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Gadmal: An endemic pulse crop from Betul district, Madhya Pradesh, India

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''Gadmal'' is one of the important pulse crops of the local people living in the southern parts of Betul, Madhya Pradesh, India. An expedition was undertaken in December, 2022 to gather germplasm of *gadmal* from Betul, a district lying almost wholly on the Satpura plateau. From the results of a structured questionnaire administered to *gadmal* cultivating farmers in targeted villages, it seemed that *gadmal* is the pulse crop cultivated in this region by tribal farmers. *Gadmal* is being used as split pulse, chapati and vada preparations by the farmers. The food items and recipes prepared from the *gadmal* are traditionally offered to tribal Gods. However, the area under this crop is shrinking due to severe infestation of yellow mosaic disease. Indian Council of Agricultural Research-National Bureau of Plant Genetic Resources (ICAR-NBPGR) has collected and conserved a specimen in the National Herbarium of Cultivated Plants (Herbarium specimen, HS25749). On-spot evaluation of morphological traits was done across the locations. The study was undertaken for preliminary morphological, biochemical and molecular assessment. Based on preliminary evaluation, *gadmal* seems to be closer to blackgram than other cultivated *Vigna* species. However, detailed taxonomic studies are required to validate the identity using morpho-molecular tools. An exploratory note was presented with indigenous traditional knowledge along with cultural practices and economic uses. The work aimed to facilitate germplasm collection, detailed evaluation and systematic study of this valuable material with the prospects of crop diversification and value addition. The preliminary morphological, biochemical and molecular profiling of collected accessions being undertaken by us will provide avenues for better utilization and recognition of this crop. Efforts are being made to document the traditional knowledge and facilitate the tribal community for germplasm registration.

Keywords: Collection, Endemic, *Gadmal*, India, Landrace, Pulse, *Vigna*

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Betul, situated in the southern region of Madhya Pradesh, occupies a somewhat remote location primarily on the Satpura plateau[1]. The areas within this district that have been studied exhibit a predominant tribal presence, with the Gonds being the predominant community. In India, the Gonds rank as the second most populous tribe, following the Bhils. The majority of Gond people are involved in various aspects of agricultural and animal husbandry activities[2]. In the southern part of the Betul district in Madhya Pradesh, India, there is an indigenous pulse crop known as "*Gadmal*" that is cultivated. This crop is relatively lesser-known but shares similarities with blackgram. Legumes, which belong to various genera within the Fabaceae family, are widely grown and serve as a highly sought-after resource for pulses, vegetables, fodder, etc,[3]. Vigna is a significant genus among all pulse crops, with about 200 cultivated and wild species[4]. Blackgram (*Vigna mungo* (L.) Hepper var. *mungo*) is thought to have domesticated from its wild progenitor species, *V. mungo* var. *silvestris*, in India[5]. India is the principal source of genetic diversity for blackgram. The crop is grown under rainfed conditions in a variety of agroecologies and cropping systems[6]. Around 17% of the total land used for the cultivation of pulses in India is devoted to blackgram[7]. Compared to other pulse crops, very little study has been done in *gadmal* to enhance the crop despite its long history of cultivation, high nutritional value, and soil-improving abilities. Traditional blackgram producers find it highly discouraging due to a lack of acceptable ideotypes, poor harvest index, vulnerability to biotic and abiotic stressors, and changing climatic conditions. Additionally, due to the

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dominant function of natural selection, there may be a steady loss of genes linked to yield and resistance[8]. As a result, immediate corrective actions are needed, including increased use of local landraces and closely related wild species in breeding programmes. The germplasm of "*Gadmal*" was gathered and conserved due to the rapid replacement of its unique germplasm by other competing crops in the reporting area and the lack of representation in the Indian National Genebank. The current research aims to provide an overview of the cultivation of this landrace in India, together with preliminary evaluations of its morphology, nutritional needs, and cultural traditions.

