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Phenotypic and biochemical characterisation of land races and variety (Chhattisgarh Tichkur-1) of East Indian arrowroot (*Curcuma angustifolia*, Roxb.)

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Abstract

East Indian arrowroot (*Cucuma angustifolia*) is widely cultivated in the tribal areas of Chhattisgarh, Northeast and certain Southern pockets of India, as source of starch. In the present study, selected eight accessions of land races of *C. angustifolia* along with its released variety and related species (*C. zedoaria*) were characterised for phenotypic and biochemical traits for selecting desirable genetic stocks. The East Indian arrowroot land races, variety and related species had morphological differences in plant, leaf and rhizome traits. This study also has helped to distinguish land races from rest of East Indian arrowroots and wild species. Investigation on quantitative characters and biochemical analysis unveiled one land race (CTCRI-CA-PM-1) collected from Thiruvananthapuram district of Kerala which showed superior performance in terms of lengthy primary rhizome (21.25 cm) coupled with highest starch content (16.8%), rhizome yield per plant (709.8 g) and rhizome dry recovery (19.15%). Other equally better promising genetic stocks selected from the present study are IGSJT-10-2 (IGKV-Variety Chhattisgarh Tikhur-1) and IGDMT-10-1(landrace from Dhamtari, Chhattisgarh). Selected genetic stocks along with other population will be further studied for molecular; biochemical and processing properties for their effective utilisation. All the germplasm accessions are conserved at ICAR-CTCRI, Thiruvananthapuram (NAGs centre), Kerala, India.

Keywords: East Indian arrowroot, PPV & FRA, DUS guidelines, starch and genetic stocks

Introduction

In addition to major tuber crops, there are several tuberous and rhizomatous minor crops namely Chinese potato, arrowroot, yam bean, Canna, *Curcuma* etc. which have good potential as starch and nutrients donors. East Indian arrowroot is one of the important underutilised crops that comes from family Zingiberaceae. *C. angustifolia* is a perennial rhizomatous herb, round to ovoid rhizome with tuberous root. It is a flowering plant, with modest and small spiked inflorescence of three or four yellow, funnel shaped flowers within tufts of pink terminal bracts. Genus *Curcuma* L. belongs to the 'ginger family' which is a source for starch yielding tubers, and is a major dietary source for some rural communities. The East, central, North East and Central India regions are bestowed with rich floral diversity, and immense

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genetic resources, which are not yet completely assessed, understood or exploited. The genus *Curcuma* L. comprises of about 120 species of rhizomatous herbs of which 40 species are reported from India (Sasikumar, 2005) and the greatest diversity of the genus occurs in India. The rhizome is the vegetative propagating plant part and has been used traditionally due to its great medicinal value from the time immemorial.

Curcuma starches are believed to have medicinal value and are used in the treatment of gastric ailments. Multipurpose utilities of starchy curcumas have been reported for food, dyes, and healthcare products in several countries (Kasai et al., 2019). It has been reported to have similar digestive properties as arrowroot starch and hence used as an infant food. Vimala and Nambisan (2005) reported that the starch content in the tubers varies from 10-20% with *C. malabarica* having the highest starch content (21.4%), indicating that these species have immense potential as crops for starch extraction.

C. angustifolia is widely cultivated in the tribal areas of Chhattisgarh and Northeast India as source of starch. Some rural villagers and tribal people used to consume the tubers of some wild turmeric species as source of edible starch. The starch isolated and characterised from curcuma species were found very much in par with the exotic arrow root, with respect to its nutritional values as well as physico-chemical properties. Starch is a major component of human nutrition and produce 70-80% of calorie consumed by humans worldwide. Different starches have been utilized for a very long time and its application in food industry is very significant. In recent decades, *Curcuma* species have emerged as an alternative source of starch and are the subsidiary food for low-income group. Apart from the medicinal properties, this starch has potential importance in the food industry as it has the tendency to modify the textural attributes of foods. It is suitable as a hydrocolloid in the processing of many sweets and desserts.

