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VL *Mandua* 378: A high yielding, medium maturing, blast resistant finger millet cultivar suitable for rainfed organic agro-ecology of Himalayan region

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Abstract
The medium duration blast tolerant finger millet variety VL *Mandua* 378 was developed at ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora from the cross between GEC-440 (early maturing genotype) and VL *Mandua*149 (blast resistant locally adapted cultivar) followed by pedigree method of selection in the segregating generations. Under rainfed organic condition, this variety has recorded an average grain yield of 2,096 kg/ha, which was 34.56 and 70.33 percent higher over the check variety VL *Mandua* 324 (1,557 kg/ha) and PRM-1 (1,230 kg/ha), respectively in SVT trials conducted over 3 years from 2015-17. It is a medium duration variety with mean maturity duration of 114 days. The grains are nutritious with higher concentration of calcium (361 mg/100 g) and iron 4.5 mg/100 g) in comparison to the check variety VL *Mandua*324 (294.0 mg/100 g and 2.8 mg/100 g, respectively). It exhibited resistant reaction to leaf blast and moderate resistant reaction to finger and neck blast in the multilocation trials conducted over 9 locations. Based on its superior performance for grain yield, grain quality and blast tolerance VL *Mandua*378 was released by State Varietal Release Committee, Uttarakhand on 19th May, 2020. Subsequently, it was notified by the Central Sub-Committee on Crops Standards, Notification and Release of Varieties for Agricultural Crops vide notification number S.O. 500 (E); dated January 29, 2021. The specific area of adaptation of this variety is the rainfed organic condition of Uttarakhand hills.

Keywords: High yielding, blast resistance, grain quality, VL *Mandua* 378

Introduction
Small millets are considered as climate resilient crops and best suited for rainfed cultivation due to their shorter growing season, C_4 photosynthesis, and capacity to yield even in poor soil under low rainfall and poor management system (Himasree *et al.*, 2017) [2]. Among the small millets, finger millet is one of the most important nutritious staple cereals, extensively grown by marginal farmers in drylands of Asia and Africa. Finger millet has huge significant potential to function as an alternative grain for assuring food and nutritional security across most parts of the globe due to high concentration of micronutrients, dietary fibre, vitamins, and phytochemicals of numerous therapeutic benefits in its grains (Joshi *et al.*, 2021) [3]. Finger millet grains are more nutrient-dense than rice, having eight times more calcium, four times more minerals, and two times more phosphorus per unit grain consumed (Malathi *et al*., 2016; Sood *et al.*, 2019) [5, 7]. Therefore, the use of finger millet as a nutritional alternative in various food preparations has gained popularity over the last decade.
In the Himalayan region, finger millet is not simply a food grain, but it is also deeply woven into the socio-cultural fabric of people living in the hills, locally known as *Mandua*. Furthermore, as compared to other crops it has better adaptability to the fragile mountain ecosystem and rainfed organic agro-ecology (Gururani *et al.*, 2021; Parihar *et al*., 2021) [1, 6]. It plays an important role in ensuring the food and nutritional security of the hill farmers, as well as meeting the fodder needs of their livestock. However, farmers generally cultivate traditional cultivars, which are blast susceptible and low yielding with loose panicles which has rendered poor productivity levels of the crop in the region (Joshi *et al*., 2022) [4]. It is generally grown without chemical fertilizer and by default it is organic. In this region cultivars of maturity duration (110-115 days) are preferred by the farmers as the crop occupies rainfed areas where the growth period is mostly limited due to less availability of water for the crop.

Further, hills are the hot spots for all three types of blasts (leaf, neck and finger) of finger millet (Sood *et al*., 2023) [8]. Therefore, early to medium maturing finger millet cultivar, which can be responsive to organic fertilizer with high to moderate resistance to blast within a locally adapted genetic background is required to cater the need of the area.

