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सूची संशोधित

CATALOGUE OF ARROWROOT GENETIC RESOURCES



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Technical Bulletin Series:

Published by

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ICAR-Central Tuber Crops Research Institute

Indian Council of Agricultural Research

Sreekariyam, Thiruvananthapuram-695017, Kerala, India

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Website: www.ctcri.org

Printed: July 2026

Printed at: Akshara Offset Thiruvananthapuram

Citation:

Catalogue of Arrowroot Genetic Resources

Technical Bulletin No. TB-125/2026

ICAR-CTCRI, Sreekariyam, Thiruvananthapuram-695017,

Kerala, India



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Annexure-1: Identification and Characterization Data



PREFACE

Arrowroot (*Maranta arundinacea* L.) is one of the oldest cultivated tropical starch producing crops and is valued for its highly digestible, premium-quality starch, which has long been used as a nutritious food and in traditional medicine. Although cultivated on a limited scale compared with major tuber crops, arrowroot continues to hold considerable importance among tribal and rural communities due to its adaptability, nutritional value and diverse industrial applications. The crop thrives well under humid tropical conditions and contributes to livelihood security by providing a dependable source of starch in marginal production environments. With increasing interest in functional foods, natural starches and climate-resilient crops, arrowroot is once again attracting attention as a valuable genetic resource for future agricultural and industrial development.

Arrowroot has been cultivated in different parts of India for several decades, particularly in Kerala and other humid tropical regions, where it is maintained largely as traditional landraces by farming communities. The crop is appreciated for its easily digestible starch, making it suitable for infant foods, convalescent diets and specialty food products. Beyond its culinary uses, arrowroot starch finds applications in the pharmaceutical, cosmetic, textile and food processing industries because of its superior physicochemical properties. Despite its economic and nutritional significance, systematic collection, conservation and characterization of arrowroot germplasm have remained relatively limited, highlighting the need for comprehensive documentation of the available genetic resources.

As the national repository for tropical tuber crop genetic resources, the ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI) being the NAGS for tropical tuber crops has undertaken sustained efforts to collect, conserve and characterize arrowroot germplasm. The Institute Field Genebank (FGB) presently maintains a valuable collection of arrowroot accessions representing the existing genetic diversity available for crop improvement and long-term conservation. The considerable variation observed among these accessions for vegetative, rhizome and biochemical traits provides an important genetic base for developing improved cultivars with enhanced yield, starch quality, nutritional attributes and adaptability to changing climatic conditions.

This catalogue presents the characterization of 35 arrowroot accessions conserved in the Institute Field Genebank, documented using standardized descriptors. The publication serves as a comprehensive reference on the diversity available within the conserved germplasm and provides valuable baseline information for researchers, plant breeders, students and policymakers engaged in genetic resource conservation and crop improvement. It is expected that this catalogue will facilitate the effective utilization of arrowroot genetic resources, strengthen conservation efforts and promote the wider recognition of this underutilized yet economically important tropical tuber crop for sustainable agriculture and food and nutritional security.

Dr. G. Byju
Director



ACKNOWLEDGEMENTS

The authors are highly grateful to Dr. Byju G., Director, ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala for the facilities provided and constant encouragement given and for the grant of necessary permission for bringing out the catalogue. The authors express their sincere thanks to Dr. Manas Ranjan Sahoo, Head, Division of Crop Improvement for the valuable support provided throughout. The authors also put on record their sincere gratitude to Dr. Sheela M.N., former Director, ICAR-CT-CRI for her timely help and encouragement in the establishment of arrowroot germplasm and support provided throughout the work including the variety release in arrowroot. The authors express their heartfelt thanks to Mr. Suresh G., Technical Officer (T-5); Mrs. Jyothi S. L., Multi-Tasking Staff, Mr. Subin P. Nair and Mr. Sudarsan S., skilled support staff for their ever-willing help in the planting of the germplasm, its maintenance and data recording. The valuable help provided by Mr. Aswin S. Kumar, Project Assistant deserves special mention in the data compilation of the catalogue. The authors are also thankful to the Scientists and staff of the Division of Crop Improvement, PME, Administrative and Finance and Accounts sections of ICAR-CTCRI for their timely support and help.

AUTHORS



ABSTRACT

The present catalogue documents the characterization of thirty-five accessions arrowroot (*Maranta arundinacea* L.) conserved in the field genebank of ICAR-CTCRI to assess the extent of morphological diversity and to identify promising germplasm for future crop improvement programmes. Considerable variation was observed in most of the vegetative characters, including plant height, stem diameter, number of tillers, leaf size, leaf sheath length and petiole length, reflecting differences in plant vigour and growth habit among the accessions. Flowering was observed in few accessions, while the majority remained non-flowering, confirming that arrowroot is predominantly propagated through its rhizomes under the prevailing conditions. Significant diversity was also observed for rhizome and yield attributes. Rhizome yield ranged from 16.10 to 29.00 t ha⁻¹, with an average of 21.8 t ha⁻¹, while yield plant⁻¹ varied from 26.83 to 48.33 g. The number of rhizomes plant⁻¹ ranged from 11 to 28, and single rhizome weight varied between 75.00 and 130.00 g. Rhizome size also exhibited wide variation, with the largest rhizome length ranging from 14.00 to 29.83 cm and width from 5.33 to 10.00 cm. Neck length (2.17-9.50 cm), node length (1.00-4.60 cm) and tip length (0.50-2.00 cm) further demonstrated variability among the accessions.



1. Introduction

Arrowroot (*Maranta arundinacea* L.) is one of the oldest domesticated tropical root crops and has been cultivated for thousands of years in the humid tropics. Native to tropical America, the crop is now widely grown across Asia, Africa, the Caribbean and Latin America for its highly digestible starch and diverse food and industrial applications (Piperno et al., 2000; Heuzé et al., 2017).

Belonging to the family Marantaceae, arrowroot is a perennial rhizomatous herb valued for the exceptional quality of its starch. The starch is characterized by its fine granule size, bland flavour, high digestibility and gluten-free nature, making it particularly suitable for infant foods, therapeutic diets, bakery products, confectionery and pharmaceutical formulations. In recent years, growing consumer preference for natural, clean-label and gluten-free ingredients has renewed global interest in arrowroot as a specialty starch crop.

In India, arrowroot is cultivated mainly in home gardens and smallholder farming systems, particularly in the southern and eastern states. Kerala possesses a rich diversity of locally adapted landraces that have been maintained by farming communities through generations of clonal selection. These traditional genetic resources exhibit considerable variation in plant morphology, rhizome characteristics, starch quality, yield potential and adaptation to diverse agroecological conditions. Such diversity represents an invaluable reservoir of genes for crop improvement, climate resilience and sustainable agricultural development. Despite its nutritional and economic importance, arrowroot remains an underutilized and neglected crop. The replacement of traditional landraces with commercial crops, shrinking cultivation areas, changing food habits and erosion of indigenous knowledge have accelerated the loss of valuable genetic diversity. The conservation and systematic documentation of these genetic resources have therefore become essential to ensure their long-term availability for research, breeding and sustainable utilization (Heuzé et al., 2017).

Origin and distribution

Arrowroot is one of the oldest domesticated starch-producing crops of the Neotropics. The crop is believed to have originated in the tropical rainforests of northern South America and Central America, where archaeological evidence indicates its utilization by indigenous populations for more than 8,000 years (Piperno and Pearsall, 1998; Asha et al., 2015). Wild populations of *M. arundinacea* are distributed throughout the humid lowlands of Central America, the Caribbean and northern South America, particularly in Brazil, Colombia, Venezuela, Guyana and the Amazon Basin. These regions are considered the primary centre of origin and diversity of the species (Andersson, 1998).

The domestication of arrowroot involved the gradual selection of plants possessing larger rhizomes, higher starch yield, reduced fibre content and improved culinary quality. Unlike many other tropical root crops, arrowroot was valued not only as a source of dietary starch but also for its medicinal properties, particularly the highly digestible starch extracted from its rhizomes. The crop exhibits excellent adaptation to humid tropical environments and



performs well in fertile, well-drained soils under partial shade, characteristics that facilitated its cultivation by early indigenous communities (Asha et al., 2015).

Following European exploration of the Americas during the sixteenth century, arrowroot was disseminated to several tropical regions of the world through colonial trade networks. The crop was introduced into Asia, Africa and the Pacific Islands, where it gradually became established as a minor food and starch crop. Owing to its adaptability to warm and humid climates, arrowroot is now cultivated throughout the tropical and subtropical regions including India, Sri Lanka, Bangladesh, Indonesia, the Philippines, China, Malaysia, Thailand, several African countries and numerous Caribbean islands (Lebot, 2009).

