success. These results match with the findings of Singh and Sharma (2012).

On the basis of GCV, it is possible to determine the amount of heritable variation. It can be found out with greater degree of accuracy when heritability in conjunction with genetic advance is studied (Johnson *et al*., 1955). Hence, both heritability and genetic advance were determined to study the scope of improvement in various characters through selection. The heritability estimates ranged from 67.60% for harvest index to 96.70% for number of seeds/pod. High estimates of heritability were also observed for number of seeds/pod, biological yield, plant height and 100-seed weight. Moderate estimates of heritability for number of branches/plant (73.3%) and seed yield/plant (71.8%) indicated that environmental effects constitute a sufficient portion of the total phenotypic variation and hence, selection for these characters will be less effective. Expected genetic advance and its estimated per cent mean for various characters (Table 1) revealed that number of pods/plant and biological yield exhibited the high genetic advance. These characters exhibited high GCV, heritability together with high genetic advance indicating the predominance of additive gene effects in controlling these characters. This confirms the findings of Ali *et al*. (2010) that GCV together with heritability estimate would give a better picture of genetic advance to be expected from selection. Singh and Sharma (2012) reported similar results and observed that high heritability in chickpea accompanied high genetic advance for plant height, 100-seed weight, seed yield/plant, pods/plant and number of seeds/pod. Thus, these parameters are strong indicators for predicting the performance of genotypes and for deciding the selection parameters *vis-a-vis* the choice of traits for genetic improvement of crop plants.

The pooled analysis of variance for stability for all the characters indicated significant variation among genotypes and environments for all the traits (Table 2). Mean squares due to genotypes x environment interactions were highly significant for all the characters, except 100-seed weight. It indicated the variable responses of genotypes to the environments. Singh and Sandhu (2006) and Singh and Sharma (2012) also observed fluctuations in the response of chickpea genotypes to different environments (locations and years). It indicates that for precise estimation of genotype x environment interactions, multilocation testing of genotype is essential. Variance values due to environment + (genotype x environment) interactions were also significantly different

Table 1. Estimates of mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability, genetic advance and correlation coefficients of 10 characters in chickpea

Character	Mean	Min	Max	PCV (%)	GCV (%)	h^2 (broad sense)	Genetic advance	*rg* with harvest index
Days to 50 % flowering	123.80	117.00	139.00	3.77	3.55	88.4	8.50	0.160
Days to 50 % maturity	153.82	147.00	169.00	3.04	2.85	88.4	8.50	0.160
Plant height	90.18	78.30	103.55	8.93	8.65	93.8	15.56	0.456*
Number of branches plant^{-1}	29.73	20.95	39.20	16.16	13.83	73.3	7.25	0.556**
Number of pods plant^{-1}	87.88	62.45	130.95	18.24	17.75	94.7	31.28	0.446*
Number of seeds pod^{-1}	1.29	0.85	1.75	18.68	18.37	96.7	0.48	0.131
100-seed weight(g)	33.62	24.90	39.50	13.78	13.30	93.2	8.95	-0.440*
Biological yield	111.88	82.60	139.95	13.74	13.48	96.2	30.47	-0.149
Seed yield plant^{-1}	25.78	13.45	39.45	26.63	23.63	71.8	9.01	0.793**
Harvest index	23.13	15.54	34.57	21.04	21.04	67.6	6.78	1.00**

Table 2. Pooled analysis (mean squares) for different characters over environments

Source	d f	Days to 50% flowering	Days to 50% maturity	Plant height	Branches/plant	Pods/plant	Seeds/pod	100-seed weight (g)	Biological yield	Seed yield/plant	Harvest index
Genotypes	28	16.54**	18.12**	1585.71**	91.03**	593.23**	0.11**	72.19**	593.13**	89.91**	193.26**
Environments	3	2826.24**	4725.44**	6805.11**	2407.56**	37944.05**	4.23**	35.51**	27642.41**	571.09**	8023.21**
Genotype x Env.	84	9.96**	9.37**	30.73**	24.17**	235.38**	3.71**	8.71	75.86**	16.86**	88.81**
Env.+ (Gen. x Env.)	87	107.08**	171.99**	264.33**	106.36	1535.87**	3.73**	9.64	1026.43**	35.97**	362.42**
Environments (Lin.)	1	8479.26**	14176.37**	20415.46**	7222.70**	113832.65**	4.71**	104.43**	82927.89**	23.34**	88.81
Gen. x Env. (Lin.)	28	9.97	4.95**	30.73**	24.17**	177.52**	2.95**	1.19**	27.97**	1713.26**	24069.98**
Pooled Deviation	58	557.78**	11.18**	24.61**	26.69	255.48**	3.95**	12.04**	98.76**	13.15**	40.23
Pooled Error	112	2.71	2.74	5.51	5.76	24.24	47.10	1.4	13.91	7.40	26.72

*,** Significant at P=0.05 and 0.01, respectively

in pooled analysis of variance for stability of all the characters except branches/plant and 100-seed weight. Singh and Singh (1989) also reported similar results for these traits. Further partioning of this component into genotype (linear) and genotype x environment (liner) showed that genotype (linear) component was highly significant for all the traits except harvest index. It indicates that a unit change in environmental conditions would bring about a unit change in environmental index of these characters. Highly significant genotype x environment (linear) variance scores for most of the traits, except days to 50% flowering, implied differential performance of genotypes under diverse environments but with considerably varying reaction norms. Significant pooled deviation for most of the traits, except branches per plant and harvest index, suggested that performance of different varieties fluctuated significantly from their respective linear path of response to environments with respect to these characters.

Prerequisite for sustainable crop production is the requirement of genotypes with high yield and stable performance over different environmental conditions. The stability parameters are presented in Table 3 and 4. The best variety was categorized by regression co-efficient (b_i) equal or close to one and mean square deviation (S^2d_i) equal or close to zero and having high mean performance. For days to 50% flowering, only four genotypes *viz.* Pusa 1108, Pusa 2024, Pusa 1105 and Pusa 1003 revealed regression co-efficient close to unity and non-significant S^2d_i values. For days to maturity three genotypes *i.e.* Pusa 1105, Pusa 1108 and Pusa 1003 revealed regression co-efficient close to unity and non-significant S^2d_i values. Further, these genotypes also showed early maturity on the basis of pooled mean. For plant height, Pusa 2024 revealed high mean, regression co-efficient (bi) near to unity and significant deviation from mean (S^2d_i). For seeds/pod, genotype DG 5009 had high mean value but less stability as indicated by significant mean square deviation (S^2d_i). Three genotypes namely Pusa 1053,

Table 3. Mean and stability parameters of different genotypes in four environments

Genotypes	Days to 50% flowering			Days to 50% maturity			Pods/plant		
	Mean	Regression coefficient (b_i)	Mean square deviation (S^2d_i)	Mean	Regression coefficient (b_i)	Mean square deviation (S^2d_i)	Mean	Regression coefficient (b_i)	Mean square deviation (S^2d_i)
Pusa1003	127.25	1.10	-0.42	160.50	1.05	-0.65	81.54	0.81	63.35
Pusa1053	126.00	1.21	3.51	159.75	1.06	2.15	94.66	0.82	65.20
Pusa1105	126.62	1.03	-1.24	159.25	1.04	-1.04	84.08	0.99	23.01
Pusa1108	126.75	1.06	-0.15	159.88	1.03	-0.01	89.03	0.87	-6.04
Pusa1088	127.25	1.12	3.77	160.38	1.06	4.57	93.24	0.67	885.48**
Pusa2024	126.75	1.06	-0.15	159.62	1.06	0.41	91.00	1.06	107.38*
Pusa2046	132.75	1.59	107.30**	165.88	1.28	121.03**	74.55	0.75	132.17
BG2050	127.25	1.25	19.76**	160.25	1.16	24.30**	69.21	0.97	30.80
BG2051	127.25	1.22	14.74*	160.75	1.14	18.24**	52.84	1.28	201.93*
BG2052	128.75	1.15	6.75	161.75	1.10	8.57	76.26	1.39	185.62*
BG2053	129.00	1.14	5.17	162.00	1.09	6.66	77.21	1.16	553.94**
BG2054	126.25	1.12	3.77	159.25	1.08	4.95	84.31	1.11	714.57**
DG5000	124.75	0.92	0.16	175.75	0.96	0.36	74.26	1.32	228.71*
DG5001	127.75	0.79	11.35	160.25	0.88	13.57*	58.09	1.02	13.45
DG5002	127.75	0.96	-0.93	160.25	0.98	-0.91	76.18	1.22	534.04**
DG5003	124.50	0.91	0.97	157.50	0.95	1.30	71.60	1.01	38.87
DG5004	124.50	0.91	0.97	157.50	0.95	1.30	77.30	1.17	346.64**
DG5005	125.00	0.77	0.97	158.00	0.95	1.30	69.75	0.80	69.27
DG5006	122.50	0.82	13.51*	155.50	0.87	16.14**	94.99	0.83	1.50
DG5007	123.75	0.80	7.53	156.75	0.90	9.05*	69.11	1.14	197.69*
DG5008	125.75	0.85	6.52	158.75	0.88	8.20*	82.36	0.96	176.56*
DG5009	125.00	0.81	2.42	157.62	0.87	4.27	67.74	0.78	94.64
DG5010	124.25	0.88	12.93*	157.25	0.90	14.91*	90.32	1.17	345.53**
DG5011	123.75	1.11	5.50	156.62	0.93	6.91	84.84	0.70	334.63**
DG5012	126.75	0.80	0.99	159.75	1.08	1.72	66.97	0.75	153.71*
DG5050	126.75	0.80	6.52	157.25	0.88	8.20	102.94	1.38	1265.87**
DG5055	124.25	0.82	7.53	158.25	0.90	9.05	78.57	1.15	193.92*
DG5056	125.25	0.97	-1.23	156.00	0.99	-1.24	85.38	0.97	13.65
DG5050	125.00	0.91	0.97	158.00	0.95	1.30	54.99	0.75	91.27
Pop (mean)			126.01			159.04			78.39
S.E. of mean			0.18			1.90			9.22
S.E. of b			1.00			0.15			0.25

*,** Significant at P=0.05 and 0.01, respectively

Table 4. Mean and stability parameters of different genotypes in four environments

Genotypes	Seeds/pod			100-seed weight			Seed yield/plant		
	Mean	Regression coefficient (b_i)	Mean square deviation (S^2d_i)	Mean	Regression coefficient (b_i)	Mean square deviation (S^2d_i)	Mean	Regression coefficient (b_i)	Mean square deviation (S^2d_i)
Pusa1003	1.14	3.30	0.00	26.61	1.59	0.93	19.27	0.69	-2.17
Pusa1053	1.49	5.72	0.15**	25.70	0.95	-0.73	26.71	0.96	-3.70
Pusa1105	1.23	1.31	0.01	35.49	2.51	42.72**	24.22	1.17	-1.09
Pusa1108	1.14	-0.96	0.08**	29.80	1.82	1.76	24.51	0.30	7.37
Pusa1088	1.49	3.26	0.00	30.07	0.96	-0.33	32.74	0.70	59.73**
Pusa2024	1.26	1.19	0.05	34.31	0.74	1.72	26.80	0.49	9.99*
Pusa2046	1.09	2.50	0.05	32.86	0.34	0.63	20.70	0.85	-3.54
BG2050	1.38	-3.00	0.00	36.60	1.35	4.05	27.28	1.05	-2.97
BG2051	1.22	-2.11	0.02	37.40	1.28	9.16	25.38	0.37	5.26*
BG2052	1.44	1.50	0.01	36.16	1.22	2.14	30.25	1.34	-1.84
BG2053	1.50	-0.85	0.00	34.49	1.46	10.97*	33.04	0.33	18.85**
BG2054	1.15	-1.69	0.01	30.42	0.34	4.73	31.35	0.32	5.36
DG5000	1.48	0.58	0.04	39.43	1.00	9.13	28.25	2.25	20.35**
DG5001	1.45	1.69	0.01	41.30	1.08	5.49	29.16	2.17	46.75**
DG5002	1.33	1.38	0.03	39.80	1.01	0.10	27.03	1.77	12.74*
DG5003	1.12	2.11	0.02	40.56	1.05	-0.19	29.61	1.03	11.32*
DG5004	1.42	2.99	0.04*	39.19	1.05	1.53	28.61	1.43	5.76
DG5005	1.05	0.00	0.0	38.20	0.67	0.51	24.90	1.20	-2.32
DG5006	1.25	-1.69	0.01	37.64	0.47	0.64	31.48	0.65	-1.65
DG5007	1.10	0.84	0.00	36.05	0.45	12.46*	25.25	1.86	17.35**
DG5008	1.00	-2.53	0.03	34.42	1.43	0.58	30.12	1.11	-2.18
DG5009	1.53	6.21	0.22**	36.95	0.44	24.93**	22.68	1.06	-2.88
DG5010	1.25	1.69	0.01	38.25	1.09	7.78	31.34	1.27	-3.00
DG5011	1.25	-3.38	0.05	37.39	0.91	-0.72	24.47	2.23	37.52**
DG5012	1.41	-3.19	0.03	32.91	-0.42	87.66**	24.59	0.95	-3.54
DG5050	1.15	5.07	0.12**	30.94	1.19	9.64	19.30	0.40	22.58**
DG5055	1.28	2.07	0.02	33.49	0.13	42.18**	13.26	0.89	-3.68
DG5056	0.90	2.53	0.03	28.71	1.42	16.52**	19.59	0.00	25.47**
DG5050	1.49	2.42	0.04	29.98	1.45	32.20**	20.60	0.90	1.99
Pop (mean)			1.25			34.65			25.94
S.E. of mean			0.11			2.00			2.09
S.E. of b			0.30			0.18			0.47

*, ** Significant at P=0.05 and 0.01, respectively

DG 5000 and DG 5002 showed high mean performance, regression co-efficient close to unity and non-significant mean square deviation. These genotypes were considered relatively stable for respective traits. For seed yield/plant, five genotypes i.e. Pusa 1105, BG 2050, DG 5003, DG 5008 and DG 5009 reveled regression coefficient (bi)=1 and non- significant S^2d_i value (except DG 5003). These genotypes were considered stable for this trait. Kumar *et al*. (2005), Prakash (2006), Singh and Sandhu (2006) and Singh and Sharma (2012) also found significant liner and non-liner components of genotypes x environmental interactions for expression of grain yield and its components in chickpea genotypes. The significance of G x E interactions for various characters indicates that the performance of chickpea genotypes is very much influenced by environmental variations indicating scope of agronomical manipulations. The regression analysis was found to be very useful in assessing the adaption of various genotypes in terms of predictability of variations in performance over environments. Joint consideration of pooled analysis of variance and response of individual genotypes suggests that one should directly attempt to see the response of a genotype in respect of the information obtained from analysis. Since the latter provides a clear picture of material individually, this may be more useful. The genotypes Pusa 1105, BG 2050, DG 5003 DG 5008 and DG 5009 were found suitable across environments and highly promising and stable for seed yield and other important yield contributing traits. While the genotypes Pusa 1003, Pusa 1053, DG 5005 and DG 5055 were found suitable for rainfed environmental conditions. Thus, besides serving as important donors, these genotypes can be considered as future cultivars after further evaluation.

Acknowledgements

The authors are grateful to Dr SS Yadav, Former Principal Scientist (Chickpea Breeding), Division of Genetics,

IARI, New Delhi, for providing the seed material of chickpea genotypes used in the present study.

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Right to Farmers' in PPV&FR Act 2001: A Way to Support Conservation of Plant Genetic Resources

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(Received: 14 August 2013; Revised: 15 December 2013; Accepted: 29 January 2014)

As a signatory of Trade Related Aspects of Intellectual Property Rights (TRIPS) Agreement of 1995, the Protection of Plant Variety & Farmers' Right Act, 2001 was enacted for the protection of plant varieties and rights of farmers and therefore, explicitly recognize the farmers' role as conserver. To achieve the said objectives, exclusive nine rights were granted to farmers termed as Farmers' Rights. A National Gene Fund has been constituted to fund the conservation activities through small project grants, which can be implemented by Biodiversity Management Committees, cash rewards and recognitions on annual basis. So far, 10 farming communities and 25 individual farmers have been recognized for their contribution in conservation, improvement and preservation of useful germplasm and biodiversity conservation as a whole. Further, to document the traditional varieties, registration of farmers' varieties is also being done by the PPV&FR Authority and a total of 1,460 applications have been received so far.

Key Words: Farmers' Rights, Plant genetic resources (PGR), Plant Varieties, Protection

Introduction

Agriculture, an open field for production of crops, is climate and weather dependent. To overcome the major challenge of climate change that the world is facing today, it is necessary to review our country's indigenous plant genetic resources (PGR) that constitute genetic diversity. Farmers' varieties are one of such traditional resources developed and maintained over a period of time by farmers/ farming communities possessing certain unique characteristics like tolerance to various biotic and abiotic stresses, high aromatic and medicinal value etc. Recently, it became necessary to protect these varieties under IPR regime so as to prevent its unauthorized use or to check biopiracy. At the same time, it is also necessary to reward and recognize those farmers who are engaged in conservation of such useful germplasm. This will not only generate awareness about such resources but will also give financial gains to the above said farmers. India has given due recognition to its farmers for their role in innovation and conservation of agro-biodiversity, a fact that is acknowledged worldwide (FAO 1989). In order to comply with Article 27.3 (b) of the TRIPs Agreement, 1995, India opted a *sui-generis* system and formulated the Protection of Plant Variety & Farmers' Right Act, 2001, a statute providing protection to plant varieties, the rights to farmers and plant breeders. This paper focusses on the conservation of agro-biodiversity by farmers in India, reward and recognition of farmers and other aspects of farmers' rights under PPV&FR Act, 2001.

Farmers' Rights: A Global Prospective and Indian Initiative

Farmers' rights were mentioned for the first time in the meeting of the Working Group of the FAO Commission on PGR in 1986 in the context of the International Undertaking on Plant Genetic Resources (IUPGR) (Nagarajan and Singh, 2010). The 25th session of the FAO conference of 1989 was a landmark in the history of recognition of farmers' right. In 2001 farmers' rights as a key issue for food security and sustainability was recognized by International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) popularly known as the Treaty. The Treaty recognised the right of farmers to use, exchange and sell farm-saved seeds and other propagating material (Article 9.3) and fair and equitable sharing of benefits arising from the use of PGR for food and agriculture, right to participate in national decision-making process about PGR (Article 9.2) and protection of traditional knowledge. The International Union for the protection of Plant Varieties (UPOV), which is a platform to provide protection to plant varieties in industrial countries, protects only the plant breeders and does not cover Farmers' Rights. There are other important international agreements related to farmers' rights like Convention on Biological Diversity (CBD), the Agreement on Trade

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Related Aspect of Intellectual Property Rights (TRIPS) of the World Trade Organization (WTO), and World Intellectual Property Organisation (WIPO) of the United Nations (UN) (Gautam, 2011).

At the national level, while formulating the PPV& FR Act, 2001, the farmers were given due attention and their role in biodiversity conservation was well recognized. Thus PPV&FR Act, 2001 provides a perfect balance between farmer's rights and protection of plant varieties developed by private/public sector. As per section 2(k) of the Act "Farmer" means any person who cultivates crops by cultivating the land himself or cultivates crops by directly supervising the cultivation of land through any other person or conserves and preserves any wild species or traditional varieties – single handed or jointly with any person, or adds value to such wild species of traditional varieties through selection and identification of their useful properties (PPV& FR Act, 2001). Farmers' variety is a variety that is traditionally cultivated and evolved by the farmers or is a wild relative or landrace or a variety about which the farmers possess the common knowledge. In other words, farmers' varieties are those varieties developed and maintained over the period of time by farmers or farming communities with distinct valuable characters (Bala, 2004; Brahmi *et al.,* 2004). Farmers' rights granted under the Act include right on farm saved seed, right to register, right to reward and recognition, right to benefit sharing, right to compensation for losses, right against undisclosed use of traditional varieties, right to access to seed, right to free services and protection in case of innocent infringement. Registered farmers variety under the act, confers right of legal ownership similar to any other property right.

Conservation of PGR by Farmers: Support under PPV&FR Act, 2001

Since ages, farmers are involved in conservation of PGR and have valuable indigenous germplasm collections, which are used to develop new varieties. In the present scenario of global warming and growing food demand due to population pressure, there is an urgent need to develop climate resilient varieties of different crops. In order to produce climate resilient varieties adapted to extreme climates, genes and alleles of indigenous varieties, landraces or wild relatives will be of primary target. In India, farmers are custodians of genetic resources and maintain valuable indigenous diversified well adapted crop varieties at their own cost. They prefer to use seeds from the previous years' crop which even in some cases reduces seed viability leading to homogeneity and less productivity. The positive aspect of this traditional method is that, it helps to increase adaptability of a crop to sustain in a changed environment (Chandrashekaran and Vasudev, 2002) and the variety may act as future gene donor. But, there exist a vast gap between the rewards given for maintaining diverse plant genetic resources (which form the basis of development on new varieties) and rewards given to new varieties that are the products of research. So to redress this gap PPV&FR authority instituted under Section 45 of the Act, a National Gene Fund which is used for payment of benefit sharing and compensation to village and local communities for supporting conservation and for recognition and award to farmers/farming communities as a support to them for conservation and sustainable use of genetic resources. The section 45.2(c) of the Act envisages the expenditure for supporting the conservation and sustainable use of PGR for *in situ* and *ex situ* conservation and for strengthening the capability of the *Panchayats* in carrying out such conservation and sustainable use. The fund ranging from ₹1–3 lakhs may be allotted by the Authority on the recommendation of the State Biodiversity Board (SBB) to the Biodiversity Management Committees (BMC) actively involved in the biodiversity conservation. Further to recognize the biodiversity heritage sites in India, the PPV&FR Authority constituted a Special Task Force which identified 22 agro-biodiversity hotspots distributed over seven agro-geographical zones and details of which were published two volume book entitled "Agro-biodiversity Hotspots in India". (for further details see http://www.plantauthority.gov.in/hotspots.htm).

The Authority has also instituted the "Plant Genome Savior Community Recognition" as a national activity to encourage and recognize the selfless services of the rural folk in ensuring the continuous availability of biodiversity for plant breeding purposes and biodiversity conservation as a whole. Details of the award and recognition made so far are given in Table 1.