Curcuma sp. is reported to be a source of easily digestible starch similar to that of arrowroot but they are expected to have high phosphorous content. The phosphorous content and cross-linkages were reported to impart good pasting behaviour to the starch in terms of breakdown and setback viscosities, it is processed by cutting, peeling, rubbing fresh rhizome bulbs on rough surface of stone or on sieves of rough surface, soaking with water, decanting and drying (Patel et al., 2015). Essential oils from *C. angustifolia* have been extracted and are used in antifungal medications. Compounds in the leaves of this plant have also been shown to have potential as antibacterial agents. Commercial cultivation and starch production from different rhizomatous *Curcuma* species is possible, which would help in leveraging income of farmers and will offer more healthy option in food industries. However, the *Curcuma* species are not been adequately exploited as a source of starch (Rajeevkumar et al., 2010). The cultivation and popularisation of these lesser known, under exploited species are strongly recommended aiming the food security of our country. Characterization of germplasm is very essential in crop plants and it is the basis for selection of accessions for use in crop improvement programmes. Conservation of PGR requires genetic investigations on stable characters, morphological and molecular markers their relationship and genetic variation among germplasm (Jan et al., 2011). With above background, selected accessions of *Curcuma angustifolia* along with released variety and related species were evaluated by adopting PPVFRA's guidelines including biochemical analysis for improvement.

Materials and Methods

In the present study eight *Curcuma angustifolia* land races, IGRJT-16-1, IGDMT-10-1, IGBT-10-2. IGBT-10-4, CTCRI-CA-PM-1, CTCRI-CA-PM 2, CTCRI-CA-PM-3 and CTCRI-CA-PM-4) one wild species, *Curcuma zedoria* (CTCRI-CZ-PM-1) and one released variety, Chhattisgarh Tikhur-1 (IGSJT-10-2) were evaluated. The passport data of accessions selected are listed in Table 1. The germplasm accessions and a variety 'Chhattisgarh Tikhur 1' were raised by adopting RBD and maintained in Block I in the field gene bank of ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), Thiruvananthapuram, Kerala. Two crops were raised in the year 2022-23 and 2023-24 for evaluation with four replications for each accession. The primary rhizome fingers of relatively uniform sizes were used as planting material during July and crops were harvested in January month for both years. Each replication had 46 plants. Therefore, two field trials were taken up with two consecutive plantings. The upper ground parameters were taken after 150 days after planting and rhizome characters were recorded at the harvesting stage, when all the leaves had dried up.

The germplasm accessions were evaluated as per Turmeric DUS guidelines of PPV&FRA, Government of India (https://plantauthority.gov.in/sites/default/files/turmeric_1.pdf). The two categories *viz*., quantitative and qualitative characters were recorded and reported separately. The quantitative characters included:

- Plant pseudo stem habit
- Plant leaf disposition
- Leaf colour on dorsal side
- Leaf colour on ventral side
- Leaf lamina length (cm)
- Leaf lamina width (cm)
- Venation pattern
- Leaf margin
- Pseudostem anthocyanin colouration

Table 1. Passport data of variety and land races of East Indian arrowroot (*Curcuma angustifolia*) including wild relative

Collection No.	IC No.	Botanical name/local name	Collection Source	Biological status	Village	Mandal	District	State	Latitude	Longitude	Altitude (m)
IGSJT-10-2	IC624134	*C. angustifolia*, Tikhur	Home Garden	Variety (Chhattisgarh Tikhur 1)*	Kamari	Shankargarh	Balrampur	Chhattisgarh	N 23°17.469'	E 83°37.068'	686
IGRJT-16-1	IC624146	*C. angustifolia*, Tikhur	Farmers field	Land race	Gharghoda	Gharghoda	Raigarh	Chhattisgarh	N 22°26.963	E 83°33.195'	606
IGDMT-10-1	IC624130	*C. angustifolia*, Batri	Farmers field	Land race	Dugali	Nagari	Dhamtari	Chhattisgarh	N 20°29.477'	E 81°52.166'	445
IGBT-10-2	IC624138	*C. angustifolia*, Batri	Fallow	Land race	Makdi	Kondagaon	Kondagaon	Chhattisgarh	N 19°59.655'	E 81°36.362'	632
IGBT-10-4	IC624141	*C. angustifolia,* Batri	Forest	Land race	Jagdalpur	Jagdalpur	Bastar	Chhattisgarh	N 19°02.789'	E 81°57.041'	559
CTCRI-CA-PM-1	IC641835	*C. angustifolia* Koova	Home Garden	Land race	Karakulam	Nedumangadu	Thiruvananthapuram	Kerala	N8° 32'42.74	E76° 32'42.74	12
CTCRI-CA-PM-2	IC641836	*C. angustifolia,* Koova	Home Garden	Land race	Karakulam	Nedumangadu	Thiruvananthapuram	Kerala	N8°32'42.74	E76°54'53.72	12
CTCRI-CA-PM-3	IC641837	*C. angustifolia,* Koova	Home Garden	Land race	Nedumangadu	Nedumangadu	Thiruvananthapuram	Kerala	N8° 36' 11.99	E 77° 0' 9.99	68
CTCRI-CA-PM-4	IC641838	*C. angustifolia,* Koova	Home Garden	Land race	Adimali	Idduki	Idukki	Kerala	N 10.0115°	E 76.9528°	650
CTCRI-CZ-PM-1	IC641839	*Curcuma zedoaria* Kattu Koova	Home Garden	Wild	Adimali	Idukki	Idukki	Kerala	N 10.0115°	E 76.9528°	650