In India, arrowroot was introduced during the colonial period and has since become a traditional tuber crop in several humid regions of the country. It is cultivated primarily in Kerala, Tamil Nadu, Karnataka, Odisha, Andhra Pradesh, West Bengal and the northeastern states, where it serves as a source of high-quality starch for food, pharmaceutical and nutraceutical applications. Although its cultivation occupies a relatively small area compared with cassava and sweet potato, arrowroot remains an important crop among tribal and rural communities because of its ease of cultivation, nutritional value and medicinal significance (Asha et al., 2015).

Arrowroot is well adapted to diverse cropping systems because of its tolerance to partial shade and its ability to perform satisfactorily under plantation ecosystems. In the humid tropics of Southern India, the crop is commonly cultivated as an intercrop in coconut, arecanut and rubber plantations as well as in homestead gardens beneath perennial fruit trees, where it contributes to efficient utilization of available land resources (Suja and Nayar, 2005; Suja et al., 2023).

Despite its widespread geographical distribution, arrowroot is predominantly cultivated on a smallholder scale and commercial production remains limited. Consequently, comprehensive global production statistics are scarce, and traditional cultivars have undergone considerable genetic erosion due to replacement by higher-yielding starch crops such as cassava, maize and potato. This decline has renewed interest in the collection, conservation and characterization of arrowroot genetic resources to safeguard its genetic diversity and promote its utilization in sustainable agriculture and the starch industry (Lebot, 2009; Asha et al., 2015).

Botany

The plant produces erect pseudostems arising from underground rhizomes and generally attains a height of 0.6-1.5 m depending on the genotype and growing conditions. The pseudostems are slender, green and may be either unbranched or sparsely branched. Considerable variation exists among accessions with respect to plant height, tillering ability and pseudostem thickness.

The leaves are simple, alternate and distichously arranged on long petioles. The leaf blades are ovate-lanceolate to elliptic-lanceolate with entire margins and an acuminate apex. They are bright green and glabrous with a prominent midrib and parallel lateral venation. A char-



characteristic pulvinus is present at the junction of the petiole and leaf blade, facilitating leaf movement in response to changes in light intensity. Variability has been observed among accessions for leaf size, petiole length, leaf orientation and foliage colour. The presence of a well-developed pulvinus enables characteristic nyctinastic leaf movement in response to changes in light intensity (Tomlinson, 1969). The leaves are amphistomatic with a thick cuticle and possess aquiferous parenchyma in the adaxial epidermis, features that contribute to tolerance against water stress and protection from pathogens and insects (Aloni and Sachs, 1973).

The root system consists of numerous adventitious fibrous roots arising from the rhizome and functioning primarily in water and nutrient absorption. The underground rhizomes are modified storage stems that accumulate starch within parenchymatous tissues. Rhizomes are generally fusiform to cylindrical and may develop either horizontally or vertically beneath the soil surface. They exhibit considerable variation in size, shape, branching pattern and starch content among different accessions. Externally, the rhizomes are covered with thin brown cataphylls, while internally they consist of distinct cortical, vascular and parenchymatous tissues containing abundant starch granules (Brito et al., 2021).

The inflorescence is terminal and consists of several partial inflorescences bearing small, white, bisexual and zygomorphic flowers. The flowers are trimerous, possessing three sepals, three petals, petaloid staminodes, a single fertile stamen and an inferior ovary (Andersson, 1981). Flowers usually open in pairs and are mirror images of one another. Native bees and hummingbirds constitute the principal pollinating agents, whereas ants, butterflies and moths function mainly as floral visitors (Kennedy, 1978; Brito et al., 2021). Fruit formation is uncommon under cultivation and consists of small capsules containing brown arillate seeds. Poor pollen fertility, irregular flowering, self-incompatibility and low seed set greatly restrict sexual reproduction; consequently, the crop is propagated almost exclusively through rhizome pieces, resulting in the maintenance of genetically stable clonal populations (Daquinta et al., 2009; Brito et al., 2021).

Cytogenetics

Arrowroot belongs to the genus *Maranta* L. of the family Marantaceae under the order Zingiberales. The genus comprises approximately 40-50 species distributed predominantly in the tropical regions of Central and South America, among which *Maranta arundinacea* L. is the only species widely cultivated for its edible starch-rich rhizomes. The family Marantaceae is closely related to Cannaceae and other families within the order Zingiberales and exhibits several morphological and cytological similarities.

Arrowroot possesses a somatic chromosome number of $2n = 48$ and is generally regarded as a tetraploid species with a basic chromosome number of $x = 12$ (Simmonds and Shepherd, 2005). The chromosomes are relatively small and morphologically similar, making detailed cytological characterization difficult using conventional chromosome staining techniques. Cytological investigations have shown that the chromosomes are relatively small and morphologically similar, making detailed karyotype analysis difficult using conventional cytogenetic



techniques (Brito et al., 2021). Comparative chromosome studies within Marantaceae have revealed variation in chromosome number among related species together with differences in chromosome morphology, suggesting that chromosomal evolution has contributed to species diversification within the family (Andersson, 1998).

The crop reproduces predominantly through vegetative propagation using rhizomes, whereas sexual reproduction is limited because of infrequent flowering, poor pollen fertility, self-incompatibility and low seed production (Daquinta et al., 2009; Brito et al., 2021). Consequently, cultivated populations are maintained as stable clonal lineages. Although this mode of propagation preserves desirable agronomic traits, it limits meiotic recombination and restricts the generation of variability through conventional breeding.

Considerable cytological stability has been observed among cultivated accessions despite the existence of substantial phenotypic variation in plant architecture, rhizome morphology and starch quality and maturity period. Such variation is considered to arise primarily through somatic mutations, clonal selection and adaptation to diverse agroecological conditions rather than frequent sexual recombination (Simmonds and Shepherd, 2005; Brito et al., 2021).

Collection, characterization and conservation of arrowroot germplasm are therefore essential for broadening the genetic base available for crop improvement. The maintenance of local landraces and wild relatives provides valuable insurance against genetic erosion resulting from the replacement of traditional cultivation systems by commercial agriculture. Molecular cytogenetic tools and in vitro techniques are expected to complement conventional breeding by facilitating the characterization and utilization of available genetic resources (Daquinta et al., 2009; Narcisa-Oliveira et al., 2018; Brito et al., 2021).

Phylogeny and molecular approaches

The phylogenetic relationships of *Maranta arundinacea* and related taxa have been investigated using both morphological characteristics and molecular markers. Molecular evidence confirms the monophyletic nature of the family Marantaceae and its close evolutionary relationship with Cannaceae within the order Zingiberales (Kress et al., 2001; APG IV, 2016). Comparative phylogenetic studies indicate that cultivated arrowroot originated from wild populations in tropical Central and South America before being disseminated to the Caribbean, Asia and Africa through human migration and trade (Piperno et al., 2000).

Because arrowroot is propagated predominantly through rhizomes, molecular markers provide reliable tools for assessing genetic diversity independent of environmental influences. Marker systems such as RAPD, ISSR, AFLP and SSR have been employed to evaluate genetic relationships among cultivated accessions and traditional landraces. These studies have demonstrated substantial polymorphism despite vegetative propagation, indicating that farmer-maintained germplasm possesses a broad genetic base for crop improvement (Madineni et al., 2012).

Chloroplast genes including *rbcL* and *matK*, together with the nuclear Internal Transcribed Spacer (ITS) region, have been widely used for DNA barcoding and phylogenetic analysis within Marantaceae and other members of Zingiberales (Kress et al., 2005). These studies have facilitated accurate species identification, clarified taxonomic relationships and improved the management of germplasm collections.

Recent advances in next-generation sequencing, transcriptome analysis and genotyping-by-sequencing provide new opportunities for understanding genome organization and identifying genes associated with starch biosynthesis, rhizome development, stress tolerance and disease resistance (Brito et al., 2021).

Agronomic requirements

Arrowroot is well adapted to humid tropical and subtropical climates and is commonly grown in homestead gardens, mixed cropping systems and smallholder farms. Owing to its low input requirements and adaptability to diverse environments, arrowroot is considered a suitable crop for sustainable and climate-resilient agriculture (Onwueme, 1978; Sasikumar, 2010). The crop performs well under warm humid climatic conditions with an optimum temperature ranging from 20 to 35°C and annual rainfall between 1,500 and 2,500 mm. Although arrowroot tolerates partial shade, it can also be cultivated successfully under full sunlight provided that adequate soil moisture is maintained throughout the growing period. It grows best in fertile, well-drained sandy loam to loam soils rich in organic matter with a slightly acidic to neutral soil reaction (pH 5.5-7.0). Poorly drained and waterlogged soils adversely affect rhizome development and reduce starch accumulation (Madineni et al., 2012).

