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Characterization of yam bean (*Pachyrizhus erosus, L. Urban)* germplasm (IC No. 635945) from Havelock (A & N) Island and comparison with Rajendra Mirshikand-1 (RM-1) variety

Out of a few tuber forming legumes (Winged bean, African yam bean, tuber cowpea etc.), yam bean (*Pachyrizhus erosus*) stands out in the forefront in terms its high edible tuber yield potential and botanical seed for non-edible purposes (Tay Fernandez et al., 2021). Seeds when mature are toxic (containing rotenone) and can be used as pesticide. This perennial nature of crop has potential record high tuber yields ranging from 80 t ha^{-1} (Zanklan et al., 2007) to 125.9 t ha^{-1} yield (Nielsen et al., 2000) under ideal condition. The tuber part of this crop is perennial and upper portion is annually dries up and it is cultivated as annual crop (Vimala and Bala Nambisan, 2011). Seed extract can be used as a biopesticide due to the presence of toxic compound called rotenoids (Noman et al., 2007). Moreover, this tuber crop is easily propagated by botanical seed (Rolland Agaba et al., 2016). Piyachomkwan et al., (2002) has reported that yam bean is important non-traditional sources of industrial starch. Researchers have also explored the use of yam bean tubers and seeds as a potential source of nutrients. Yam bean is originated in South America, from where it is distributed to other parts of the world including India. It is mostly grown in states like Odisha, Bihar, Jharkhand, Eastern Uttar Pradesh, West Bengal and Assam (Pati et al., 2020). ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI) conserves more than 200 germplasm accessions in the field gene bank including the released varieties, RM-1, RM-2 and RM3. Nevertheless, it has a narrow genetic base; almost all the germplasm/landraces conserved in India might be progenies of breeding lines introduced from Mexico to Dholi during 1973 (Singh et al. 2019). Systematic and intense breeding programme have been undertaken at ICAR-CTCRI Regional Station Bhubaneswar, Odisha, ICAR-CTCRI Head Quarters and Dholi Centre of AICRP on TC. Notably, variety with high dry matter content or moisture content are given priority in the breeding objective of yam bean. Characterisation is emphasised for variety with desirable traits. In the present article, the results of characterisation of a newly collected landrace on qualitative, quantitative, and proximate composition presented in comparison to the check variety, RM-1 for possible utilisation in the ongoing breeding programme.

At ICAR-CTCRI, Thiruvananthapuram (NAGS centre of tropical tuber crops), a total 53 yam bean germplasm accessions along with other tuber crops have been maintained and conserved in the field gene bank and seed bank at Division of Crop Improvement. A new landrace from Havelock, Andaman & Nicobar Islands was added to the germplasm pool which was introduced from ICAR-NBPGR through Material Transfer Agreement (MTA). The new collection, Havelock landrace (IC No. 635945) along with the check variety, RM1 were characterised during 2022-23 and 2023-24. RM-1 is a variety released from Dholi, Rajendra prasad Central Agricultural University (RPCAU), Pusa, Bihar, India (Sing et al., 1981). The passport data of the Havelock landrace is given in Table 1 and pedigree details of yam bean variety RM-1 is given in Table 2. Seeds of RM-1 variety and Havelock landrace were planted at Block No I of

Table 1. Passport data of Havelock yam bean landrace

Collector No.	IC No.	Vernacular name/name	Biological status	Type of material	Collecting site	Frequency	Site of collection	Latitude (N)	Longitude (E)	Altitude (M)
JPNAJ/20-147	IC- 635945	Jimeekand	Weedy	Seed/ tuber	Road side	Rare	Havelock, Andaman and Nicobar Island, India	11.66928	92.74254	27

Table 2. Pedigree and other details of RM-1 variety of yam bean

Sl. No	Description and basic information	Particulars
1	Name of the variety	Rajendra Mishrikand -1
2	Breeding method	Mass Selection clonal selection
3	Parent	Line No. 29 of Mexican breeding lines
4	Year of release/notification	1992
5	Maturity period for tuber (days)	120
6	Maturity for seed (days)	150
7	Tuber yield (t ha^{-1})	36- 40
8	Specialty of the variety	High tuber yield
9	Variety released institution	All India Coordinated Research Project on Tuber Crops (AICRPTC), Dholi Centre, Dr. Rajendra Prasad Central Agricultural University, PUSA, Samastipur, Bihar, India

