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NOTES ON NEGLECTED AND UNDERUTILIZED CROPS

Vigna khandalensis (Santapau) Raghavan et Wadhwa: a promising underutilized, wild, endemic legume of the Northern Western Ghats, India

Suraj D. Umdale · Jaykumar J. Chavan · Mahendra L. Ahire · Parthraj R. Kshirsagar · Nikhil B. Gaikwad · Kangila V. Bhat

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Abstract *Vigna khandalensis* (Santapau) Raghavan et Wadhwa, is an endemic legume belonging to subgenus *Ceratotropis* (Asian *Vigna*), genus *Vigna* of the family Fabaceae. It is commonly known as 'Ranmung', 'Jungli mung' or 'Badamung'. *V. khandalensis* is sporadically distributed at high altitude areas in the Northern Western Ghats, India. It is an annual, erect, tall herb growing along roadsides, hilly slopes, pond sides and near human settlements. The legume seeds are utilized by human beings at the time of famine. Surprisingly, the plant remains neglected and underutilized although its high nutritional value. The scant information on *V. khandalensis* leads us to investigate this underexploited and underutilized legume as a food source for human. The present paper deals with geographical distribution, taxonomy, ecology, agro-morphological characterization, nutritional content and phytochemical analysis. The results obtained in the present investigation provide information on agro-morphological traits and nutritional potential of *V. khandalensis*. Furthermore, it is promoted as a legume 'Crop for the Future' for food security.

Keywords Crop wild relative · Genetic resources · Malnutrition · Nutritional value · Underutilized legume · *Vigna khandalensis*

S. D. Umdale (✉) · J. J. Chavan · M. L. Ahire
Department of Botany, Yashavantrao Chavan Institute of Science, Satara, MS 415 001, India
e-mail: milindumdale@gmail.com

P. R. Kshirsagar
Department of Biotechnology, Shivaji University, Kolhapur, MS 416 004, India

N. B. Gaikwad
Department of Botany, Shivaji University, Kolhapur, MS 416 004, India

S. D. Umdale · K. V. Bhat
Division of Genomic Resources, National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi 110 012, India

Introduction

The Indian subcontinent and South Asia is the area of greatest dependence on proteinaceous edible legumes. However, off and on, these areas especially the Indian subcontinent are facing the most serious problem of protein malnutrition (Singh and Singh 1992; Siddhuraju and Becker 2001). To combat hunger and to overcome malnutrition, there is an increased demand to explore underutilized legumes (Chel-Guerrero et al. 2002). For the accomplishment of the demand for protein-rich foods, it has become obvious to search safe, reliable and cheap protein resources. The use of less-known legumes provides one possibility, which is not used to an important extent by the human population. Many of the known wild and underutilized legumes possess an adequate amount of proteins, essential minerals and vitamins (Bhat and Karim 2009). In this regard, our scientists have focused their efforts in search of wild legumes, which have remained either underutilized or neglected in a particular region.

The genus *Vigna* Savi is one of the most important genera among all the pulse crops. The genus consists of nearly 104 species distributed throughout the world with the greatest diversity occurring in the Africa (subgenera *Haydonia*, *Plectotropis* and *Vigna*), America (subgenus *Lasiospron*), followed by Asia (Subgenus *Ceratotropis*) (Maréchal et al. 1978; Lewis et al. 2005; Delgado-Salinas et al. 2011). India represents a center of diversity for the subgenus *Ceratotropis* consisting of 24 species distributed in three sections namely *Ceratotropis*, *Aconitifoliae* and *Angulares* (Bisht et al. 2005; Yadav et al. 2014; Umdale et al. 2017a, b). Among these, the domesticated *Vigna* species, Mungbean (*V. radiata* (L.) R. Wilkzek), Urdbean (*V. mungo* (L.) Hepper), Mothbean (*V. aconitifolia* (Jacq.) Marechal), Ricebean (*V. umbellata* (Thunb.) Ohwi et Ohashi) and Adzuki bean (*V. angularis* (Willd.) Ohwi et Ohashi) are the most important in terms of pulse production. Furthermore, several underutilized *Vigna* species (*V. trilobata* (L.) Verdc.; *V. vexillata* (L.) A. Rich.; *V. stipulacea* (Lam.) Kuntz) are consumed in different regions of Asia (Siddhuraju et al. 1992; Bravo et al. 1999) in small quantity.

In view of this, we focus mainly on the exploration of wild underutilized legumes within Asian *Vigna* species for future commercial exploitation as food and feed to overcome the problems associated with malnutrition and food security. In the present investigation, we propose one such underutilized wild legume, *Vigna khandalensis*, as a 'Crop for the Future'.

Vigna khandalensis (Santapau) Raghavan et Wadhwa, commonly known as 'Badamung' or 'Ranmung' belongs to the section *Aconitifoliae* of subgenus *Ceratotropis* of genus *Vigna*. The plant is endemic to the Northern Western Ghats in the state of Maharashtra, India (Lakshminarasimhan and Sharma 1991; Deshpande et al. 1993). Few authors (Mishra and Singh 2001; Kumar and Sane 2003) suggested this species may be present in the states of Gujarat, Karnataka and Tamil Nadu, however, its occurrence in these areas remains uncertain because of the lack of data in floras and herbaria. Currently, *V. khandalensis* is considered as an endangered species being classified as 'Near Threatened' in the IUCN Red List of Threatened Species (Chadburn 2012). It is a robust species of higher altitudes (600–1200 m.a.s.l) growing along the roadside, near ponds and in open grasslands (Dixit et al. 2011). The seeds are rich in nutritionally important ingredients such as proteins, essential amino acids, carbohydrates, and vitamins. Babu et al. (1987) reported the seeds may be eaten during famines as an alternative source of food. Both unripe and mature seeds of this species are cooked as a vegetable or eaten raw (Bhagat et al. 2016).