Materials and Methods

Germplasm exploration and morpho-taxonomic studies

On December 22 and 23, 2022, an exploration was conducted in the district of Betul, Madhya Pradesh. The district's fields and marketplaces were exhaustively examined for variations in "*Gadmal*" and feedback on consumer preferences was sought. "*Gadmal*" seeds were gathered from farmers' field and local markets in the surveyed area. To deposit the seeds in the National Genebank at the ICAR-National Bureau of Plant Genetic Resources (ICAR-NBPGR), New Delhi, mature pods were dried, and processed[9]. Eleven farmers were included in the survey and data collection where they provided their cultivation methods and yield information. Based on information from the aforementioned sources, a distribution map (Fig. 1) showing areas of crop availability and collection was created using software (DIVAGIS7.5). For documenting morphological data and traditional knowledge, 11 seed samples were obtained from farmers' farms, residences, and markets. Data were recorded according to the *Vigna* (descriptor) for taxonomic identification. Comparative research was carried out with other species, and features were

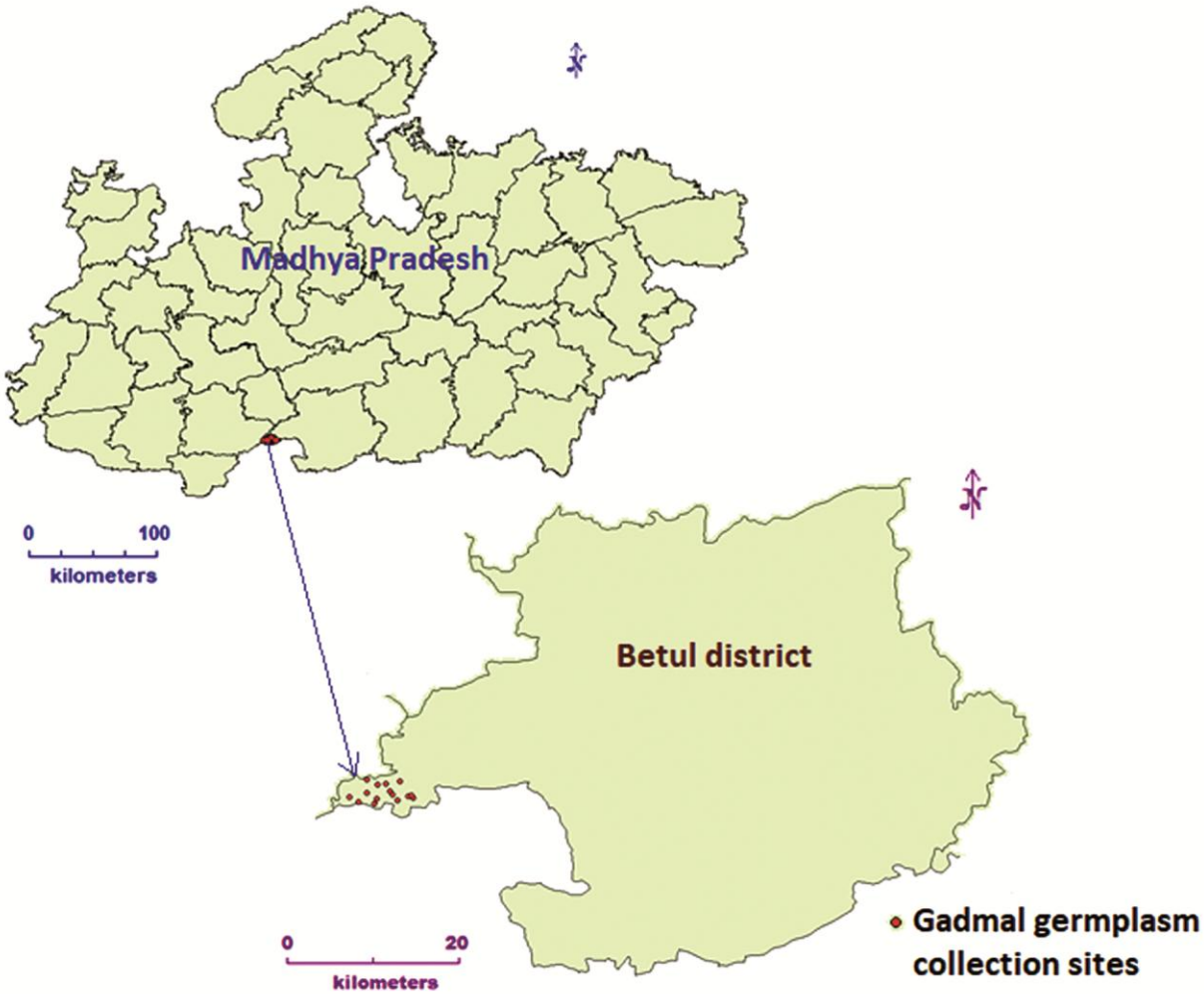

Fig. 1 — Area of collection of germplasm, survey and cultivation of ‘‘*Gadmal*’’ in India (DIVA-GIS 7.5)

validated using data from herbarium notes. Herbarium voucher (HS25749) of selected material containing flowers and pods were prepared in the field according to conventional herbarium methods and placed in the National Herbarium of Cultivated Plants (NHCP), ICAR-NBPGR, New Delhi. The National Genebank (IC647441) contains germplasm from chosen types.

Biochemical profiling

The biochemical composition was determined using the standard methods[10] *viz.*, moisture (AOAC 934.01), protein (AOAC 2001.11) and fat (AOAC 920.58), total soluble sugar (anthrone reagent method)[11], starch content (AOAC 996.11) and total dietary fibre by AOAC Official Method 985.29.

DNA extraction, PCR, electrophoresis

Briefly, genomic DNA was extracted from fresh leaf tissues using a plant DNA isolation kit (Qiagen) following the instructions mentioned therein and PCR assays were carried out[12]. SSR primers as reported earlier have been used for screening *gadmal* along with reference varieties of blackgram and greengram[13-15]. PCR 20 µL reaction mixture (50 ng genomic DNA + 1X PCR buffer+2.5 mM $MgCl_2$+0.2 mM of each dNTPs+1l µL forward and reverse primer+ 1U Taq DNA polymerase) was set with the following conditions: Initial