Arrowroot is propagated almost exclusively through vegetative means using whole rhizomes, rhizome sections and sprouts or rooted stem cuttings obtained from freshly harvested plants. Micropropagated planting materials have also been developed for rapid multiplication and the production of disease-free planting material, although their commercial utilization remains limited (Daquinta et al., 2009; Narcisa-Oliveira et al., 2018; Brito et al., 2021). Healthy rhizomes weighing about 50-70 g possessing at least one viable bud are generally preferred for planting, and approximately 2-3 t ha⁻¹ of seed rhizomes are required for commercial cultivation (Brito et al., 2021).

Planting is usually carried out at the onset of the rainy season to ensure rapid establishment and uniform crop growth. The land is prepared by thorough ploughing followed by incorporation of well-decomposed farmyard manure or compost. Depending on soil conditions and rainfall, planting is undertaken on raised beds, ridges or furrows to facilitate drainage and promote rhizome development. Rhizomes are generally planted at a depth of about 15 cm, while spacing varies with cultivar and production system. Under Brazilian conditions, planting in furrows approximately 15 cm deep is recommended under limited moisture availability, whereas a spacing of 15 cm between plants and 30 cm between rows has been reported under intensive cultivation (Stephens, 1994; Coelho et al., 2005).



Arrowroot responds well to organic nutrient management and generally requires relatively low fertilizer inputs owing to its efficient association with arbuscular mycorrhizal fungi, which enhance nutrient and water uptake (Coelho et al., 2005). Production technology for organic management of arrowroot has been developed by Suja et al. (2023). Nevertheless, balanced application of nitrogen, phosphorus and potassium fertilizers promotes vigorous vegetative growth and higher rhizome yield. Fertilizer recommendations vary according to soil fertility and production system, with applications ranging from 40 kg ha⁻¹ NPK under experimental conditions to 110 kg ha⁻¹ NPK applied both at planting and as a side dressing during crop growth (Guilherme et al., 2017).

Under South Indian conditions, the recommended production technology includes planting during May-June on raised beds at 30 × 15 cm spacing with application of 10 t FYM ha⁻¹ and fertilizers at 50:25:75 kg N:P₂O₅:K₂O ha⁻¹, resulting in a crop duration of approximately 9-10 months (Suja et al., 2003, Suja et al., 2006, Suja and Nayar, 2005; 2006, Suja and Nedunchezhiyan, 2018).

Intercultural operations include timely weeding, earthing-up and mulching to maintain favourable soil conditions for rhizome development. At least three manual weedings are recommended during the crop cycle to minimize competition from weeds (Coelho et al., 2005). Earthing-up encourages rhizome expansion and prevents exposure of developing rhizomes, while straw mulching conserves soil moisture, suppresses weed growth and improves productivity. Arrowroot is highly suitable for intercropping with short-duration crops and green manures having crop cycles of up to four months. Intercropping with carrot has been reported to improve overall system productivity without adversely affecting arrowroot yield (Zárate et al., 2007; Vieira et al., 2015).

Compared with many tropical tuber crops, arrowroot is relatively free from serious pests and diseases. However, insect pests such as cabbage caterpillar (*Ascia monuste orseis*), mole crickets (*Neocurtilla hexadactyla* and *Scapteriscus vicinus*), and the leaf-feeding caterpillar *Calpodes ethlius* have occasionally been reported in different production regions (Alam, 1987; Reddy, 2015). Diseases caused by *Rhizoctonia solani*, *Pellicularia filamentosa*, *Rosellinia bunodes*, *Xanthomonas marantae* and root-knot nematodes (*Meloidogyne enterolobii*) have also been recorded under favourable conditions (Ebenezar et al., 1996; Zhuo et al., 2010; Reddy, 2015). Adoption of healthy planting material, proper drainage, crop rotation, field sanitation and integrated crop management practices effectively minimizes pest and disease incidence.

The crop generally reaches physiological maturity 8-14 months after planting, depending on the genotype, environmental conditions and intended use of the rhizomes. Maturity is indicated by yellowing and drying of leaves followed by senescence of the aerial portions. Harvesting is carried out manually or by partial mechanization, after which the rhizomes are separated into seed, small and large grades. Seed rhizomes are retained for subsequent planting, whereas larger rhizomes are utilized for starch extraction and smaller rhizomes



are often used as livestock feed (Leonel and Cereda, 2002; Coelho et al., 2005; Brito et al., 2021). Under favourable growing conditions, fresh rhizome yields generally range from 12.5 to over 31 t ha⁻¹, although productivity varies considerably depending on genotype, crop management and environmental conditions (Kay and Gooding, 1974; Moreno et al., 2017).

Research and development

Although arrowroot (*Maranta arundinacea* L.) is one of the oldest cultivated tropical starch crops, research on the species has remained comparatively limited when compared with major root and tuber crops such as cassava, potato and sweet potato. Nevertheless, growing demand for natural starches, gluten-free foods and biodegradable raw materials has renewed scientific interest in the crop during the past two decades. Recent research has focused on crop production, germplasm conservation, starch quality, processing technologies, nutritional properties and industrial applications (Madineni et al., 2012).

Collection and conservation of arrowroot genetic resources have received increasing attention in several countries because traditional landraces are gradually being replaced by other commercial crops. Germplasm collections maintained by research institutions provide an important source of variability for traits such as rhizome yield, starch content, plant architecture and adaptability. The characterization and documentation of these collections using standardized morphological descriptors have facilitated the identification of superior genotypes and have strengthened the conservation and utilization of arrowroot genetic resources (Brito et al., 2021).

Crop improvement in arrowroot has largely depended on the evaluation and selection of superior clones because the crop is propagated vegetatively and sexual reproduction is infrequent. Considerable variation has been reported among cultivated accessions for plant growth, rhizome morphology, starch yield and physicochemical properties of starch, indicating substantial scope for selection and varietal improvement. Long-term evaluation of local germplasm under different agroecological conditions has contributed to the identification of high-yielding and better-adapted genotypes for cultivation (Brito et al., 2021).

Biotechnological approaches have also contributed to arrowroot improvement. Protocols for in vitro propagation have been developed using shoot-tip and rhizome explants to facilitate rapid multiplication of planting materials. Studies have demonstrated successful establishment of cultures on Murashige and Skoog medium supplemented with suitable concentrations of growth regulators, although contamination during culture establishment remains a major constraint because of the subterranean nature of the propagules (Daquinta et al., 2009; Narcisa-Oliveira et al., 2018).

Research on arrowroot starch has expanded considerably because of its unique physicochemical and functional properties. Arrowroot starch is characterized by high digestibility, low gelatinization temperature, high paste clarity, desirable viscosity and excellent gel-forming ability. These characteristics make it suitable for the preparation of infant foods, bakery products, gluten-free formulations, edible films and biodegradable packaging materials.



Comparative studies have further demonstrated that the starch exhibits functional properties comparable with or superior to several commercially important starches, thereby increasing its industrial potential (Madineni et al., 2012).

Several investigations have also demonstrated the nutritional and medicinal significance of arrowroot. Rhizomes contain easily digestible starch together with bioactive phytochemicals, including phenolic compounds, flavonoids, glycosides and saponins. Experimental studies have reported antioxidant, antimicrobial, antidiarrhoeal and prebiotic activities, although many of these findings require further validation through detailed pharmacological and clinical investigations before commercial utilization (Harmayani et al., 2011; Nishaa et al., 2013; Kumalasari et al., 2012).

Future research should focus on the systematic characterization of available germplasm, development of improved cultivation practices, enhancement of disease-free planting material through micropropagation, and detailed investigations on starch biosynthesis and functional quality. Greater emphasis on molecular characterization, conservation of traditional landraces, value addition and industrial utilization will further strengthen the role of arrowroot as an economically important tropical starch crop (Madineni et al., 2012).

Although *M. arundinacea* maintains a minor crop status relative to global staples like rice (Bergman et al., 2004), its substantial starch yield potential, favorable functional properties, and broad pedoclimatic adaptability underline its strategic value for bio-economic development (Guilherme et al., 2017). Integrating advanced molecular marker frameworks with systematic agronomic selections will be indispensable for developing high-yielding, biotic and abiotic-stress-resistant *M. arundinacea* cultivars suitable for sustainable, commercial-scale agricultural systems (Pratama and Daryono, 2022).



2. Descriptors

Characterization of arrowroot involves the systematic observation and documentation of its morphological, agronomic and biochemical traits using standardized descriptors. These descriptors provide a uniform basis for the identification, comparison and conservation of germplasm maintained in field gene banks. Characterization is essential for assessing genetic variability, identifying superior accessions for crop improvement and facilitating the utilization of germplasm in breeding programmes.

The present study characterized 35 arrowroot accessions using a set of quantitative and qualitative descriptors. Quantitative observations were recorded at the appropriate stage of crop growth, whereas qualitative traits such as flowering were recorded through field observations. The descriptors comprised characters related to plant morphology (7), reproductive behaviour (2), rhizome and yield attributes (9), and biochemical quality traits (6).