So far, information is available on the importance of this species is meager. Therefore, there is a need to examine the full potential of this taxon. In the present investigation, attempts were made on collection, taxonomy, distribution, botanical description, nutritional and agro-morphological evaluation of *V. khandalensis*. The information collected aims to focus more attention on this neglected species as a potential food legume.

Materials and methods

Collection of plant material

The thirteen populations of *V. khandalensis* were sampled over a 360 km^2 range between latitudes 17°–19° North, in the Northern Western Ghats region of India (Fig. 1). Altitude varied from 615 to 1182 m a.s.l. At random we sampled 25 individuals from thirteen populations (Table 1). The agro-morphological characterization and collection of seed material was done in months of August to October during 2010–2016 at Panchagani, Satara, MS, India.

Plant identification and authentication

The identification and authentication of *V. khandalensis* was carried out by using available literature including Flora, (Cooke 1903); monographs (Tomooka et al. 2002; Yadav et al. 2014), and herbaria (Shivaji University Kolhapur; National Herbarium of Cultivated Plants (NHCP), NBPGR, New Delhi). The voucher specimen (SUK-43) is submitted to Herbarium, Department of Botany, Shivaji University, Kolhapur.

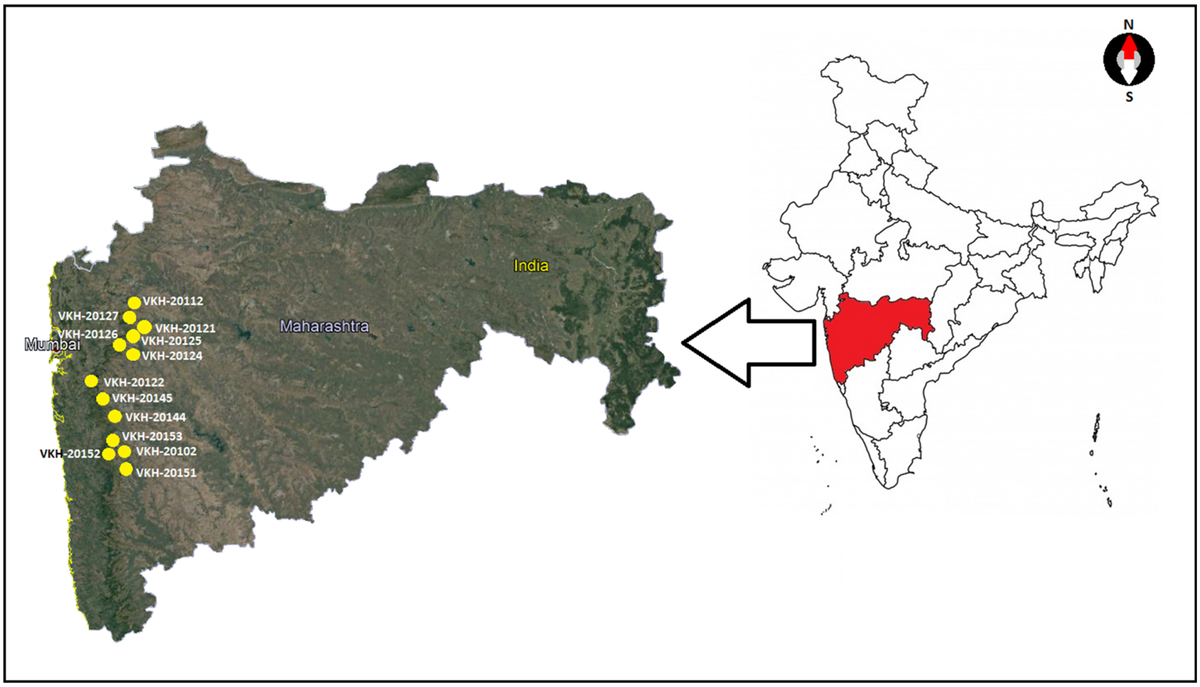

Fig. 1 The location map of sampled *V. khandalensis* populations in the Northern Western Ghats, India

Table 1 Details of site of collections and distribution range of *V. khandalensis*

Sr. no.	Collection no.	Village, District	Latitude (N)	Longitude (E)	Altitude (m)	Habitat
1	VKH-20151	Yevteshvar, Satara	17°14′	73°41′	901	PS
2	VKH-20152	Panchgani, Satara	17°56′	73°49′	1152	RS
3	VKH-20153	Mahabaleshwar, Satara	17°55′	73°43′	615	RS
4	VKH-20144	Sinhagad, Pune	18°21′	73°45′	1127	NHS
5	VKH-20145	Mulshi, Pune	18°29′	73°32′	1099	PS
6	VKH-20121	Malshej ghat, Pune	19°20′	73°46′	705	RL
7	VKH-20122	Khandala, Pune	18°44′	73°23′	616	RS
8	VKH-20112	Sinnar, Nasik	19°44′	73°55′	734	WL
9	VKH-20102	Kelghar ghat, Satara	17°50′	73°45′	1182	BY
10	VKH-20124	Junnar, Pune	19°11′	73°51′	830	NHS
11	VKH-20125	Ganesh ghat, Junnar	19°24′	73°47′	673	NHS
12	VKH-20126	Darya ghat, Junnar	19°24′	73°46′	802	CL
13	VKH-20127	Kalsubai, Ahmednagar	19°36′	73°43′	1009	F

CL cultivated land, *WL* waste land, *RS* road side, *PS* pond side, *BY* backyard, *RL* range land, *F* forest, *NHS* near human settlement