denaturation (94°C for 5 min); denaturation (35 cycles at 94°C for 30 s); primer annealing (48-52°C for 30 s); extension (72°C for 1 min) and final extension (72°C for 7 min). The PCR products were electrophoresed on 3% MetaPhor agarose gel stained with ethidium bromide using 1X TAE buffer, at a constant 120 V with 100 bp DNA ladder (GBiosciences) and the gels were then visualized in the gel documentation system. Band size was scored using alpha imager software, Alpha View SA-Version: 3.4.0.0 with manual curation.

Results and Discussion

Germplasm collected and variability study

Betul district stretches between 21-22 and 22-24 degrees North Latitude and 77-10 and 78-33 degrees East Longitude and has a compact shape, approximately square with small protrusions on the East and West. The exploration conducted in the southwestern section of Betul, which is the adjoining territory of Maharashtra state, demonstrated the presence of cultivar "*Gadmal*" in farmer's fields as well as markets (Fig. 1). The district's southern boundary extends approximately parallel to the southern slopes of the Melghat range, but excludes the Hattighat and Chikhaldara hills in Maharashtra's Amravati district. According to the survey, the area under cultivation of this landrace is decreasing; currently, it is cultivated primarily for self-consumption by a small number of farmers. This crop has been cultivated for over two centuries, but in recent decades, it has been restricted to a few villages[16].

Cultivation practices

Based on the information shared by farmers, akin to growing other pulse crops, *gadmal* yielded favourable financial returns. Typically, the planting of this crop took place in the pre-winter season, around September-October, using broadcasting methods. One round of weeding was carried out, accompanied by the application of Farm Yard Manure (FYM). Flowering commenced approximately 40-45 days after the initial sowing.

While the crop was sometimes grown alongside maize as an intercrop, it was noted that this practice could potentially lead to a reduction in overall yield. Among the various challenges faced in cultivation, the most significant threat was the Yellow Mosaic Disease (YMD), which had a detrimental impact on yield. Additionally, Bruchids were identified as the primary storage pests, causing economic losses of up to 100%. However, there were no reports of other diseases affecting the cultivation in the area. However, it was observed that heavy rainfall could result in a decline in the number of pods produced.