Morphological Characters

Sl. No.	Descriptor	Time of observation	Method/Descriptor states
P-1	Plant height (cm)	At harvest	Measured from the soil surface to the tip of the tallest leaf using a measuring tape.
P-2	Stem diameter (cm)	At harvest	Measured at the basal portion of the pseudostem
P-3	Number of tillers	At harvest	Total number of tillers arising from each plant was counted.
P-4	Leaf lamina length (cm)	At harvest	Measured from the base of the lamina to the leaf apex.
P-5	Leaf lamina width (cm)	At harvest	Maximum width of the lamina measured at the broadest point.
P-6	Leaf sheath length (cm)	At harvest	Length of the leaf sheath measured from the point of attachment to the junction with the petiole.
P-7	Leaf petiole length (cm)	At harvest	Measured from the sheath-lamina junction to the base of the leaf blade.

Reproductive Characters

Sl. No.	Descriptor	Time of observation	Descriptor states	Score
P-8	Flowering	During crop growth	Absent	A
			Present	P
P-9	Senescence (%)	At harvest	Percentage of natural leaf senescence observed at harvest.	Recorded as percentage

Rhizome and Yield Characters

Sl. No.	Descriptor	Time of observation	Method
P-10	Rhizome yield (t ha ⁻¹)	At harvest	Estimated based on fresh rhizome yield per plot and converted to tonnes per hectare.
P-11	Number of rhizomes plant ⁻¹	At harvest	Total number of marketable rhizomes harvested from each plant was counted.
P-12	Average rhizome weight (g)	At harvest	Calculated as average weight of individual rhizomes.
P-13	Length of largest rhizome (cm)	At harvest	Measured from the base to the tip of the largest rhizome.
P-14	Width of largest rhizome (cm)	At harvest	Maximum diameter of the largest rhizome measured using a vernier caliper.
P-15	Neck length (cm)	At harvest	Length of the constricted neck portion of the rhizome measured using a scale.
P-16	Node length (cm)	At harvest	Distance between two successive nodes on the rhizome.
P-17	Tip length (cm)	At harvest	Length of the terminal growing portion of the rhizome.

Biochemical Characters

Sl. No.	Descriptor	Method
P-18	Moisture (%)	Determined by oven drying and expressed as percentage of fresh weight.
P-19	Total dry matter (%)	Calculated from moisture loss after oven drying.
P-20	Ash (%)	Estimated by incineration in a muffle furnace and expressed on fresh weight basis.
P-21	Total starch (%)	Estimated using the standard starch estimation procedure and expressed as percentage.
P-22	Total sugars (%)	Estimated by standard biochemical methods and expressed as percentage.
P-23	Crude fibre (%)	Determined by standard AOAC procedures and expressed as percentage.

3. Morphological Characters

A total of seven morphological traits were recorded for the characterization of the 35 arrowroot accessions. The observations revealed considerable variation for most of the vegetative traits, indicating the existence of substantial phenotypic diversity among the evaluated germplasm (Fig. 1).

Plant height varied from 78.00 to 120.33 cm, with an average of approximately 101.3 cm. The majority of the accessions (15) belonged to the 100.00-109.99 cm class, followed by 11 accessions in the 90.00-99.99 cm range. Five accessions attained heights between 110.00 and 120.99 cm, while only four accessions were shorter than 90 cm. The tallest accession recorded a height of 120.33 cm, whereas the shortest measured 78.00 cm. The predominance of medium-height plants indicates that the evaluated arrowroot germplasm generally possesses a compact to moderately vigorous growth habit, while the presence of taller and shorter accessions demonstrates useful variability for selection in breeding programmes.

Stem diameter exhibited moderate variation, ranging from 3.50 to 5.97 cm. Most accessions (10) possessed stem diameters between 5.00 and 5.49 cm, followed by 8 accessions in the 5.50-5.99 cm category. Seven accessions exhibited stem diameters between 4.00 and 4.49 cm, whereas only four accessions recorded stem diameters below 4.00 cm. Thick stems are generally associated with greater plant vigour and improved lodging resistance; therefore, accessions possessing larger stem diameters may be useful in future selection programmes. The number of tillers plant⁻¹ ranged from 13 to 21.67, indicating appreciable variability among the accessions. Most accessions (13) produced 17-18 tillers, followed by 8 accessions with 13-14 tillers. Six accessions each produced 15-16 and 19-20 tillers, while only two accessions developed more than 21 tillers. The predominance of intermediate tillering suggests that the germplasm possesses a balanced vegetative growth habit, whereas highly tillering accessions could be explored for their influence on rhizome production.

Leaf morphology also exhibited noticeable variation. Leaf lamina length ranged from 22.87 to 34.00 cm, with most accessions (15) falling within the 30.00-31.99 cm class. Ten accessions exhibited lengths between 28.00 and 29.99 cm, whereas seven accessions exceeded 32 cm. Only one accession possessed leaves shorter than 25 cm. The observed variability indicates differences in photosynthetic surface area among the accessions, which may contribute to differences in biomass accumulation and yield.

Leaf lamina width varied from 8.33 to 11.07 cm. The majority of the accessions (15) recorded widths between 9.50 and 9.99 cm, followed by 6 accessions between 10.00 and 10.49 cm. Five accessions exhibited widths greater than 10.50 cm, while only two accessions recorded widths below 9.00 cm. Compared with leaf length, variation in leaf width was relatively narrow, suggesting that this trait is comparatively stable among the evaluated germplasm. Leaf sheath length ranged from 22.60 to 42.50 cm. Eleven accessions belonged to the 25.00-29.99 cm class, followed by 9 accessions between 30.00 and 34.99 cm and 8 accessions in

the 35.00-39.99 cm category. Only three accessions recorded sheath lengths above 40 cm, while four accessions possessed sheath lengths below 25 cm. The observed variation reflects differences in pseudostem development and vegetative architecture among the accessions. Leaf petiole length showed appreciable variation, ranging from 33.93 to 59.50 cm. The majority of the accessions (11 each) were distributed in the 45.00-49.99 cm and 50.00-54.99 cm classes. Six accessions exhibited petiole lengths greater than 55 cm, whereas seven accessions recorded petiole lengths below 40 cm. Longer petioles may facilitate better leaf orientation and light interception, thereby contributing to improved photosynthetic efficiency.

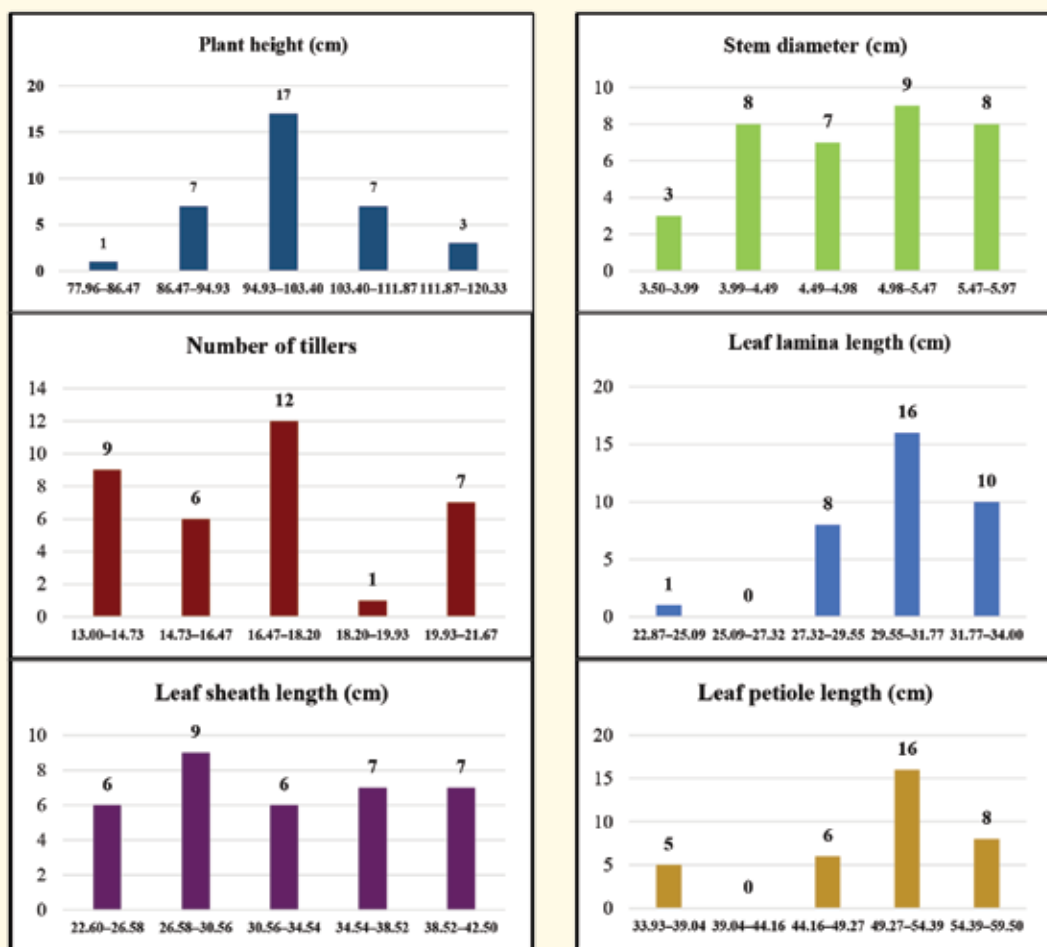


Fig. 1. Morphological Traits



4. Reproductive Characters

Flowering was recorded in only five accessions, whereas thirty accessions remained non-flowering throughout the observation period. The flowers were invariably white in colour and sterile in nature. The predominance of non-flowering accessions indicates that flowering is relatively uncommon under the prevailing environmental conditions, suggesting that vegetative propagation remains the principal mode of multiplication in arrowroot.