Process of Farmers' Variety Registration

Farmers' variety for the purpose of registration is grouped under extant category. Under the Act, the major steps of registration of farmers' variety includes filing of application, examination of application, conducting grow out test, evaluation of grow out test results and publication of passport data in the *Plant Variety Journal*

Table 1. Details of awards and recognition received by farmers representing states

Details of awards/ recognitions	Plant genome saviour recognition certificates	Plant genome saviour community award	Plant genome saviour farmer rewards	Plant genome saviour farmer recognitions
2007-08	**5** (Uttarakhand, Kerala, Odisha, Rajasthan, and Karnataka)	–	–	–
2008-09	**4** (**2** for Kerala; **1** each for Jharkhand and WB)	–	–	–
2009-10	–	**2** (Karnataka and Odisha)	–	–
2010-11	**7**(**2** for Gujrat; **1** each for Maharashtra, UP, MP, Kerala and TN)	**4** (**2** for Kerala; **1** each for TN and WB)	–	–
2011-12	–	**4** (Maharashtra, Kerala, AP and TN)	**10** (**2** each for Kerala, UP & WB; **1** each for Manipur, Rajasthan, Karnataka and MP.	**15** (**3** for Assam; **2** for, Gujrat, Karnataka, Maharashtra, Kerala; **1** each for HP, Chattisgarh, WB and Punjab)

of India for calling objections (if any) within a specified time frame and finally issue of registration certificate to the applicant. Limited number of selection criteria is used for selection of a farmers' variety like yield stability, risk avoidance, low dependence on external inputs and attributes relate to storage, cooking, taste, etc. (Nagarajan *et al.,* 2008). So far, 105 DUS test centres have been established for conducting DUS Test as well Grow-Out test. The Grow-Out test for farmers' variety is carried by multi-location field evaluation for one year. The number of off-types in farmers' variety is permitted twice of what has been prescribed for a new variety. Farmer's variety application need not be accompanied with GURT affidavit, declaration that parental material has been acquired lawfully and passport data of parental lines. They are also exempted from all types of fee other than annual fee for maintenance of registered variety. The duration of protection of farmers' variety is same as that of other categories i.e. the certificate of registration are valid initially for nine years in the case of tree and vines and six years for other crops and may be renewed for remaining period on payment of prescribed fee. However, the total period of validity is not more than 18 years in case of trees and vines and 15 years in case of other crops from the date of registration of the variety. As per the Act, Authority needs to maintain the seed samples or propagating material for all registered varieties including farmers' varieties. For this purpose, the Authority has established the National Gene Bank at old campus of National Bureau of Plant Genetic Resources (NBPGR), New Delhi. The seed samples are kept in medium term storage at low temperature (4°C) to maintain seed viability. After the expiry of protection period, seed material is mandated to be submitted to National Gene Bank at NBPGR or any public repository (Choudhury, 2009). Till date the Authority has also established four Field Gene Banks – at Dapoli (Maharashtra) for tropical and sub-tropical crops, Ranchi (Jharkhand) for eastern ecosystem, Mashobra (Himachal Pradesh) for temperate fruit crops and Central Arid Zone Research Institute (CAZRI), Jodhpur (Rajasthan) for arid crops. These facilities are useful for capacity building, documentation and training for farmers and breeders (Singh *et al.,* 2011).

Status of Protection

The office of the registry started receiving applications for registration of varieties from 21 May 2007. A total of 4,607 applications have been received so far for 57 crop species notified in the Gazette of India. Out of 1,460 applications covering 15 different crops belong to farmers' varieties. In 2011 a sharp increase in number of applications accepted for registration of farmers' variety indicates growing trust of farmers and increase in awareness by the Authority (Fig. 1). Applications for registration received from farmers include ten drought tolerant lines of rice. Highest number of applications so far received by the Authority is in rice (1,404) followed by 13 applications in pigeon pea (Fig. 2). State wise farmers' variety applications shows that highest number of applications has been received from Odisha (969) followed by West Bengal (142). Single application was

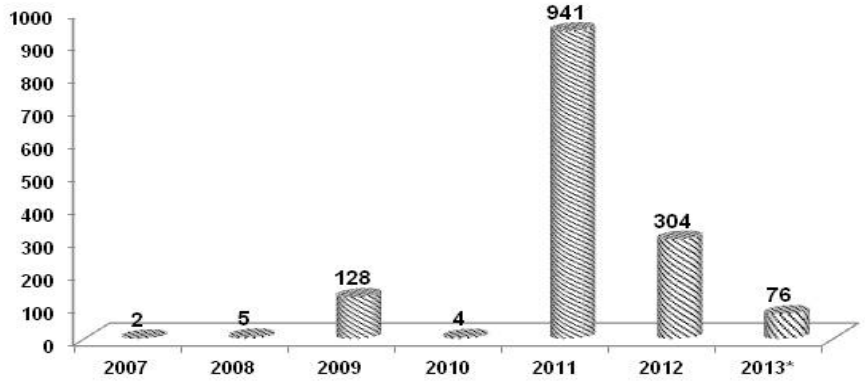

Fig. 1. Year wise application received for farmers' varieties

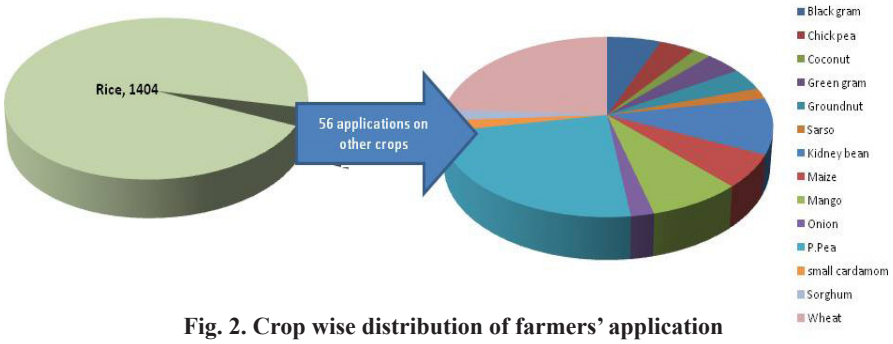

Fig. 2. Crop wise distribution of farmers' application

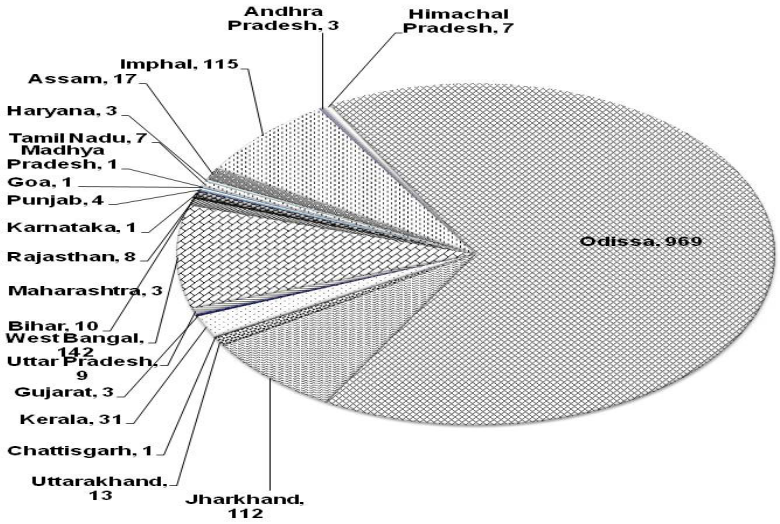

Fig. 3. State wise application received for farmers' varieties

reported from Goa, Madhya Pradesh and Karnataka which may be due to lack of awareness among farmers (Fig. 3). As of July 2013, a total of 14 farmers' varieties have been registered under the Act. It includes 12 rice and two bread wheat varieties. Interestingly two of these registered rice varieties are aromatic. Few of these varieties have red coloured decorticated grains along with other distinguishing characters. All formalities for issuance of certificates of another 23 varieties have been completed and are published in Plant Variety Journal of August, 2013 for any opposition.

Conclusion

The role played by farmer as cultivator is well understood while, farmer as conserver has not gained adequate attention. Therefore, to explicitly recognize the role of farmer in agro-biodiversity conservation, India is the first South Asian country to implement the *sui generis* protection in the form of PPV&FR Act, 2001. The Authority not only recognize and reward the farmers for their commendable efforts in conservation, improvement and preservation of useful germplasm but, is also supporting the *in situ* and *ex situ* conservation and sustainable use of PGR by funding BMCs from the National Gene Fund for biodiversity conservation. Although good number of applications has been received so far but most of the applications are from few states, which depicts a lack of awareness among the farming community. Therefore, the Authority has taken up steps to conduct more workshops with the help of Krishi Vigyan Kendras (KVKs) across the country to increase awareness among farming community, helping them to register their varieties and make the system more effective and beneficial for farmers in India.

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Notes on *Luffa* (Cucurbitaceae) Genetic Resources in India: Diversity Distribution, Germplasm Collection, Morphology and Use

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(Received: 29 August 2013; Revised: 31 December 2013; Accepted: 25 January 2014)

Genus *Luffa* has two major cultivated species, namely, ridged gourd and sponge gourd exhibiting rich diversity in the Indian subcontinent. In the present communication data from germplasm collections of cultivated and wild *Luffa* by the National Bureau of Plant Genetic Resources from different phytogeographical regions of India have been used to pinpoint areas for future collection. Fruit and seed morphological characters were studied for developing field identification key. Some less known uses of *Luffa* are discussed in the perspective of genetic resources in India.

Key Words: Cucurbitaceae, Cultivated and wild species, Field identification key, *Luffa,* Morphology, Phytogeographical distribution

Introduction

Genus *Luffa* (Cucurbitaceae) has two cultivated tropical, one American and the other Old World species (Ali *et al*., 2010). Four species namely *Luffa acutangula* Roxb., *L. aegyptiaca* Mill. [*L. cylindrical* (L.) M.J. Roem.], *L. echinata* Roxb., *L. graveolens* Roxb. occur in India (Chakravarty, 1982; Renner and Pandey, 2013). Cultivated species *L. acutangula* (ridged gourd) and *L. aegyptiaca* (sponge gourd) are widely grown whereas a local cultivar 'Satputia' that bears fruits in cluster (trimonoecious form of *L. acutangula* syn. *L. hermaphrodita* Singh & Bhandari) is confined to eastern region (Charkravary, 1990). Among the wild species, bitter-fruited *L. acutangula* var. *amara* (Roxb.) Clarke, *L. graveolens* and *L. echinata* occur in different agro-ecological regions of India. Linguistic support from Sanskrit literature (name *koshataki*) indicates early history of cultivation and use of *Luffa* in India.

Three subspecies are recognized in *L. acutangula; L. acutangula* var. *acutangula* (called angular loofah, Chinese okra, ridged gourd) was probably domesticated in Asia (de Candolle, 1959) or India (Heiser and Schilling 1990), whereas the bitter wild var. *amara* occurs wild throughout India (http://www.efloras.org/florataxon.aspx?flora_id=5&taxon_id=119075; Heiser and Schilling, 1990). Morphological evidences suggest that cultivated *L. acutangula* var. *acutangula* was derived from var. *amara* (Heiser and Schilling, 1988). On the basis of cytogenetical investigations, the two wild species, *L. graveolens* and *L. echinata* have been indicated closer (Dutt and Roy, 1969; 1971). Study based on morphology of leaves, flowers, fruit, reproductive biology and flavonoids has grouped *L. acutangula* and *L. aegyptiaca* into a single clade, apart from the other species (Heiser and Schilling, 1990). Local cultivar of *L. acutangula* 'Satputia' has cross compatibility with *L. acutangula* (Zeven and de Wet, 1982) and has also been included under *L. acutangula* (Marr *et al*., 2005a, b; Ali *et al*., 2010; Prakash *et al*., 2013).

India is one of the diversity rich regions for cultivated and wild *Luffa*. Variability available in different phytogeographical regions needs to be collected for conservation and use, besides utilization in other genetic resource programmes. Therefore, the present work on genetic resources of *Luffa* was envisaged with primary objective to study: 1) diversity distribution *vis-à-vis* germplasm collection for conservation in India, and 2) morphological variability in fruit and seed of cultivated and wild taxa and developing field identification key. Priorities were worked out for future collecting of *Luffa* germplasm from India.

Materials and Methods

The present study was undertaken to identify gaps for future collecting in the genus *Luffa* based on data on germplasm collection from different phytogeographical regions for three decades *vis-à-vis* diversity distribution. The sites of germplasm collections made by the National Bureau of Plant Genetic Resources (NBPGR) were plotted on map using DIVA-GIS version 7.1 software (Hijmans

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et al., 2001). A coarse grid plotting of location (site) data was prepared to pinpoint the sites of germplasm collecting *vis-à-vis* diversity conserved. Information on diversity distribution pattern, use(s)/ potential value of species was drawn from authors' field experience, non-formal interaction with farmers in areas of occurrence and published literature.

Plants of 36 accessions representing major areas of collections including four species (five taxa; accessions used in parenthesis) *viz*. *Luffa aegyptiaca* (16), *L. acutangula* (16), *L. acutangula* var. *amara* (2), *L. echinata* (1) and *L. graveolens* (1) were raised in earthen pots in net house at the Division of Plant Exploration and Germplasm Collection (NBPGR), New Delhi, during the months of May-September 2010-12. Quantitative and qualitative data on fruit and seed morphology were recorded for visual observations and using hand lens (x10 magnification) from five plants each of the representative species and presented as an average value. Most prominent morphological characters were used for preparing a field identification key.

Results and Discussion

Diversity Distribution

Among the cultivated species *L. aegyptiaca* is widely grown throughout India but is less popular in the peninsular region where the other cultivated species *L. acutangula* is more popular. Former species is also reported under semi-wild conditions in disturbed habitats and forest openings. *L. acutangula* is widely cultivated throughout India for tender fruits used as vegetables. Satputia (*L. hermaphrodita*) is widely grown in eastern Uttar Pradesh, Bihar, West Bengal and Rajasthan. This species is characterized by fruits borne in clusters with skin having 8-10 ribs and smooth skin. *L. acutangula* var. *amara,* wild form of ridged gourd, bears small but extremely bitter fruits. It occurs mainly in the lower altitudes of Himachal Pradesh, Rajasthan, Maharashtra, all over the peninsular India and more sporadically in drier habitats of Gujarat and Madhya Pradesh. Of the two wild taxa, *L. echinata* occurs in disturbed habitats of North-western Himalayas, central India and upper-Gangetic to eastern plains whereas *L. graveolens* in Bihar, Maharashtra, Sikkim and West Bengal. Diversity distribution of *Luffa* species is given in Fig. 1a-d.

Germplasm Collection and Conservation

Majority of the germplasm collected represented three cultivated taxa from all over the cultivation range. A total of 2,310 accessions of *Luffa* were collected from diverse habitats all over India during 1976-2013 (Malik and Srivastava, 2006; Plant Germplasm Reporter, 2000-2012; Fig. 1) by National Bureau of Plant Genetic Resources (NBPGR). Status of collected germplasm (cultivated, semi-wild and wild) was recorded based on passport information (collection sites) and herbarium specimens in the National Herbarium of Cultivated Plants (NHCP), NBPGR, New Delhi followed by published literature.

In cultivated *Luffa*, a total of 1,252 accessions in ridged gourd (*Luffa acutangula*), 956 in sponge gourd (*L. aegyptiaca*) and 53 in Satputia (*L. hermaphrodita*) were collected. Major areas of collecting of ridged gourd were Uttar Pradesh (123), Andhra Pradesh (94), Odisha (52) and Assam (56); sporadic collections were also made from Gujarat, Rajasthan, Orissa and Tamil Nadu. In sponge gourd diversity was gathered from eastern Uttar Pradesh (198), Jharkhand (70), Bihar (77) and sporadic representations from Chhattisgarh, Gujarat, Haryana, Madhya Pradesh, Maharashtra and Rajasthan. Collections were made of Satputia from the North-eastern Uttar Pradesh (16), Bihar (14), and Jharkhand (6) and sporadic distribution in other states. During exploration to Uttar Pradesh and Madhya Pradesh, Satputia was also recorded from abandoned (appeared to be escapes from cultivation) habitats. Accessions of *L. acutangula* var. *amara* (8) from Andhra Pradesh (3), Maharashtra (3), Madhya Pradesh (1) and Kerala (1) were collected from dry habitats and road side in Himachal Pradesh, Gujarat, Madhya Pradesh, Maharashtra, Tamil Nadu and Rajasthan. Populations of *L. echinata* were recorded occurring on heaped soil and disturbed/marginal farm areas whereas *L. graveolens* occurred as weedy type in sugarcane fields in Gujarat, Himachal Pradesh, Madhya Pradesh and Uttar Pradesh. In Uttar Pradesh *L. graveolens* locally known as *guslainth* or *guslaria* was often seen along roadsides and as a weed in sugarcane fields.

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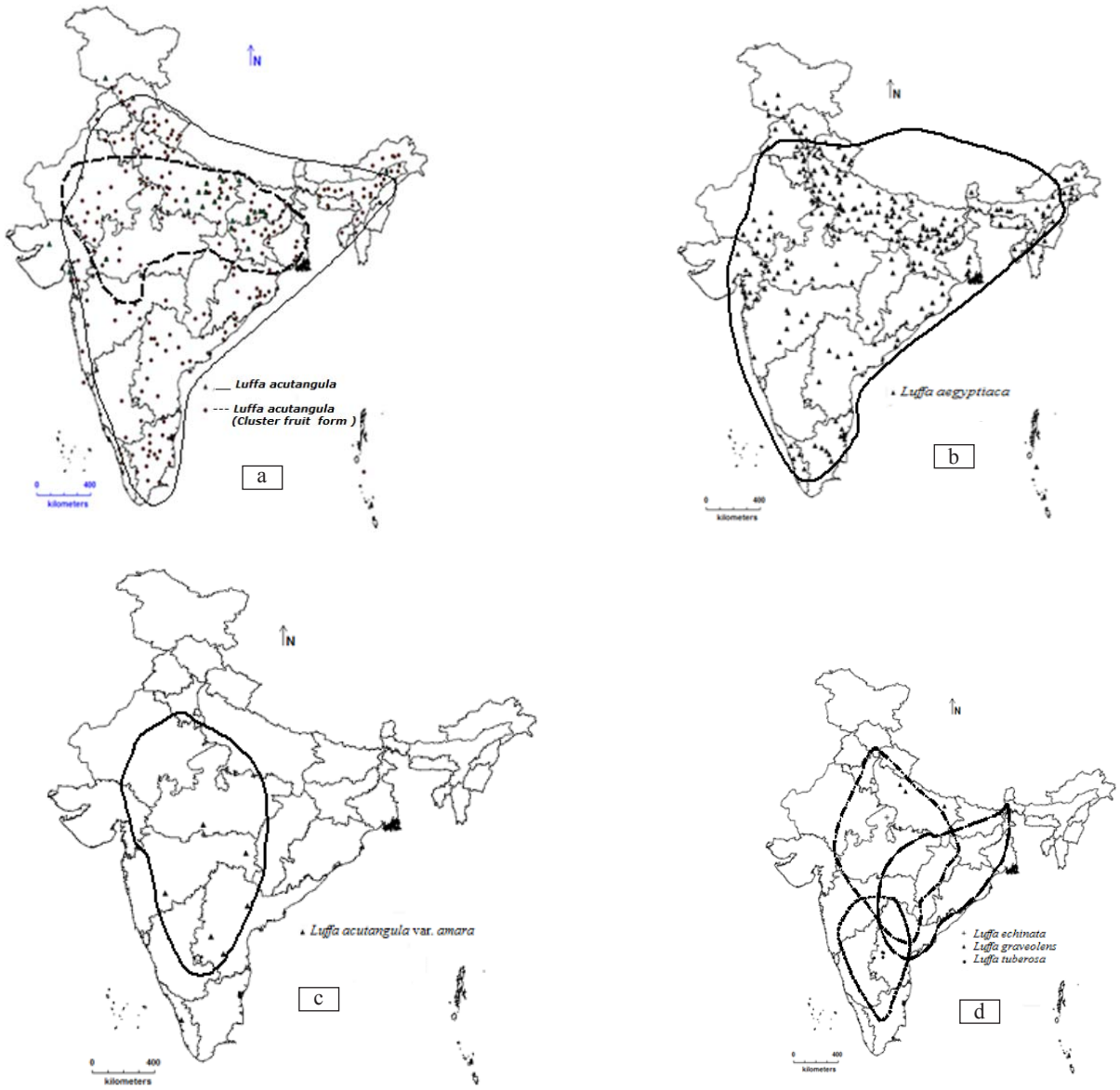

Fig. 1. Diversity distribution (marked with line) in *Luffa* species collected from different states of India: a) *L. acutangula* (monoecious and trimonoecious form); b) *L. aegyptiaca*; c) *L. acutangula* var. *amara*; d) other wild taxa

(over 60 cm) types from southern Uttar Pradesh (Varanasi, Jaunpur, Ghazipur, and Allahabad). Black seeded types were commonly available in the areas of cultivation as compared to grey-white seed types. Germplasm with small (3.2 cm) ball like fruits were collected from Maharashtra. Among the local cultivars/ landraces, namely, *faizabadi, barsati, nenua safed, nenua hara* having adaptability traits to diverse agro-ecological regions, resistance to diseases and pests as well as stress environments including drought, were among the diversity collected.

Ridged gourd and Satputia mainly varied in fruit shape (elliptical, elongated, globose/oblong; straight/ curved, smooth to sharp angled); fruit skin colour (green to pale green), skin with prominent ridges and sunken ribs; fruit skin glossiness (mostly dull) and flesh texture (smooth, grainy/soft). Among the local cultivars/landrace diversity in ridged gourd *Pusa Nasdar* and sponge gourd *Pusa Chikni* are selections from germplasm collected from Neemuch in Madhya Pradesh. Some promising accessions were early types with good bearing. In Satputia some promising types were small fruited types

(5.1-7.5 cm) with profuse bearing and good taste from eastern Uttar Pradesh.

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Study on Fruit and Seed Morphology

A total of 37 accessions were shortlisted based on representation from major collection sites of different species assembled from diverse region. Data on morphological characters were recorded for fruit and seed; *L. acutangula* and *L. hermaphrodita* differed in fruit borne singly or borne in cluster and seed testa surface. Fruit was green-pale green, pericarp with prominent lines in *L. aegyptiaca* and *L. hermaphrodita,* prominent longitudinal ridges in *L. acutangula*, prominently ovoid, densely bristled in *L. echinata* and densely tuberculated in *L. graveolens*.

Fruit wall was dry, fibrous at maturity in all species of *Luffa*. However, nature of fibrous wall varied in different species (thickly knitted in *L. aegyptiaca, L. acutangula* and *L. hermaphrodita* and loosely knitted in *L. graveolens* and *L. echinata*). Length of the fruit varied from long in *L. aegyptiaca, L. acutangula* var. *acutangula,* medium in *L. hermaphrodita* and *L. acutangula* var. *amara,* smaller in *L. echinata* and *L. graveolens*. Fruits were generally cylindrical (rarely round) in cultivated species and oval-globose in wild species. The fruits of wild *L. acutangula* var. *amara* were smaller in size than cultivated *L. acutangula* and fruit shape was narrow and pointed at both ends.

Seed shape is a distinguishing character in all species. It varied from elongated-oblong in *L. aegyptiaca*; ovate with prominent beak in *L. actangula*; and oval-ovate in *L. echinata* and *L. graveolens.* Seed surrounded by papery membranous wing in *L. aegyptiaca* was the most distinguishable character.