Botanical description and morphological study

Occurs in cultivation; Erect herb; Plant is 40-80 cm long; total plant is covered with hairs; densely pubescent; white-yellowish colour hairs found on total plant body; Stem is solid, robust or woody, slender appears in green to purple colour; 5-11 lateral branches found. Trifoliate leaves and pubescent; terminal leaflet obliquely ovate, purple pigmentation appears in veins; petiole slightly purple in colour. Stipules elliptic, lanceolate, medifixed, and measuring 12-14 x 3-4 mm. Inflorescence 5-6 flowered; flowers yellow in colour and measuring 2.5 x 3.5 cm; standard petal size 1.2-1.4 cm, lateral petal 1.1 x 0.5 cm, keel petal 1.4 x 2.2 cm; keel pocket appears in one side and measures 0.4 cm; peduncle length about 14-16 cm. Immature pods are green in colour and densely pubescent; whereas mature pods are slightly curved

and sometimes pods are straight; dark brown or slightly black; cylindrical and appear in 4.9-5.2 cm size. Seeds are bold and oval in shape, mottled, and dark brown; measuring 4-5.5 mm, 5-7 seeds per pod; hilum prominently visible. The flowering starts at 38-44 days whereas pod maturing takes place in 70-75 days. Depiction of *gadmal* is given in Figure 2.

Following a comparative analysis of morphological characteristics with other cultivated *Vigna* species, the authors have suggested that this shares similarities with blackgram cultivars. However, it's important to note that the current findings are based on the materials that were readily accessible. Therefore, there is a pressing need for a more comprehensive