All the accessions exhibited a uniform senescence level of 25%, indicating the absence of variation for this descriptor. The uniformity observed may be attributed to the evaluation of all accessions at the same physiological stage under similar environmental conditions.

5. Rhizome and Yield Characters

Considerable variation was observed among the 35 arrowroot accessions for rhizome morphology and yield-related traits, indicating the presence of substantial genetic variability (Fig. 2).

Rhizome yield ranged from 16.10 to 29.00 t ha⁻¹, with an average of approximately 21.8 t ha⁻¹. The highest frequency of accessions (11 each) was recorded in the 18.00-19.99 t ha⁻¹ and 22.00-23.99 t ha⁻¹ classes. Four accessions produced yields between 24.00 and 25.99 t ha⁻¹, while three accessions yielded 26.00-27.99 t ha⁻¹. Only one accession exceeded 28 t ha⁻¹, whereas two accessions produced yields below 18 t ha⁻¹. The occurrence of high-yielding accessions demonstrates the scope for selecting elite genotypes for commercial cultivation. The number of rhizomes plant⁻¹ ranged from 11 to 28, indicating considerable diversity in rhizome production. The majority of the accessions (12) produced 15-18 rhizomes, followed by 11 accessions with 19-22 rhizomes. Six accessions belonged to the 11-14 rhizomes category, while only two accessions produced more than 26 rhizomes. The predominance of intermediate rhizome numbers suggests that most accessions balance rhizome number and rhizome size.

Single rhizome weight varied considerably from 75.00 to 130.00 g. The highest frequency was observed in the 100.00-109.99 g and 120.00-130.00 g classes, each represented by 10 accessions. Seven accessions produced rhizomes weighing between 110.00 and 119.99 g, while only three accessions recorded rhizome weights below 90 g. This wide range indicates substantial variability in assimilate partitioning among the accessions.

The length of the largest rhizome ranged from 14.00 to 29.83 cm. Most accessions produced rhizomes between 14.00 and 22.99 cm, although eight accessions developed rhizomes exceeding 26 cm in length. Likewise, rhizome width varied from 5.33 to 10.00 cm, with the majority (14 accessions) falling within the 8.00-8.99 cm class, followed by 10 accessions with widths greater than 9 cm. These observations indicate considerable diversity in rhizome size and shape, attributes that are directly associated with market preference and processing quality.

Neck length exhibited a wide range from 2.17 to 9.50 cm, with the highest number of accessions (13) possessing neck lengths between 8.00 and 9.99 cm. Node length varied from 1.00 to 4.60 cm, with most accessions distributed in the 2.00-3.99 cm range. Tip length ranged from 0.50 to 2.00 cm, and the majority of the accessions exhibited tip lengths between 1.00 and 2.00 cm.

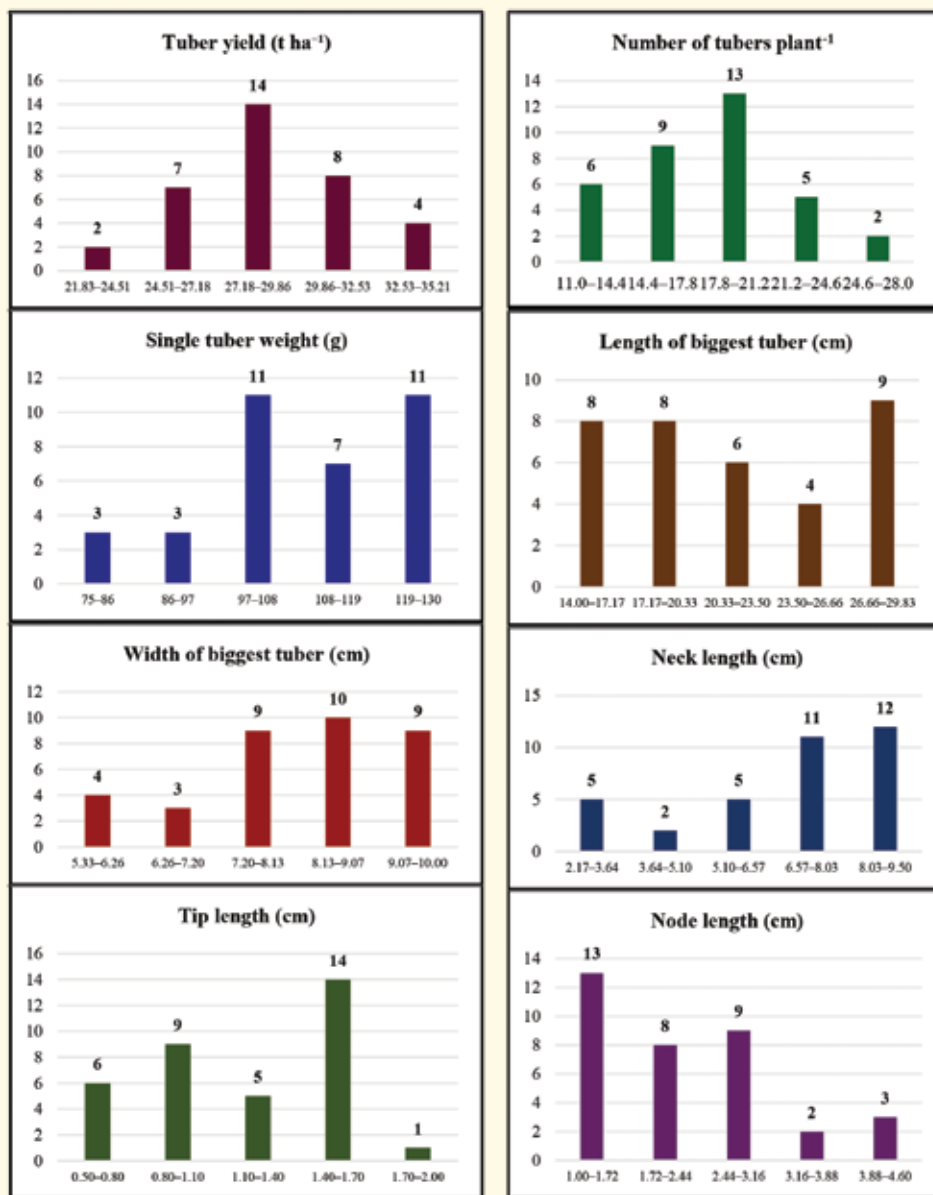


Fig. 2. Rhizome and Yield Traits

6. Biochemical characters

Considerable variation was observed among the 35 arrowroot accessions for the biochemical characters, indicating the presence of appreciable genetic variability for quality-related traits that could be effectively utilized in breeding programmes aimed at improving nutritional and processing quality (Fig. 3).

Moisture content ranged from 64.20 to 79.10%, with an average of approximately 67.06%. The highest frequency of accessions (13) was recorded in the 64.00-65.99% class, followed by 12 accessions in the 66.00-67.99% class. Nine accessions possessed moisture content between 68.00 and 69.99%, while only one accession recorded moisture content above 72%. The predominance of accessions with moderate moisture content indicates good suitability for storage and processing.

Total dry matter varied from 20.90 to 35.80%, with an average of approximately 32.87%. Most of the accessions (26) were distributed in the 32.00-35.99% range, whereas eight accessions recorded dry matter between 28.00 and 31.99%. Only one accession exhibited dry matter below 24%. The predominance of accessions with high dry matter content suggests the availability of promising genotypes for starch extraction and industrial utilization. Total starch content exhibited considerable variation, ranging from 16.07 to 23.94%, with a mean of approximately 21.17% on fresh weight basis. The majority of the accessions (27) recorded starch content between 20.00 and 21.99%, while seven accessions belonged to the 22.00-23.99% class. Only one accession recorded starch content below 18%. The predominance of accessions with high starch content highlights their potential for both food and industrial applications.