Comparision of seed characters for qualitative and quantitative characters is given in Tables 1-2. Seed was bigger in *L. aegyptiaca,* medium in *L. actangula* and *L. hermaphrodita,* smaller in *L. echinata* and *L. graveolens.* The seed coat surface was mostly rough but intermediate types were also present in some accessions of the three cultivated species. *L. aegyptiaca* showed variation in seed coat colour-black seeded and white seeded with

Fig. 2. Fibrous sponge obtained from dry fruit wall of *Luffa* species is a characteristic feature of the genus: a) *L. aegyptiaca* (sponge well developed, compact, easy to separate), b) *L. acutangula* var. *acutangula*, c) *L. acutangula* var. *amara* (sponge well developed, difficult to separate), d) *L. graveolens* (sponge poorly developed, not well formed), e) *L. echinata* (sponge soft, loosely knitted, breaks on separation)

Table 1. Quantitative traits recorded in fruit and seed of *Luffa* species

S.No.	Character	*L. aegyptiaca*	*L. acutangula*	*L. graveolens*	*L. echinata*
1.	Length of fruit (cm)	27.15 x 5.71	12.75-22.58 x 3.95-4.85	5.91 x 3.35	3.5 x 3.0
2.	Seed size (mm)	11.53 x 7.50	10.17-10.65 x 5.57-6.02	4.83 x 3.33	4.70 x 3.50
3.	100 seed weight (gm)	11.35	10.58-11.32	3.44	2.83

Table 2. Morphological traits recorded in fruit and seed characters of different species of *Luffa*

S.No.	Character	*L. aegyptiaca*	*L. acutangula*	*L. graveolens*	*L. echinata*
1.	Fruit shape	Elongated, cylindrical	Elongated-cylindrical and spindle shaped (in *amara* type)	Cylindrical-oblong	Spherical-round
2.	Extension on fruit surface	Absent	Ribbed-non ribbed (in satputia)	Tuberculate bristles	Echinate
3.	Fruit skin colour	Green (uniforn or with with specles)	Smooth with continuous lines (in satputia), rugose	Rough	Echinate, long bristles
4.	Flesh colour, taste	White-yellow	White	Yellow	Pale yellow
5.	Fruit borne singly or in cluster	Single	Single, cluster (in satputia)	Single	Single
6.	Seed shape	Oblong-elongated	Ovate	Oblong-ovate	Oblong-ovate
7.	Seed coat colour	Ivory, black, greyish-black	Greyish black-black	Grey	Grey
8.	Seed coat extension	Membranous wing	Apical notch	Absent	Absent
9.	Seed coat surface	Smooth, non-shiny	Smooth, non-shiny	Rough, non-shiny	Rough, non-shiny
10.	Bitter	Sweet (but bitter in wild type)	Sweet (but bitter in wild type)	Bitter	Extremely bitter

smooth wall. Seeds of *L. hermaphrodita* though were similar in shape but had distinctly shiny smooth seed surface as compared to *L. acutangula* which had rugose surface. Accessions of *L. acutangula* var. *amara* had variable degree of roughness in seed coat. However, the seed coat surface of *L. graveolens* and *L. echinata* were rough (finely pitted in former and coarsely pitted in latter species) and greyish-black. In general seeds of cultivated species were bold whereas the wild species were smaller.

Key to species in *Luffa* (using characters of fruit and seed)

While handling germplasm of *Luffa,* characters of mature fruit (fruit wall/pericarp and fibrous wall/ sponge) (Fig. 2) and seed morphology are important especially during collection, sorting, packaging and other activities relevant to plant genetic resource management. The authors have attempted developing key on the basis of fruit and seed morphology for on-spot identification of different species of *Luffa.*

Seed with membranous wing

Fruits solitary, sponge well formed with thickly knitted fibres in mature fruit, seed oval-round, compressed, white, black or gradation of black

---------- *L. aegyptiaca*

Seed with no membranous wing

Fruit wall smooth, borne in clusters, sponge well formed with thinly knitted fibres in mature fruit, seeds dark black and shiny

---------- *L. acutangula* (cluster form/Satputia)

Fruits wall not smooth

Fruit wall prominently ridged, sponge not easily separable

Fruit wall not ridged; fruit with poorly formed sponge at maturity, easy to separate

Cultigen, fruits clavate-oblong, size 22.58x4cm, born singly, pericarp hard on maturity

---------- *L. acutangula*

Fruit pale brown, round-ovoid, wall densely covered with echinate long bristles, seed coat verrucose (coarsely pitted), yellowish-brown to black, seeds extremely bitter (with pungent smell)

---------- *L. echinata*

Fruit grey, ovoid, spasely tuberculate-spinose, seed white- ash, seed coat smooth (finely pitted), bitter (no pungent smell)

---------- *L. graveolens*

Uses

Besides the commonly reported use of sponge gourd as vegetable the sponge from mature fruit wall is also

used as bath sponge, abrasive for glassware and kitchen utensils pot holders, table mats, bathroom mats, etc. We report some lesser known uses of *Luffa* in India. During exploration to Pilibhit-Puranpur region, Uttar Pradesh the second author observed wild population of sponge gourd. Local people use freshly harvested male flower buds from wild plants for use as vegetable and also sell them in markets. Ridged gourd is more popular vegetable in eastern and the peninsular region as compared to sponge gourd. The vegetable prepared from tender fruits of Satputia was the tastiest among all cultivated *Luffa* species; the fruits were very soft and generally cooked without peeling off the fruit (Sh. Krishna Prakash from Bihar; pers. comm.).

In the North-eastern region (Nagaland, Tripura and elsewhere), tender leaves of sponge gourd were reported to be cooked as vegetable (mature leaves are bitter) or used in preparation of soups, quiche, etc. (Sh. Ajit Uchoi from Tripura; pers. comm.). In East Asian regions young leaves of sponge gourd (in Malaysia) and male flowers/ flower buds (in China) are popularly used in curries. In Uttar Pradesh, fruits of *L.* graveolens are used for fever and stomach problems in cattle; they are poisonous if used in high dosage.

Future Thrust

Assessment of diversity of *Luffa* germplasm collected and conserved from different regions of India provides future road map for future collecting besides generating valuable information on less known uses of *Luffa* from India. The following areas have been identified for augmenting more diversity in:

- ridged gourd from drier tracts of western Karnataka and North eastern hill region (Mizoram, Manipur and Nagaland),
- sponge gourd from Karnataka, Chaattisgarh and adjoining Odisha,
- less known cultivated type Satputia from eastern Uttar Pradesh, North Odisha, Bihar and adjoining Nepal region, and
- wild species *L. echinata* and *L. graveolens* from major areas of distribution.

Acknowledgements

Authors express their sincere thanks to the Director, NBPGR, for guidance as well as for rendering help during the course of study. Thanks are also due to NBPGR Regional Station, Hyderabad, for sharing material. Acknowledgements are also due to Dr. E Roshini Nayar and Dr. KC Bhatt for sharing the study material and information; Ms. Rita Gupta and Sh. Shashi K Sharma for their help in various ways.

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Notes on *Luffa* (Cucurbitaceae) Genetic Resources in India: Diversity Distribution, Germplasm Collection, Morphology and Use

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(Received: 29 August 2013; Revised: 31 December 2013; Accepted: 25 January 2014)

Genus *Luffa* has two major cultivated species, namely, ridged gourd and sponge gourd exhibiting rich diversity in the Indian subcontinent. In the present communication data from germplasm collections of cultivated and wild *Luffa* by the National Bureau of Plant Genetic Resources from different phytogeographical regions of India have been used to pinpoint areas for future collection. Fruit and seed morphological characters were studied for developing field identification key. Some less known uses of *Luffa* are discussed in the perspective of genetic resources in India.

Key Words: Cucurbitaceae, Cultivated and wild species, Field identification key, *Luffa,* Morphology, Phytogeographical distribution

Introduction

Genus *Luffa* (Cucurbitaceae) has two cultivated tropical, one American and the other Old World species (Ali *et al*., 2010). Four species namely *Luffa acutangula* Roxb., *L. aegyptiaca* Mill. [*L. cylindrical* (L.) M.J. Roem.], *L. echinata* Roxb., *L. graveolens* Roxb. occur in India (Chakravarty, 1982; Renner and Pandey, 2013). Cultivated species *L. acutangula* (ridged gourd) and *L. aegyptiaca* (sponge gourd) are widely grown whereas a local cultivar 'Satputia' that bears fruits in cluster (trimonoecious form of *L. acutangula* syn. *L. hermaphrodita* Singh & Bhandari) is confined to eastern region (Charkravary, 1990). Among the wild species, bitter-fruited *L. acutangula* var. *amara* (Roxb.) Clarke, *L. graveolens* and *L. echinata* occur in different agro-ecological regions of India. Linguistic support from Sanskrit literature (name *koshataki*) indicates early history of cultivation and use of *Luffa* in India.

Three subspecies are recognized in *L. acutangula; L. acutangula* var. *acutangula* (called angular loofah, Chinese okra, ridged gourd) was probably domesticated in Asia (de Candolle, 1959) or India (Heiser and Schilling 1990), whereas the bitter wild var. *amara* occurs wild throughout India (http://www.efloras.org/florataxon.aspx?flora_id=5&taxon_id=119075; Heiser and Schilling, 1990). Morphological evidences suggest that cultivated *L. acutangula* var. *acutangula* was derived from var. *amara* (Heiser and Schilling, 1988). On the basis of cytogenetical investigations, the two wild species, *L. graveolens* and *L. echinata* have been indicated closer (Dutt and Roy, 1969; 1971). Study based on morphology of leaves, flowers, fruit, reproductive biology and flavonoids has grouped *L. acutangula* and *L. aegyptiaca* into a single clade, apart from the other species (Heiser and Schilling, 1990). Local cultivar of *L. acutangula* 'Satputia' has cross compatibility with *L. acutangula* (Zeven and de Wet, 1982) and has also been included under *L. acutangula* (Marr *et al*., 2005a, b; Ali *et al*., 2010; Prakash *et al*., 2013).

India is one of the diversity rich regions for cultivated and wild *Luffa*. Variability available in different phytogeographical regions needs to be collected for conservation and use, besides utilization in other genetic resource programmes. Therefore, the present work on genetic resources of *Luffa* was envisaged with primary objective to study: 1) diversity distribution *vis-à-vis* germplasm collection for conservation in India, and 2) morphological variability in fruit and seed of cultivated and wild taxa and developing field identification key. Priorities were worked out for future collecting of *Luffa* germplasm from India.

Materials and Methods

The present study was undertaken to identify gaps for future collecting in the genus *Luffa* based on data on germplasm collection from different phytogeographical regions for three decades *vis-à-vis* diversity distribution. The sites of germplasm collections made by the National Bureau of Plant Genetic Resources (NBPGR) were plotted on map using DIVA-GIS version 7.1 software (Hijmans

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et al., 2001). A coarse grid plotting of location (site) data was prepared to pinpoint the sites of germplasm collecting *vis-à-vis* diversity conserved. Information on diversity distribution pattern, use(s)/ potential value of species was drawn from authors' field experience, non-formal interaction with farmers in areas of occurrence and published literature.

Plants of 36 accessions representing major areas of collections including four species (five taxa; accessions used in parenthesis) *viz*. *Luffa aegyptiaca* (16), *L. acutangula* (16), *L. acutangula* var. *amara* (2), *L. echinata* (1) and *L. graveolens* (1) were raised in earthen pots in net house at the Division of Plant Exploration and Germplasm Collection (NBPGR), New Delhi, during the months of May-September 2010-12. Quantitative and qualitative data on fruit and seed morphology were recorded for visual observations and using hand lens (x10 magnification) from five plants each of the representative species and presented as an average value. Most prominent morphological characters were used for preparing a field identification key.

Results and Discussion

Diversity Distribution

Among the cultivated species *L. aegyptiaca* is widely grown throughout India but is less popular in the peninsular region where the other cultivated species *L. acutangula* is more popular. Former species is also reported under semi-wild conditions in disturbed habitats and forest openings. *L. acutangula* is widely cultivated throughout India for tender fruits used as vegetables. Satputia (*L. hermaphrodita*) is widely grown in eastern Uttar Pradesh, Bihar, West Bengal and Rajasthan. This species is characterized by fruits borne in clusters with skin having 8-10 ribs and smooth skin. *L. acutangula* var. *amara,* wild form of ridged gourd, bears small but extremely bitter fruits. It occurs mainly in the lower altitudes of Himachal Pradesh, Rajasthan, Maharashtra, all over the peninsular India and more sporadically in drier habitats of Gujarat and Madhya Pradesh. Of the two wild taxa, *L. echinata* occurs in disturbed habitats of North-western Himalayas, central India and upper-Gangetic to eastern plains whereas *L. graveolens* in Bihar, Maharashtra, Sikkim and West Bengal. Diversity distribution of *Luffa* species is given in Fig. 1a-d.

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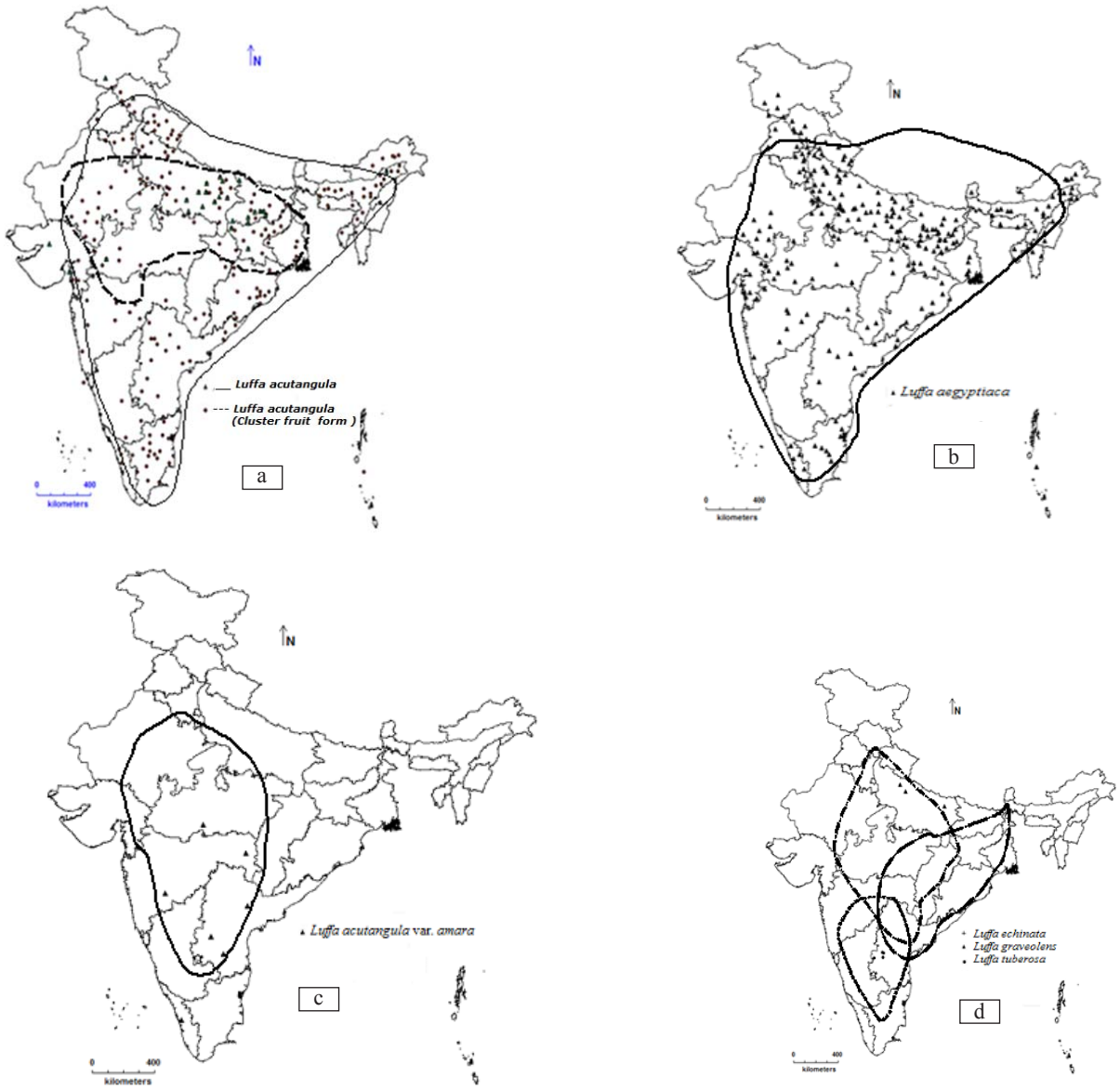

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Study on Fruit and Seed Morphology

A total of 37 accessions were shortlisted based on representation from major collection sites of different species assembled from diverse region. Data on morphological characters were recorded for fruit and seed; *L. acutangula* and *L. hermaphrodita* differed in fruit borne singly or borne in cluster and seed testa surface. Fruit was green-pale green, pericarp with prominent lines in *L. aegyptiaca* and *L. hermaphrodita,* prominent longitudinal ridges in *L. acutangula*, prominently ovoid, densely bristled in *L. echinata* and densely tuberculated in *L. graveolens*.

Fruit wall was dry, fibrous at maturity in all species of *Luffa*. However, nature of fibrous wall varied in different species (thickly knitted in *L. aegyptiaca, L. acutangula* and *L. hermaphrodita* and loosely knitted in *L. graveolens* and *L. echinata*). Length of the fruit varied from long in *L. aegyptiaca, L. acutangula* var. *acutangula,* medium in *L. hermaphrodita* and *L. acutangula* var. *amara,* smaller in *L. echinata* and *L. graveolens*. Fruits were generally cylindrical (rarely round) in cultivated species and oval-globose in wild species. The fruits of wild *L. acutangula* var. *amara* were smaller in size than cultivated *L. acutangula* and fruit shape was narrow and pointed at both ends.

Seed shape is a distinguishing character in all species. It varied from elongated-oblong in *L. aegyptiaca*; ovate with prominent beak in *L. actangula*; and oval-ovate in *L. echinata* and *L. graveolens.* Seed surrounded by papery membranous wing in *L. aegyptiaca* was the most distinguishable character.

Comparision of seed characters for qualitative and quantitative characters is given in Tables 1-2. Seed was bigger in *L. aegyptiaca,* medium in *L. actangula* and *L. hermaphrodita,* smaller in *L. echinata* and *L. graveolens.* The seed coat surface was mostly rough but intermediate types were also present in some accessions of the three cultivated species. *L. aegyptiaca* showed variation in seed coat colour-black seeded and white seeded with smooth wall. Seeds of *L. hermaphrodita* though were similar in

Fig. 2. Fibrous sponge obtained from dry fruit wall of *Luffa* species is a characteristic feature of the genus: a) *L. aegyptiaca* (sponge well developed, compact, easy to separate), b) *L. acutangula* var. *acutangula*, c) *L. acutangula* var. *amara* (sponge well developed, difficult to separate), d) *L. graveolens* (sponge poorly developed, not well formed), e) *L. echinata* (sponge soft, loosely knitted, breaks on separation)

Table 1. Quantitative traits recorded in fruit and seed of *Luffa* species

S.No.	Character	*L. aegyptiaca*	*L. acutangula*	*L. graveolens*	*L. echinata*
1.	Length of fruit (cm)	27.15 x 5.71	12.75-22.58 x 3.95-4.85	5.91 x 3.35	3.5 x 3.0
2.	Seed size (mm)	11.53 x 7.50	10.17-10.65 x 5.57-6.02	4.83 x 3.33	4.70 x 3.50
3.	100 seed weight (gm)	11.35	10.58-11.32	3.44	2.83

Table 2. Morphological traits recorded in fruit and seed characters of different species of *Luffa*

S.No.	Character	*L. aegyptiaca*	*L. acutangula*	*L. graveolens*	*L. echinata*
1.	Fruit shape	Elongated, cylindrical	Elongated-cylindrical and spindle shaped (in *amara* type)	Cylindrical-oblong	Spherical-round
2.	Extension on fruit surface	Absent	Ribbed-non ribbed (in satputia)	Tuberculate bristles	Echinate
3.	Fruit skin colour	Green (uniforn or with with specles)	Smooth with continuous lines (in satputia), rugose	Rough	Echinate, long bristles
4.	Flesh colour, taste	White-yellow	White	Yellow	Pale yellow
5.	Fruit borne singly or in cluster	Single	Single, cluster (in satputia)	Single	Single
6.	Seed shape	Oblong-elongated	Ovate	Oblong-ovate	Oblong-ovate
7.	Seed coat colour	Ivory, black, greyish-black	Greyish black-black	Grey	Grey
8.	Seed coat extension	Membranous wing	Apical notch	Absent	Absent
9.	Seed coat surface	Smooth, non-shiny	Smooth, non-shiny	Rough, non-shiny	Rough, non-shiny
10.	Bitter	Sweet (but bitter in wild type)	Sweet (but bitter in wild type)	Bitter	Extremely bitter

shape but had distinctly shiny smooth seed surface as compared to *L. acutangula* which had rugose surface. Accessions of *L. acutangula* var. *amara* had variable degree of roughness in seed coat. However, the seed coat surface of *L. graveolens* and *L. echinata* were rough (finely pitted in former and coarsely pitted in latter species) and greyish-black. In general seeds of cultivated species were bold whereas the wild species were smaller.

Key to species in *Luffa* (using characters of fruit and seed)

While handling germplasm of *Luffa,* characters of mature fruit (fruit wall/pericarp and fibrous wall/ sponge) (Fig. 2) and seed morphology are important especially during collection, sorting, packaging and other activities relevant to plant genetic resource management. The authors have attempted to develop a key on the basis of fruit and seed morphology for on-spot identification of different species of *Luffa.*

1. ***Fruit wall smooth***
   2. Fruits solitary, sponge well formed with thickly knitted fibres in mature fruit, seed oval-round, compressed with membranous wing, white, black or gradation of black
      → *L. aegyptiaca*
   2. Fruits borne in cluster, sponge well formed with thinly knitted fibres in mature fruit, seeds dark black and shiny
      → *L. hermaphrodita*

1. ***Fruit wall not smooth***
   3. Fruit wall prominently ridged, sponge not easily separable
      4. Cultigen, fruits clavate-oblong, size 22.58 x 4 cm, non-bitter, pericarp hard on maturity
         → *L. acutangula*
      4. Plant occurs in wild, fruits 12.75 x 4.8 cm, obovoid-conical, both ends obtuse, bitter, pericarp papery on drying
         →*L. acutangula* var. *amara*
   3. Fruit wall not ridged; fruit with poorly formed sponge at maturity, easy to separate
      5. Fruit pale brown, round-ovoid, wall densely covered with echinate long bristles, seed coat verrucose (coarsely pitted), yellowish-brown to black, seeds extremely bitter (with pungent smell)
         → *L. echinata*
      5. Fruit grey, ovoid, sparsely tuberculate-spinose, seed white- ash, seed coat smooth (finely pitted), bitter (no pungent smell)
         → *L. graveolens*

Uses

Besides the commonly reported use of sponge gourd as vegetable the sponge from mature fruit wall is also used as bath sponge, abrasive for glassware and kitchen

utensils pot holders, table mats, bathroom mats, etc. We report some lesser known uses of *Luffa* in India. During exploration to Pilibhit-Puranpur region, Uttar Pradesh the second author observed wild population of sponge gourd. Local people use freshly harvested male flower buds from wild plants for use as vegetable and also sell them in markets. Ridged gourd is more popular vegetable in eastern and the peninsular region as compared to sponge gourd. The vegetable prepared from tender fruits of Satputia was the tastiest among all cultivated *Luffa* species; the fruits were very soft and generally cooked without peeling off the fruit (Sh. Krishna Prakash from Bihar; pers. comm.).