Agro-morphological characterization

Agro-morphological characterization and yield parameters of *V. khandalensis* were evaluated in the field where natural population exists at Panchagani, Satara in the Northern Western Ghat region of India. The evaluation was carried out from August to October 2010–2016. Observations on 35 selected morphological traits comprising 11 vegetative and 24 reproductive traits were scored at mature stage of

Table 2 Diversity in agro-morphological characters of *V. khandalensis* collected from the Northern Western Ghats, India

Sr. no.	Character (s)	Average (mean ± SE)[a]	Range	SD	Coefficient of variance (%)
1	Plant height (m)	1.74 ± 0.06	1.28–2.36	0.31	17.72
2	No. of branches per plant	3.92 ± 0.27	2–6	1.35	34.48
3	No. of nodules per plant	33.92 ± 1.04	23–42	5.22	15.39
4	Terminal leaflet length (cm)	17.58 ± 0.26	14.90–19.40	1.30	7.41
5	Terminal leaflet width (cm)	16.16 ± 0.27	13.20–18.20	1.36	8.44
6	Petiole length (cm)	5.52 ± 0.08	4.80–6.30	0.41	7.47
7	No. of nodes per plant	16.92 ± 0.79	10–25	3.96	23.39
8	Stem diameter (cm)	1.93 ± 0.12	1.01–3.00	0.61	31.65
9	Number of primary branches	1.72 ± 0.12	1–3	0.61	35.68
10	Stipule length (cm)	5.60 ± 0.14	4.60–6.70	0.69	12.38
11	Stipule width (cm)	4.60 ± 0.17	2.80–6.20	0.87	18.82
12	Days to flowering	146.96 ± 2.08	123–161	10.38	7.06
13	No. of flowering branches per plant	2.88 ± 0.19	1–5	0.97	33.72
14	No. of flowers per raceme	19.48 ± 0.93	12–28	4.63	23.76
15	Peduncle length (cm)	11.94 ± 0.67	7.60–18.20	3.37	28.22
16	Flower bud size (cm)	0.97 ± 0.05	0.12–1.32	0.26	26.79
17	Days to maturity	18.84 ± 0.73	13–26	3.66	19.42
18	First pod-bearing node	5.60 ± 0.26	4–8	1.29	23.05
19	Fruit setting capacity (%)	67.99 ± 2.28	46.66–93.33	11.41	16.78
20	No. of pods per peduncle	8.36 ± 0.33	6–12	1.63	19.50
21	No. of unfilled pods	2.72 ± 0.19	1–5	0.94	34.42
22	No. of pods per plant	76.44 ± 1.67	59–98	8.37	10.95
23	Pod length (cm)	5.91 ± 0.17	3.29–7.03	0.84	14.17
24	Pod width (cm)	0.52 ± 0.01	0.36–0.62	0.05	9.49
25	No. of seeds per pod	8.28 ± 0.38	4–12	1.88	22.73
26	Seed length (mm)	3.69 ± 0.08	2.86–4.43	0.41	11.04
27	Seed width (mm)	3.09 ± 0.10	1.65–3.82	0.51	16.55
28	Seed diameter (mm)	3.25 ± 0.09	2.24–3.91	0.43	13.28
29	Hilum length (mm)	1.44 ± 0.03	1.20–1.69	0.16	11.41
30	Hilum width (mm)	0.57 ± 0.01	0.46–0.68	0.06	10.86
31	Seed size (mm^2)	12.59 ± 0.30	8.71–15.38	1.52	12.06
32	Seed weight (g)	0.036 ± 0.01	0.029–0.041	0.004	11.05
33	100-seed weight (g)	3.61 ± 0.08	2.86–4.43	0.40	12.02
34	Total no. of seeds/plant	648.28 ± 29.18	336–888	145.9	22.51
35	Yield per plant (g)	23.41 ± 1.22	9.61–39.34	6.11	26.11

[a]The values represented in the table are mean ± SE of 25 replicates and entire experiment for each parameter was repeated at least thrice

the plant (Table 2). For morphological evaluation the descriptors developed for urdbean and mungbean (IBPGR 1985) and for Asian *Vigna* species (Bisht et al. 2005) were used. Twenty five plants were randomly selected from each population and studied for various agronomical and morphological traits as mentioned in Table 1. The data obtained were presented in the form range, mean ± SE and coefficient of variance (CV) for each parameter (Table 2).

Proximate composition analysis

The seeds were thoroughly cleaned and ground using a Willey mill to pass through 1 mm mesh and stored in the airtight bags for further analysis. The moisture content (%) was determined by drying 25 transversely cut seeds in an oven at 80 °C for 24 h. The ash content was estimated by heating 2 g of the dried seed sample in a silica dish at 600 °C for 6 h (AOAC 2005). The total carbohydrate content was estimated using Anthrone method (Hedge and Hofreiter 1962). The nitrogen content (N) was estimated by the micro-Kjeldahl method as modified by Cocon and Daine (1973) and crude protein content was calculated (N × 6.25) (AOAC 2005). Total protein (true protein) was first extracted and purified by precipitation with cold 20% trichloroacetic acid (TCA) and estimated by the method of Lowry et al. (1951). The total dietary fibre (TDF) was estimated by nonenzymatic-gravimetric method (Li and Cardozo 1994). The calorific value of the seed (kJ) was estimated by multiplying the percentage of crude protein, crude lipid and nitrogen-free extract by factors 16.7, 37.7 and 16.7, respectively (Siddhuraju et al. 1996).