Total sugars varied from 0.55 to 0.62% on fresh weight basis, with an average of approximately 0.57%. Most of the accessions (18) were distributed in the 0.55-0.56% class, followed by 11 accessions in the 0.57-0.58% range. Four accessions recorded sugar content between 0.59 and 0.60%, while only two accessions exceeded 0.61%. The comparatively narrow range suggests that total sugar content is a relatively stable biochemical trait in the evaluated germplasm.

Crude fibre content ranged from 0.66 to 1.12%, with a mean of approximately 0.82% on fresh weight basis. The highest frequency of accessions (15) was observed in the 0.70-0.79% class, followed by eight accessions in the 0.90-0.99% range. Six accessions possessed fibre content between 0.80 and 0.89%, while three accessions each were recorded below 0.70% and above 1.00%. The observed variation in crude fibre content provides scope for selecting accessions with desirable fibre levels for different end uses and consumer preferences. Ash content ranged from 0.92 to 1.35%, averaging approximately 1.09%. The highest number of accessions (14) belonged to the 1.00-1.09% class, followed by 10 accessions in the 1.10-1.19% range. Six accessions recorded ash content below 1.00%, while five accessions exceeded 1.20%. The relatively narrow variation observed for ash content indicates a fairly uniform mineral composition among the evaluated accessions.

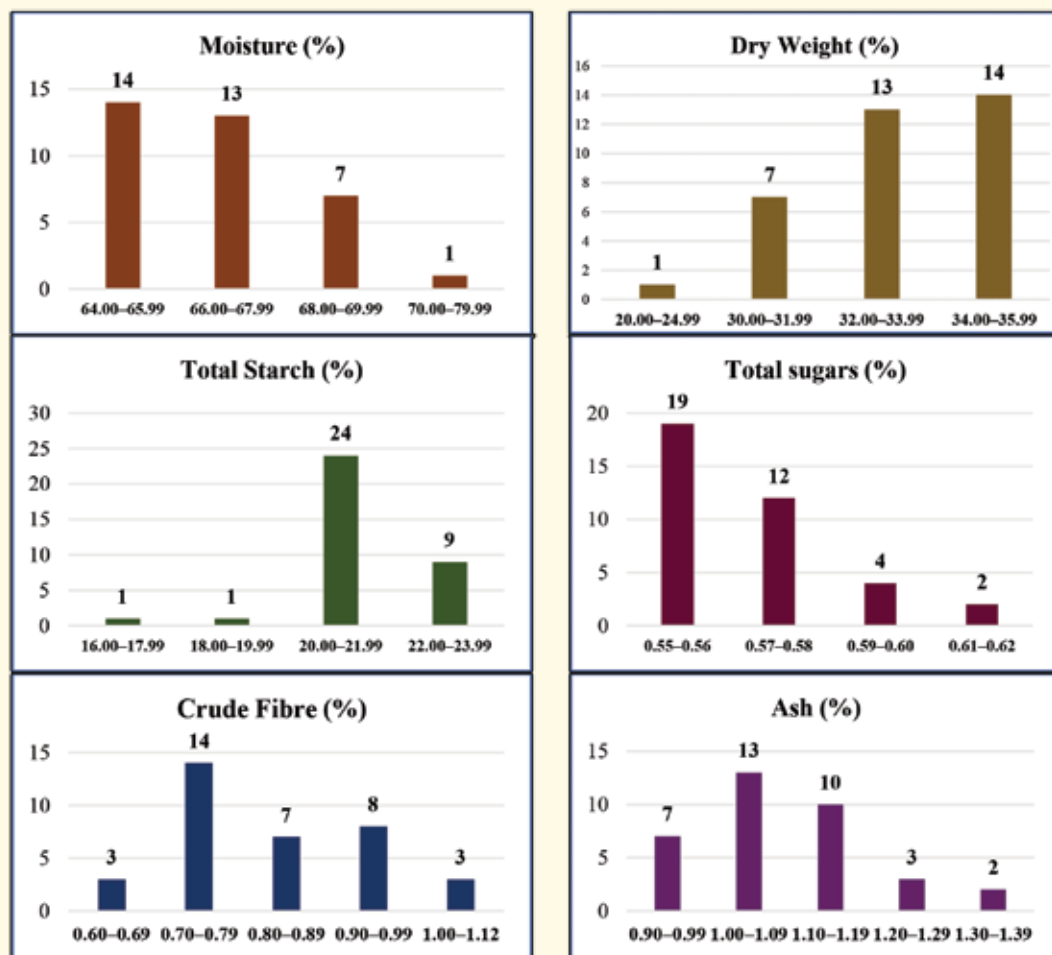


Fig. 3. Biochemical Traits



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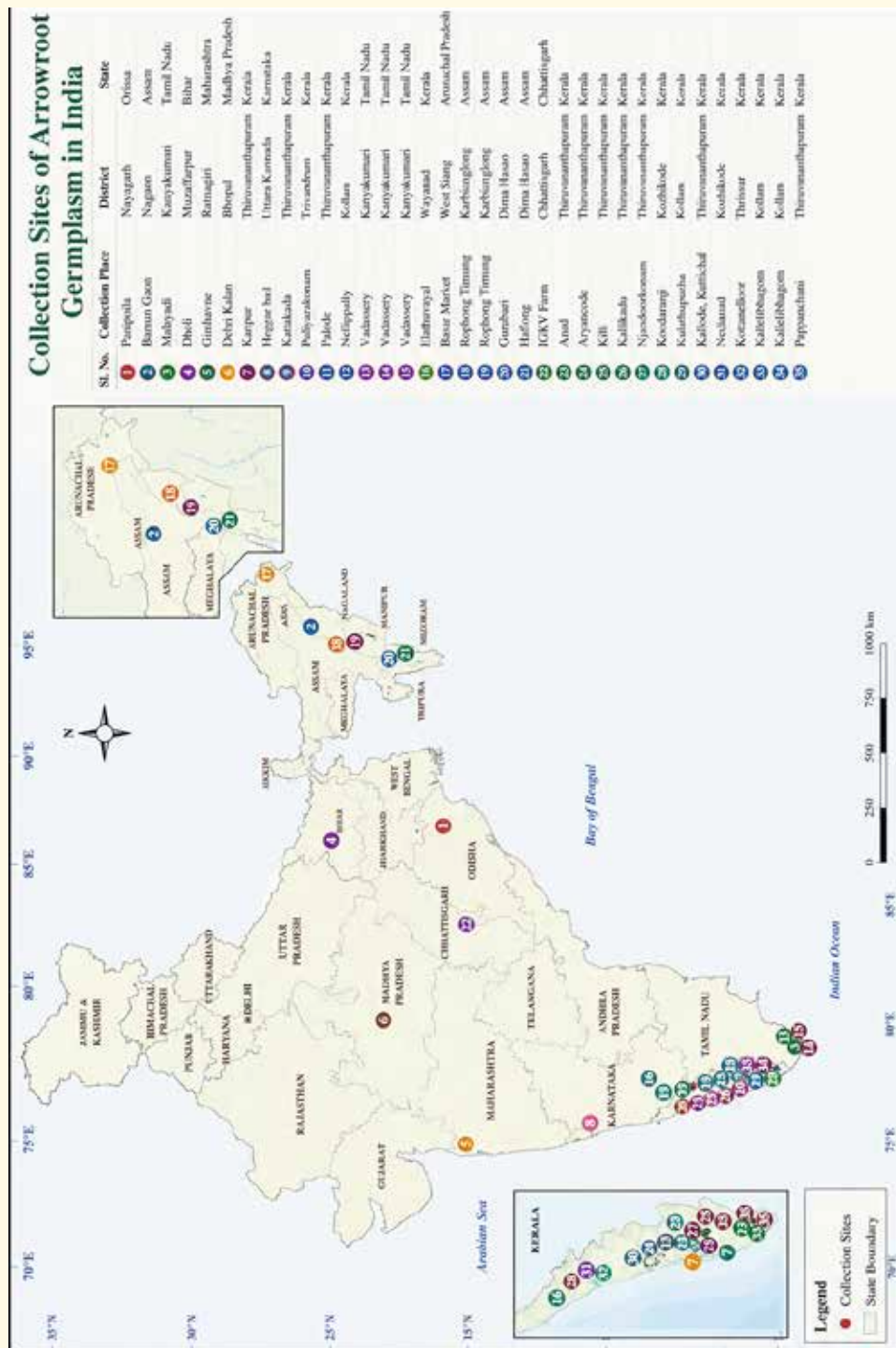
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Appendix - 1