*State released variety from Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh state, India

- Rhizome habit
- Rhizome shape
- Rhizome internode pattern
- Status of tertiary rhizomes
- Rhizome inner core colour
- Duration to maturity

The following quantitative characters were recorded:

- Plant height (cm)
- Number of shoots
- Number of leaves on main shoot
- Leaf petiole length (cm)
- Leaf lamina length (cm)
- Leaf lamina width (cm)
- Rhizome length (primary, cm)
- Number of mother rhizomes
- Rhizomes internode patterns (cm)
- Duration (number of days)
- Rhizome yield (g) plant^{-1}
- Dry recovery (%)

The fresh rhizomes were analyzed for proximate parameters *viz*., moisture content, total starch, total sugar, crude fat, crude fibre, and total ash with replicated samples as per standard procedures (AOAC, 1995). The data were statistically analysed and qualitative descriptive DUS characters were also documented.

Results and Discussion

Qualitative traits

There has been intense research focus nowadays on germplasm characterization, conservation of plant genetic resource and utilization especially in indigenous crops. Crop plants belong to Zingiberaceae has very high economic value. The wide genetic base is important for any breeding programme and variability present for heritable and economically important traits because range of available genetic variation is crucial for selection and utilisation for further improvement. For genetic improvement of starchy Curcumas, collection, characterisation and evaluation are prerequisite for both conventional and biotechnological approaches of breeding. Many parameters are involved in characterisation processes which need to be systematically followed for practical outcome. In this direction, there is a need to collect and characterise the targeted germplasm and it has now been possible to group, screen and select superior genotypes for improving desirables for improvement through simple clonal selection procedures.

To assess the genetic variation in indigenous East Indian arrowroot landraces, variety and wild species, a total of 10 germpalsm accessions were used as experimental material and were studied for 15 qualitative and 12 quantitative traits. As per DUS guidelines of PPVFRA, turmeric varieties are grouped based on some key phenotypic characters of plant, colour of coma bract, rhizome characters and duration of the crop etc. Accordingly, evaluation of the selected Indian arrowroot and wild species revealed that wild relative had long lamina length and broad lamina width whereas variety and land races of East Indian arrowroot showed medium lamina length except IGRJT-16-1 and IGDMT-10-1. Notably, both IGRJT-16-1 and IGDMT-10-1 had narrow lamina width which is distinct character than others. Wild species showed compact rhizome habit and others had loose habits. The rhizome internodal pattern is an important qualitative character reported for crop plants of Zingiberaceae family. In this respect, rhizomes of land races of IGRJT-16-1, IGDMT-10-1 and wild species had close pattern and others had distant pattern. The whole rhizome bunch views of all the germplasm accessions are given in Fig. 1 (a, b, c d, e, f g, h, i & j). Thus, studied germplasm accessions showed morphological differences in plant, leaf and rhizome characteristics. The overall appearance of many species of *Curcuma* is almost similar