Minerals analysis

A total of 500 mg of *V. khandalensis* seed flour per sample was acid digested with a mixture of 10 mL concentrated nitric acid, 4 mL of 60% perchloric acid, and 1 mL of concentrated sulfuric acid. The digested material was diluted with 50 mL of deionized water and filtered through Whatman filter paper No. 42. The final volume was made up to 100 mL in a volumetric flask with deionized water and used for mineral analysis. The minerals content were analyzed using an atomic absorption spectrophotometer (Shimadzu, Kyoto, Japan) (Issac and Johnson 1975), whereas the phosphorus content in the tri-acid digested extract was determined colorimetrically (Dickman and Bray 1940).

Result and discussion

Nomenclature

Vigna khandalensis (Santapau) Raghavan et Wadhwa. Curr Sci 41:429, 1972, synonyms *Phaseolus khandalensis* Sant. in Kew Bull. 1948: 276, 1948. *Phaseolus grandis* Dalz. In Dalz. and Gibs., Bombay Fl. 72, 1861 non Wall. nec Benth. 1852; Baker in Hook. F. Fl. Brit. India. 2:202, 1876; Cooke, Fl. Pres. Bombay 1:400. 1958.

Common names

Ranmung, Jungli mung, Badamung.

Flowering and fruiting

August to October.

Distribution and ecology

Vigna khandalensis is only known from an area of the Northern Western Ghats, India at higher elevation 615–1182 m a.s.l.). It is endemic to the Western Ghats region and sparsely distributed around the Nashik, Thane, Pune, Ahmednagar, and Satara districts of Maharashtra state (Mishra and Singh 2001; Bhagat et al. 2016). The distribution range overlaps with that of other species of subgenus *Ceratotropis* of *Vigna*. It grows at higher elevation slopes, forests, on wasteland, pond side, in backyards, on rangeland, along roadsides, near human settlements, and even on cultivated land. The farmers of Darya Ghat region (Pune) are cultivating *V. khandalensis* along the bunds of crop fields.

Taxonomic characters

It is an erect, robust, annual herb up to 1.28–2.36 m high (Fig. 2a–c). Stems straight, 1–2 primary branches at the base, dark green with purple coloration, 5-angled, sparsely covered with 0.6–1.2 mm yellowish white hairs. Leaf petioles 3–4 cm long; sparsely covered with yellowish white hairs. Leaves large (13.20–19.40 cm), trifoliolate, dark green, sparsely strigose on both surfaces with appressed bristly yellowish hairs; Leaflets variable in shape, distantly wavy margin, terminal leaflet conspicuously trilobed, broadly ovate, lateral leaflet 2–3 lobed, acute at the apex (Fig. 2d). Stipules very large, foliaceous, variable in size, sub-medifixed, ovate-cuspidate, sparsely ciliate, cordate at the base, obtuse at apex, ciliate at margin, cilia whitish (Fig. 2e).

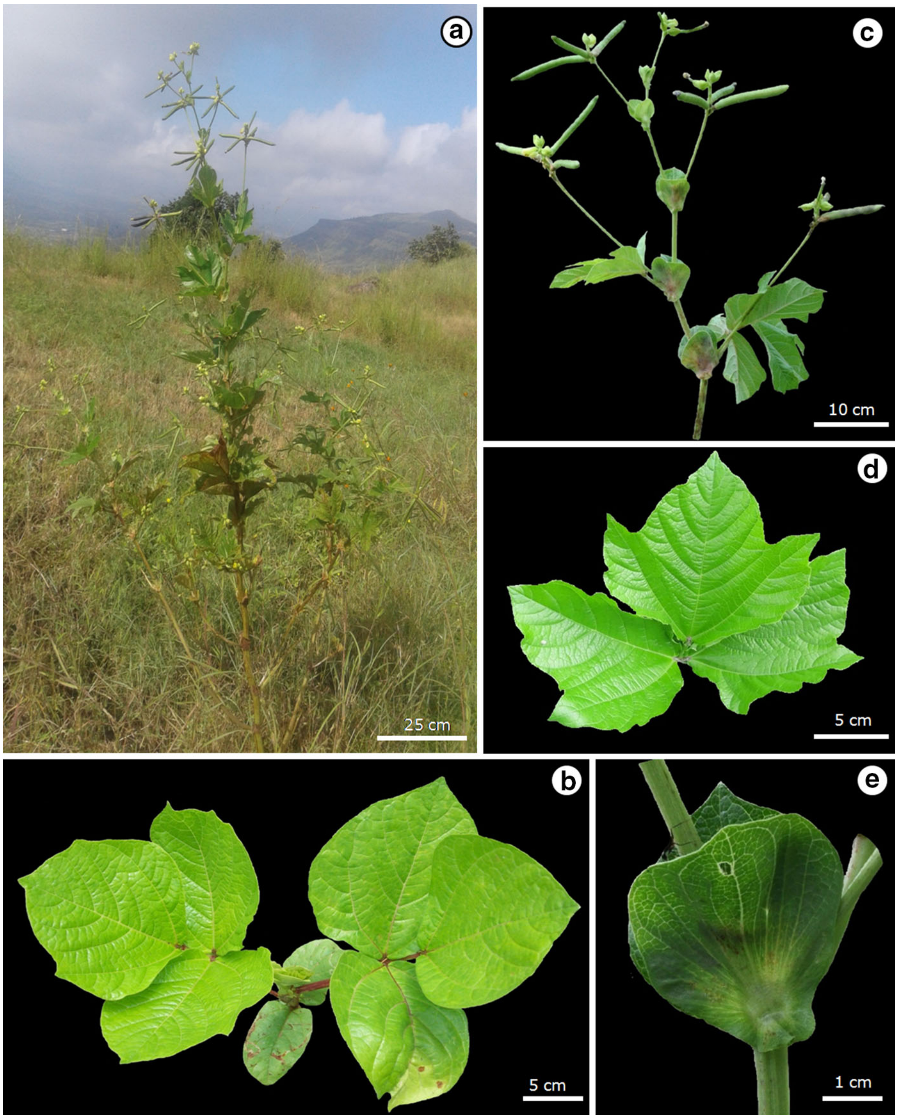

Fig. 2 **a** Naturally growing plant of *V. khandalensis*; **b** young plant; **c** apical twig bearing flowers, buds and pods; **d** trifoliolate leaf; **e** stipule