Passport Data of Accessions

Sl. No.	Collector No.	IC No.	Date	Collection Place	Taluk/Mandal/Tehsil	District	State	Latitude (N)	Longitude (E)	Altitude (m)
1	CICRI/2010-1	IC650779	2010	Pampola	Nayagarh	Nayagarh	Orissa	20.21	85.11	131.17
2	CICRI/2010-2	IC650780	2010	Bamun Gaon	Udali	Nagarn	Assam	26.36	92.64	82.22
3	MNS/2010-1	IC650781	2010	Malayadi	Vilavancode	Kanyakumari	Tamil Nadu	8.35	77.18	101.81
4	CICRI/2010-3	IC650782	2010	Dhodi	Tulit	Muzaffargarh	Bihar	26.01	85.59	78.42
5	CICRI/2010-4	IC650783	2010	Gimhane	Dapoli	Ratnagiri	Maharashtra	17.77	73.18	194.00
6	CICRI/2010-5	IC650784	2010	Dehri Kalam	Huzur	Bhopal	Madhya Pradesh	23.14	77.43	487.88
7	MNS/2010-2	IC650785	2010	Karipur	Nedumangad	Thiruvananthapuram	Kerala	8.61	77.61	81.00
8	VIAKI/2017-11	IC650786	11/01/2017	Heggar bail	Siddapur	Uttara Kannada	Karnataka	14.34	74.89	583.00
9	MNSAKI/2014-1	IC650787	22/11/2014	Kattikkada	Kattikkada	Thiruvananthapuram	Kerala	8.50	77.09	71.00
10	MNSAKI/2014-9	IC650788	22/11/2014	Puliyankorram	Neyyattinkara	Trivandrum	Kerala	8.54	77.02	37.00
11	AKI/ATMA/2016-15	IC650789	20/12/2016	Palode	Nedumangad	Thiruvananthapuram	Kerala	8.73	77.04	144.00
12	ADAKI/2016-2	IC650790	27/03/2016	Nellipally	Punalur	Kollam	Kerala	9.03	76.93	52.51
13	ADAKI/2014-3	IC650791	12/01/2014	Vadassery	Agasteeswaram	Kanyakumari	Tamil Nadu	8.19	77.43	28.00
14	ADAKI/2014-4	IC650792	12/01/2014	Vadassery	Agasteeswaram	Kanyakumari	Tamil Nadu	8.19	77.43	28.00
15	ADAKI/2014-5	IC650793	12/01/2014	Vadassery	Agasteeswaram	Kanyakumari	Tamil Nadu	8.19	77.43	28.00
16	JAS/2015-16	IC650794	06/02/2015	Elathuvayal	Mananthavadi	Wayanad	Kerala	11.79	76.02	743.63
17	JASSM/2014-28	IC650795	25/11/2014	Basar Market	Basar	West Singh	Arunachal Pradesh	27.98	94.69	594.00
18	HDG/PAK/2016-140	IC650796	29/11/2016	Rophong Umang	Dipin Sudar	Karhainglong	Assam	25.89	93.53	208.00
19	HDG/PAK/2016-153	IC650797	30/11/2016	Rophong Umang	Bokajan Civil	Karhainglong	Assam	26.11	93.34	356.00
20	HDG/PAK/2016-166	IC650798	02/12/2016	Gurbari	Harlong Sudar	Dima Hasao	Assam	25.25	93.02	951.00
21	HDG/PAK/2016-182	IC650799	03/12/2016	Harlong	Harlong Sudar	Dima Hasao	Assam	25.17	93.02	966.00
22	SAS/SD/2016-46	IC650800	16/12/2016	IGKV Farm	Jagdalpur	Chhattisgarh	Chhattisgarh	21.24	81.71	291.00
23	AKI/ATMA/2016-1	IC650801	20/12/2016	Anad	Nedumangad	Thiruvananthapuram	Kerala	8.64	77.01	65.00
24	AKI/ATMA/2016-7	IC650802	20/12/2016	Aryancode	Neyyattinkara	Thiruvananthapuram	Kerala	8.47	77.13	58.00
25	AKI/ATMA/2016-8	IC650803	20/12/2016	Kulh	Kattikkada	Thiruvananthapuram	Kerala	8.51	77.07	98.37
26	AKI/2015-1	IC650804	01/08/2015	Kattikkada	Kattikkada	Thiruvananthapuram	Kerala	8.53	77.12	73.00
27	AKI/ATMA/2016-1	IC650805	18/11/2016	Njandookorram	Thiruvananthapuram	Thiruvananthapuram	Kerala	8.59	76.92	31.00
28	AVAKI/2017-1	IC650806	09/02/2017	Koodranji	Thamassery	Kozhikode	Kerala	11.35	76.04	66.00
29	MP/AK/2018-7	IC650807	17/07/2018	Kulthapuzha	Palhampuram	Kollam	Kerala	8.87	77.11	592.00
30	MNSAKI/2018-1	IC650808	15/08/2018	Kattikode	Kattikode	Thiruvananthapuram	Kerala	8.56	77.10	92.21
31	AKI/AS/2020-1	IC650809	09/03/2020	Nellurad	Kozhikode	Thiruvananthapuram	Kerala	11.37	75.86	42.06
32	AAVAKI/2022-9	IC650810	28/02/2022	Kottanellloor	Mukundapuram	Thrissur	Kerala	10.30	76.24	18.00
33	AKI/2023-4	IC650811	27/06/2023	Kattilbhagam	Karanagapally	Kollam	Kerala	9.05	76.56	12.00
34	AKI/2023-5	IC650812	27/06/2023	Kattilbhagam	Karanagapally	Kollam	Kerala	9.05	76.56	12.00
35	AKI/ND/2023-9	IC650813	22/08/2023	Pappancham	Thiruvananthapuram	Thiruvananthapuram	Kerala	8.44	76.98	18.00

Table. 1. Morphological and Reproductive Traits

Coll. No.	Acc. No.	P-1	P-2	P-3	P-4	P-5	P-6	P-7	P-8	P-9
CTCRI/2010-1	IC650779	78.00	5.70	20.00	27.67	8.63	23.83	37.83	A	25.00
CTCRI/2010-2	IC650780	96.00	5.33	17.33	29.67	9.17	38.33	53.67	A	25.00
MNS/2010-1	IC650781	100.67	4.80	18.00	31.33	8.33	42.50	55.67	A	25.00
CTCRI/2010-3	IC650782	107.67	4.90	17.00	28.17	11.00	39.50	57.50	A	25.00
CTCRI/2010-4	IC650783	120.33	4.63	17.33	33.67	10.83	36.33	57.33	A	25.00
CTCRI/2010-5	IC650784	102.33	5.93	20.33	33.83	9.83	38.93	49.90	A	25.00
MNS/2010-2	IC650785	102.67	5.10	16.33	31.50	11.07	35.67	49.67	A	25.00
VIAKI/2017-11	IC650786	96.33	4.13	20.33	34.00	10.17	28.07	53.33	A	25.00
MNSAKI/2014-1	IC650787	92.67	5.07	17.67	32.50	9.83	29.50	1.00	A	25.00
MNSAKI/2014-9	IC650788	102.33	5.17	17.67	31.10	10.00	33.67	58.17	A	25.00
AKI/ATMA/2016-15	IC650789	103.00	5.93	15.33	32.53	10.17	39.67	59.50	A	25.00
ADAKI/2016-2	IC650790	99.33	5.00	20.33	31.27	9.83	28.50	53.07	A	25.00
ADAKI/2014-3	IC650791	101.67	5.23	17.33	30.77	9.93	33.83	55.07	A	25.00
ADAKI/2014-4	IC650792	99.00	5.97	14.33	31.17	10.40	35.33	53.00	P	25.00
ADAKI/2014-5	IC650793	94.67	5.80	15.00	32.17	10.33	34.67	50.00	A	25.00
JAS/2015-16	IC650794	91.67	5.17	14.67	31.07	10.17	24.57	49.33	A	25.00
JASSM/2014-28	IC650795	110.33	5.57	14.67	32.50	9.93	37.33	54.33	P	25.00
HDG/PAK/2016/140	IC650796	120.00	5.83	14.33	29.00	9.90	40.50	54.67	A	25.00
HDG/PAK/2016/153	IC650797	112.33	4.40	15.00	32.17	10.63	40.00	58.83	A	25.00
HDG/PAK/2016/166	IC650798	106.00	4.93	14.67	31.00	10.37	30.83	53.83	A	25.00
HDG/PAK/2016/182	IC650799	102.00	5.40	21.67	30.50	9.67	30.23	45.33	A	25.00
SAS/JSD/2016-46	IC650800	106.67	5.00	21.00	30.33	9.50	26.83	48.33	A	25.00
AKI/ATMA/2016-1	IC650801	103.33	5.77	18.00	29.33	9.50	30.50	52.77	A	25.00
AKI/ATMA/2016-7	IC650802	100.67	4.60	17.67	31.33	9.70	36.83	50.83	P	25.00
AKI/ATMA/2016-8	IC650803	104.33	4.07	17.33	31.83	9.33	22.83	50.17	P	25.00
AKI/2015-1	IC650804	105.33	4.43	17.33	31.27	9.67	29.17	53.67	A	25.00
AKI/JS/2016-1	IC650805	106.67	4.23	19.67	30.93	9.27	32.17	52.57	A	25.00
AVAKI/2017-1	IC650806	101.33	4.07	20.67	22.87	9.13	39.67	49.67	A	25.00
MP/AK/2018-7	IC650807	103.00	3.50	16.33	32.00	9.47	28.33	46.40	A	25.00
MNSAKIS/2018-1	IC650808	89.67	4.03	14.67	30.00	9.83	32.90	45.50	A	25.00
AKIAS/2020-1	IC650809	93.00	4.67	14.33	30.27	9.00	32.50	44.43	P	25.00
AAVAKI/2022-9	IC650810	90.33	3.77	13.33	28.50	9.90	28.60	33.93	A	25.00
AKI/2023-4	IC650811	98.33	4.30	16.00	29.17	9.50	24.20	33.97	A	25.00
AKI/2023-5	IC650812	88.00	3.50	13.00	27.50	10.00	25.80	38.60	A	25.00
AKIAD/2023-9	IC650813	100.00	4.50	17.00	29.00	9.00	22.60	35.00	A	25.00