field gene bank at ICAR-CTCRI, Thiruvananthapuram, Kerala. The experimental site has laterite soil with maximum, minimum temperature of 32-35°C and 20-23°C, respectively. The field trials were conducted for two years (2022-23 and 2023-24) with one growing cycle. Twenty plants were raised in block with 60 x 30cm spacing for germplasm as well as variety. Twelve randomly selected plants were taken for observation or 12 parts from 12 plants as per the observation requirements. Seventeen DUS characters were evaluated for two experimental materials namely RM-1 variety and Havelock landrace of IC-635945 by adopting DUS guidelines (PPV & FRA, 2020). (https://plantauthority.gov.in/sites/default/files/DraftDUSYambeanfinal21012020.pdf). The predominant colour and pubescence of the stem of the primary branches were noted during active vegetative stage at 50 days after planting. The number of teeth of the terminal leaflet of the compound leaf, texture of the leaf surface, adaxial surface of the fifth fully opened leaf of the primary branch were also recorded. Flower density of inflorescence, standard and wing petals colour were observed. Apart from the sepal colour, the length of the flower stalk was also measured. The number of mature pods per branch, the length of the pod, number of seeds per pod, tuber shape, tuber surface, colour and shape of the seeds were characterized as per the guidelines. Proximate analysis of tuber samples was conducted using fresh samples of both landrace and RM-1 variety by adopting AOAC (1995) method and mean and grand mean of the nutrient parameters were reported. The statistical analysis of the biochemical parameters was carried out as per the procedure given in Panse and Sukhatme (1967).

The characterisation results on phenotypic and proximate parameters of Havelock landrace and RM-1 variety are presented and discussed here.

Phenotypic characters

The comparison of characteristics between two Landrace (Havelock) and RM-1 across two seasons (2022-23 and 2023-24) were given in Table 3. The evaluation clearly showed that among 17 characters studied many characters expressed uniformity whereas some qualitative characters exhibited differences. As per general growth habit of Fabaceae, yam bean is climbing or trailing type. The leaves are alternate, trifoliate and large with toothed leaflets. The result showed that Havelock landrace showed lengthy vine growth when compared to short vine in RM-1. Leaflet shape and tooth number differ between varieties, with landrace (Havelock) having more teeth and RM-1 having fewer teeth in both seasons. Leaf shape and vine growth habits are key characters for varietal identification in tuber crops. (Reddy et al., 2018). Vine length had a positive correlation and exerted maximum influence on tuber and seed yield in genetic trial conducted with 50 accessions of African yam bean (Aremu and Ibirinde, 2012). Distinct differences were observed for shape of the trifoliate leaves and the germplasm had prominent acuminate tip whereas check RM-1 possessed inconspicuous tip of terminal lobe (Fig. 1). Shape and type of the lobe of the terminal leaflet along with growth habit, days to flowering and days to physiological maturity in 31 accessions of Pachyrhizus tuberosus in Costa Rica. These authors reported that the outline of the terminal leaflet and seed shape had the highest influence on variety discrimination. It should be noted that qualitative characters are stable and useful

Table 3. Qualitative and quantitative characters of Havelock landrace and RM-1 variety of yam bean evaluated during 2022-23 and 2023-24

Sl. No.	Characteristics	Havelock landrace		RM-1 variety	
		2022-23	2023-24	2022-23	2023-24
1	Stem colour	Yellowish green	Yellowish green	Light green	Light green
2	Stem Pubescence	Sparse (9 cm^{-2})	Sparse (9 cm^{-2})	Sparse (9 cm^{-2})	Sparse (9 cm^{-2})
3	Leaflet shape	8	7.5	6	5
4	No. of teeth of terminal leaf	More (Terminal leaf of central teeth is lengthy)	More (Terminal leaf of central teeth is lengthy)	Medium (Terminal leaf of central teeth is short)	Medium (Terminal leaf of central teeth is short)
5	Vine length	Lengthy vines	Lengthy vines	Short vines	Short vines
6	Leaf surface (Adaxial)	Smooth	Smooth	Smooth	Smooth
7	Flower density	High (18)	High (17.5)	Low (8)	Low (9.5)
8	Colour of standard and wing petal	Violet blue	Violet blue	Light blue	Light blue
9	Sepal colour	Light brown	Light brown	Light brown	Light brown
10	Flower stalk length	4.4cm	4.1 cm	2.3 cm	2.1 cm
11	No. of pods per 1-5 inflorescence/primary branches	Low (8)	Low (8.5)	Low (10)	High (12)
12	No. of pods per primary inflorescence	Low (<6) 6	Low (<6) 6	High (>6) 6	High (>6) 6
13	Mature pod length (cm)	Long (>6) 14.5	Long (>6) 14.0	Long (>6) 13cm	Long (>6) 13.5
14	No. of seeds per pod	High (9)	High (9.5)	High (8)	High (8.5)
15	Tuber shape	Round & Cylindrical	Round & Cylindrical	Fusiform	Fusiform
16	Neck length (cm)	Short (4.8)	Short (5)	Short (4.0)	Short (4.1)
17	Tuber rings (no.)	Many (3)	Many (3.5)	Many (4)	Many (3.5)
18	Tuber surface	Smooth	Smooth	Smooth	Smooth
19	Seed colour	Brown	Brown	Light brown	Light brown
20	Seed shape	Round	Round	Square with curved corners	Square with curved corners