In the North-eastern region (Nagaland, Tripura and elsewhere), tender leaves of sponge gourd were reported to be cooked as vegetable (mature leaves are bitter) or used in preparation of soups, quiche, etc. (Sh. Ajit Uchoi from Tripura; pers. comm.). In East Asian regions young leaves of sponge gourd (in Malaysia) and male flowers/ flower buds (in China) are popularly used in curries. In Uttar Pradesh, fruits of *L.* graveolens are used for fever and stomach problems in cattle; they are poisonous if used in high dosage.

Future Thrust

Assessment of diversity of *Luffa* germplasm collected and conserved from different regions of India provides future road map for future collecting besides generating valuable information on less known uses of *Luffa* from India. The following areas have been identified for augmenting more diversity in:

- ridged gourd from drier tracts of western Karnataka and North eastern hill region (Mizoram, Manipur and Nagaland),
- sponge gourd from Karnataka, Chaattisgarh and adjoining Odisha,
- less known cultivated type Satputia from eastern Uttar Pradesh, North Odisha, Bihar and adjoining Nepal region, and
- wild species *L. echinata* and *L. graveolens* from major areas of distribution.

Acknowledgements

Authors express their sincere thanks to the Director, NBPGR, for guidance as well as for rendering help during the course of study. Thanks are also due to NBPGR Regional Station, Hyderabad, for sharing material. Acknowledgements are also due to Dr. E Roshini Nayar and Dr. KC Bhatt for sharing the study material and information; Ms. Rita Gupta and Sh. Shashi K Sharma for their help in various ways.

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Assessment of Variability and Selection of Promising Genotypes in Mango Ginger (*Curcuma amada* Roxb.) Accessions from Kerala

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(Received: 11 July 2013; Revised: 28 January 2014; Accepted: 12 March 2014)

Curcuma amada Roxb. (mango ginger) of the family Zingiberaceae is an under-exploited spice and tuber crop which grows luxuriantly on tropical soils. Being a marginalized crop, conservation and improvement are very important for the popularization of the crop as a food component, for product diversification and also for effective conservation of the genotypes. In Kerala, local landraces are being used extensively for cultivation and they show very high level of variability with respect to growth and yield. In this context a study was carried out during 2005-2009 to collect and conserve the available germplasm of mango ginger from Kerala and to evaluate their genetic potential. Fifty diverse accessions collected were evaluated in RBD in the first crop season for three consecutive years by adopting standard management practices. All the 15 growth/yield characters studied showed significant variation indicating the strength of the genetic base of the crop. Among the characters, the highest variability was observed in yield/plant followed by tiller number, leaf area and plant height. Accession No. CUM 34 showed the highest performance index with 494.44 g yield/plant followed by CUM 35 with 450 g yield/plant.

Key Words: *Curcuma amada*, Genetic variability, Mango ginger, Performance evaluation

Introduction

Curcuma amada Roxb. of the family Zingiberaceae is an under-exploited spice crop which grows luxuriantly on tropical soils. The plant grows wild and is also cultivated as an annual for its commercially important rhizomes. It is known as mango ginger in English, *karpuraharidra* in Sanskrit, *amada* in Bengali and *manga inchi* in Malayalam. The plant is indigenous to Bengal but now it is cultivated throughout India. The specific epithet *amada* is derived from Bengali meaning mango ginger referring to the rhizome having characteristic taste of unripe mango (Saji and Sasikumar, 2004). *Curcuma amada* is a rhizomatous aromatic herb with pseudostem and petiolate leaves. Inflorescence is lateral or central in position with sterile light violet terminal comma bracts. The underground part is the rhizome which is branched and showing sympodial growth (Sabu, 2006).

The tubers are regarded as cooling and useful in prurigo. They are employed as carminative and stomachic (Watt, 1972). The rhizome is used for preparing salads, chutneys and different value added products. Due to its exotic flavour and medicinal properties, it is used in the preparation of special foods, beverages and pharmaceutical and cosmetic products. It has a long history of traditional uses ranging from folk medicine to several culinary preparations. It has antibacterial, insecticidal, antifungal and antioxidant properties (Shankaracharya, 1982; Nadkarni, 2005; Jatoi *et al.*, 2007; Policegoudra and Aradhya, 2008).

Various types of mango gingers differing in rhizome morphology are reported from India (Saji and Sasikumar, 2004). Being a marginalized crop, conservation and improvement are very important for popularization of the crop as food component and also for product diversification. The only improved variety reported from India is Amba, which is a selection of local germplasm from High Altitude Research Station, Orissa University of Agriculture and Technology, Pottangi, Orissa. In Kerala, local cultivars are being used for cultivation and they show very high level of variability. Being a homestead crop which is not cultivated on a commercial scale in the state, the evaluation of its genetic potential and initiatives to conserve and improve the materials are highly essential. Jayasree *et al.* (2006) have made a preliminary study on the variability of mango ginger in Kerala. The present experiment was carried out to select the promising accessions for documentation and conservation.

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Materials and Methods

The experiment was conducted in the experimental net house of the Genetics and Plant Breeding Division of the Department of Botany, University of Calicut, Kerala, India during 2005-2009. The experiments were laid out in randomized block design with three replications of 50 accessions of *C. amada* collected from different locations of Kerala. Fresh, healthy rhizomes were collected from different localities in Kerala during March/April 2005 and planted in the first week of May 2005. The rhizomes were separated into fingers and one finger each planted in 38 cm x 35 cm polybags filled with garden soil, sand and enriched compost in 4:1:1 ratio. *Gliricidia sepium* leaf mulch was provided occasionally. Enriched compost was applied @ 60 g/plant at the end of the second and fourth month. Weeding was carried out regularly and optimum soil moisture was maintained. The plants were grown organically except for plant protection and package of practices of Kerala Agricultural University (Anonymous, 2003) was followed for plant protection. Data on growth, yield and rhizome characters were recorded at the end of six months by destructive sampling (Table 1). The data were analyzed for variability and related statistics and comparative performance of the accessions was analyzed based on major growth and yield characters with the help of performance index calculated as per Amaravenmathy and Sreenivasan (2003). To calculate performance index, accession means of the characters were divided by the grand mean of the corresponding character in the experimental population.

Results and Discussion

All the 15 growth/yield characters studied showed significant variation indicating the strength of the genetic base of the crop (Table 1). Among the characters, the highest variability was shown by yield/plant followed by tiller number, leaf area and plant height. Accession No. CUM 34 showed the highest performance index with 494.44g yield/plant followed by CUM 35 with a 450 g yield/plant.

PCV was higher than GCV in case of all the characters indicating the quantitative nature of control of the characters studied. Heritability was the highest in case of plant height followed by leaf length and leaf area. Yield/plant showed 48.32% of heritability. Genetic advance was the highest in case of yield/plant. Performance indices of tested accessions are given in Table 2. CUM 34 showed highest performance index with 449.44 g yield/plant followed by CUM 35.

Table 1. Growth and yield characters of *Curcuma amada* accessions

Acc. No.	Characters														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CUM 1	98.72	1.00	8.67	40.30	8.76	243.24	4.44	14.44	9.57	7.02	2.27	2.03	4.97	2.70	293.89
CUM 2	117.95	1.10	9.33	50.06	10.08	350.00	4.55	18.44	10.80	6.68	2.55	2.24	6.61	2.89	430.00
CUM 3	115.50	1.33	8.22	48.17	10.17	341.69	5.11	17.78	1.89	6.60	2.47	2.24	5.40	2.86	452.22
CUM 4	112.33	1.20	9.78	49.32	10.02	340.52	5.11	17.11	10.24	7.04	2.19	1.96	5.61	2.77	415.55
CUM 5	102.33	1.00	8.33	41.61	9.33	268.65	5.44	13.78	9.98	7.08	2.31	2.14	5.91	3.27	314.44
CUM 6	104.89	1.00	8.67	43.83	8.84	268.55	4.45	15.00	10.69	6.65	2.31	2.13	5.77	3.29	301.11
CUM 7	94.95	1.00	8.56	40.63	7.85	217.49	4.33	12.67	9.06	6.37	2.22	1.97	5.10	2.89	257.22
CUM 8	93.89	1.10	9.00	39.78	7.81	215.58	4.78	14.00	9.26	5.47	2.27	1.93	4.67	2.74	242.78
CUM 9	107.11	1.23	8.78	40.81	8.38	233.59	4.78	14.89	10.35	6.44	2.27	1.97	5.07	2.78	266.67
CUM 10	104.28	1.23	9.40	41.48	8.49	244.85	4.89	13.89	9.23	7.05	2.39	2.07	5.42	3.18	353.33
CUM 11	100.17	1.00	9.55	41.55	8.62	245.39	4.55	12.33	10.39	7.17	2.43	2.12	4.82	2.85	265.55
CUM 12	103.11	1.00	9.22	43.68	8.34	248.66	4.89	15.00	10.26	7.18	2.37	2.16	4.70	2.83	296.67
CUM 13	109.44	1.33	8.78	43.37	8.62	256.82	5.22	14.78	10.19	6.54	2.53	2.35	4.98	2.79	323.11
CUM 14	107.56	1.10	9.11	41.61	8.46	248.72	4.89	14.11	9.37	6.63	2.30	2.18	5.11	2.93	313.33
CUM 15	112.50	1.10	8.22	45.46	8.98	283.36	4.89	12.33	9.82	7.18	2.59	2.20	5.27	3.34	387.78
CUM 16	107.11	1.10	8.89	42.77	9.04	265.76	5.00	14.33	10.08	7.59	2.23	2.27	5.34	3.25	312.78
CUM 17	115.61	1.00	9.22	46.89	9.53	309.12	5.22	16.89	10.48	7.71	2.52	2.22	5.70	3.53	420.00
CUM 18	114.44	1.00	9.22	47.62	9.64	310.61	4.56	13.00	10.23	8.28	2.51	2.38	5.72	3.71	386.67

Contd.

Table 1 contd.

Acc. No.	Characters														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CUM 19	107.11	1.10	8.89	45.49	9.92	311.52	5.00	16.66	10.53	8.11	2.62	2.39	5.17	3.16	549.44
CUM 20	88.72	1.00	8.34	39.00	8.41	225.02	5.00	14.55	10.88	7.34	2.44	2.24	5.49	3.19	305.55
CUM 21	101.61	1.00	9.67	43.94	8.86	255.14	5.11	16.78	11.35	8.45	2.57	2.40	5.35	3.82	455.55
CUM 22	91.39	1.00	8.44	38.70	8.30	219.72	4.11	12.78	9.63	5.49	2.47	2.10	4.62	2.98	229.45
CUM 23	87.52	1.33	8.11	37.89	9.25	239.10	4.55	13.11	9.41	7.41	2.27	2.16	4.94	3.32	277.22
CUM 24	80.67	1.70	7.57	35.57	8.63	211.01	4.67	17.89	9.71	6.36	2.38	2.12	5.30	3.17	259.44
CUM 25	86.72	1.10	8.89	37.72	9.02	231.88	5.56	15.89	10.76	6.56	2.47	2.22	5.04	3.13	307.22
CUM 26	82.78	1.10	7.78	34.77	8.62	205.54	4.22	11.33	9.08	5.18	2.31	1.92	4.90	3.07	192.78
CUM 27	90.28	1.43	8.33	38.61	9.68	254.46	5.44	16.11	9.91	7.35	2.43	2.17	5.40	3.48	326.11
CUM 28	89.55	1.43	8.11	39.03	9.64	257.80	5.33	15.89	9.73	7.54	2.30	2.27	5.03	3.41	374.44
CUM 29	63.72	1.33	8.44	30.34	7.36	156.58	5.33	9.55	7.42	4.61	1.93	1.68	4.27	2.81	150.00
CUM 30	75.12	1.80	7.78	37.13	9.49	242.48	5.00	15.11	10.16	7.05	2.40	2.12	5.37	3.63	361.89
CUM 31	107.83	1.43	8.45	46.96	10.29	319.76	5.67	16.66	10.53	8.73	2.60	2.35	6.05	3.77	468.33
CUM 32	114.07	1.00	10.22	48.64	10.88	361.81	5.33	15.67	9.78	7.54	2.35	2.20	5.65	3.26	377.22
CUM 33	111.28	1.20	8.78	48.40	11.61	397.45	5.89	16.22	10.81	8.64	2.53	2.46	5.57	3.61	441.67
CUM 34	110.50	1.43	9.22	48.33	11.41	375.30	5.56	18.56	9.82	8.87	2.47	2.38	6.17	3.83	494.44
CUM 35	114.00	1.43	8.67	48.69	10.88	362.62	5.56	17.67	10.60	8.03	2.25	2.34	6.16	3.84	450.00
CUM 36	109.11	1.43	8.78	46.59	11.01	350.86	5.33	13.56	9.80	8.26	2.32	2.24	6.16	4.12	406.11
CUM 37	96.72	1.10	9.22	41.84	10.06	290.60	5.00	13.66	10.53	7.76	2.39	2.21	5.45	3.28	390.00
CUM 38	89.45	1.90	7.44	41.37	9.96	280.99	5.33	17.57	10.96	8.85	2.35	2.28	5.44	3.51	458.33
CUM 39	73.67	1.43	8.00	35.35	9.07	218.61	5.78	15.34	10.33	7.02	2.31	2.09	5.87	3.25	300.00
CUM 40	77.89	1.70	6.89	35.33	8.94	226.30	5.44	16.44	10.28	7.42	2.26	2.18	4.89	3.25	273.33
CUM 41	80.28	1.80	7.33	36.11	9.19	225.84	5.55	15.00	9.45	8.45	2.43	2.13	4.49	3.90	336.11
CUM 42	71.55	1.67	7.33	33.05	8.66	194.89	5.33	15.00	9.87	6.69	2.21	1.97	5.09	3.24	235.00
CUM 43	78.61	1.20	9.78	34.90	9.20	220.28	5.44	14.56	9.99	6.20	2.21	2.04	4.66	2.98	187.22
CUM 44	74.83	1.33	8.22	34.81	8.46	200.29	5.89	14.11	10.33	7.28	2.36	2.10	5.28	3.27	283.89
CUM 45	80.56	1.00	8.67	35.50	8.73	210.93	4.89	13.00	10.38	7.49	2.52	2.18	6.03	3.84	290.56
CUM 46	77.61	1.30	7.44	33.35	9.03	206.93	5.56	9.55	8.29	5.16	1.82	1.63	4.91	2.67	146.67
CUM 47	78.56	11.67	7.44	34.39	9.26	217.62	5.78	14.56	10.42	8.10	2.40	2.21	5.33	3.51	343.89
CUM 48	72.50	1.90	7.22	32.76	8.87	198.43	5.67	15.33	10.56	8.73	2.41	2.28	5.17	3.64	341.67
CUM 49	64.11	1.90	7.11	31.84	8.55	187.19	5.56	14.34	8.84	6.58	2.13	1.98	4.42	2.84	255.56
CUM 50	65.83	1.67	9.00	32.30	8.93	199.12	5.89	10.44	8.68	5.52	2.07	1.75	5.02	2.58	149.44
Mean	94.32	1.29	8.53	40.55	9.22	258.97	5.18	14.75	9.99	7.15	2.36	2.15	5.30	3.24	329.07
Range	46-141	1-3	5-12	21.00-61.33	4.43-14.80	66.32-578.33	3-9	3-47	2.50-15.17	1.40-12.07	0.82-3.36	0.66-3.08	2.8-9.6	1.37-6.11	30-1230
SD	15.90	0.29	0.78	5.47	0.91	56.25	0.46	2.10	0.74	1.02	0.16	0.18	0.49	0.38	92.62
CV	16.86	22.48	9.14	13.49	9.87	21.72	8.88	14.24	7.41	14.27	6.78	8.37	9.25	11.73	28.15
CD @ 5%	11.94	0.39	1.41	5.10	1.30	63.98	0.95	4.04	1.22	1.57	0.27	0.28	0.88	0.48	134.30
GCV	16.26	18.60	6.10	12.73	8.57	19.89	6.18	10.44	6.00	11.89	5.94	6.51	6.98	10.80	24.17
PCV	18.02	27.13	12.30	14.87	12.15	24.99	12.74	19.73	9.60	17.90	9.32	10.23	12.45	14.19	34.76
Heritability (broad sense) (%)	81.47	50.00	32.72	73.19	49.60	63.34	22.72	27.80	39.13	43.64	40.00	40.00	32.56	57.14	48.32
Genetic advance (%)	30.23	27.95	8.30	22.42	12.41	32.60	5.96	11.30	7.75	16.09	7.68	8.43	8.35	16.71	34.60

1. Plant height (cm); 2. Number of tillers; 3. Number of leaves/tiller; 4. Leaf length (cm); 5. Leaf breadth (cm); 6. Leaf area (cm2); 7. Number of primary fingers; 8. Number of secondary fingers; 9. Length of primary fingers (cm); 10. Length of secondary fingers (cm); 11. Diameter of primary fingers (cm); 12. Diameter of secondary fingers (cm); 13. Length of mother rhizome (cm); 14. Diameter of mother rhizome (cm); 15. Yield/plant (g)

Table 2. Performance indices of *Curcuma amada* accessions

Acc. No.	Characters/Performance index																Rank of performance
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	
CUM 1	1.05	0.78	1.02	0.99	0.95	0.94	0.86	0.98	0.96	0.98	0.90	0.87	0.94	0.83	0.89	13.94	39
CUM 2	1.25	0.85	1.09	1.23	1.09	1.35	0.88	1.25	1.08	0.93	1.01	0.96	1.25	0.89	1.31	16.42	7
CUM 3	1.22	1.03	0.96	1.19	1.10	1.32	0.99	1.21	1.09	0.92	0.98	0.96	1.02	0.88	1.37	16.24	9
CUM 4	1.19	0.93	1.15	1.22	1.09	1.31	0.99	1.16	1.03	0.98	0.87	0.84	1.06	0.85	1.26	15.93	13
CUM 5	1.08	0.78	0.98	1.03	1.01	1.04	1.05	0.93	1.00	0.98	0.91	0.91	1.12	1.01	0.96	14.79	25
CUM 6	1.11	0.78	1.02	1.08	0.96	1.04	0.86	1.02	1.07	0.92	0.92	0.91	1.09	1.02	0.92	14.72	27
CUM 7	1.01	0.78	1.00	1.00	0.85	0.84	0.84	0.86	0.91	0.88	0.88	0.84	0.96	0.89	0.78	13.32	44
CUM 8	1.00	0.85	1.06	0.98	0.85	0.83	0.93	0.95	0.93	0.76	0.90	0.82	0.88	0.85	0.74	13.33	43
CUM 9	1.14	0.95	1.03	1.01	0.91	0.90	0.93	1.01	1.04	0.89	0.90	0.84	0.96	0.86	0.81	14.18	36
CUM 10	1.11	0.95	1.11	1.02	0.92	0.95	0.95	0.94	0.93	0.98	0.94	0.88	1.02	0.98	1.07	14.75	26
CUM 11	1.06	0.78	1.12	1.02	0.93	0.95	0.88	0.84	1.04	1.00	0.96	0.91	0.91	0.88	0.81	14.09	38
CUM 12	1.09	0.78	1.08	1.08	0.90	0.96	0.95	1.02	1.03	1.00	0.94	0.92	0.89	0.87	0.90	14.41	31
CUM 13	1.16	1.03	1.03	1.07	0.93	0.99	1.01	1.00	1.02	0.91	1.00	1.00	0.94	0.86	0.98	14.93	23
CUM 14	1.14	0.85	1.07	1.03	0.92	0.96	0.95	0.96	0.94	0.92	0.91	0.93	0.96	0.90	0.95	14.39	32
CUM 15	1.19	0.85	0.96	1.12	0.97	1.09	0.95	0.84	0.98	1.00	1.02	0.94	0.99	1.03	1.18	15.11	19
CUM 16	1.14	0.85	1.04	1.06	0.98	1.03	0.97	0.97	1.01	1.05	0.88	0.97	1.01	1.00	0.95	14.91	24
CUM 17	1.23	0.78	1.08	1.16	1.03	1.19	1.01	1.15	1.05	1.07	1.00	0.95	1.08	1.09	1.28	16.15	11
CUM 18	1.21	0.78	1.08	1.17	1.05	1.20	0.88	0.88	1.03	1.15	0.99	1.02	1.08	1.15	1.18	15.85	14
CUM 19	1.14	0.85	1.04	1.12	1.08	1.20	0.97	1.13	1.06	1.13	1.04	1.02	0.98	0.98	1.67	16.41	8
CUM 20	0.94	0.78	0.98	0.96	0.91	0.87	0.97	0.99	1.09	1.02	0.96	0.96	1.04	0.98	0.93	14.38	33
CUM 21	1.08	0.78	1.13	1.08	0.96	0.99	0.99	1.14	1.14	1.17	1.02	1.03	1.01	1.18	1.38	16.08	12
CUM 22	0.97	0.78	0.99	0.95	0.90	0.85	0.80	0.87	0.97	0.76	0.98	0.90	0.87	0.92	0.70	13.21	45
CUM 23	0.93	1.03	0.95	0.93	1.00	0.92	0.88	0.89	0.94	1.03	0.90	0.92	0.93	1.02	0.84	14.11	37
CUM 24	0.86	1.32	0.89	0.88	0.94	0.81	1.10	1.21	0.97	0.88	0.94	0.91	1.00	0.98	0.79	14.48	29
CUM 25	0.92	0.85	1.04	0.93	0.98	0.90	1.08	1.08	1.08	0.91	0.98	0.95	0.95	0.97	0.93	14.55	28
CUM 26	0.88	0.85	0.91	0.86	0.93	0.79	0.82	0.77	0.91	0.72	0.91	0.82	0.92	0.95	0.59	12.63	47
CUM 27	0.96	1.11	0.98	0.95	1.05	0.98	1.05	1.09	0.99	1.02	0.96	0.93	1.02	1.07	0.99	15.15	18
CUM 28	0.95	1.11	0.95	0.96	1.05	1.00	1.03	1.08	0.98	1.05	0.91	0.97	0.95	1.05	1.14	15.18	17
CUM 29	0.68	1.03	0.99	0.75	0.80	0.60	1.03	0.65	0.74	0.64	0.76	0.72	0.81	0.87	0.46	11.53	49
CUM 30	0.80	1.40	0.91	0.92	1.03	0.94	0.97	1.02	1.02	0.98	0.95	0.91	1.01	1.12	1.11	15.09	21
CUM 31	1.14	1.11	0.99	1.16	1.12	1.23	1.10	1.13	1.06	1.21	1.03	1.00	1.14	1.16	1.42	17.00	4
CUM 32	1.21	0.78	1.20	1.20	1.18	1.40	1.03	1.06	0.98	1.05	0.93	0.94	1.07	1.01	1.15	16.19	10
CUM 33	1.18	0.93	1.03	1.19	1.26	1.53	1.14	1.10	1.08	1.20	1.00	1.05	1.05	1.11	1.34	17.19	3
CUM 34	1.17	1.11	1.08	1.19	1.24	1.45	1.08	1.26	0.98	1.23	0.98	1.02	1.16	1.18	1.50	17.63	1
CUM 35	1.21	1.11	1.02	1.20	1.18	1.40	1.08	1.20	1.06	1.12	0.98	1.00	1.16	1.19	1.37	17.28	2
CUM 36	1.16	1.11	1.03	1.15	1.19	1.35	1.03	0.92	0.98	1.15	0.92	0.96	1.16	1.27	1.23	16.61	5
CUM 37	1.03	0.85	1.08	1.03	1.09	1.12	0.97	0.93	1.06	1.08	0.94	0.94	1.03	1.01	1.19	15.35	15
CUM 38	0.95	1.47	0.87	1.02	1.08	1.09	1.03	1.19	1.10	1.23	0.93	0.97	1.03	1.09	1.39	16.44	6
CUM 39	0.78	1.11	0.94	0.87	0.98	0.84	1.12	1.04	1.04	0.98	0.91	0.89	0.92	1.00	0.91	14.33	35
CUM 40	0.83	1.32	0.81	0.87	0.97	0.87	1.05	1.11	1.03	1.03	0.89	0.93	0.92	1.00	0.83	14.46	30
CUM 41	0.85	1.40	0.86	0.89	1.00	0.87	1.08	1.02	0.95	1.17	0.96	0.91	1.04	1.20	1.02	15.22	16
CUM 42	0.76	1.29	0.86	0.82	0.94	0.75	1.03	1.02	0.99	0.93	0.87	0.84	0.96	1.00	0.71	13.77	40
CUM 43	0.83	0.93	1.15	0.86	1.00	0.85	1.05	0.99	1.00	0.86	0.87	0.87	0.88	0.92	0.57	13.63	41
CUM 44	0.79	1.03	0.96	0.86	0.92	0.77	1.14	0.96	1.04	1.01	0.93	0.90	1.00	1.01	0.86	14.18	36
CUM 45	0.85	0.78	1.02	0.88	0.95	0.81	0.95	0.88	1.04	1.04	1.00	0.93	1.14	1.19	0.88	14.34	34
CUM 46	0.82	1.01	0.87	0.82	0.98	0.80	1.08	0.65	0.83	0.72	0.72	0.70	0.93	0.82	0.45	12.20	48
CUM 47	0.83	1.29	0.87	0.85	1.00	0.84	1.12	0.99	1.05	1.13	0.95	0.94	1.01	1.08	1.05	15.00	22
CUM 48	0.77	1.47	0.85	0.81	0.96	0.77	1.10	1.04	1.06	1.21	0.95	0.97	0.98	1.12	1.04	15.10	20
CUM 49	0.68	1.47	0.83	0.79	0.93	0.72	1.08	0.97	0.89	0.91	0.84	0.85	0.83	0.88	0.78	13.45	42
CUM 50	0.70	1.29	1.06	0.80	0.97	0.77	1.14	0.71	0.87	0.77	0.82	0.75	0.95	0.80	0.45	12.85	46

1. Plant height; 2. Number of tillers; 3. Number of leaves/tiller; 4. Leaf length; 5. Leaf breadth; 6. Leaf area; 7. Number of primary fingers; 8. Number of secondary fingers; 9. Length of primary fingers; 10. Length of secondary fingers; 11. Diameter of primary fingers; 12. Diameter of secondary fingers; 13. Length of mother rhizome; 14. Diameter of mother rhizome; 15. Yield/plant

The superior accessions show significantly high level of agronomic characters and these accessions can be subjected to further selection procedures so that superior planting material could be made available to the farmers. In spite of the presence of a strong genetic base at present, serious efforts are required to conserve the germplasm of this under-exploited crop. Efforts should also be made to popularize the inclusion of this crop in the day to day food of the common man both for its richness in starch content and also for its curative properties.