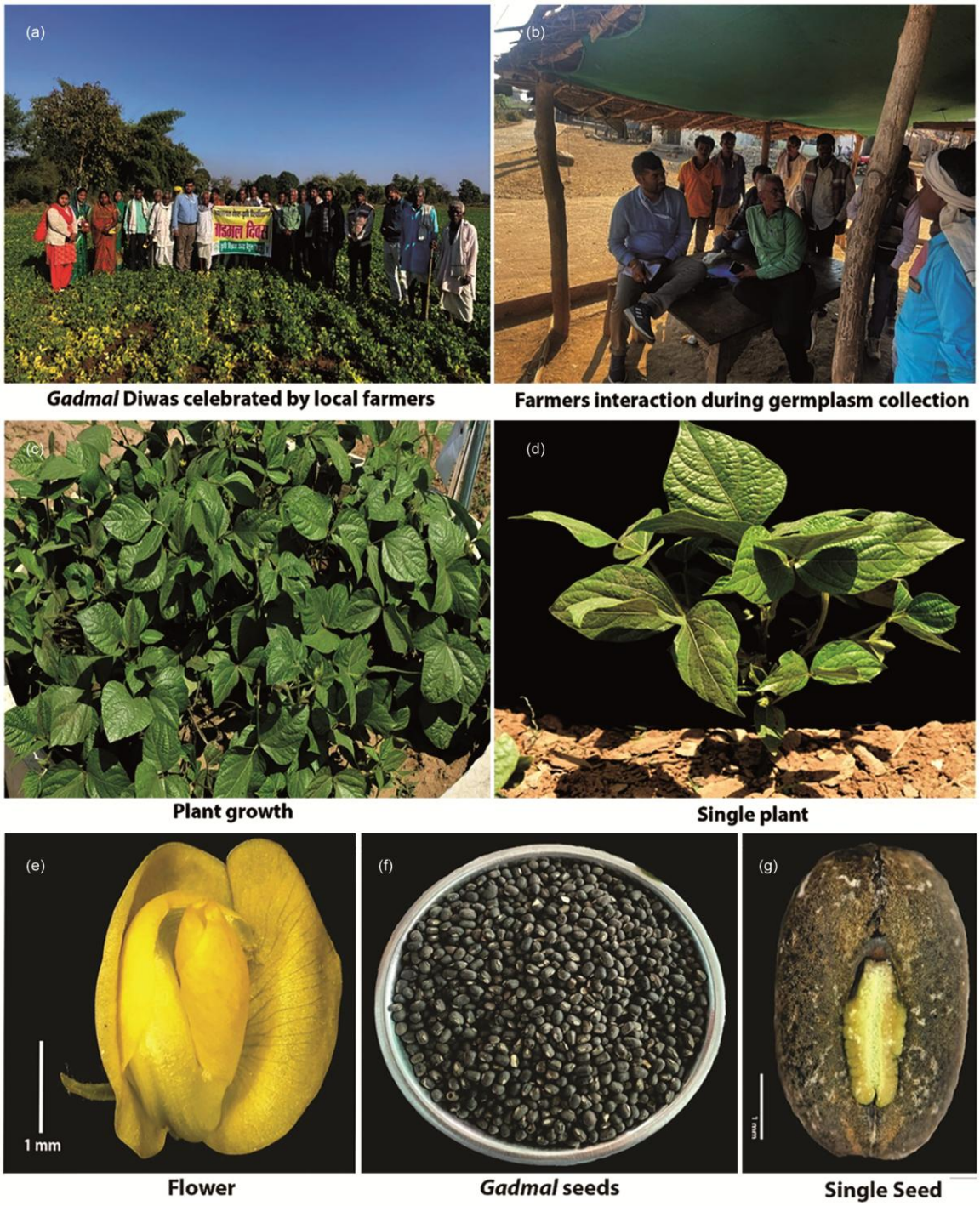

Fig. 2 — Germpalsm survey and depiction of ‘‘*Gadmal*’’ plant, flower and seeds

investigation to inform researchers and farmers more effectively.

The proximate composition of *gadmal* is compared with *V. stipulacea*, rice bean, adzuki bean, blackgram, cowpea, greengram and mothbean (Table 1). Hierarchical clustering based on proximate composition data using squared Euclidean distance and wards method resulted in grouping of *gadmal* with *V. stipulacea*, blackgram, cowpea, greengram and mothbean in major cluster 1, ricebean and adzuki bean falling in major cluster 2 (Fig. 3). However, the whole analysis is preliminary and this is based on the seeds of *gadmal* collected from the Betul. A detailed comparison is required to assess the germplasm of every targeted species based on the harvest from the same environment.

DNA profile of *gadmal* was generated along with three reference varieties of each of blackgram (KU06, Mash114 and, PU11-14) and greengram (PDM 139, MH421, and Virat) using 43 SSR markers including 21 and 22 SSR primers of blackgram and greengram, respectively (Fig. 4 and 5). All the blackgram and greengram SSRs have shown amplification of the expected size in *gadmal*. In the case of blackgram SSRs, from 21 primers, 7 primers did not show amplification in any of the reference varieties of greengram, however, clear amplification was observed in the case of *gadmal* (Fig. 5). Further, in most cases, SSR banding pattern was similar to that of blackgram reference varieties (Fig. 4 and 5). SSRs bands of expected size from 43 SSR loci in greengram and blackgram were scored in *gadmal* as well as the

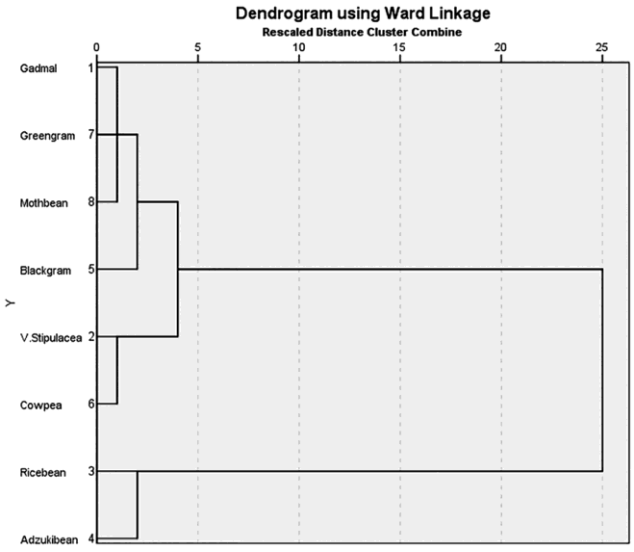

Fig. 3 — Hierarchical clustering based on proximate composition data of eight *Vigna* species