Inflorescence axillary, 15–25 flowered; peduncles long, sparsely covered with brownish-black retrorse bristly hairs. Flowers arranged in axillary spicate racemes (Fig. 3a). Pedicels short; bracts broadly ovate, acute, deciduous; bracteoles very large, oblong or obovate-oblong, obtuse, veined, concealing the flower in bud. Calyx long, clothed outside with small blackish hairs; teeth short, deltoid; Corolla long, pale yellow (Fig. 3b). Standard broadly elliptic; wings petals broadly ovate. Keel erect, incurved; keel pocket 0.2–0.3 mm long; stamens diadelphous; style prolonged beyond stigma to form a beak; beak straight; stigma terminal and hairy. Pods linear, cylindric, brownish black or black when mature, septate between the seeds, densely pubescent with white or brown bristles, pod tip obcordate, flat and pointed when mature (Fig. 3c, d). About 10–12 seeds per pod were observed; seeds dark brown to black when mature, sub-cylindrical, truncate at the ends; hilum central, linear, not protruding; aril not developed, seed testa rough (Fig. 3e–g). The seed germination is epigeal (Fig. 3h, i) (Raghavan and Wadhwa 1972; Tomooka et al. 2002; Bisht et al. 2005; Yadav et al. 2014; Umdale et al. 2017b).

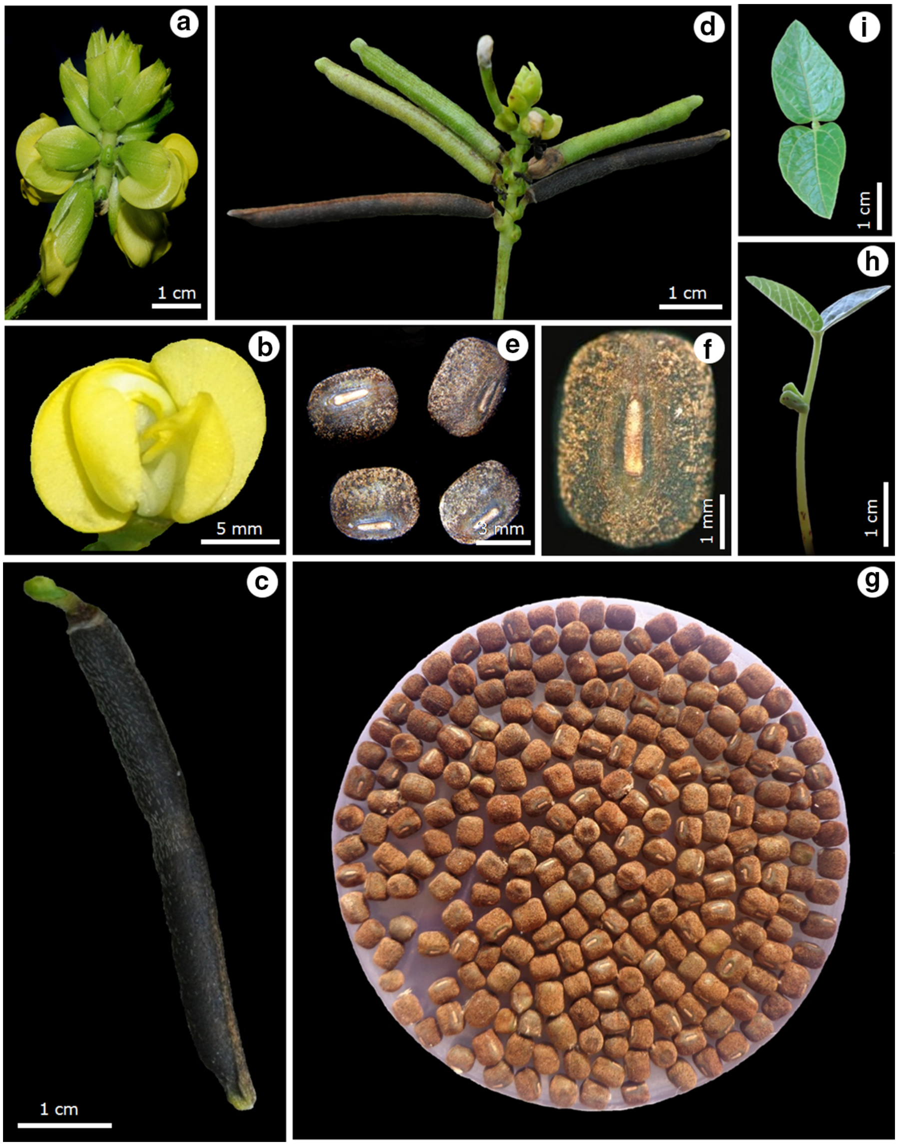

Fig. 3 **a** Inflorescence; **b** flower; **c** mature pod; **d** fruiting inflorescence; **e** seeds; **f** single seed with hilum; **g** seeds harvested; **h** seedling; **i** first leaf

Agro-morphological characterization

The collection, evaluation of agro-morphological traits and utilization of germplasm is prerequisite for successful and efficient breeding programmes for any of the neglected and underutilized crop species (Bisht et al. 2005; Toklu et al. 2009). In the present investigation, data based on 35 diverse agro-morphological characters of *V. khandalensis* were generated which serve as a valuable information for the cultivation and exploitation of this legume (Table 2).