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Short Communication

Collection and Conservation of Cold Adapted Indigenous Rice Landraces from Western Ghats, South India

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(Received: 14 August 2013; Revised: 04 March 2014; Accepted: 12 March 2014)

Efforts were made to collect and conserve cold adapted rice germplasm from parts of Western Ghats in South India which resulted in the augmentation of 56 accessions of rice germplasm. Majority of the landraces (38 accessions) were red kernelled and the germplasm varied significantly for grain and kernel traits *viz.,* grain length (5.58-9.47 mm), grain breadth (2.2-3.79 mm), 100-seed weight (0.9-3.5 g), kernel length (3.72-6.63 mm), kernel breadth (2.4-3.0 mm) and kernel length/breadth ratio (1.67-2.67). Conservation strategies for these cold adapted landraces are also discussed.

Key Words: Cold tolerance, Collection, Red rices, Rice germplasm, Western Ghats

Rice is a warm season crop grown broadly in the humid tropical and subtropical regions of the world including the Indian sub-continent. It is the ancient and most important staple food crop of India, grown in diverse eco-systems on a variety of soils under differing climatic and hydrological settings across various agro-climatic zones of the country including cold regions. Domestication of rice is believed to have begun about 9,000 years ago within a broad geographic region spanning eastern India, Indo-China and parts of southern China. The present cultivated form of rice (*Oryza sativa* var. *indica*) which is consumed primarily in India, Bangladesh and other lowland regions of South and Southeast Asia appears to have been domesticated from its wild species *Oryza rufipogon* Griffin. of Indo-Chinese origin. There are evidences to support the hypothesis of multiple geographic and independent domestication of rice across the globe. The Western Ghats of India are known for the cultivation of cold adapted Indica rice landraces since time immemorial. With the advent of high yielding rice varieties, the cultivation of cold adapted landraces is only in very few pockets of Western Ghats mainly patronized by the tribal communities inhabiting the region. Low temperature stress is a major constraint to rice production in the hill tracts of India, including the southern plains and North Eastern region. In order to combat this stress, the genes from the rice landraces which are under cultivation and well adapted in the colder regions for a long time can be exploited in the breeding programmes to increase productivity. An attempt has been made to collect and conserve the indigenous rice germplasm adapted to cold environment of the Western Ghats in collaboration with Directorate of Rice Research (DRR) and Tamil Nadu Agricultural University (TNAU) under the National Initiative on Climate Resilient Agriculture (NICRA) project of Indian Council of Agricultural Research (ICAR) which aims to enhance gearing up of Indian agriculture to climate change.

Rice is under cultivation since time immemorial in the Western Ghats. Several landraces which are adapted to cold conditions are still under continuous cultivation in this area in spite of the introduction of improved cultivars. In order to collect the endemic genetic diversity in rice adapted to low temperatures, an exploration was undertaken during October, 2011 in parts of Western Ghats covering Nilgiri and Dindigul districts of Tamil Nadu and Wayanad district of Kerala. The planning and logistics and the sampling procedures for the collecting of rice germplasm were followed as per the guidelines suggested by Engels *et al.* (1995) and Brown and Marshall (1995). Farmer's field was taken

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as a unit area and random samples of the populations and biased samples of elite material were collected. Germplasm samples were also collected from threshing yards and farm stores. Geographical coordinates of the collection sites were recorded using hand-held global positioning system (Garmin 12). Passport information on the collected germplasm was recorded and documented. The IRRI descriptors for rice, *Oryza sativa* L. was used for studying the variability in the collected germplasm. SAS enterprise guide version 4.3 was used for statistical analysis.

The survey resulted in the collection of 56 accessions of cold adapted rice landraces from 23 villages of Western Ghats region in South India. The altitude of the collection sites ranged from 974 to 6,225 feet above the mean sea level. Out of 56 germplasm accessions collected, 38 were red kernelled and the remaining 18 accessions possessed white kernels. The white kernelled cultivars include IR-20 and Ponni, two popular released varieties adapted to low temperatures prevailing in the Western Ghats region. Some of the indigenous scented landraces of rice *viz*, *Jeerakasala, Gandhakasala* and *Mallikuruvai* which possess white kernels were also collected. The crop duration of collected rice germplasm falls under early, medium and late groups varying from 120 to >200 days maturity. Majority of them are grown as a rainfed crop and few under semi-irrigated conditions too. The habitat of rice germplasm varied from flooded to aerobic situations depending upon the terrain of collection sites. Sizeable variation was observed in panicle structure, grain morphological traits *viz.*, glume and awn colour (black/brown/gold/straw), shape of grain (slender/medium/bold), grain colour (white/light brown/speckled brown/brown/red) (Fig. 1), 100-seed weight and length and breadth of grain and kernel (Table 1). The variability depicting the grain and kernel shape of collected germplasm is provided in Fig. 1. Similar kind of variability was reported by earlier researchers in landraces of rice augmented through gene pool sampling from various parts of India (Hore, 2005; Kumar *et al.*, 2010; Latha *et al.*, 2013; Dikshit *et al.*, 2013; Rana *et al.*, 2009; Sivaraj *et al.,* 2000).

Traditionally, red rices have held a special place in India. *Adhira, Adukkan, Aiyrankanni, Cherutti, Chettuvali, Chinthamani, Edavaka, Kadaikannan, Kalyani, Karunellu, Karuvali, Kattathondi, Kudaivali, Kudaivilaiyan, Kuruvatti, Malainellu, Mannuvilaiyan, Mullampunjan, Navara, Palthondi, Pavalam, Thondi* and *Valisuri* are some of red rice landraces which are adapted to cold conditions. Seeds of these landraces possess a red bran layer and a tinge of red remains even after milling. Ancient literature *viz., Taittiriya Samhita* of *Yajurveda* and *Satapatha Brahmana* referred about the offering of coloured rice to propitiate different deities/divinities and in the Ayurvedic works by Susruta, Charaka and Vagbhata also there was a mention of medicinal uses of red rices (Ahuja *et al.*, 2007). Red kernelled landraces form an important group of all the rice landraces grown in Asian countries including India and are considered highly nutritive and having medicinal value as well. Some of the red rice landraces collected in Western Ghats *viz.*, *Mullampunjan* and *Njavara* are reported by the locals as useful for medicinal purposes particularly to relieve rheumatic pains.

Interestingly, *Mullampunjan,* a rice landrace with extra-long awns is reportedly cultivated to prevent entry of elephants into the fields. High market demand for white rices and introduction of improved/ high-yielding rice cultivars resulted in drastic reduction of area under red rice cultivation in India. However, recognizing their importance, improved cultivars of red rice with special traits were released by various institutions in India for various abiotic stresses *viz.*, cold conditions (*Jatu, Matali, Majehra, Jhaildu, Lal nakanda* 41), deep water/ flood/submergence situations and drought conditions. *Ex situ* and *in situ* conservation strategies are ideally suited for these cold adapted landraces. There is a need for encouragement for the farmers from Western Ghats region to sustain the cultivation of red rice landraces in view of good potential. Two cold adapted rice landraces *viz.*, *Jeerakasala* and *Ghandakasala* were granted protection under Geographical Indications (Registration and Protection) Act, 1999 from Wayanad region of Western Ghats. The utilization of long adapted cold

Table 1. Variability for grain and kernel characters in cold adapted rice landraces from Western Ghats

Trait	Minimum	Maximum	Mean ± standard error	Standard deviation	Coefficient of variation (%)
Grain length (mm)	5.58	9.47	7.87±0.11	0.88	11.18
Grain breadth (mm)	2.20	3.79	2.97±0.04	0.37	12.46
100-seed weight (g)	0.90	3.50	2.44±0.08	0.64	26.23
Kernel length (mm)	3.72	6.63	5.46±0.08	0.66	12.09
Kernel breadth (mm)	2.40	3.00	2.62±0.03	0.25	9.54
Kernel length/breadth ratio	1.67	2.67	2.09±0.03	0.24	11.48

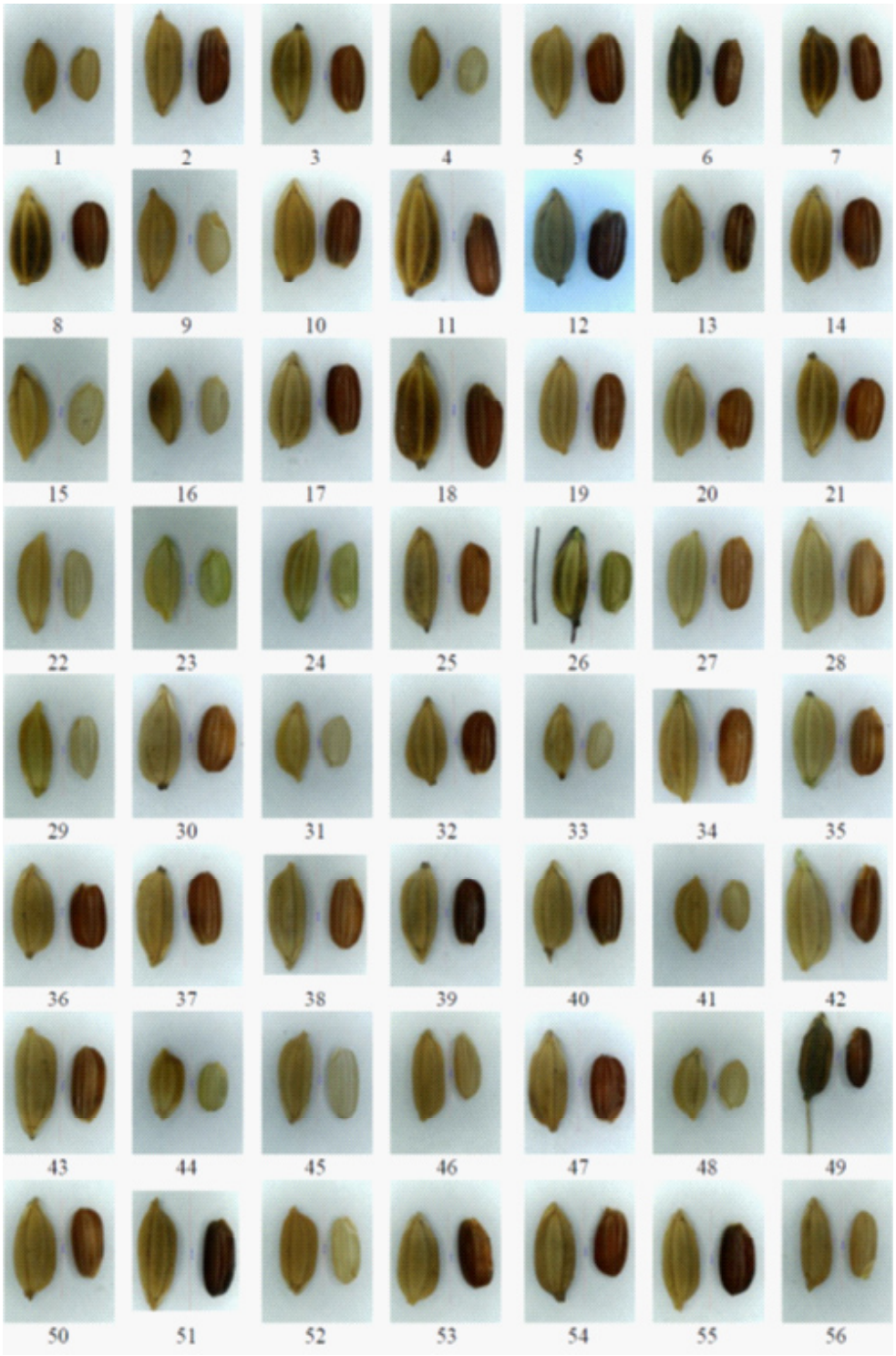

Fig. 1. 1) Ghandakasala; 2) Bharathy; 3) Kadaikannan; 4) Ghandkasala; 5) Adukkan; 6) Mullampunjan; 7) Chinthamani; 8) Karuvali; 9) Ghandkasala; 10) Mannuvilaiyan; 11) Maranellu; 12) Kudaivilaiyan; 13) Mannuvilaiyan; 14) Kalyani; 15) Ponni; 16) Ghandakasala; 17) Maranellu; 18) Chinthamani; 19) Adhira; 20) Palthondi; 21) Kattathondi; 22) Jeerakasala; 23) Mallikuruvai; 24) Jeerakasala; 25) Thondi; 26) Thondi (variant); 27) Valisuri; 28) Cherutti; 29) Jeerakasala; 30) Adukkan; 31) Wayanad Jeerakasala; 32) Edavaka; 33) Wayanad Ghandakasala; 34) Cherutti; 35) Cherutti (variant); 36) Chettuvali; 37) Kudaivali; 38) Aiyrankanni; 39) Maranellu; 40) Pavalam; 41) Gandhakasala; 42) Valisuri; 43) Adukkan; 44) Channa; 45) Masuri; 46) Nellu; 47) Kuruvatti; 48) Ghandakasala; 49) Njavara; 50) Maranellu; 51) Vellainellu; 52) IR-20; 53) Malainellu; 54) Karunellu; 55) Malainellu; 56) Nellu

tolerant rice landraces from Western Ghats in breeding programmes to derive varieties and hybrids which are resistant/ tolerant to cold conditions will substantially increase the production and productivity in the regime of climate change.

A set of the cold adapted rice germplasm is being conserved in the National Gene Bank at National Bureau of Plant Genetic Resources (NBPGR), New Delhi and also at Ramiah Gene Bank, Tamil Nadu Agricultural University, Coimbatore. This material was also shared with the breeders of Directorate of Rice Research, Hyderabad and Tamil Nadu Agricultural University, Coimbatore for characterization, evaluation and utilization in breeding programmes.

Cold weather damage is a serious problem affecting rice production in Western Ghat area and with the dwindling patronage for cultivation of native landraces, the collection efforts are timely to conserve the cold adapted rice genetic resources.

Acknowledgements

The authors are thankful to the Directors, NBPGR, New Delhi; DRR, Hyderabad and Director of Research, TNAU, Coimbatore for support and help. The generous funding for this exploration programme by Indian Council of Agricultural Research through NICRA project is gratefully acknowledged.

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Short Communication

Evaluation of Released Varieties and Hybrids of Pearl Millet for Seed and Stover Yields in Hot Arid Climate of Rajasthan

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(Received: 08 October 2013; Revised: 31 January 2014; Accepted: 13 March 2014)

Nine open pollinated varieties (OPVs) during *kharif* 2007, 2008 and 2010 and nine hybrids during *kharif* 2011 and 2012 were evaluated for seed yield and stover yield in hot arid climate of Rajasthan at Agricultural Research Station, Keshwana, Jalore. The significant differences among experimental varieties and hybrids for seed as well as stover yields were observed. In case of OPVs, higher seed yield per hectare was recorded for Raj-171 (2,606 kg), JBV-2 (2,565 kg) and Pusa-266 (2,565 kg). However, higher stover yield per hectare was observed for JBV-3 (14,930 kg), JBV-2 (13,009 kg) and Pusa-266 (12,894 kg). Similarly, hybrids GHB-744 (3,938 kg), RHB-173 (3,779 kg) and GHB-732 (3,465 kg) out yielded other hybrids in terms of seed yield per hectare. The higher stover yield per hectare was exhibited by RHB-173 (7,765 kg), GHB-744 (5,942 kg) and HHB-197 (5,912 kg). Though in different years but under similar agronomic practices in the arid and hot climatic conditions OPVs out yielded hybrids by 93.38% for stover yield whereas, hybrids out yielded OPVs by 31.74% for seed yield. The hybrid HHB-67 improved was early and took 34 days for exhibiting 50% flowering.

Key Words: Hybrids, Open pollinated varieties, Pearl millet, Seed yield, Stover yield

Pearl millet [*Pennisetum glaucum* (L). R. Br.] is one of the most important *kharif* cereals of arid and semi-arid environment. It is primarily used as food grain for human consumption and fodder for animals. In Rajasthan, pearl millet occupied an area of 4.96 million hectares (average of 2006-07 to 2010-11) with grain production of 4.03 million tonnes. Barmer, Jodhpur, Nagaur, Churu, Jalore, Sikar, Jaipur, Jhunjhunu, Alwar and Bikaner are major pearl millet growing districts of the state. The average productivity of pearl millet in Rajasthan is 776 kg/ha (Anonymous, 2011-12). Pearl millet is largely grown as rainfed in Rajasthan, therefore, its production and productivity is highly erratic and varies year after year with the amount and distribution of rainfall. Under such adverse growing conditions, selection of high yielding cultivars with appropriate maturity duration attains paramount importance.

In pearl millet improvement programme there is successful development of high yielding hybrids and open pollinated varieties with good adaptation to diverse environments. Despite the availability of newly developed cultivars, many of the obsolete varieties and traditional landraces are still occupying large area under cultivation and contributing to poor productivity of pearl millet. Hence, there is an urgent need to replace them with newly developed high potential cultivars for better production and profitability. Present studies were conducted to evaluate released hybrids and open pollinated varieties (OPVs) of pearl millet for seed and stover yields in arid Rajasthan.

Materials and Methods

Two separate experiments on released pearl millet varieties and hybrids were conducted at experimental farm of Agricultural Research Station, Keshwana, Jalore (latitude of 25º 22'N and longitude of 72º 58'E, elevation 162 msl). The experimental site has tropical arid climate with mean annual rainfall of 421 mm. Soil at the site was clay loam, slightly saline (pH 8.7) and low in organic carbon (0.23%). In first experiment, nine early to medium maturity OPVs were tested for three years and planting was done on 03.07.2007, 07.07.2008 and 11.07.2010, respectively. In second experiment, nine hybrids were tested for two years and planting was done on 15.07.2011 and 20.07.2012, respectively. Experiments were conducted during rainy season but under moisture stress situation irrigation was also applied as per requirement of the crop.

Both experiments were laid out in randomized block design with 3 replications. Plot size was kept 2.5 m x 4.0 m accommodating 8 rows at 30 cm distance with seed rate of 4 kg/ha. A fertilizer dose of N 40 kg/ha

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and P 20 kg/ha was applied to the crop. A half dose of N and full dose of P were applied at the time of sowing in the form of urea and DAP. The remaining half dose of the N was top dressed in the form of urea at 20 days after sowing. Additional spray of 1% soluble NPK (19:19:19) at flowering and grain development stage was also applied to the crop for harvesting the higher yield. Two hand weedings were carried out 15 and 30 days after sowing, to have the crop free from weeds. Data recorded for grain and stover yield was analyzed using standard analysis of variance (ANOVA) through Excel software of Microsoft Office.

Performance of OPVs: Differences among open pollinated varieties for seed yield were found statistically significant during all three years. Year-wise average seed yield ranged between 2,178 and 2,674 kg/ha (Table 1). The experiment was conducted during rainy season, therefore, fluctuation in the productivity is largely affected by the amount and distribution of rainfall along with the change in temperature and relative humidity in different years. Variety-wise seed yield ranged between 1,832 and 3,012 with the average of 2,429 kg/ha. Average number of days to 50% flowering among varieties varied between 34 and 47 and earliest flowering was observed in CZP-9802. On the basis of three years' yield data, varieties such as Raj-171, JBV-2, Pusa-266, and JBV-3 performed above average and provided grain yield of 2,606; 2,565; 2,565 and 2,453 kg/ha, respectively (Table 1). The lowest seed yield was recorded in ICTP-8203. Air dried average stover yield ranged between 7,281 and 14,930 kg/ha with the average of 11,106 kg/ha, and maximum has been produced by JBV-3 followed by JBV-2, Pusa-266 and Raj-171 with 13,009, 12,894 and 12,828 kg/ha, respectively. The lowest stover yield was recorded in CZP-9802.

Among OPVs, Raj-171, JBV-2, Pusa-266, and JBV-3 appears to be promising and appropriate for dual purpose cultivation in arid Rajasthan. Pusa Composite-443 tested for one year also seems to be a promising dual purpose variety but it needs further testing for validation.