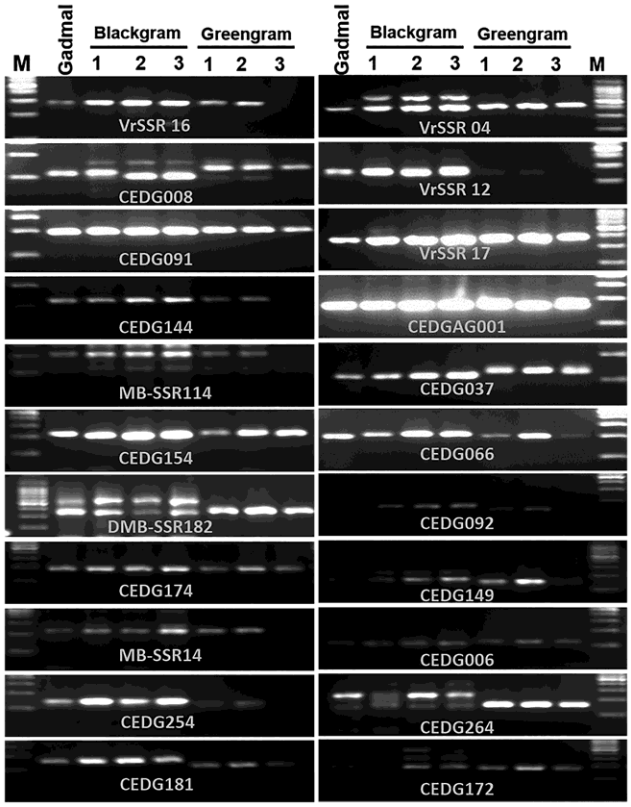

Fig. 4 — SSR Profile of *gadmal* along with three reference varieties of blackgram (KU06, Mash114 and PU11-14) and greengram ((PDM 139, MH421 and Virat)) using 22 greengram SSR markers. The name of SSR primers pair has been indicated at the bottom of each gel. M indicates 100 bp DNA ladder.

Table 1 — Comparative nutritional profile of *gadmal* studied and reported in other *Vigna* species

S.N.	Crop	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Dietary Fibre (%)	Total Sugar (%)	Total Starch (%)
1	*Gadmal*	11.1	3.31	23.8	2.31	19.3	4.96	34.9
2	*V. stipulacea*	11.6	3.39	21.7	1.89	19.2	4.49	37.1
3	Ricebean	11.01	4.13	21.7	1.84	16.3	3.07	43.8
4	Adzuki bean	9.64	2.71	24.4	1.95	15.6	4.6	42.5
5	Blackgram	9.91	3.28	26.2	2.13	19.3	5.64	33.2
6	Cowpea	10.4	3.5	24.1	1.59	17.2	5.48	36.7
7	Greengram	11.1	3.39	24.7	1.37	19.8	3.7	34.9
8	Mothbean	11.8	3.62	23.6	1.67	22.2	3.31	34.2

reference varieties and used for calculating the molecular distance matrix using GenAlEx v6.5 program. The molecular distance matrix was used to construct an unweighted neighbour-joining tree using MEGA X[17]. The SSR-based phylogenic tree clustered *gadmal* along with blackgram varieties (Fig. 6). The above results suggest a proximity of *gadmal* to the blackgram compared to the greengram.