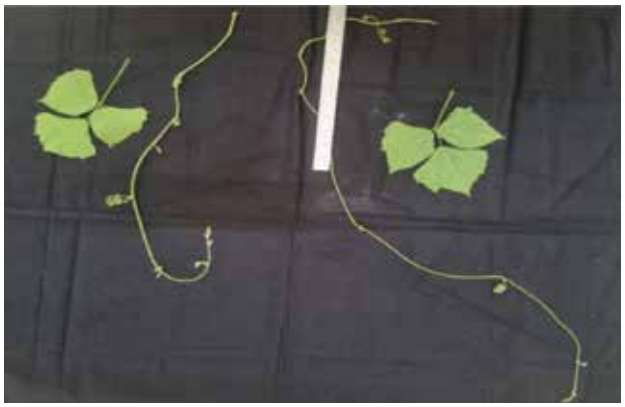

Fig. 1. View of leaf shape and vine growth of variety RM-1 (left) and germplasm Havelock (right)

for varietal identification in the breeding programme (Srivastava and Singh, 2017). Both the materials have similar stem colour, pubescence, leaf surface, sepal colour, and seed shape across both seasons. Similarities were also observed for high number of seeds per pod and pod length. Significant distinct characters in case of both varieties observed were general growth habitat, leaf growth, leaf orientation, flower density, flower structure and tuber shape of yam bean. Flower density differed between the two, with the germplasm having higher flower density (17.5-18 nos.), while RM-1 had lower flower density (8-9.5 nos.). Havelock germplasm possessed distinct stable character of lengthy pedicel (4.1 to 4.4 cm) when compared to short pedicel of RM-1

Fig. 2. View of pedicel and other structures of Havelock germplasm (top) and RM-1 variety (bottom)

(Fig. 2). This difference in pedicel length could be an important distinguishing characteristic between the two genetic resources. In yam bean, pedicel length can be an indicator of fertility. Karuniawan and Wicaksana (2006) analysed the genetic relationship of yam bean P. erosus based on the flower and leaf characteristics. Aremu and Ibirinde, 2012) revealed that the characteristics of vine length, branching pattern, pod and peduncle number, pod length, seed number, and seed yield determined the tuber production. Longer pedicel may indicate increased fertility, which could result in higher seed yields. The stability of this character in Havelock germplasm across two seasons suggests that it is a consistent trait that can be relied upon for variety identification and selection. This characteristic could be useful in breeding programs aimed at improving yam bean seed yields and fertility.

Tuber shape and neck length differ, with Landrace Havelock germplasm having round and cylindrical tubers with shorter necks (Fig. 3a), while RM-1 has fusiform tubers with shorter necks (Fig. 3b). Another important character of difference was observed in seed shape, i.e., seeds of Havelock produced globose seeds (Fig 4a) and RM-1 produced had square shaped flat seeds with curved corners (Fig. 4b) and it was remained stable for two seasons. Seed shape is an important varietal character in legume tubers, as it can significantly impact germination, growth, and yield. According to Singh et al. (2018), seed shape is one of the key morphological characteristics used to distinguish between different varieties of legume tubers and confirmed its stability was confirmed by recording high heritable value ($h^2 = 0.85$) as it remains relatively consistent across three locations and two seasons. It is evident from all reports that seed shape is key trait in identifying and selecting new varieties of yam bean. These findings suggest that Havelock landrace and variety RM-1 had distinct qualitative characteristics *viz*., pedicel length, leaflet shape, seed shape and tuber shape that can be utilized in breeding programs to develop high-yielding varieties/interspecific hybrids with desirable traits. Havelock is rare genetic stack as it was collected from isolated island and must be genetically pure. Moreover, yam bean is self-pollinated crop but amenable for crossing and hybridisation (Grüneberg et al., 2003).