Performance of Hybrids: Differences among hybrids for seed and stover yield were found statistically significant in both the years (Table 2). Year-wise average seed yield ranged between 2,603 and 3,797 kg/ha; however, variety-wise it varied between 2,302 and 3,938 with the average of 3,200 kg/ha. Days to 50% flowering among different hybrids varied between 34 and 42 and earliest flowering was observed in HHB-67 Imp. On the basis of two years' yield data, hybrids *viz.*, GHB-744, RHB-173, GHB-732, RHB-121 and GHB-719 performed above average and provided seed yield of 3,938; 3,779; 3,465; 3,384 and 3,317 kg/ha, respectively (Table 2). The lowest seed yield was recorded in HHB-67 Imp. Air dried stover yield ranged between 4,952 and 7,765 kg/ha with the average of 5,743 kg/ha, and maximum has been produced by RHB-173. Therefore, based on the seed and stover productivity, GHB-744 and RHB-173 appears to be higher productive and appropriate hybrids for arid Rajasthan. Akmal *et al*. (2002), Bidinger *et al*. (2008), Kaushik and Gautam (1987) and Choi *et al*. (1988) studied the varietal performance in pearl millet and reported similar results.

Table 1. Seed and stover yield of open pollinated varieties of pearl millet

Open pollinated varieties	Seed yield (kg/ha)				Mean stover yield (kg/ha)	Days to 50% flowering
	2010	2008	2007	Mean		
CZP-9802	2,253	2,273	2,273	2,266	7,281	34
ICMV-221	2,363	2,047	2,100	2,170	10,594	37
ICTP-8203	1,889	1,947	1,660	1,832	8,878	42
JBV-2	2,747	2,740	2,207	2,565	13,009	46
JBV-3	3,383	1,743	2,233	2,453	14,930	47
Pusa-266	2,892	2,537	2,267	2,565	12,894	45
Pusa-383	2,625	2,033	2,520	2,393	10,472	43
Pusa Comp.443	3,012	–	–	3,012	9,067	43
Raj-171	2,904	2,107	2,807	2,606	12,828	46
Mean	2,674	2,178	2,258	2,429	11,106	–
CD (p=0.05)	515	375	377	–	–	–

Table 2. Seed and stover yield of different hybrids of pearl millet

Hybrids	Seed yield (kg/ha)			Stover yield (kg/ha)			Days to 50% flowering
	2011	2012	Mean	2011	2012	Mean	
GHB 538	3,852	2,377	3,115	5,648	5,223	5,436	37
GHB 719	3,956	2,677	3,317	6,933	4,257	5,595	40
GHB 732	3,830	3,100	3,465	5,933	4,833	5,383	41
GHB 744	4,968	2,907	3,938	7,657	4,227	5,942	42
HHB 67 Imp	2,893	1,710	2,302	4,833	6,490	5,662	34
HHB 197	3,902	2,367	3,135	5,990	5,833	5,912	37
RHB 121	3,925	2,843	3,384	6,117	3,957	5,037	39
RHB 173	4,455	3,103	3,779	8,367	7,163	7,765	39
RHB 177	2,400	2,343	2,372	2,847	7,057	4,952	37
Mean	3,797	2,603	3,200	6,036	5,449	5,743	–
CD (p=0.05)	448	431	–	900	1,393	–	–

Table 3. Comparative performance of pearl millet hybrids and open pollinated varieties

Particulars	Seed yield (kg/ha)	Stover yield (kg/ha)	Cost of seed (₹/ha)	Total returns (₹/ha)	Additional benefit (₹/ha)
Open pollinated varieties	2,429	11,106	88.00	50,665.00	–
Hybrids	3,200	5,743	540.00	53,414.50	2,297.50

Market rate of pearl millet grain: ₹ 14/kg; and stover: ₹ 1.50/kg
Market rate of pearl millet hybrid seed: ₹ 135/kg; and OPVs seed: ₹ 22/kg

Comparative Performance of Hybrids and OPVs: The experiments on OPVs and hybrids were conducted in different years but under similar agronomic practices at same location. The average performance of both groups of cultivars revealed that OPVs out yielded hybrids by 93.38% for stover yield whereas, hybrids out yielded OPVs by 31.74% for seed yield. Economic analysis indicates that in general, hybrid cultivation is more profitable than OPVs in arid Rajasthan. An additional income of ₹ 2,297.50 per hectare may be earned merely by the use of hybrid seed (Table 3). OPVs appear to be more suitable for dual purpose cultivation.

Pearl millet hybrids and OPVs exhibited a wide range of variability in flowering, seed yield and stover yield. OPVs *viz.,* Raj-171, JBV-2, Pusa-266, and JBV-3; and hybrids GHB-744, RHB-173, GHB-732, RHB-121 and GHB-719 were found to be high yielding and appropriate for cultivation in arid Rajasthan.

Acknowledgements

The cooperation of Project Coordinator, All India Coordinated Pearl Millet Improvement Project, Jodhpur is thankfully acknowledged for providing seed material of pearl millet hybrids and OPVs for experimentation.

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Plant Germplasm Registration Notice*

The Plant Germplasm Registration Committee of ICAR in its XXVII[th] meeting held on July 31, 2013 at the National Bureau of Plant Genetic Resources, New Delhi approved the registration of following 25 germplasm lines out of 123 proposals considered. The information on registered germplasm is published with the purpose to disseminate the information to respective breeders for utilization of these genetic stocks in their crop improvement programmes. Upon request, the developer(s)/author(s) is/are obliged to distribute the material for crop improvement programme of National Agricultural Research System.

1. HW 3601 (IC0598203; INGR13051), a Wheat (*Triticum aestivum*) Germplasm with Resistance to Brown Black Rust, it Carries Gene for Leaf Rust Resistant, *Lr* 19 and Stem Rust Resistant *Sr* 36

VK Vikas[1], M Sivasamy[1], P Jayaprakash[1], Jagdish Kumar[1], EP Venkatasalam[1], Vinod[2], Sushma Tiwari[2], RS Tomar[2], Bhanwar Singh[2], JB Sharma[2], SMS Tomar[2] and Suresh Chand[3]

HW 3631 (IC0598414; INGR13052), a Wheat (*Triticum aestivum*) Germplasm with Resistance to Stem and Leaf Rust, it Carries Gene for Leaf Rust Resistance *Lr*19 and Stem Rust Resistance *Sr*36

VK Vikas[1*], M Sivasamy[1], P Jayaprakash[1], Jagdish Kumar[1], Vinod[2], Sushma Tiwari[2], RS Tomar[2], Bhanwar Singh[2], JB Sharma[2], SMS Tomar[2] and Suresh Chand[3]

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The stem and leaf rusts of wheat respectively caused by *Puccinia graminis* Pers. f.sp. *tritici* Eriks. & E. Henn. (*Pgt*) and *P. triticina* Eriks. (*Pt*) are of countrywide importance in India. Both the diseases survive and spread from the source of their primary inocula available all-the-year-around in Nilgiri / Palni hills of South Hill Zone and Himalayas of North Hill Zone (Nagarajan and Joshi, 1985). From epidemiological point of view, the Pgt urediospore dispersal in India is unidirectional from the southern hills only (Nagarajan *et al*., 2006). On the other hand, primary inoculum of *Pt* originates both from Nilgiri/Palni hills and Nepal Himalayas, establish initial disease foci respectively in Peninsular/ Central India and adjoining Himalayan tarai areas and spread further to other parts of the country (Nagarajan and Joshi, 1985).

Central zone (CZ) is the migratory route of stem and leaf rust urediospores originating from Nilgiri/Palni hills. Rust inocula disseminate through CZ with the help of wind systems (as defined in Indian Stem Rust Rules) to main wheat growing areas in Northern plains of India (Nagarajan and Joshi, 1985). Rust inoculum built up on any susceptible variety in CZ will be of serious threat to the wheat crop in the Indian wheat bowl of NWPZ. Hence, the development and release of rust resistant high yielding wheat varieties and their cultivation in CZ is the envisaged strategy of wheat rust control which rests on diversifying the genetic basis of rust resistance for curtailing build up of rust inoculum in CZ.

Keeping in mind the objective of rust free production of wheat in CZ and to check the northwards spread of leaf and stem rust inoculum originating from south Indian hills, stem rust (*Sr*) and leaf rust (*Lr*) resistant genetic stocks were developed at Indian Agricultural Research Institute, Regional Station, Wellington-643 231, The Nilgiris, Tamilnadu, by the introgression of two independent segments of linked genes, *Sr*25/*Lr*19 (from *Agropyron elongatum*) and *Sr*36/*Pm*6 (from *Triticum timopheevi*) into the genetic background of

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Table 1. Seedling reactions of parents and genetic stocks to selected pathotypes of stem and leaf rusts

Sl. No.	Parents/Genetic stocks	Reaction to pathotypes							
		Stem rust			Leaf rust				
		40A	40-1	117-6	12-3	77-5	77-7	77-8	104-2
1	Cook*6/C 80-1	; 1	; 1	; 1	; 1+	0 ;	; 1	3C	;
2	C 306	4	4	4	3+	3+	2C	3C	3+
3	HW 3601	; 1	; 1	; 1	; 1	; 1	;	3	; 1
4	WH 147	4	4	4	3+	3+	3+	3+	3+
5	HW 3631	; 1	; 1	; 1	; 1	; 1	; 1	3+	; 1

high yielding, well adapted and rust susceptible wheat cultivars, C306 and WH147 of CZ.

Australian line, Cook*6/C 80-1, carrying stem/leaf rust resistance genes, *Sr*25/*Lr*19 and *Sr*36/*Pm6* used as donor parent and rust susceptible well adapted cultivars, C306 and WH147 were used as recurrent/recipient parents. Three cycles of back crossing were performed and final constitution made at BC_3-F_5 generation. Evaluation of the BC_3-F_5 lines along with their recurrent parents and controls carrying specific *Sr* and *Lr* genes under natural and artificial conditions indicated that the newly constituted lines confer resistance to most of the leaf and stem rust pathotypes at seedling (Table 1) and adult plant stages. Presence of *Sr*25/*Lr*19 and *Sr*36/*Pm6* were validated by applying the SCAR markers SCS 265, SCS 253 and Gb for *Lr*19 and SSR marker Stm 773 for *Sr*36 (Sivasamy *et al.,* 2009).

Thus, the newly constituted lines would serve as donor for leaf and stem rust resistance genes and the availability of combination of major and genetically diverse resistance genes in well adapted wheat cultivars would facilitate the strategic deployment to achieve enhanced resistance.

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2. UP 2672 (IC0597682; INGR13053), a Wheat (*Triticum aestivum*) Germplasm with High Protein Content (14.1%)

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UP 2672 possesses high protein content i.e.>14%. It was continuously tested for 5 years at many locations and has given consistently high protein content (>14%). In addition to high protein content it also possesses high thousand grain weight (46.6 g) and was found good for flour recovery. It is being used as check in Quality Component Screening Nursery (QCSN) for protein content.

3. MCM-11/01 (IC0524594; INGR13054), a Maize (*Zea mays*) Germplasm with 3-4 Cobs per Plant and Early Maturing

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Maize (*Zea mays* L.) is one of the important crops of Nagaland state in NEH region of India. The production of maize in the state is 0.13 mT with an average yield of ~2.0 tonnes/ha. Maize yield is determined by a number of traits including cobs/plant. Generally, 1-2 cobs/plant are observed in the present cultivars. A maize line (MCM-11/01) with multiple cobs (3-5) was selected from trial plot of an indigenous collection (IC0524594) in 2009. This accession was collected from Zubza village (latitude 25.7ºN, longitude 94.03ºE, altitude 983 m) of Kohima (Nagaland). Selected plants were grown in isolation for two consecutive years (2010 and 2011) at NBPGR Regional Station, Umiam (Meghalaya). Data were recorded on a number of agro-morphological traits. Mean data for some of the traits along with three check varieties are presented in Table 1. The MCM-11/01 had higher (3.4) number of cobs/plant, while all checks recorded single cob per plant. This is a unique trait as it has not been observed in the existing germplasm of NEH region. Although the selection had a higher number of cobs/plant, the grain yield/plant was not significantly higher than the checks, mainly due to its small grain size. The MCM-11/01 had dark brown coloured husk and cream coloured kernel. Breeding approaches can be initiated to incorporate this multi-cob trait into improved maize varieties.

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Table 1. Agro-morphological characteristics of selection (MCM-11/01), parent (IC524594) and checks

Trait	MCM-11/01	IC524594	RCM-1-3	Delhi check	Local red
No. of cobs/plant	3.4	1.0	1.0	1.0	1.0
Cob length (cm)	20.0	20.4	23.0	24.8	27.0
Cob width (cm)	4.8	4.4	5.2	3.4	5.8
Cob height (cm)	93.3	188	174.0	134.0	160.0
Plant height (cm)	200	348	307	268	262
Days to maturity	114	115	112	118	115
100-seed weight (g)	18.3	24.2	24.9	25.3	30.0
Grain yield/plant (g)	128.4	113.4	106.2	130.5	125.4
Husk cover	Good	Intermediate	Intermediate	Intermediate	Good
Husk colour at maturity	Dark brown	Dark brown	Dark brown	Dark brown	Dark brown
Kernel row arrangement	Regular	Straight	Straight	Straight	Straight
Kernel colour	Dull yellow	Yellow	Yellow	Yellow	Yellow
Grain shape	Indented	Indented	Indented	Indented	Indented
Grain size	Medium	Medium	Medium	Bold	Bold

4. SSG 226 (IC0597771; INGR13055), a Sorghum (*Sorghum bicolor*) Germplasm with Low Hydrocyanic Acid (HCN) (66.6 ppm), High Digestibility and High Leaf-Stem Ratio

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SSG 226 was the mutagenic derivative of the forage sorghum variety, SSG 59-3 which was released in 1974. To date, it has been used as a check variety in All India Coordinated Sorghum Improvement Project forage sorghum trials, since a multi-cut variety that could perform better than SSG 59-3 was not available at the National level. The line, SSG 226 was the outcome of the efforts made to create variability in SSG 59-3 and to identify lines with improved quality. Leaf parameters such as leaf length, leaf breadth are also important in forage sorghum as these increase the intake by the animal. Among the quality traits, low Hydrocyanic acid (HCN), high protein and high digestibility are important as far as forage sorghum is concerned. HCN is an anti-nutritional factor in forage sorghum which is potentially toxic to the animal when fed on 30-35 days old sorghum crop. Digestibility of fodder is the most important forage quality parameter which helps in better absorption of the feed taken in by the animal and studies show that small changes of IVDMD of 3-4% units would result in improvements of 17-24% in daily gains and production per hectare. SSG 226 had the lowest level of HCN (66.6 ppm vs 82.9 ppm of SSG 59-3) among all the lines tested with high IVDMD values compared to SSG 59-3. Its leaf-stem ratio was more compared to SSG 59-3. SSG 226 had the lowest level of HCN (66.6 ppm vs 82.9 ppm of SSG 59-3) among all the lines tested with high IVDMD values compared to SSG 59-3 (Table 1). Its leaf-stem ratio was more compared to SSG 59-3. This line with a combination of improved traits may be of interest to forage sorghum breeder aiming towards improving multi-cut forage sorghum for earliness and fodder quality.

Table 1. Performance of SSG 226 over two years

Line	HCN			IVDMD %			Leaf: Stem ratio		
	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pool
SSG 226	64.05	69.2	66.6	51.57	54.63	53.10	0.44	0.34	0.39
SSG 59-3	90.05	75.7	82.9	46.06	48.18	47.12	0.23	0.35	0.29
lsd 5%	19.20	14.0	15.6	03.10	04.28	04.0	0.02	0.14	0.10

5. NSS-7809 (IC0283734; INGR13056), a Sorghum (*Sorghum bicolor*) Germplasm with Popping Traits

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Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is an annual, diploid, highly allogamous cereal crop. It is cultivated in a vast range of environmental conditions including frequent drought events and poor soil fertility. Popping trait is a potential area to be studied in the case of pearl millet as these grains can also be popped like corn, sorghum and rice (Murugeshan, 1986; Murty *et al.,* 1988); but its popping yields are usually low (<40%). Therefore, the present study was aimed to evaluate and search the unique germplasm/genetic stock for popping

trait, so that the identified germplasm can be used for genetics study as well as trait introgression into elite cultivars through appropriate breeding tools.

Morpho-agronomic Characteristics: The accession IC 283734 (INGR 13056) was identified with unique popping traits. This acc. had high popping yield (76.23±2.6%), puffing index (10.31±0.58), pop size (8.84±0.68mm) and expansion ratio around 3.07 %. It was having early maturity (82±2 days) and tall plant height (230±5 cm). The spike length, spike girth and seed weight of this accession were found to be 23.7±1.2 cm, 2.51±0.24 cm and 13.2±1.1 g respectively. Apart from this it has nodal tillers, nodal pubescence and short bristle length.

Associated Characters and Cultivated Practices: This accession is moderately resistant for blast and rust and resistant for downy mildew disease based on field screening. It can be grown for dual purpose to be used as fodder as well as food. Its early maturity property has the added advantage for fitting into multiple cropping systems. This accession belongs to related species *P. squamulatum* and was collected from Nandhikotkur district of Andhra Pradesh. It can also be used for identification of causal gene, inheritance of the trait and mapping and tagging of underlying genes by making crosses between contrast parents.

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6. BAR-062 (IC426765; INGR13057), a Blackgram (*Vigna mungo*) Germplasm as a Photosensitive Line (Flowers only in Post Rainy/*Rabi* season)

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Black gram *(Vigna mungo* (L) Hepper) also known as *urdbean*, *minumulu* (Telugu), *mash*, *black mapte* etc. is an important short duration pulse crop grown in many parts of India. Blackgram is of very ancient cultivation and believed to have originated in India (Purseglove, 1974). Breeding efforts to develop improved, high yielding varieties in black gram have resulted in release of 107 varieties in India catering to the diverse agro ecological regions of the country and local preferences. Most of the varieties released are photo-insensitive and therefore can be grown during any time of the year. A perusal of NORV database indicated the availability of only one photosensitive line (LBG-17) is known to exist in this crop, which flowers in short-day conditions (www.nbpgr.ernet.in). However, there is a need to identify more photosensitive lines in order to have parental diversity for varietal development, keeping the location specific requirements. One such accession was identified during evaluation and characterisation of germplasm collected from Andhra Pradesh.

Morpho-agronomic Characteristics: One hundred and sixty accessions of black gram germplasm lines were grown at the NBPGR RS experimental farm, Hyderabad, India, during Rainy 2005, 2006 and Post-rainy 2005-06, 2006-07 seasons for evaluation. The days to 50% flowering of the germplasm lines ranged from 34 to 52 days in rainy seasons and 46 days to 60 days in post rainy seasons. An accession *viz.* IC426765 (Collector No: BAR-62), did not flower in both the rainy seasons. However the above mentioned accession produced productive pods during the successive post-rainy seasons and recorded 49 days to 50% flowering indicating its photosensitive nature (Babu Abraham *et al.,* 2013). Morpho-agronomic traits of the blackgram germplasm accession are given below:

Morpho-agronomic traits of blackgram accession – IC426765

Descriptor	Descriptor state
Plant habit	Indeterminate
Primary leaf shape	Ovate lanceolate
Leaf colour	Dark green
Leaf pubescence	Dense
Pod pubescence	Dense
Seed colour	Black
Mean of two seasons (post rainy2005-06 & 2006-07)	
Days to 50% flowering (no.)	49
Plant height (cm)	20.51
Primary branches/plant (no.)	2.8
Clusters/plant (no.)	15
Pods/cluster (no.)	3.6
Seeds/pod (no.)	4.77
100-seed weight (g)	4.8
Pod length (cm)	3.75
Peduncle length (cm)	5.8
Pods/plant (no.)	17.4

The performance of this photosensitive line was analyzed in comparison to released check varieties in the post rainy 2005-06 and 2006-07. In post rainy 2005-06, accession IC426765 performed better than LBG-20 in plant height and 100-seed weight (CD 0.05).The superior performance of these accession in some of the quantitative traits *viz.,* plant height and 100-seed weight over released checks indicate its potential in the breeding programmes for black gram crop improvement.

IC426765 had indeterminate growth habit and dense pod pubescence. These qualitative characters indicate that it is a primitive landrace. In addition, the qualitative characteristics of this photosensitive accession were compared with Krishnayya (LBG 17), a photosensitive variety released by Acharya NG Ranga Agricultural University, Andhra Pradesh. It differed from the released variety (LBG-17) in leaf colour, primary leaf shape and seed colour indicating the different genetic background.

This accession IC426765 (BAR-62) is a new report of photosensitive black gram germplasm line. The dominance of photoperiod insensitivity over photoperiod sensitivity has already been reported (Verma, 1971). It is well documented that, the photosensitive trait in any plant is a primitive character as loss of photoperiodic response is considered as a sign of domestication (Paroda *et al.*, 1988). Further, the alternate use of the accession such as forage, cover crop and green manure crop can also be exploited during the rainy season by detailed studies on the biomass yield and nitrogen fixation in the field in view of the prolonged nodulation in the absence of reproductive phase. Disintegration of the nodules has been correlated with the onset of pod formation stage (Singh, 1974). Therefore, this line can be utilized in the pulses breeding programmes to develop multipurpose varieties of blackgram suitable for different agro-climatic zones of Andhra Pradesh.

The passport data details show that, IC426765 was collected from Killoyi village, Mandasa mandal in Srikakulam district of Andhra Pradesh.

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7. IC0486088 (IC0486088; INGR13058), an Upright Podding Chickpea Genotype Suitable for Mechanical Harvesting

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Cultivated chickpea (*Cicer arientinum* L.) has two distinct forms, *i.e. Desi* (small seeded, angular shaped and colored seeds with high percentage of fibre) and *Kabuli* types (large seeded, owl shaped, beige colored seeds with a low percentage of fibre). The average yield of chickpea is still low in India and further genetic improvement is constrained by the non-availability of appropriate germplasm. Further, there is a scope for widening the genetic base of cultivated varieties through pre-breeding. Plant genetic resources are the reservoir of useful gene/allele sources and provide basic raw materials for further genetic improvement.

The National Bureau of Plant Genetic Resources, New Delhi, undertook a large scale characterization and evaluation programme of the entire gene bank chickpea germplasm at Mahatma Phule Krishi Vidyapeeth (MPKV) Rahuri, Maharashtra, in a collaborative mode to enhance their proper utilization during *rabi* 2011-12. The experiment was conducted at the Pulse Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri in which a total of 18,873 germplasm accessions were grown under Augmented Block Design with three improved check varieties, *viz*., *Vijay, Digvijay* and *Vishal.*

The observations were recorded on twenty agro-morphological traits in the entire chickpea germplasm. While recording these various traits in the chickpea germplasm, one accession namely, IC486088 was found to bear upright peduncle and podding behaviour. This unique trait was further validated in the off-season Himalayan nursery at Chaudhary Sarwan Kumar, Himachal Pradesh Agricultural University, Research Station, Sangla during summer 2012 and the upright podding behaviour was found to be true to its type. The upright podding trait has a special significance for its possible utility in mechanical harvesting of chickpea which is becoming increasingly important in view of huge labour requirement for manual harvesting of crop and the associated drudgery involved with it. This unique accession bearing special trait of interest can be further investigated to understand its inheritance pattern and can be suitably incorporated in future chickpea breeding programme for developing varieties suitable for mechanical harvesting.