Fig. 1. Whole rhizome bunch views of ten germplasm accessions of *C. angustifolia*

a. IGSJT-10-2, b. IGRJT-16-1, c. IGDMT-10-1, d. IGBT-10-2, e. IGBT-10-4, f. CTCRI-CA-PM-1, g. CTCRI-CA-PM 2, h. CTCRI-CA-PM-3, i, CTCRI-CA-PM-4 and j. CTCRI-CZ-PM-1

Table 2. Qualitative characters of variety and land races of East Indian arrowroot *(Curcuma angustifolia)* and related wild species

DUS Characters	Variety code	Land races code								*Curcuma Zedoaria* code
	IGS-JT-10-2	IGR-JT-16-1	IGD-MT-10-1	IGBT-10-2	IGBT-10-4	CTCRI-CA-PM-1	CTCRI-CA-PM 2	CTCRI-CA-PM-3	CTCRI-CA-PM-4	CTCRI-CZ-PM-1
Plant Psudo stem habit	Open	Close	Open	Open	Open	Open	Open	Open	Open	Open
Plant Leaf disposition	Semi erect	Erect	Semi erect	Semi erect	Semi erect	Semi erect	Semi erect	Semi erect	Semi erect	Semi erect
Leaf colour on dorsal side	Light green	Light green	Light green	Light green	Light green	Light green	Light green	Light green	Light green	Light green
Leaf colour on ventral side	Green	Green	Green	Green	Green	Green	Green	Green	Green	Dark green
Leaf lamina length(cm)	Medium	Long	Long	Medium	Medium	Medium	Medium	Medium	Medium	Long
Leaf lamina width (cm)	Medium	Narrow	Narrow	Medium	Medium	Medium	Medium	Medium	Medium	Broad
Venation Pattern	Distant	Distant	Distant	Distant	Distant	Distant	Distant	Distant	Distant	Close
Leaf margin	Even	Even	Even	Even	Even	Even	Even	Even	Even	Wavy
Pseudo stem Anthocyanin colouration	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Rhizome habit	Loose	Loose	Loose	Loose	Loose	Loose	Loose	Loose	Loose	Compact
Rhizome Shape	Straight	Straight	Straight	Straight	Straight	Straight	Straight	Straight	Straight	Straight
Rhizome Internodes pattern	Distant	close	close	Distant	Distant	Distant	Distant	Distant	Distant	close
Status of tertiary rhizomes	Present	Absent	Present	Present	Absent	Absent	present	present	present	Present
Rhizome inner core colour	Lemon yellow	Lemon yellow	Lemon yellow	Lemon yellow	Lemon yellow	Lemon yellow	Lemon yellow	Lemon yellow	Lemon yellow	Lemon yellow
Duration to maturity	Short duration	Short duration	Short duration	Short duration	Short duration	Short duration	Short duration	Short duration	Short duration	Short duration

as they differ in small morphological details (Sirirugsa, 1996).

Phenotypic and horticultural traits of the collected germplasm help to identify germplasm with desirable trait (Amanullah and Hatham, 2000). Qualitative characterisation has helped to distinguish two land races from rest of East Indian arrowroots and wild species. The wild species (*Curcuma zedoaria*) has some distinct features such as dark green leaf colour on ventral side, long lamina length, broad lamina width, compact rhizome habit and close inter node pattern. Qualitative DUS characters of variety, land races of East Indian arrow root and related wild species are given in Table 2.

Quantitative traits

Significant levels of differences were reported by germplasm accessions as per the results of selected quantitative traits. Germplasm displayed differences in many traits of horticultural importance including plant height, leaf length, leaves number, etc. The quantitative observation showed that wild species had maximum height (87.13) followed by IGRJT-16-1 (89.15), CTCRI-CA-PM-4 (70.88), IGDMT-10-1(70.65) and IGSJT-10-2(68cm) with overall standard deviation and CV% of 9.52 and 13.43, respectively. In general, in many of the crops, plant height is measured as they influence on yield. One report on turmeric revealed that plant height and number of leaves determines the yield potential of the genotype (Narayanpur and Hanamashetti, 2003). However, semi dwarf plant types are preferred over tall plants of many crops. The germplasm CTCRI-CA-PM-1 had moderate height when compared to other accessions. Maximum petiole length of 41.25 cm was recorded in wild species (CTCRI-CZ-PM-1) whereas variety (IGSJT-10-2) had shortest petiole length of 21.95 cm. Variation in petiole length (15 – 35 cm) in *Curcuma sattayasaii*, in *C. zedoaroides* (8 – 12 cm) has been reported by Chaveerach et al., (2008).