Table. 2. Rhizome and Yield Traits

Coll. No.	Acc. No.	P-10	P-11	P-12	P-13	P-14	P-15	P-16	P-17	P-18
CTCRI/2010-1	IC650779	17.31	28.73	23	75.00	29.83	8.67	5.17	1.00	0.90
CTCRI/2010-2	IC650780	17.90	29.71	18	101.67	26.50	8.33	3.33	1.17	1.17
MNS/2010-1	IC650781	20.27	33.65	17	93.33	27.50	9.33	5.50	4.33	1.50
CTCRI/2010-3	IC650782	17.81	29.56	20	128.33	27.83	9.50	2.17	1.57	1.00
CTCRI/2010-4	IC650783	17.56	29.15	23	98.33	28.67	10.00	3.00	1.13	1.50
CTCRI/2010-5	IC650784	18.15	30.13	18	113.33	29.83	9.83	5.00	1.43	1.67
MNS/2010-2	IC650785	18.33	30.43	28	76.00	29.33	8.33	7.50	3.33	0.90
VHAKI/2017-11	IC650786	21.21	35.21	12	113.33	21.33	8.50	8.33	1.13	1.17
MNSAKI/2014-1	IC650787	17.49	29.03	21	126.67	27.33	10.00	8.33	2.17	1.00
MNSAKI/2014-9	IC650788	17.81	29.56	20	128.33	15.33	7.00	9.33	3.00	1.50
AKI/ATMA/2016-15	IC650789	20.27	33.65	14	120.00	17.33	8.33	5.33	2.33	1.00
ADAKI/2016-2	IC650790	19.15	31.79	18	113.33	15.33	7.67	8.17	2.33	2.00
ADAKI/2014-3	IC650791	18.33	30.43	28	76.00	20.67	7.67	8.67	4.33	0.83
ADAKI/2014-4	IC650792	16.33	27.11	21	90.00	23.00	6.00	7.00	3.00	1.17
ADAKI/2014-5	IC650793	18.11	30.06	15	125.00	15.67	7.00	6.33	1.50	1.50
JAS/2015-16	IC650794	19.00	31.54	15	120.00	19.00	8.00	7.67	2.33	1.00
JASSM/2014-28	IC650795	16.82	27.92	17	105.00	22.67	9.00	7.67	2.33	1.50
HDG/PAK/2016/140	IC650796	18.37	30.49	18	130.00	25.00	9.50	6.00	3.16	1.67
HDG/PAK/2016/153	IC650797	17.94	29.78	11	111.67	19.50	8.00	7.00	2.67	0.73
HDG/PAK/2016/166	IC650798	14.10	23.41	19	106.67	19.00	8.00	8.00	3.00	1.40
HDG/PAK/2016/182	IC650799	16.15	26.81	15	111.67	14.00	5.33	9.00	1.67	0.67
SAS/JSD/2016-46	IC650800	16.38	27.19	14	100.00	15.67	5.50	9.50	3.00	0.67
AKI/ATMA/2016-1	IC650801	18.56	30.81	17	100.00	20.00	7.50	8.00	2.33	1.17
AKI/ATMA/2016-7	IC650802	17.20	28.55	14	125.00	16.00	8.00	8.00	4.60	0.80
AKI/ATMA/2016-8	IC650803	16.56	27.49	23	98.33	14.83	6.33	8.50	3.62	1.50
AKI/2015-1	IC650804	19.77	32.82	24	108.33	29.17	9.50	3.00	1.33	1.50
AKI/JS/2016-1	IC650805	16.33	27.11	21	90.00	24.67	9.33	8.00	3.00	0.50
AVAKI/2017-1	IC650806	17.92	29.75	21	106.67	18.67	8.17	9.33	2.17	1.50
MP/AK/2018-7	IC650807	16.33	27.11	22	125.00	19.50	8.67	8.50	3.00	1.67
MNSAKIS/2018-1	IC650808	16.81	27.90	21	120.00	20.67	7.67	8.17	2.67	1.50
AKIAS/2020-1	IC650809	17.56	29.15	15	105.00	15.67	9.50	8.67	2.33	1.50
AAVAKI/2022-9	IC650810	16.33	27.11	14	130.00	25.00	5.33	8.00	1.67	1.00
AKI/2023-4	IC650811	13.15	21.83	16	106.67	19.00	8.00	7.00	1.43	0.73
AKI/2023-5	IC650812	16.10	26.73	19	106.67	27.83	8.50	5.00	1.43	1.67
AKIAD/2023-9	IC650813	16.15	26.81	15	111.67	20.67	8.83	2.17	1.57	1.00

**Table. 3. Biochemical Traits**

Coll. No.	Acc. No.	P-19	P-20	P-21	P-22	P-23
CTCRI/2010-1	IC650779	31.80	0.92	20.45	0.55	0.70
CTCRI/2010-2	IC650780	35.10	1.03	21.42	0.56	0.73
MNS/2010-1	IC650781	34.30	0.94	22.50	0.57	0.90
CTCRI/2010-3	IC650782	33.40	1.12	21.45	0.56	0.70
CTCRI/2010-4	IC650783	33.90	1.02	16.07	0.56	0.82
CTCRI/2010-5	IC650784	32.00	1.10	21.02	0.57	1.00
MNS/2010-2	IC650785	35.10	1.35	20.45	0.58	0.71
VIIAKI/2017-11	IC650786	32.30	0.99	23.94	0.61	0.92
MNSAKI/2014-1	IC650787	31.00	1.14	22.50	0.56	0.78
MNSAKI/2014-9	IC650788	35.50	1.21	20.45	0.56	0.72
AKI/ATMA/2016-15	IC650789	30.80	1.30	21.88	0.55	0.77
ADAKI/2016-2	IC650790	33.00	1.01	20.27	0.59	0.66
ADAKI/2014-3	IC650791	20.90	0.98	21.31	0.57	0.74
ADAKI/2014-4	IC650792	32.50	1.21	20.45	0.55	1.12
ADAKI/2014-5	IC650793	30.50	1.09	21.02	0.55	0.72
JAS/2015-16	IC650794	33.20	1.08	20.96	0.57	0.81
JASSM/2014-28	IC650795	34.70	1.05	20.47	0.58	1.02
HDG/PAK/2016/140	IC650796	31.60	1.17	20.73	0.56	0.94
HDG/PAK/2016/153	IC650797	35.30	0.97	22.18	0.59	0.69
HDG/PAK/2016/166	IC650798	32.80	1.11	20.58	0.55	0.98
HDG/PAK/2016/182	IC650799	34.10	1.00	21.67	0.57	0.79
SAS/JSD/2016-46	IC650800	33.00	1.15	21.14	0.55	0.86
AKI/ATMA/2016-1	IC650801	33.70	1.06	20.84	0.56	0.83
AKI/ATMA/2016-7	IC650802	35.80	1.24	22.36	0.59	0.71
AKI/ATMA/2016-8	IC650803	32.10	1.13	20.41	0.56	0.97
AKI/2015-1	IC650804	34.50	1.02	21.95	0.58	0.75
AKI/JS/2016-1	IC650805	16.33	27.11	21	90.00	24.67
AVAKI/2017-1	IC650806	17.92	29.75	21	106.67	18.67
MP/AK/2018-7	IC650807	16.33	27.11	22	125.00	19.50
MNSAKIS/2018-1	IC650808	16.81	27.90	21	120.00	20.67
AKIAS/2020-1	IC650809	17.56	29.15	15	105.00	15.67
AAVAKI/2022-9	IC650810	16.33	27.11	14	130.00	25.00
AKI/2023-4	IC650811	13.15	21.83	16	106.67	19.00
AKI/2023-5	IC650812	16.10	26.73	19	106.67	27.83
AKIAD/2023-9	IC650813	16.15	26.81	15	111.67	20.67



Published by

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