8. IND 001 – Kappadam Tall (IC0430667; INGR13059), a Coconut (*Cocos nucifera*) Germplasm with Low Husk (33 to 36%) and High Copra Content (215 to 280 g)

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Kappadam Tall coconut – a selection from the west coast populations (WCT) coconut population has scientific and commercial value as it has potential to be used in breeding programmes for increased fruit size and lower husk content. The accession also known as 'Chappadan' in some parts of Kerala, is a robust palm from the South-west coast of India. The accession was collected and planted at CPCRI, Kasaragod during 1935. An *inter se* mated population of this collection is conserved in the National Gene Bank at CPCRI.

Morpho-agronomic Traits: Compared to the other Indian varieties from WCT, this accession gives heaviest fruits with thinner husk. The fruits of this selection are predominantly green, oblong to round in shape. The palms of this selection are tall statured with clear bole on the stem and about 25 leaf scars over the stem between 1 and 2 m from the ground. The leaves are longer (3.7 m) with broader and longer leaflets. The palms are strictly cross pollinating as there is no overlapping of male and female phases within and between inflorescences. The palm starts flowering after 6 to 7 years of age yielding heavier nuts. The average fruit weight is around 1200 g with dehusked fruit weight of about 800 g. The kernel weight ranged from 400 to 550 g which gives 215 to 280 g of copra.

Cultivation Practices: The palms of Kappdam Tall selection can be grown with the regular recommended package of practices with summer irrigation for sustained yield of nuts. It can be grown in all coconut growing regions for conservation and further utilization. It has good potential for use in breeding programmes aiming for increasing the nut size and copra yield.

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9. IND 030-Laccadive Micro Tall (IC0430669; INGR13060), a Coconut (*Cocos nucifera*) Germplasm with Cluster Bearing Heavy Bunches of Micro Nuts

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The accession was first introduced from Lakshadweep islands to mainland India in 1940, Conserved in field gene banks and evaluated in replicated trials. The Laccadive Micro Tall is a selection from the tall coconut populations of Lakshadweep Islands known for cluster bearing, heavy bunches of micro nuts with high oil content. The accession is unique for its heavy bunches with large number of micro nuts and has scientific and commercial value as it has recorded highest copra oil content (75%) among the conserved coconut accessions. The accession is also found suitable for ball copra production as the very slow rate of germination, small

nuts with less nut water aiding in very low spoilage during storage for making ball copra.

Morpho-agronomic Traits: The palms of this selection are tall statured with clear bole on the stem. The palms start flowering after 6 to 7 years of age but profuse fruit production generally observed after 9 to 10 years of planting. The mean annual bunch production is 11 with a range of 8 to 12. The average yield varies from 100 to 320 fruits per annum in Kasaragod whereas still higher in selected palms in few years. The palms are mostly alternate bearers, nuts are small, kernel is thick with average copra content of about 90 g. The copra oil content is 75%, the highest recorded among the germplasm evaluated so far. The nuts of Laccadive Micro tall are suitable for production of ball copra mainly due to the slow rate of germination resulting in lowest damage during storage which is required for ball copra production. The inflorescences are longer with strong peduncle with partial overlapping of male and female phases in alternate years during successive inflorescence production making the palms self pollinated to some extent. The fruits are green or greenish brown, oval to round shaped. The dehusked nuts are also oval or round shaped with a pointed tip.

Cultivation Practices: The palms of Laccadive Micro Tall selection can be grown with the regular recommended package of practices with irrigation for sustained yield of nuts. It can be grown in all coconut growing regions for conservation and further utilization. It has good potential for use in breeding programmes aiming for increasing the nut yield, oil content and more copra out turn.

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10. IND 092 - Cameroon Red Dwarf (IC0598219; INGR13061), a Dwarf Coconut (*Cocos nucifera*) Germplasm with Distinct Bright Orange Colored Nuts. Higher Content of Tender Nut Water and High Copra Content

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The said type of CRD selection was made from the originally introduced orange dwarf population from Cote d'Ivoire and conserved during 1977 in the field gene bank at CPCRI. Palms developed from the seed nuts through *inter se* mating of selected mother palms have been conserved at National Genebank at CPCRI. After evaluation for decades, the present selection was made having higher copra among the dwarf accessions with bright orange coloured fruits among the germplasm with dwarf plant stature. The nuts produced from the selected palms were used to establish progeny blocks at CPCRI. The selection has both scientific and commercial value owing to the dwarfness coupled with attractive orange fruits with good quantity of tender nut water and high copra content.

Morpho-agronomic Traits: The palms of this dwarf selection are dwarf statured attaining a height of 4.4 m at 18 years of planting. The palm does not possess bole but the stem is not very slender with a girth of about 76 cm. The internodal length is very short and the length of 10 internodes is about 25 cm. The palms start flowering after 6 years of age. The inflorescences are short with

strong peduncle with complete overlapping of male and female phases making the palms autogamous. The fruits are attractive orange red in colour, medium sized, oval shaped with a pointed apical end. The dehusked nuts are also oval, medium sized with strong shell and thick kernel. The palms tend to bear in alternate years with an average bunch production of 10 per year. The average nut yield is 80 fruits per palm per year. The fruit weighs about 945 g, with a smaller percentage of husk to whole fruit weight (27.8%). The nut without the husk weighs about 657 g and produces nearly 220 g of copra per nut which is highest among the conserved orange dwarf accessions in the genebank.

Cultivation Practices: The palms of Cameroon Red Dwarf selection can be grown with the regular recommended package of practices with irrigation for sustained yield of nuts. It can be grown in all coconut growing regions for conservation and further utilization. It has good potential for use as apparent in breeding programmes aiming for earliness, tender nut yield, copra yield and attractive coloured fruits.

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11. IND 414 – Chowghat Yellow Dwarf (IC0598220; INGR13062), Distinct Dwarf Coconut (*Cocos nucifera*) Germplasm with Yellow Coloured Nuts and Erect Leaves

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Chowghat Yellow Dwarf is a unique indigenous yellow dwarf coconut line developed through selection from the original population of Chowghat Orange Dwarf conserved at National Gene Bank at CPCRI. The palms in the gene bank were developed through the *inter se* mated original mother palms available at CPCRI followed by progeny selection at CPCRI for nut colour. After evaluation of the progenies for inheritance of the trait, the selection was made for the unique trait of yellow fruits, rachis, flowers and petiole. As there are no indigenous yellow dwarf population exists in the mainland India, the selection is considered unique. Useful variety as a parent for crossing with selected talls to produce hybrids and hence of commercial value.

Morpho-agronomic Traits: Most yellow dwarf populations of the coconut growing regions of the world has been related to Malayan dwarfs which are characterized with drooping leaves and straight spindle. The Chowghat Yellow Dwarf is observed as having erect leaves, large sized nuts with higher tender nut water, higher nut yields has excellent adaptability to the coconut growing environment in the country as it is a selection from the Chowghat Orange dwarf. The inheritance of the yellow colour traits is also confirmed as the *inter se* mated seedling progenies exhibited mostly seedlings with yellow coloured petiole and few with orange colour. The typical palms of this type could be selected based on the petiole colour.

The number of fruits per bunch was observed to range from 12 to 20. The palms belong to dwarf type of coconut with a stem girth of 55 cm at 1 m height and an average leaf length of 3.45 m at the age of 30. The bunch production in the selected palms are regular and ranged from 9 to 13 bunches per year after

commencement of flowering. The colour of the fruit is yellow, oval shape with a fruit length of 37cm and fruit breadth of 16.5cm. The tender nuts contained more sweet water ranging from 250 to 340ml per nut (Average 290ml) with average TSS of about 6.7º brix.

Cultivation Practices: The palms of Chowghat Yellow Dwarf can be grown with the regular recommended package of practices with summer irrigation for sustained yield. It can be grow in all coconut growing regions for conservation and further utilization.

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12. IND 221 – Andaman Horned Cocos (IC0598221; INGR13063), a Coconut (*Cocos nucifera*) Germplasm with Distinct Character of Horny Nuts

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Horned cocos is a unique coconut type developed through selection from the original population collected from Andaman islands during 1999 and conserved at National Gene Bank at CPCRI research centre, Karnataka. The palms in the gene bank were developed through the nuts collected from the original mother palms available at natural coconut populations of South Andaman district followed by seedling selection at CPCRI. After evaluation of the said accession for inheritance of the trait, the selection was made for the unique trait of presence of multiple ovaries female flowers which results in horn like structures over the matured coconut fruits. The trait is unique and not present in any other accession in the gene bank. The extent of genetic diversity in the accession was evaluated using 14 highly polymorphic microsatellite markers. The observed heterozygosity was 0.19, while the observed heterozygosity was 0.25. This indicated a tendency towards inbreeding within the population. It had a fixation index (FST) of 0.25 indicating a high level of genetic differentiation. It come handy as a marker in breeding programmes.

Morpho-agronomic Traits: Coconut produces female flowers with one ovary without any appendages over the set fruits. The candidate accession *viz*., Horned cocos produces female flowers with three or more divided part of ovary (multiple ovaries) which result in the horn like appendages over the fruits making it unique. The inheritance of the traits is also confirmed as the second generation palms at the field genebank of CPCRI also exhibited the trait. The original mother palms are identified with this unique trait among the natural coconut populations at South Andaman district collected during 1999. Subsequently the seedling progenies were planted and evaluated at National Field Gene Bank of coconut under CPCRI Research Centre, Kidu, Karnataka. Hence the performance is known at two locations i.e. Andaman and Karnataka

The number of fruits per bunch ranged from 10 to 21 in the initial years of flowering fruiting from 2009 to 2011. The palms belong to tall type of coconut with a stem girth of 85 cm at 1 m height and an average leaf length of 3.6 m at the age of nine. The bunch production is regular and ranged from 7 to 10 bunches per year after commencement of flowering. The setting percentage of fruit is about 30 percent. The colour of the fruit is green with oval shape. The husked fruit is round with a hard shell measuring an average of 4 mm thick. The cavity volume ranged from 120 to 140 ml.

Cultivation Practices: The palms of Horned cocos are normal in all other morphological traits similar to other coconut accessions. They can be grown with the regular recommended package of practices with summer irrigation for sustained yield. It can grow in all coconut growing regions.

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13. IND 331-Laccadive Mini Micro Tall (IC0598222; INGR13064), a Coconut (*Cocos nucifera*) Germplasm with Distinct Character of Extremely Small Nuts with Very Low Copra Content, not found in any other Coconut Variety

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Mini Micro Tall is a unique coconut type present in Minicoy Island of Lakshadweep, known for its smallest fruits. This unique type was collected through selection from the original coconut population of Minicoy Islands and conserved at National Gene Bank at CPCRI research centre, Karnataka. The palms in the gene bank were developed through embryo culture of nuts collected from the original mother palms available at CPCRI Regional station, Minicoy. The trait of smallest nuts in all bunches of the palms is unique and not present in any other accession in the gene bank. The nuts of this type do not germinate under natural conditions. The germplasm has academic and scientific value besides the potential for ornamental planting. This could be of interest to breeders trying to increase the number of nuts per bunch.

Morpho-agronomic Traits: This type is a tall coconut type with morphological traits similar to other coconut accessions but differing in the nut component traits. The female flowers develop into small fruits recording lower values for most nut component traits. The average fruit weight was about 31 g with copra content of 5 g. The accession was observed with lowest husk content also. The colour of the fruits in this accession is green or greenish brown with round shape. The kernel sometimes fills the entire cavity with the embryo completely embedded in the kernel. The cavity has very less water of about 1.1 ml and the copra has 73% oil.

Cultivation Practices: As the Mini Micro nuts do not germinate under natural conditions owing to the less nut water and quick drying of nuts, they need to be multiplied through embryo culture. The vegetative growth of Mini Micro Tall palms is normal with similar morphological traits compared to other coconut accessions. They can be grown with the regular recommended package of practices with summer irrigation.

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14. IND 099 – Niu Leka Green Dwarf (EC0415218; INGR13065), a Coconut (*Cocos nucifera*) Germplasm of Short Statured Palm but Possessing the Advantageous Characters of Talls

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Niu Leka Dwarf selection is a unique coconut type selected from the original population collected from Fiji islands during 1983, conserved and evaluated at World Coconut Germplasm Centre, CARI, Sipighat over 25 years. The palms of this selection planted in the National Gene Bank at CPCRI, were developed through *inter se* mating of selected original mother palms available at Andaman followed by seedling selection. The present selection was made having higher copra among the dwarf accessions in the germplasm with dwarf plant stature, allogamous trait and robust growth. The selection has both scientific and commercial value owing to its dwarfness coupled with higher copra content and attractive green nuts. This variety has good commercial potential since it combines commercially favorable traits of tall and dwarf varieties

Morpho-agronomic Traits: This accession is a Green Dwarf with higher copra content among the dwarf populations in the gene bank. The palms are very dwarf with nuts and pollination behaviour similar to talls. The average weight of dehusked fruit is about 800 g with kernel weight of about 450 g yielding about 260 g of copra. Generally, dwarf accessions of coconut are highly self pollinated due to the overlapping of male and female phases in the inflorescences. However, this Niu Leka Dwarf selection is observed with a greater degree of cross pollination owing to its non-overlapping phases. The palms are dwarf characterized with higher number of leaf scars (over 33 in 1 m) on the stem making the selection is exhibiting the higher level of dwarfness. The stem of the palms are robust with girth at 1 m over 100 cm which is unlikely in other dwarf accessions. The stem is intermittently constricted which is a unique trait of this selection whereas the stem is smooth in other tall and dwarf accessions. The palms come to flowering in about 4 to 5 years; the leaves are shorter and stiff, leaflets closely arranged (nearly plicate) allowing less light below the crown. The fruits are green in colour, oblong to round in shape, with a cavity volume of over 300 ml in mature nuts. The tender nuts are large with a fresh weight of about 2 kg having on an average of 470ml of sweet tender nut water. Biometric clustering revealed that the grouping of this accession with talls due to the allogamous nature and higher copra.

Cultivation Practices: The palms of Niu Leka dwarf selection has to be established with careful selection of mother palms followed by *inter se* mating among them and seedling selection to maintain the dwarfness and other desirable traits. They can be grown with the regular recommended package of practices with summer irrigation for sustained yield. It can grow in all coconut growing regions for further utilization. It has tremendous potential to be used in the coconut improvement programme for breeding for dwarfness coupled with higher copra out turn and tender nut yield.

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15. Ole-9-P2-P1-P22 (IC0597598; INGR13066), a Safflower (*Carthamus tinctorius*) Germplasm as a High Oleic Acid (18.63%) and High Oil (34%) Content Line

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Safflower (*Carthamus tinctorius* L.) is an important oilseed crop, its oil demand is increasing world over because of its potential for multi-purpose uses. Oleic content in safflower oil is generally around 17-20% making it unsuitable for deep frying (Gecgel *et al*. 2007). High oleic safflower oil is stable at high temperatures and makes it superior for frying. High oleic oil is also suitable as a biodiesel fuel additive (Bergman and Flynn, 2001).

The high oleic safflower line, Ole-9-P2-P1-P22, having 81% oleic content was developed from a cross, EC523367-9 x EC548816-14, through back-crossing followed by sib-crossing and simultaneous selection for high oleic and high oil content at the Directorate of Oilseeds Research, Hyderabad, India (Praduman and Anjani, 2012). The parent, EC-523367-9 is a high oleic selection and the parent, EC-548816-14 is a lenoleic selection possessing high seed weight.

Ole-9-P2-P1-P22 possesses high oil content (34%). It is spiny in nature with profuse branching habit, serrate obvate upper leaves and green stem. It matures in 70-75 days and matures in 120 to 125 days after planting. It also exhibited resistance to wilt (*Fusarium oxysporum* f.sp *carthami)* in wilt sick plot over three years at the Directorate of Oilseeds Research, Hyderabad.

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16. TCH 1728 (IC0597400; INGR13067), a Cotton (*Gossypium hirsutum*) Germplasm with Leaf Hopper (*Amrasca bigutulla*) Resistance, More Leaf Thickness, Higher Number of Trichomes

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The proposed breeding line TCH 1728 is an assured source for leaf hopper resistance. It has unique characteristic features of more leaf thickness and higher number of leaf trichomes. The breeding line was developed at Department of Cotton, Tamil Nadu Agricultural University, Coimbatore during 2004-05 from the parental hybridization of H 26 X H 56-9-6-4-1 followed by pedigree selection breeding.

Morpho Agronomic Characteristics: The breeding line TCH 1728 recorded a boll weight of 4.6 g and with about 32 numbers of bolls per plant. Boll shape of the entry is oval with pointed tip and had medium size boll. Under All India Co-ordinated Varietal Trial, the breeding line TCH 1728 was recorded 1,811 kg/ha and ranked 2nd place in South zone during 2010-11 in Br.02a Initial Evaluation trial of *G. hirsutum*. This was 18.9% and 16.8% increase yield over the local check MCU 13 (1,523 kg/ha) and zonal check surabhi (1,550 kg/ha) respectively. In respect of fibre quality parameters, the breeding line TCH 1728 possessed a ginning outturn of 31.1%. It is registered as long staple

cotton with 30.9mm span length and fibre strength of 21.9 mm. It matures in 160 days.

Associated Characters and Cultivated Practices: The entry TCH 1728 performed well against leaf hopper in North zone locations and recorded grade 1 for jassid injury in 1-3 scale during 2010-11 in preliminary screening (Br.02a) to sucking pests. Under epizotic screening at Rahuri during 2011-12, the entry TCH 1728 recorded grade 2 for jassid injury. In South zone, the entry TCH 1728 was tested under Br.03a PVT of *G.hirsutum* in AICCIP during 2011-12. The result showed that the entry TCH 1728 recorded moderate resistance to leaf hopper. The same result was also obtained in advanced screening of promising entries for leaf hopper resistance. Based on the study the culture is highly suitable and adaptable for all the three zones *viz*., Northern, Central and south.

Variations in leaf anatomical structures contributing for resistance against leaf hopper are given hereunder.

Characters	Entries	
	TCH 1728	Check DCH 32
Leaf thickness (µ)	111.31	96.57
Trichomes / sq.cm	165.6	17.0
Distance of phloem from lower epidermis (µ)	222.78	214.76
Palisade cell structure compact / semi-compact	Compact	Semi-compact
Palisade cell height (µ)	57.33	36.98
Thickness of phloem (µ)	79.01	59.13

The culture TCH 1728 registered higher number of leaf trichomes of 165.6/sq. cm and leaf thickness recorded was 111.31 µ which was higher as compared to the check DCH 32. This showed that the entry has the ability to disrupt the setting behaviors of the leaf hopper in leaves. Higher leaf thickness associated with a thick epidermis and with high percentage of straight trichomes on leaves resulted in difficulty for leaf hopper to pierce the leaf surface. The entry TCH 1728 recorded compact palisade cell structure and higher palisade cell height of 57.33 µ which showed that leaf hopper was unable to puncture the leaf at right angle to the long axis of its body and it could not reach the tissue directly above the point of puncture. This leads to resistance against leafhopper in TCH 1728. The other character such as thickness of phloem and distance of phloem from lower epidermis was also higher in TCH 1728. From this study it is concluded that the breeding line TCH 1728 is superior against leaf hopper. Hence, this breeding line can be used as resistant source for leaf hopper.

17. IC 553688 (IC0553688; INGR13068), a Chilli (*Capsicum chinense*) Germplasm as a Unique Material for High Capsaicin Adapted to the Tropical Humid Climate

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During the last few decades, there has been substantial increase in area under crops with high nutraceutical values and accordingly there lies a constant scope for identification of genotypes with higher content of any active principle. *Capsicum chinense* is well known for its exceptional heat (Scoville score) and the extracts have a huge national and international market owing to their diverse use. Hence, hot chillies and peppers have huge potential in nutraceutical industry. The capsaicinoids content of the chilli fruits greatly vary among the species, cultivars, and the growing conditions. The native chilli variety '*Bhut Jolokia*' found in northeastern regions of India was recently reported to be the hottest chilli pepper in the world (Mathur *et al*., 2000). IC 553688,

a locally grown chilli landrace, was collected from a place known as '47 Kilometre Point', south of Indira Point (6.75° N, 93.83° E) of Andaman & Nicobar Islands and evaluated at Central Horticultural Experiment Station, a regional research station of Indian Institute of Horticultural Research, Bengaluru.

The leaf surface of the genotype IC 553688 had the characteristic crinkled pattern between the veins, had greenish-white petals, blue anthers, flowers borne in clusters of 2-4, fruits had constriction between calyx and pedicel. It also has distinct traits like crinkle leaf surface between the veins, presence of a calyx constriction, multiple flowers per node, greenish corolla, and blue anthers and the fruits had distinct aroma. The fruit had undulating surface and distinct aroma resembling clarified butter. The length of fruits ranged from 4.0-6.0 cm and weighed about 4.98-7.40 g. IC 553688 was analysed using HPLC against the pungency of a '*bhut jolokia*' strain which revealed a rating of 1,147,384 and 508,623 SHU respectively. The '*bhut jolokia*' hitherto known to be the hottest chilli variety of India because of its higher pungency recorded as have 855,000 SHU and 1,041,427 SHU in 2000 and 2004 respectively. However, the present comparison has revealed that (IC 553688) has more heat unit than '*bhut jolokia*' reported in every occasion.

IC 553688 has become well adapted to hot and humid climate during the long course of cultivation in Andaman and Nicobar Islands and therefore, it can be successfully cultivated in hot humid climatic zones with better recovery of pungent principles. Under the climatic condition of Bhubaneswar, a single plant produces around 150 fruits weighing 800 g/plant. Hence, it enjoys good chances of commercial exploitation of the genotype in areas having similar environmental conditions. Thus, *C. chinense* accession IC 553688 rich in capsaicin content can be exploited for use in pharmaceutical industry.

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18. NKO-24 (IC0573223; INGR13069), a Spiked Ginger Lily (*Hedychium spicatum*) Germplasm with Bold Seed, Early Emergence and Late Senescence

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Spiked Ginger Lily (*Hedychium spicatum* Buch.-Ham. ex J.E. Smith) a genus of Zingiberaceae, is found abundantly in the wild state in the forest land of Uttarakhand. It is known locally as *van-haldu, siura, bagaldu, kachoor, kapur-kachari, kapur-kachali* and *gandh sathi.* In the Greek language *Hedychium* (*hedys,* sweet; *chion,* snow) refers to the fragrant white flowers of some species. World-wide, it has 50 species reported from Madagascar, South-west China, Nepal and Indo-Malaysia, whereas, 35 species are available from the hills of east, south and central India, Jammu and Kashmir, Himachal Pradesh, Arunanchal Pradesh and Uttarakhand. It is widely available in moist, damp-shady and evergreen forests of oak-rhododendron and oak-deodar at an altitude of 800 to 2,800 m above mean sea-level. It has several ethnobotanical notes and much popular in traditional systems for the treatment of diarrhoea, piles, bronchial asthma, semen disorders, skin diseases and stomach ailments (Gaur, 1999).