The agro-morphological evaluation of *V. khandalensis* was done at flowering and fruiting stages. It is a robust species with an erect habit and very distinct from all other species of the section *Aconitifoliae* of Asian *Vigna* (subgenus *Ceratotropis*) species. The plant height was found to be in the range of 1.28–2.36 m with an average of 1.74 m (Table 2). The plant height is always influenced by habitat and surrounding environment which could affect the agronomical observations of the plant (Kizil 2006). Besides that, plant height significantly contributes in the number of branches. Furthermore, the number of branches directly influences the number of pods per plant, an important agronomic character. The number of nodes ranges from 10 to 25 per plant, which influences the height of the plant. The number of root nodules per plant also varied between a minimum 23 and a maximum 42 per plant (Table 2). The stem diameter ranged from 1 to 3 cm which depict the robust habit of *V. khandalensis*. The terminal leaf length and width ranged from 17.58 to 16.16, respectively. The number of branches varies from 2 to 6, which increases the canopy of the plant. The large foliaceous stipule (c. 5.6 × 4.6 cm) of *V. khandalensis* is very distinct from all other species of the section *Aconitifoliae*.

The days to flowering is an important agronomic character for crop improvement programmes. In the present investigation, we found that the period required for flowering was ranged from 126 to 161 days after sowing. The production of pods and the seeds per plant increased with increase in a number of branches. The plants produced 2–6 branches, 12–28 racemes and 6–12 pods per peduncle. Besides that, we recorded an average of 2.72 unfilled pods per peduncle, this influence the average seed production. The number of pods per plant varied from 59 to 98 with 4 to 12 seeds per pod (Table 2).

The plant yield depends on the seed characteristics. The seed length, width, and diameter ranged from 2.86–4.43, 1.65–3.82 to 2.24–3.91 mm respectively (Table 2). Individual seed weight varied from 0.029 to 0.041 g with 2.86–4.43 g per 100 seeds. The total number of seeds varied from 336 to 888 with an average of 648.28 ± 29.18 per plant. The average yield was 23.41 g per plant and varied from 9.61 to 39.34 g per plant (Table 2). On contrary, an average yield of 2.29 g per plant was recorded by Bisht et al. (2005). In the present study, evaluation of agro-morphological characters of *V. khandalensis* was carried out in its natural habitat. The cultivation approaches, edaphic factors as well as climatic factors might be responsible for differential yield. The lower or higher values of coefficient of variance (CV) for each parameter revealed minimum or maximum variation among the individual agro-morphological characters of *V. khandalensis* (Table 2). The advanced agricultural techniques could improve the agro-morphological characters of plant species such as the number of branches, peduncles, and pods per plant.

Nutrient content and phytochemical analysis

The proximate composition of seeds are depicted in Table 3. The ash content (3.20 ± 0.12) of *V. khandalensis* investigated in the present study which is found to be higher than *V. trilobata* and lower than other *Vigna* species (Kalidass and Mohan 2012; Bravo et al. 1999). The moisture content is 6.12 ± 0.06, which is higher than *V. aconitifolia*, *V. bourneae*, *V. sublobata*, *V. trilobata* and *V. umbellata* and lower than *V. radiata* (Khan et al. 1979). In the current investigation, it appears that *V. khandalensis* has a similar amount of carbohydrates (48.1 ± 0.10) when compared with other cultivated Asian *Vigna* species (Kalidass and Mohan 2012) while lower than cultivated African *Vigna* species, *V. subterranea* (Amarteifio and Moholo 1998). The crude protein content (24.56 ± 0.28) was found to be higher than other cultivated and wild *Vigna* species commonly consumed in Indian subcontinent such as *V. aconitifolia*, *V. mungo*, *V. radiata*, *V. trilobata*, and *V. umbellata* (JCR-152), while lower than cultivated *V. aconitifolia*, *V. mungo* (NARC-Marsh-97) and *V. vexillata*. The crude lipid content was more or less equal to the other *Vigna* species. The total dietary fibre content was found to be higher as compared with other wild and cultivated Asian *Vigna* species. However, the total dietary fibre content was less as compared with *V. trilobata* (Kalidass and Mohan 2012). The energy value investigated in the present study was lower than that of *V. aconitifolia*, *V. bourneae*, *V. sublobata*, *V. trilobata*, *V. umbellata*, *V. vexillata*, (Kalidass and Mohan 2012); while higher than *V. radiata* and its wild relative *V. sublobata* (Kalidass and Mohan 2012).

Wild legumes (Crop Wild Relatives) have been recognized as valuable resources of several minerals. The mineral profile of *V. khandalensis* is shown in Table 4. Of the minerals determined, potassium is the most abundant (1720 mg per 100 g), followed by phosphorus (240 mg per 100 g). However, the range of potassium, evaluated in the present investigation was found to be higher compared with cultivated varieties *V. mungo* (NRC-Marsh-97) (Zia-Ul-Haq et al. 2014) and *V. umbellata* (JFR-152) (Katoch 2013) and wild species, *V. trilobata* (Amarteifio and Moholo 1998; Kalidass and Mohan 2012) and the lower potassium content and higher phosphorus content was depicted as compared with *V. aconitifolia*, *V. bourneae* *V. sublobata* and *V. umbellata* and

Table 3 Proximate composition of *V. khandalensis* seeds (content in %)