Coefficient of variation (CV %) ranged from 2.33 to 39.73 for various traits. The highest coefficient of variation was observed for primary rhizome length of ten germplasm accessions, while the lowest level was showed by crop duration to rhizome maturity of germplasm. Highest values of 41.25 and 47.18 were recorded in

Table 3. Quantitative characters of variety, land races of East Indian arrow root (*Curcuma angustifolia*) and related wild species

DUS Characters	Variety code	Land races code								*Curcuma zedoaria*	Grand Mean	Stdev	CV (%)
	IGS-JT-10-2	IGR-JT-16-1	IGD-MT-10-1	IGBT-10-2	IGBT-10-4	CTCRI-CA-PM-1	CTCRI-CA-PM 2	CTCRI-CA-PM-3	CTCRI-CA-PM-4	CTCRI-CZ-PM-1			
Height (cm)	68	89.15	70.65	62.43	64.8	63.5	64.9	67.53	70.88	87.13	70.90	9.52	13.43
Number of shoots	2	2	2	2	3	2	2	2	2	1	2.00	0.47	23.57
Number of leaves on main shoot	5	5	4	5	5	5	4	4.25	5	6.75	4.90	0.78	15.99
Leaf petiole length (cm)	21.95	35.23	39.15	25.9	25.2	30.83	29.4	35.55	38.15	41.25	32.26	6.58	20.39
Leaf lamina length (cm)	33.73	40.98	41.1	33.8	36.38	34.3	33.28	31.78	34.33	47.18	36.69	4.86	13.24
Leaf lamina width (cm)	10.25	10.93	12.18	9.83	9.68	12.38	11.33	10.45	10.4	15.63	11.30	1.77	15.68
Rhizome length (Primary) (cm)	16.5	14.13	14.68	9.5	9.23	21.25	9.13	8	7.88	7.13	11.74	4.66	39.73
No. of mother rhizomes	2	3.5	3	2	3	2	2	2	2	2	2.35	0.58	24.67
Internodes pattern (cm)	2.4	1.59	0.95	1.93	1.58	2.5	1.88	2	1.88	1.5	1.82	0.45	24.79
Duration (number of days)	175	185	185	185	180	175	185	185	185	185	182.50	4.25	2.33
Rhizome yield (g plant^{-1})	525.8	610	481	498.25	514	709.8	543.75	471	402.25	487.5	524.34	84.25	16.07
Dry recovery (%)	16.97	16.46	15.35	12.3	15.6	19.15	12.1	12.3	10.6	18.85	14.97	3.00	20.03

wild species for leaf lamina length and lamina width, respectively. Multiple regression analysis in ginger crop indicated that yield of rhizome can be predicted by plant height, number of leaves and breadth of last fully opened leaf at 90th and 120th day after planting (Rattan et al., 1988). The performance under quantitative category in terms of primary rhizome length, rhizome internode pattern and rhizome yield (g) plant^{-1} is superior in the land race CTCRI-CA-PM-1. Similarly, the dry recovery was highest (19.15) in CTCRI-CA-PM-1 followed by wild species (18.85) and IGSJT-10-2-variety (16.97). In other germplasms, dry recovery did not vary much which recorded a range from 10.6 (CTCRI-CA-PM-4) to 16.46 (IGRJT-16-1). Sajitha et al., (2014) has studied dry recovery of two species of *Curcuma* along with phonological variation. Rhizome harvest was done when all the leaves completely dried up and this has happened during maturity duration of 175 days (IGSJT-10-2 and CTCRI-CA-PM-1), 180 days (IGBT-10-4) and 185 days (IGRJT-16-1, IGDMT-10-1 and IGBT-10-2, CTCRI-CA-PM 2, CTCRI-CA-PM-3, CTCRI-CA-PM-4 and CTCRI-CZ-PM-1).