Fig. 3. Tuber shape of (a) Landrace Havelock and (b) Var. RM-1

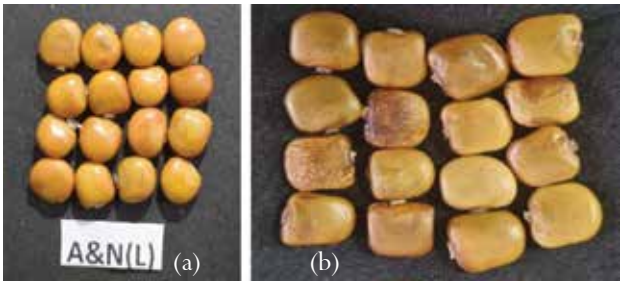

Fig. 4. (a) Seed shape of landrace Havelock and (b) var. RM-1

Proximate composition

Yam bean tuber is low calorie food (38 kcal 100 g^{-1}) and rich in vitamin C. The biochemical characteristics

Table 4. Proximate composition of fresh tubers of yam bean landrace Havelock and var. RM-1 during 2022-23 and 2023-24

Parameter (%)	Landrace Havelock			Variety RM-1			Grand Mean	Standard deviation
	2022-23	2023-24	Mean	2022-23	2023-24	Mean		
Moisture	88.3	87.3	87.8	83.8	83.8	83.8	85.80	2.83
Starch	8.95	10.1	9.52	8.38	8.57	8.475	9.00	0.74
Sugar	0.30	0.30	0.30	0.29	0.29	0.29	0.30	0.01
Fiber	1.07	1.57	1.32	0.53	0.52	0.525	0.92	0.56
Fat	1.13	1.35	1.24	2.43	2.50	2.465	1.85	0.87
Ash	0.35	0.35	0.35	0.31	0.31	0.31	0.33	0.03

(moisture, starch, sugar, fibre, fat, and ash content) of fresh tubers of yam bean landrace Havelock and Variety RM-1 during two seasons (2022-23 and 2023-24) are presented in Table 4. Landrace Havelock had significantly higher moisture content (88.3% in 2022-23 and 87.3% in 2023-24) compared to var. RM-1 (83.8% in both seasons). This reflects comparatively low dry matter content in landrace Havelock tubers. This higher moisture content may affect the storage and processing properties of the tubers "lvan Den Berg and Lentz, 1973). Variety RM-1 had slightly lower starch content (8.38% in 2022-23 and 8.57% in 2023-24) compared to Landrace Havelock (8.95% in 2022-23 and 10.1% in 2023-24) and this varietal differences on starch content may impact the culinary and other uses of the tubers. However, the starch content of both materials was higher than the average starch content in 60 accessions of yam bean reported by Vimala and Bala Nambisan, (2011) and was in a range of 3 to 6%. Both materials had similarities for sugar content (0.30% in Landrace Havelock and 0.29% in Variety RM-1) and ash content (0.35% in Landrace Havelock and 0.31% in Variety RM-1). The result on sugar and ash contents suggested that both materials have similar mineral and sugar profiles. The standard deviations recorded for moisture, starch, sugar, fiber, fat and ash contents were 2.83, 0.74, 0.01, 0.56, 0.87 and 0.03, respectively indicating moderate to low variability in the biochemical characteristics between the two seasons. Overall, the results suggest that the landrace, Havelock and Variety RM-1 have distinct biochemical profiles mainly on moisture, starch, fibre, and fat content which may influence their uses and processing properties. These differences might be attributed to genetic variations between the two varieties. It is concluded that Havelock landrace can be identified and classified as a separate group from the presently available cultivated yam bean genetic stock of RM-1 (check) and need to be utilised for ongoing breeding programme of ICAR-CTCRI.

The study conducted on yam bean (*Pachyrhizus erosus*) landrace Havelock and Variety RM-1 revealed significant differences in phenotypic characters. Havelock landrace showed more lengthy vine growth, longer flower stalks, and higher moisture content compared to RM-1. These findings highlight the genetic diversity between the two genetic resources, which can be exploited in breeding programs to develop high-yielding and adaptable yam bean varieties. The distinct characteristics of Havelock landrace, such as its lengthy vine growth and longer flower stalks, make it a valuable genetic resource for improving yam bean production. The selected genetic stocks will be utilised for developing varieties with desired economic traits such as high tuber yield with good quality edible starch.

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