Components	Ash	Moisture	Carbohydrates	Crude protein (Kjeldhal N × 6.25)	Total protein	Crude lipids	TDF (total dietary fibre)	Caloric value (per 100 g DM)	Reference
V. khandalensis	3.20 ± 0.12	6.12 ± 0.06	48.1 ± 0.10	24.56 ± 0.28	23.68 ± 0.39	5.48 ± 0.23	7.36 ± 0.17	1579.01 ± 0.29	Present study
V. aconitifolia	4.12 ± 0.58	3.84 ± 0.06	–	24.40 ± 0.10	–	5.26 ± 0.53	6.78 ± 0.71	1598.43	Kalidass and Mohan (2012)
	3.51 ± 0.01	–	–	25.03 ± 0.54	–	–	–	–	Bravo et al. (1999)
V. bourneae	3.38 ± 0.05	4.24 ± 0.05	–	21.40 ± 0.01	–	4.20 ± 0.02	5.25 ± 0.05	1614.08	Kalidass and Mohan (2012)
V. mungo	3.51 ± 0.00	–	–	23.6 ± 0.26	–	–	–	–	Bravo et al. (1999)
V. mungo (NARC-Mash-97)	5.26 ± 0.18	–	54.81 ± 1.75	28.60 ± 1.72	–	6.22 ± 0.09	5.11 ± 1.60	–	Zia-Ul-Haq et al. (2014)
V. radiata	3.45 ± 0.03	–	–	24.5 ± 0.17	–	–	–	–	Bravo et al. (1999)
	3.90	6.70	–	20.31	–	–	5.10	1572.30	Khan et al. (1979)
V. sublobata	3.48 ± 0.56	4.48 ± 0.08	–	25.64 ± 0.17	–	3.58 ± 0.56	6.12 ± 0.58	1504.87	Kalidass and Mohan (2012)
V. subterranea	4.04 ± 0.14	–	63.5 ± 0.02	18.3 ± 0.12	–	–	5.2 ± 0.13	–	Amarteifio and Moholo (1998)
V. trilobata	3.12 ± 0.56	5.54 ± 0.05	–	22.10 ± 0.46	–	6.48 ± 0.59	7.48 ± 0.34	1629.06	Kalidass and Mohan (2012)
	2.71	5.19	–	24.50	–	–	8.81	1593.96	Siddhuraju et al. (1992)
V. umbellata	4.04 ± 0.04	5.56 ± 0.02	–	16.12 ± 0.56	–	4.18 ± 0.50	4.74 ± 0.01	1611.15	Kalidass and Mohan (2012)
V. umbellata (JCR-152)	–	–	52.23 ± 0.12	24.40 ± 0.45	–	2.02 ± 0.02	4.22 ± 0.02	–	Katoch (2013)
V. vexillata	3.94 ± 0.56	6.94 ± 0.01	–	25.84 ± 0.56	–	5.80 ± 0.17	4.89 ± 0.05	1627.90	Kalidass and Mohan (2012)

All values are of means of triplicate determination expressed on dry weight basis; ± denotes standard error

Table 4 Mineral composition of *V. khandalensis* seeds (mg per 100 g seed flour)

Components	Sodium	Potassium	Calcium	Magnesium	Phosphorus	Iron	Zinc	Copper	Manganese	References
Reference daily intake (RDI)[a]	2300	4700	1300	420	1250	18	11	0.9	2.3	FDA (2010)
V. khandalensis	50.11 ± 0.003	1720 ± 0.860	100.23 ± 0.005	135.1 ± 0.018	240.43 ± 0.15	7.09 ± 0.543	7.18 ± 0.591	0.99 ± 0.012	4.16 ± 0.078	Present study
V. aconitifolia	24.78 ± 0.58	2452.78 ± 0.6	264.12 ± 1.53	144.10 ± 0.58	141.28 ± 0.02	6.48 ± 0.01	1.21 ± 0.01	0.48 ± 0.02	0.94 ± 0.01	Kalidass and Mohan (2012)
V. bourneae	27.34 ± 0.58	2142.30 ± 0.57	438.14 ± 0.01	168.20 ± 1.20	231.16 ± 0.31	7.54 ± 0.01	2.10 ± 0.01	0.72 ± 0.01	2.66 ± 0.01	Kalidass and Mohan (2012)
V. mungo (NRC Marsh-97	261.33 ± 1.79	1600.03 ± 2.61	394.19 ± 2.04	221.77 ± 1.18	440.90 ± 0.80	6.55 ± 0.33	1.94 ± 0.76	4.51 ± 0.34	3.22 ± 0.18	Zia-Ul-Haq et al. (2014)
V. sublobata	32.10 ± 0.03	1948.40 ± 0.01	284.20 ± 1.72	158.24 ± 0.56	212.12 ± 0.57	8.40 ± 0.01	1.74 ± 0.01	0.84 ± 0.01	1.24 ± 0.01	Kalidass and Mohan (2012)
V. subterranea	3.7 ± 0.29	1240 ± 12.08	78.00 ± 4.7	–	296 ± 19.7	5.9 ± 0.17	–	–	–	Amarteifio and Moholo (1998)
V. trilobata	34.12 ± 0.01	1696.10 ± 5.2	418.46 ± 0.01	242.00 ± 0.57	178.18 ± 0.02	9.48 ± 0.11	2.56 ± 0.01	1.22 ± 0.05	2.34 ± 0.03	Kalidass and Mohan (2012)
	24.26	1397.68	464.14	290.71	168.78	11.60	8.44	2.44	4.23	Siddhuraju et al. (1992)
V. umbellata	22.18 ± 0.02	2618.16 ± 2.39	274.14 ± 0.38	156.10 ± 0.58	126.20 ± 0.58	6.12 ± 0.57	0.78 ± 0.01	0.54 ± 0.01	1.10 ± 0.01	Kalidass and Mohan (2012)
V. umbellata (JCR-152)	347.40 ± 0.56	1632.12 ± 1.25	499.12 ± 0.62	356.12 ± 0.45	489.23 ± 0.97	7.45 ± 0.11	3.25 ± 0.07	4.74 ± 0.03	5.45 ± 0.05	Katoch (2013)
V. vexillata	26.48 ± 0.57	2012.62 ± 1.08	258.54 ± 0.56	178.10 ± 0.01	248.08 ± 0.58	10.40 ± 0.58	1.58 ± 0.57	1.10 ± 0.01	2.50 ± 0.01	Kalidass and Mohan (2012)