During the project period (April, 2008 - June, 2012) entitled "Studies on relationship between ecogeography of the chemotypic variation of nine important but highly threatened medicinal plant species and prospects of their cultivation" financed by NAIP-IV, a total of 34 accessions of Spiked Ginger Lily were collected from North-west Himalayas and Central Himalayan Region of India and identified a superior genotype *i.e.*, bold seeded, early emergence and late senescence. The Spiked Ginger Lily germplasm (NKO-24/IC573223) was collected and identified from Kausani, District - Bageshwar at an altitude of 1600 m asl of Uttarakhand. It was successfully raised and thrives well with luxuriant

growth in Field Gene Bank/ Herbal Garden, NBPGR, R/S Bhowali, Nainital, Uttarakhand. The present genetic stock of *Hedychium spicatum* Buch.-Ham. ex J.E. Smith germplasm collection NKO-24/IC573223 showed bold seeded, early emergence and late senescence as compared to other accessions including local check collected from Central Himalayan region (Koranga *et al.,* 2011).

Morpho-agronomic Characteristics: It is aromatic, branched, perennial, 100-120 cm. high. Leaves broadly ovate–lanceolate, 35.0-45.0 X 5.0-6.0 cm, acuminate, glabrous above, sparsely pubescent beneath; flowers fragrant, white, orange–red base, in dense, terminal, 12.0-15.5 cm long spike; capsules globose, 3-valved with an orange–red lining; seeds black with red aril (Tables 1 and 2).

Table 1. Qualitative and quantitative characters studied in different accessions of *Hedychium spicatum*

S.No.	Plant character	IC 573203 (Local check)±SE	IC 573223 (Bold seeded genotype) ±SE	Genotypes* (32 accessions) ±SE
1.	Plant habit	Perennial	Perennial	Perennial
2.	Mode of reproduction	Asexual & sexual	Asexual & sexual	Asexual & sexual
3.	Plant growth habit	Semi-erect/erect	Semi-erect/erect	Semi-erect/erect
4.	Rhizome length (cm)	37.0±8.4	42.0±13.3	35.2±13.2
5.	Rhizome thickness (cm)	36.9±6.3	24.6±9.7	30.2±13.6
6.	No of primary branches/rhizome	1.2±0.4	2.2±0.7	1.30±0.4
7.	Month to 50% sprouting	May	April	May
8.	Aerial stem length (cm)	60.6±9.5	116.3±8.21	64.2±12.14
9.	Number of leaves/clum	8.7±1.4	9.8±1.8	7.9±1.4
10.	Lamina attachment (angle on clum)	Acute	Acute	Acute
11.	Lamina length (cm)	29.2±4.8	42.5±3.7	29.8±5.8
12.	Lamina width (cm)	8.5±1.4	5.9±0.4	7.5±1.5
13.	Lamina shape	Oblanceolate	Oblanceolate	Oblanceolate
14.	Month to flower initiation	July	June	July
15.	Number of spike/plant	01	01	01
16.	Spike length (cm)	10.6±3.7	15.2±5.7	14.7±5.5
17.	No. of flowers/spike	25.7±2.6	17.9±4.8	16.5±3.2
18.	Flower colour	White, orange-red base	White, orange-red base	White, orange-red base
19.	Corolla tube length (cm)	7.9±0.4	7.5±0.3	7.9±0.4
20.	Floral bract length (cm)	3.1±0.37	3.0±0.39	2.9±0.30
21.	Floral bract colour	Green	Green	Green
22.	Floral bract shape	Oblong	Oblong	Oblong
23.	Month to capsule maturity	August	July	August
24.	No. of capsule/spike	2.4±2.23	1.7±2.79	2.8±3.02
25.	Capsule shape	Globose	Globose	Globose
26.	Seed yield/plant (g)	84.5±82.1	67.0±114.2	101.5±107
27.	Seed colour	Brown	Brown	Brown
28.	Aril type	Lacerated	Lacerated	Lacerated
29.	Aril colour	Red	Red	Red
30.	100-seed weight (g)	0.76±0.02	2.57±0.15	0.81±0.03
31.	Month of senescence	September-October	October-November	September-October

* Mean value of 32 accessions

Table 2. 100-seed weight of *Hedychium spicatum* accessions

S. No.	Collector No.	IC Number	100 seeds weight ± SD	Area of Collection	State	Alt m asl
1.	MMBO-3043	IC589078	0.80±0.040	Dhakuri, Bageshwar	UK	2876
2.	MMBO-3057	IC589081	0.80±0.021	Shama, Bageshwar	UK	1967
3.	NBH-01	IC574525	0.82±0.029	Mandal, Gopeshwar	UK	2200
4.	NBH-02	IC574524	0.82±0.067	Shimla, Shimla	HP	2200
5.	***NKO-24**	**IC573223**	**2.57±0.153**	**Kausani, Bageshwar**	**UK**	**1603**
6.	NKO-27	IC573226	0.80±0.036	Meckludganj, Kangra	HP	1831
7.	NKO-29	IC573228	0.81±0.035	Harabagh, Mandi	HP	1450
8.	****NKO-2965**	**IC573203**	**0.76±0.017**	**Niglat, Nainital**	**UK**	**1480**
9.	NKO-37	IC573233	0.79±0.050	Kandi, Kullu	HP	2066
10.	NKO-43	IC574506	0.85±0.026	Bara Pathar, Nainital	UK	1556
11.	NKO-46	IC574509	0.83±0.017	Sigadi, Nainital	UK	2202
12.	NKO-53	IC574515	0.80±0.012	Dhanachuli, Nainital	UK	2234
13.	NKO-55	IC574517	0.82±0.060	Momaulla, Champawat	UK	2149
14.	NKO-59	IC574521	0.82±0.012	Shillong Peak, Shillong	MG	1888
15.	NKO-67	IC589086	0.80±0.026	Gorikund, Rudraprayag	UK	1931
16.	NKO-71	IC589089	0.79±0.035	Sunil gaon, Chamoli	UK	2075
17.	NKSK-01	IC573205	0.82±0.025	Ramgarh, Nainital	UK	1702
18.	NKSK-06	IC573207	0.80±0.023	Kasyalekh, Nainital	UK	2290
19.	NKSK-07	IC573208	0.78±0.015	Dudkani dhar, Nainital	UK	2104
20.	NMB-2874	IC566778	0.81±0.030	Almora	UK	1700
21.	NMB-2882	IC566786	0.76±0.021	Deedihat, Pithoragrah	UK	1710
22.	NMB-2886	IC566790	0.76±0.015	Selapani,Pithoragrah	UK	1740
23.	NMB-2938	IC566842	0.84±0.006	Lohaghat, Champawat	UK	1580
24.	NMB-2939	IC566843	0.81±0.006	Lohaghat, Champawat	UK	1800
25.	NMB-2940	IC566844	0.77±0.015	Munch, Champawat	UK	1785
26.	NMB-2941	IC566845	0.84±0.006	Chatrabhot, Champawat	UK	2130
27.	NMJO-2985	IC582502	0.81±0.030	Dhanpur, Champawat	UK	1860
28.	NMJO-3000	IC582517	0.81±0.044	Radi, Uttarkashi	UK	2040
29.	NMJO-3005	IC582522	0.84±0.006	Shi Ram chatty, Uttarkashi	UK	1960
30.	NMJO-3090	IC589094	0.79±0.021	Pharsari, Tehri	UK	1520
31.	NMJO-3105	IC589095	0.81±0.044	Mussorie, Dehradun	UK	1782
32.	NMO-2971	IC582488	0.84±0.035	Jundana, Tehri	UK	1400
33.	NMVMKO-12	IC573211	0.82±0.052	Dunagiri, Almora	UK	2000
34.	NKO-74	IC589097	0.81±0.042	Deewakhal, Pauri	UK	2011

*NKO-24/ IC573223 Bold seeded, Early emergence and late senescence type; **NKO-2965/ IC573203 Local check UK: Uttarakhand; HP: Himachal and MG: Meghalaya

Associated Characters and Cultivated Practices: Rhizomes and seeds, both may be used for propagation but vegetative propagation of rhizomes is faster and easy method to get healthy produces. Vegetative propagation (rhizomes and cut-eyes) is the most reliable method for successful establishment and early flowering in plants. Active parts of rhizome with vegetative buds (eye) (2-3 cm) planted during April-May gave 100% rooting and sprouting. Rhizome pieces with apical buds are buried in soil at 15 cm depth containing soil, litter and FYM (farmyard manure) in equal amounts. Nursery is raised in April or early May when the rhizomes sprouts out. Propagules sprout within a month.

It can be cultivated between 1000-3000 m altitude in the sub-tropical and temperate zones but rich porous soil, moist and shady places with rich forest humus are highly suitable for the growth and productivity of the species. Fields with gentle slopes are suitable for cultivation.

Rooting in old rhizomes and vegetative buds can be increased by the treatment of IAA (500 ppm) or IBA (500 ppm). Approximately 70-85 thousand seedlings are required for cultivation in one-hectare land. Raised beds are suitable for optimum growth of the plants. The market price of dry rhizomes is Rs. 15/- – 25/- per kg and essential oil extracted from roots cost around Rs. 3000/- – Rs. 3500/- per kg.

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19. SES 159 (IC0561900; INGR13070), a Wild Sugarcane (*Erianthus arundinaceus*) Germplasm Possessing High Biomass, High Yield, High NMC and C.O.D., Amenability for *in vitro*

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So far, genetc improvement in sugarcane has been focused on high sugar, high yield and disease resistant. In the present scenario of fuel and energy crisis, international attention has shifted to biofuel and Biotechnology and new terms such as bioethanol, biodiesel, energy-cane, etc. have come into picture. Research is being directed on high biomass/energy crops and germplasm is searched for potential sources. Attention has turned to C4 perennial grasses like sugarcane and its wild relatives such as *Erianthus, Miscanthus* as potential candidates. SES 159 was found to be superior among all evaluated clones *viz.* SES 159, SES 3, Mythan A, EA Cuttack, IMP 1536 and CR 1. Next to SES 159, SES 3 (35 t/acre) gave the highest cane yield followed by Mythan (32 t/acre), EA Cuttack (25.5 t/acre), IMP 1536 (23.3 t/acre) and CRI 1 (22.7 t/acre). The COD values, of juice especially the SES 159 (93,974 mg/l), indicates that theoretically one litre of juice can produce 40 L of biomas and one tonne of cane, by simply crushing without any milling can produce roughly about 250 liter of juice and 10 m^3 biomas with a calorific value of 5,400 kcal/Nm^3. Therefore, juice from one tonne of wildcane would save 6.0 L of furnace oil. The high yielding SES 159 gave the bagasse yield of 53% with fibre pith ratio of 2.2:1. All the colnes studied have given more than 50% bagasses yield which is much more than the commercial sugarcane where the bagasses yield would be around 28-30%. This wild sugarcane has a good potential as a renewable and sustainable source of fibre or fuel and alcohol as a substitute.

20. SBI 1148-11-13-2-225 (IC0598218; INGR13071), a Sugarcane (*Saccharum.* spp. Hybrid) Germplasm Possessing High Sucrose and Red Rot Resistance in Addition to the other Agronomic Traits of Co 1148

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SBI 1148-11-13-2-255 is a fourth generation self of Co 1148, a promising sub-tropical commercial variety which was under cultivation for over 50 years. Co 1148 is high yielding with drought tolerant but has medium sucrose content and susceptibility to red rot disease. SBI 1148-11-13-2-255 was developed through repeated selfing of Co 1148, followed by selection for sucrose content and red rot resistance keeping the yield potential of Co 1148 at Sugarcane Breeding Institute (ICAR), Coimbatore. The characters for which the self is registered are a rare self at fourth generation developed from the popular subtropical variety of sugarcane *viz.* Co 1148. Possessing high sucrose and red rot resistance in addition to the other agronomic traits of Co 1148– improved by repeated selfing of the medium sucrose and red rot susceptible Co 1148.

Morph-agronomic Characters: This self is identified for registration as a genetic stock based on its *per se* and progeny performances. *Per se* performance: Performance of this self in clonal trials showed significant improvement in sucrose content (19.44 %) over Co 1148 (17.14 %) and was moderately resistant reaction to red rot, while was on par with Co 1148 for other yield parameters.

Progeny Performance: Among eight crosses involving the inbred derivatives as parents evaluated in plant and ratoon crops, the cross involving 1148-13-11-2-255 as female was the most promising with improvement in Brix, number of millable canes, cane diameter and cane length (SBI Annual report, 2004-05). Subsequent evaluation of the progeny in the clonal trials led to the identification of two Co canes *viz.* Co 2010-11 and Co 2010-20 from the cross 1148-13-11-2-255 x Co 775 (SBI Annual report, 2010-11), thus demonstrating its value as a donor parent for important agronomic traits of sugarcane.The genotype has attained high level of homozygosity after four generations of selfing as proved using molecular markers. Sugarcane, being a complex polyploid, parents like this self are needed to improve precision of breeding programmes.

The genotype flowers during the first fortnight of November and has low pollen fertility of 30% unlike the original parent (>60%), hence can be used as a female parent. The clone is characterized by erect, medium thick canes with long internodes and long bud grooves, small flat buds, nearly closed green canopy with light green leaf sheath, lanceolateligular process and yellow wax band.

This genetic stock improved over a proven parent through selfing is probably the first of its kind developed in sugarcane and owes promise in breeding varieties for the subtropical India to develop varieties as good as Co 1148 with stability in yield and wide adaptability across the subtropical states with the additional benefits of red rot resistance and high sucrose.

References

Sugarcane Breeding Institute Annual Report (2004-05), p 20.

Sugarcane Breeding Institute Annual Report (2009-10), pp 17-18.

21. DBQW 1 (IC0595583; INGR13072), a Wheat (*Triticum aestivum*) Germplasm for Good Biscuit Making Quality

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Our previous study demonstrated that most of the wheat varieties developed in India are hard in grain texture have poor biscuit making quality. The primary requirements of good biscuit making quality are soft grain and weak gluten. Therefore, soft wheat germplasm lines were identified in wheat germplasm collection at DWR, Karnal. However, soft wheat germplasm showed low yield and susceptible to lodging, and hence used as the donor for soft grain characteristics. Detailed molecular analysis showed that null mutation in *Pina* is primarily responsible for harder grain texture in Indian wheats. Back cross populations were developed using high yielding and widely adapted variety HD 2687 as recurrent parent and germplasm line EC 378793 as donor for soft grain characteristics that has wild allele of *Pina*. Foreground selection was made using markers for *Pina* and selecting wild alleles of puroindoline a present in EC 378793. Plants with BC_2F_2 and subsequent generations were evaluated for puroindoline profiles and SKCS hardness Index. Microlevel test utilizing 1 gram of whole meal flour was used in identifying superior segregants in recombinant lines of breeding.

Some of the lines in BC_2F_4 generation showed transgressive segregants towards softer grain characteristics and higher biscuit spread factor. The material was advanced to BC_2F_7 generation and evaluated for two years (2011-12 and 2012-13) for biscuit making quality and yield determining traits. Superior lines with higher spread factor were identified and then evaluated for grain weight and yield subsequently. DBQW 1 showed higher yield potential and 60% enhancement in biscuit spread factor (The ratio between cookie diameter and thickness: W/T)) as compared to HD 2687. Therefore, it can be used as the genetic stock for these unique characteristics in future breeding programs to improve the biscuit making quality in wheat.

Morpho-Agronomic characteristics of **DBQW 1** (Data based on two crop seasons; 2011-12 and 2012-13).

Characteristic / morpho-agronomic description	Remark / Observation
Average plant height	102 cm
Days to maturity	118 days
1000-grain weight	38.1g
Grain hardness Index	30.2
Biscuit spread factor	11.80
Grain protein content	11.80% (14% mb)

22. RPMRE 6 (IC0594593; INGR13073), a Paddy (*Oryza sativa*) Germplasm with Broad Spectrum Gall Midge Resistance, Multiple Resistance to GM+BPH+WBPH

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The breeding line RPMRE-6 (Rice Project Multiple Resistance Entomology-RP4680-1-2-23) was developed at DRR by making a cross between ARC15831 X RP2068-18-3-5 and subsequently following pedigree selection method. RPMRE-6 showed resistance to rice Gall midge, Brown plant hopper and White backed plant hopper consistently for the last 2 years in All India Coordinated Rice Improvement Programme (AICRP) trials (DRR 2008, DRR2009). The morpho agronomic characters are given in the Table 1.

Table 1. Morpho-agronomic characters of RPMRE6

Character	Details
Time of heading	105 Days (Medium Duration)
Basal leaf sheath colour	Purple
Stem length	60 Cms (Very Short)
Decorticated grain type	Short bold
Decorticated grain colour	Light brown
Decorticated grain aroma	Absent
Resistance to gall midge biotypes	Resistant to biotypes1,2,4,& 4M
Resistance to brown plant hopper (BPH)	Resistant at Raipur & DRR
Resistance to white backed plant hopper (WBPH)	Resistant at Coimbatore

Amplification of genomic DNA with gene specific markers confirmed presence of Gm3, Gm4 and Gm8 genes in the line conferring resistance to gall midge biotypes 1, 2, 4 & 4M. Genetics of BPH and WBPH resistance in this line needs to be studied.

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Directorate of Rice Research (DRR) 2009 Progress Report All India Coordinated Rice Improvement Project–National Screening Nurseries, DRR, Hyderabad, pp 66-69.

23. DMR QPM 102 (IC0594369; INGR13074), a Maize (*Zea mays*) Germplasm with Medium Maturity, Low ASI, High Tryptophan, High Protein

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DMR QPM 102 (IC 0594369, INGR 13074), a Medium Maturing Quality Protein Maize Inbred Line

Maize is a major cereal crop for both livestock feed and human nutrition, worldwide. With its high content of carbohydrates, fats, proteins, some of the important vitamins and minerals, it has acquired a well-deserved reputation as a 'poor man's nutricerea'. However, conventional maize is a poor quality food as it lacks the full range of amino acids especially lysine and tryptophan. With the discovery of *opaque-2* (*o-2*) gene and its modifiers, and elucidation of role of hard endosperm (*He*) gene, it became possible to modify the contents and profile of amino acids of proteins in maize. As a consequence, Quality Protein Maize (QPM) germplasm was developed and released in different parts of the world including India. Directorate of Maize Research (DMR) is actively involved in QPM research. It has developed QPM inbred lines with high tryptophan (≥0.6%) and lysine (>2.4%) in protein. In this communication, information on unique traits in respect of DMR QPM 102 (IC 0594369 and INGR 13074) is reported. This inbred line has been derived from exotic germplasm CLQ-RCYQ 30 after evaluating, selecting and selfing for 5-7 generations. Each time the kernels were assayed biochemically for tryptophan content and screened on white board for opaqueness. The semi-opaque/semi normal kernels with tryptophan >0.6% were retained and line developed thereof. The proposed line is a medium maturing QPM line with low anthesis silking interval (ASI) of one day, high tryptophan (0.65%) and high protein content (13.02%). It also exhibited moderate resistance against Maydis Leaf Blight (MLB).

Morpho-agronomic Characteristics: In the present study, data were recorded on agro-morphological, phenological and quality traits especially tryptophan (%) and protein (%). Based on the average data of two years (2010 and 2011), the line displayed mean male flowering i.e. anthesis (50%) in 53 days and mean female flowering i.e. silking (50%) in 54 days thereby indicating low anthesis silking (ASI) interval of only one day which is a potential indicator of the line being tolerant to moisture deficit situations. It also showed sparse tassel density of spikelets with wider angle (>45^0) between main axis and lateral branches which are strongly curved. The line is of short stature (93 cm) with median ear placement. A field view of the DMR QPM 102 at flowering and milky-dough stages showed it as genetically uniform and productive line. A scrutiny of post-harvest data revealed its conical ear shape with 10-12 numbers of rows of yellow, flint, toothed grains. It possessed straight kernel row arrangement and 1000 kernel weight of 192 g. The biochemical analysis displayed that it contains

0.65% tryptophan in protein which is more than double than the normal inbred line *viz.,* HKI 1105 (0.33%) with high protein content of 13.02% protein (Kaul *et. al*., 2012).

DMR QPM 102 along with a set of elite lines and checks was screened for Maydis Leaf Blight (*Cochliobolus heterostrophus* (Drechs.) Drechs. [anamorph = *Bipolaris maydis (Nisikado*) Shoemaker] in the years 2009, 2010, 2011 and 2012 under artificial conditions at identified hot spots i.e. Delhi, Ludhiana and Karnal. The lines were rated as Resistant (0-2), Moderately Resistant (2.1-3.0), Susceptible (3.1-4.0) and Highly Susceptible (4.1-5.0) as per the rating scale of 1-5 (Guidelines of All India Co-ordinated Research Project on Maize Pathology). Most of the lines displayed moderate resistance with mean rating of 2.7 with susceptible and resistant checks showing 3.9 and 2.0 average score, respectively. On the basis of four years data, DMR QPM 102 displayed reaction rating in the range of 1.5 to 2.5 with a mean rating of 2.1. At all the hot spots, the mean rating of the line was found 2.5, 2.2, 1.7 and 2.3 over the period of study, respectively. Hence, it could be deduced that the proposed line is a stable source of resistance to MLB.

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24. NKG 134 (IC0218988; INGR13075), a Pea (*Pisum sativum*) Germplasm as a Resistant Against Four Isolates *viz. rangway, trilokinath, stingri, kangra* of Powdery Mildew (*Erysiphe pisi*) in Pea

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Pea (*Pisum sativum* L.) belongs to family Fabaceae is an important multipurpose crop grown for green pods and grains in the cool temperate zones and tropical highlands of the world (Ali *et al.,* 1994; Azmat *et al.,* 2010). Generally, pea is grown in winter season in the Indian plains but it is an important summer (off-season) crop in the high hills (Rana *et al.,* 2010; Bala *et al.,* 2011). Powdery mildew of pea caused by *Erysiphe pisi* DC is one of the most serious diseases resulting 25–50 % losses in yield and quality worldwide (Katoch *et al*., 2010).

In order to identify the resistant germplasm we screened 701 germplasm lines which were grown in Augmented Block Design along with six check varieties *viz.* Lincoln and Azad pea as susceptible and HFP4, DMR11, DMR7 and Rachna as moderately resistant to resistant for *E. pisi* in the winter season of 2008-2010. Infector row of two susceptible checks i.e. Lincoln and Azad pea were grown in each block to have uniform speared and infection of the disease to avoid escapes. Under laboratory condition, 64 accessions which were found resistance under field screening along with six check varieties were screened against four isolates of *E. pisi* using detached leaf technique. The four isolates *viz*., *rangway, trilokinath, stingri* had been collected from temperate region while and *kangra* from sub-tropical region where powdery mildew is a major disease on pea crop. The infection types 0, 1 and 2 were scored as resistant reaction whereas 3 and 4 as susceptible reaction.

INGR13075 showed resistant reaction with 0 score under field conditions while 1 against *rangway, trilokinath,* and *kangra* isolates and 2 against *stingri* isolate of powdery mildew. It has been observed that plant breeders invariably have resistant germplasm in their breeding stocks but majority of them have poor agronomic background carrying several undesirable gene. This makes gene transfer more cumbersome. Therefore, it is good to obtain additional information on the extent of genetic diversity and agronomic performance of resistant germplasm accessions (Singh *et al.,* 2011). The additional horticultural attributes of

INGR13075 were no of primary branches (4.0), no of pods clusters/plant (11.50), pod length (5.80cm), no. of pods/plant (21.0), no. of seeds/pod (6.0), and 100-seed wt. (15.46). The seed colour was white and round. The overall performance of the INGR13075 showed that it has high level of resistance to powdery mildew along with sufficient amount genetic diversity and agronomic superiority, which can be used for breeding pea varieties with resistance to powdery mildew and high yield.

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