The maximum standard deviation (84.25) was observed for rhizome yield plant^{-1} followed by leaf petiole length (6.58). Similarly, highest CV% (39.73) was recorded for rhizome length followed by internodes pattern (24.79) and least (2.33) value was recorded in crop duration for maturity. Quantitative characters of variety, land races of East Indian arrow root (*Curcuma angustifolia*) and related wild species is given in Table 3. Among all the qualitative characters presented above, primary rhizome length is very important one which holds maximum weight out of total bunch weight. Hence, germplasm having maximum primary rhizome length is preferred for improvement of clonal selection. In view of economic importance, quantity of starch content in rhizome needs to be superimposed on other desirable characters. Hence, the proximate parameters of the matured rhizome have been carried out for drawing inference about the selection of desirable accession(s).

Proximate analysis

The results of proximate analysis of ten germplasm accessions are presented in Table 4. Lowest CV % values were observed for moisture (2.42) and sugar % and highest data was reported in case of crude fibre and crude fat with a range value of 0.35 (IGBT-10-4) to 0.57 (CTCRI-CZ-PM-1) and 0.11 (IGSJT-10-2) to 0.19 (CTCRI-CZ-PM-1), respectively. The total starch (11.48) and total ash contents (11.59) had more or

Table 4. Proxmite compsotion of fresh rhizomes of variety and land races of East Indian arrowroot (*Curcuma angustifolia*) and related wild species

Variety/land race	Moisture (%)	Total starch (%)	Sugar (%)	Crude fat (%)	Crude fibre (%)	Total Ash (%)
IGSJT-10-2	68.45	15.80	0.30	0.11	0.47	0.45
IGRJT-16-1	70.25	13.50	0.305	0.16	0.39	0.37
IGDMT-10-1	71.35	13.20	0.295	0.16	0.47	0.43
IGBT-10-2	66.90	11.55	0.335	0.19	0.38	0.47
IGBT-10-4	72.40	13.00	0.26	0.13	0.35	0.32
CTCRI-CA-PM-1	68.50	16.80	0.35	0.17	0.51	0.47
CTCRI-CA-PM 2	69.15	13.10	0.33	0.15	0.46	0.46
CTCRI-CA-PM-3	69.20	13.30	0.30	0.16	0.41	0.41
CTCRI-CA-PM-4	71.60	14.20	0.33	0.18	0.37	0.43
CTCRI-CZ-PM-1	70.50	12.45	0.35	0.19	0.57	0.47
Mean	69.83	13.67	0.32	0.16	0.44	0.43
Stdev	1.69	1.57	0.03	0.03	0.07	0.05
CV (%)	2.42	11.48	9.01	15.87	15.96	11.59

less equal CV %. Maximum starch content (16.8) was reported in CTCRI-CA-PM-1 followed by IGSJT-10-2 (15.8). The land race IGBT-10-2 had lowest starch content of 11.5%. Among the 10 accessions evaluated, a land race code named CTCRI-CA-PM-1 showed maximum starch content (16.8%). The many *Curcuma* species such as *Curcuma malabarica*, *C. brog and C. caesia,* are reported to yield 21, 19.9 and 18% of starch, respectively (Vimala and Bala Nambisan, 2010). Starch from East Indian arrowroot has been extensively used in food, ayurveda and cosmetic industries (Vimala and Bala Nambisan, 2010). Due to the presence of essential oil, excellent aroma and other physico-chemical properties, starchy *Curcuma* warrants full fledges focused R&D for their commercial cultivation and domestication to newer area as cultivation of this crop is mostly reported in East, Central and NE India only.

Conclusion

In the present study, ten accessions of germplasm were described based on DUS guidelines for turmeric and variation has been reported among variety, land races and related wild species. Phenotypic and horticultural traits of the germplasm facilitated in identification and selection for desirable traits. Investigation on quantitative characters and biochemical analysis was useful in identifying germplasm accession (CTCRI-CA-PM-1) having lengthy primary rhizome (21.25) coupled with highest starch content (16.8), yield plant^{-1} (709.8 g) and dry recovery (19.15%) in the rhizome. Other equally better promising genetic stocks selected from the present study are IGSJT-10-2 (IGKV-Variety Chhattisgarh Tikhur-1) and IGDMT-10-1 (Land race from Dhamtari, Chhattisgarh). Hence, special efforts are needed to conserve selected germplasm and in-depth studies on molecular, biochemical aspects are required for all the precious genetic resources maintained in the field gene bank.

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