All values are of means of triplicate determination expressed on dry weight basis; ± denotes standard error

[a]Reference daily intake in 101.9 (c) (8) iv for adult. FDA U.S. Food and Drug Administration (2010)

V. vexillata (Kalidass and Mohan 2012). The calcium level seems to be low compared to other Asian *Vigna* species (Kalidass and Mohan 2012) but slightly higher than Bambara groundnut (*V. subterranea*) (Amarteifio and Moholo 1998). The sodium level is generally low, 50.11 ± 0.003 mg per 100 g, as compared with cultivated varieties *V. mungo* (NRC-Marsh-97) (Zia-Ul-Haq et al. 2014) and *V. umbellata* (JFR-152) (Katoch 2013). However, the seeds showed higher levels of sodium than other Asian *Vigna* species. The calcium level in seeds of *V. khandalensis* is lower than wild and cultivated *Vigna* species, except *V. subterranea*, where higher calcium level was recorded by Amarteifio and Moholo (1998). The magnesium content was lower than other *Vigna* species (Kalidass and Mohan 2012). The zinc content is higher in *V. khandalensis* as compared with other *Vigna* species, except *V. trilobata* (Siddhuraju et al. 1992). The copper content of *V. khandalensis* is found to similar as other *Vigna* species (Amarteifio and Moholo 1998, Kalidass and Mohan 2012). The iron content (7.09 mg per 100 g) was higher than the cultivated *V. aconitifolia* (6.48 mg per 100 g) *V. umbellata* (6.12 mg 100 g) and *V. subterranea* (5.9 mg 100 g) (Amarteifio and Moholo 1998; Kalidass and Mohan 2012). The manganese content in seeds of *V. khandalensis* was found higher than that of the recommended dietary allowance by FDA (2010). The wide variation in the mineral content of *V. khandalensis* may be a reflection of the difference in the mineral status of the soils. The mineral content in *V. khandalensis* showed that there is a vast variation compared with earlier reports in the other Asian *Vigna* species (Siddhuraju et al. 1992; Amarteifio and Moholo 1998; Kalidass and Mohan 2012; Katoch 2013; Zia-Ul-Haq et al. 2014).

Production and yield

There is no known information on large-scale production of *V. khandalensis* in the Western Ghats region of Maharashtra; consequently, accurate statistics on yield and production are lacking. Based on our own measurements in farmer fields, ran mung can yield 9.61–39.34 g per plant and 250 kg per ha. Moreover, the presently advanced crop improvement programmes could improve the agro-morphological characters of plant species such as the number of flowering branches and number of seeds per plant. Pandiyan et al. (2010) reported the successful interspecific hybridization of *V. khandalensis* (pollen parent) with *V. radiata*. This cross resulted in only 8% crossability and a single seedling attended the maturity. Cultivation of such promising underutilized, wild and neglected legume species with desirable traits could help to establish an alternative protein legume crop.

Threats and conservation status

Vigna khandalensis is an endemic to the Northern Western Ghats, India and there is no information about its distribution outside Maharashtra. The distribution range along the hill slopes is subjected to the interferences due to the cultivation of commonly used mungbean (*V. radiata*) and urdbean (*V. mungo*) by local tribes and the wild population is likely to face abrupt habitat loss. Threats include overgrazing due to an increasing population of domestic animals as this is a palatable species. The plant in a vegetative stage is unknowingly cut along with grasses by local grass cutters for livestock. Urbanization and infrastructural development, mining and dam construction along the distribution range of the plant create additional threats (Rawat et al. 2001). *V. khandalensis* is reported to be rare by Singh and Kulkarni (1990) and is listed as Rare in IUCN Red List of Threatened Plants (Walter and Gillett 1998). In view of the sporadic distribution and threats, it has been shifted towards the threatened category. Later, it has been assessed as 'Near Threatened (NT)' following the IUCN Red List Categories and Criteria version 3.1 (Chadburn 2012).

Future perspectives

Vigna khandalensis is a useful plant resource that could be helpful to alleviate protein malnutrition. It has a great potential as protein food (legume) for tribal peoples and local populations. It is not considered to be at risk, due to the lack of data on actual distribution and population size. Further surveys and mapping are required to establish and monitor the current population status and further threats. It is considered as one of the wild relatives of cultivated Asian *Vigna* species. Therefore, the systematic position of this species in Asian *Vigna* species is needed in order to clarify its closest relatives, which further useful for future crop improvement programmes. According to IUCN categories, *V. khandalensis* is in 'Near Threatened' category and it is up to us to use this crop wild relative or otherwise lose it. To promote the sustainable use of *V. khandalensis*, we suggest to intensify the knowledge on agricultural and cultivation practices for increased seed production, crossability with cultivated Asiatic *Vigna* species, developing cultivated lines, and ensuring conservation of this wild genetic resource as a 'Crop for the Future'.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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