Conservation status and use

The landrace known as "*Gadmal*" was documented at its collection site, where it had been under on-farm conservation for over a century. Feedback from farmers indicated discernible trends of vulnerability, as they reported the replacement of this crop with other pulse varieties and a diminishing interest among farmers to cultivate it. Notably, there is currently no germplasm of "Gadmal" preserved in the Indian National Genebank at ICAR-NBPGR. A total of 39 accessions representing cultivated *Vigna* species from Betul were conserved in INGB. The maximum conserved *Vigna* accessions belong to blackgram (18) followed by cowpea (10), greengram (9) and mothbean (2) (PGR Portal, 2023). A herbarium specimen (HS25749) deposited to NHCP, New Delhi (Fig. 7)

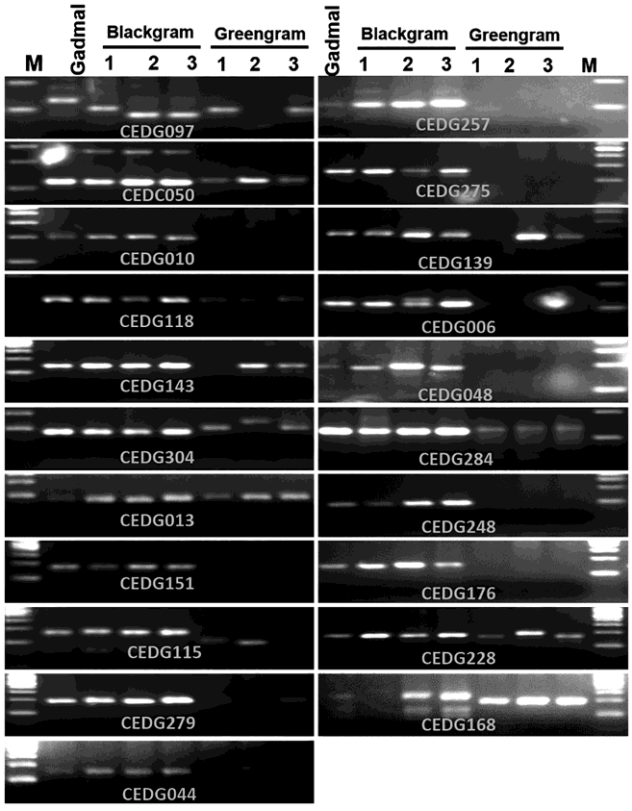

Fig. 5 — SSR Profile of *gadmal* along with three reference varieties of blackgram (KU06, Mash114 and PU11-14) and greengram (PDM 139, MH421 and Virat) using 21 blackgram SSR markers. The name of SSR primers pair has been indicated at the bottom of each gel. M indicates 100 bp DNA ladder.

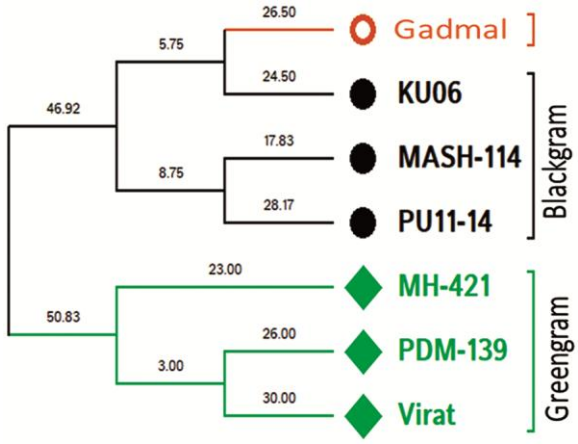

Fig. 6 — Clustering of *gadmal* along with reference varieties of blackgram and greengram using SSR data from 43 SSR loci in blackgram and greengram. Reference varieties of blackgram and greengram have been given in black and green colour font respectively.

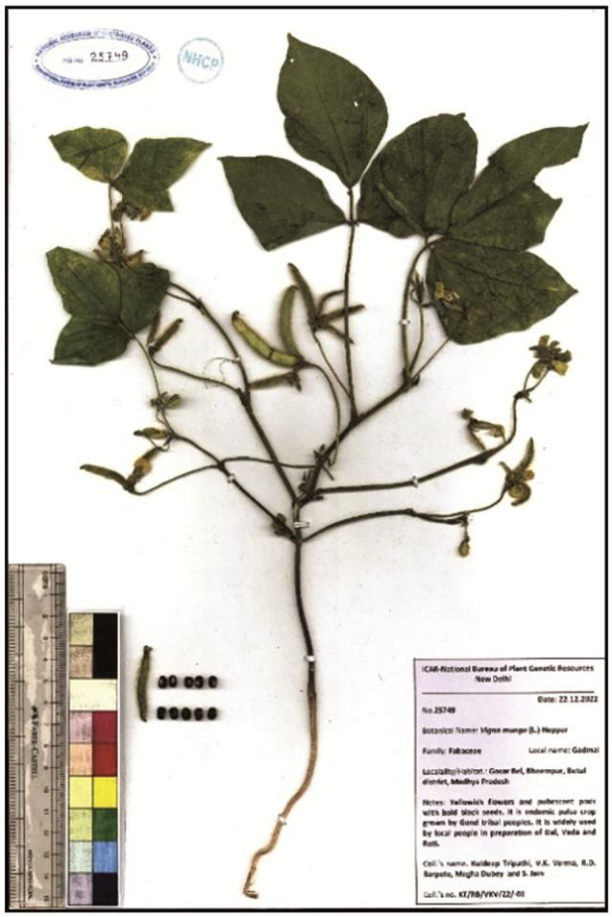

Fig. 7 — Herbarium specimen of *Gadmal*

The Gonds are an ethnolinguistic group in India. During farmer's interaction of Bhimpur Block of the district Betul, it was told that *gadmal* was sown after the celebration of Bhadrapada. The months of September and October in the Gregorian calendar correlate to Bhadrapada month, which is the sixth month in the Hindu calendar. ‘‘*Gadmal*’’ is one of the important pulse crops in the surveyed area reported here for consumption in many forms, *i.e.*, as a dahl and flour for savouries and roti making. Consumption as a pulse is the same as that of the blackgram. As the pulse crop is highly delicious and is being used by the tribes in their several local festivities and religious events, this is recognized as a promising pulse crop in the region. Use as confectionaries is preferred for a good crunchy taste. Value addition can expand the scope of cultivation to greater areas, benefiting farmers economically[18]. The food items and recipes prepared from the *gadmal* are traditionally offered to tribal Gods. It may fit as a sandwich crop for the Kharif cafeteria. Based on the feedback of tribal farmers, it was said that the extracted oil from *gadmal* seeds was used as a paste to smoothen the surface of hand grenades during ancient times. There is a need for validation of the traditional knowledge of ancient use recorded during the survey for utilizing and promoting the endemic genetic resource of *gadmal* which will not only promote the crop but enhance the socio-economic upliftment of tribal farmers of the region.

Future thrust

Given the socio-economic relevance of "*Gadmal*" and their acclimatization in limited patches, the following points should be highlighted:

- Acquisition and preservation of germplasm from available areas (areas to be covered-adjoining areas of Betul district of Madhya Pradesh)
- Detailed evaluation for multiple traits including nutritional evaluation
- Taxonomic study (morpho-molecular) aspects
- Development of market and value chain
- Development of cultivation technology
- Validation of traditional knowledge recorded
- Need for improved “*Gadmal*” with Yellow Mosaic Disease (YMD) resistance

To the best of our knowledge and available literature, "*Gadmal*" is locally cultivated in the above-described region and hasn't even been referenced in the bordering areas. Before it is replaced by new crops, it is necessary to gather, assess, and conserve the germplasm from the cultivated regions. According to our initial analysis, the "*Gadmal*" was discovered to be more similar to blackgram than other cultivated *Vigna*. However, to validate the same, comprehensive taxonomic data is needed. To assist the tribal people with the germplasm registration of this novel crop, efforts are being made to characterize the germplasm and document traditional knowledge.

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Declaration

The authors declare that photographs were captured during the official function “*Gadmal* Divas” where *gadmal* cultivating farmers were invited.

Conflict of Interest

Authors unanimously proclaim that they do not have a conflict of interest.

Author Contributions

Conceptualization: KT, RG; Exploration and Collection of germplasm accessions: KT, VV: Supervision: GS; Writing - original draft: KT, DW, RB; Writing - review & editing: RG, GS, SC.

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