Thus, with the objective to develop a high yielding, blast resistant and nutritionally superior finger millet variety specifically suited to rainfed and organic agro-ecology of hills the variety VL *Mandua* 378 was developed to add finger millet diversity for organic farming in the country as a whole and in the Himalayan region in particular.

Materials and Methods

In order to develop a high yielding, blast resistant and nutritionally superior finger millet variety, the inter-varietal hybridization was carried out between GEC 440 and VL *Mandua* 149 and followed by pedigree method of selection (Figure 1). GEC 440 is early maturing genotype whereas, VL *Mandua* 149 is blast resistant and locally adapted finger millet genotype. During the segregating generations of the progenies (F_2 to F_5) derived from the cross GEC 440 × VL 149, selections were made with a keen emphasis on high yield, maturity (110-115 days) and resistance to leaf, neck and finger blast diseases. Uniform lines were bulked in 2011 and a homozygous and homogeneous genotype VL 378 was tested in station trial during 2012 and 2013. Subsequently, the culture was tested in multi-locational state varietal trials of Uttarakhand along with checks VL *Mandua* 324 and PRM-1 during the rainy season of2015, 2016 and 2017 at following randomized complete block design with 3 replicates under organic conditions. The recommended sowing time of June was followed and the row to row distance of 22.5 cm and row length of 3 m with plot of 5 rows were followed uniformly at all the locations. The crop was raised under organic conditions by recommended dose of FYM @15t/ha. The strain was also nominated to All India Coordinated Small Millets (AICRP-SM) Trial-2014 and was evaluated in multi-location All India Coordinated Small Millets Early and Medium Duration Trials conducted in inorganic conditions during 2014-2015. Disease screening was done in the natural field conditions of 9 hot spot locations in AICRP-SM IVT trials.

Results and Discussion

The overall mean performance of finger millet pre-release culture VL 378 in SVT trials is presented in Table 1. A total of 12 multi-location trials (MLTs) were conducted during SVT in Uttarakhand hills to evaluate the performance of the pre-release culture in comparison to the checks. In the overall mean performance, VL *Mandua* 378 recorded average grain yield of 2,096 kg/ha and out-yielded the checks VL *Mandua* 324 (1,557 kg/ha) and PRM-1 (1,230 kg/ha) by an impressive margin of 34.56 and 70.33 percent, respectively inSVT trialsconducted under organic conditions over three years. Based on the mean grain yield performance of AICRP-SM IVT trial conducted at 10 locations under inorganic conditions VL *Mandua* 378 (3,082 kg/ha) out yielded national checks VL 352 (2,810 kg/ha) and VR 708 (2,263) by an impressive margin of 9.68 and 36.19%, respectively (Table 2). However, at state level VL *Mandua*378 (3,556 kg/ha) was at par with the national checks VL *Mandua*352 (3,518 kg/ha) and out yielded the check VR 708 (1,386) by an impressive margin of 156.57 percent in AICRP-SM Initial Varietal Trials (Table 2).

Among the various diseases, blast plays a detrimental role in production and productivity of finger millet in hills (Sood *et al.* 2019) [7]. In the coordinated trials, conducted across 9 diverse hot spot locations of blast, the percent damage due to leaf blast in VL *Mandua*378 was very low (disease score 1.8) and it fell in the resistant (R) reaction category with the checks VR 708 (2.6), VL *Mandua*352 (2.0) and GPU 45 (2.0) (Table 3). The percent damage due to finger blast in VL *Mandua* 378 was low (11.6%) and was grouped in the disease scale category of 11-20% (moderately resistant reaction). Likewise, the percent damage due to neck blast in VL *Mandua* 378 (10.0%) was low and fell in the disease scale category of 1-10% (resistant reaction) with the national checks (Table 3).

The late maturing varieties of finger millet do not perform well in higher hills since their maturity phase coincides with low temperatures, resulting in prolonged approach to maturity or failure to mature altogether. Further, the delay in sowing of the successive *rabi* crops caused by the long duration cultivars in the Himalayan region adversely affects the germination and initial growth of crops due to continuously falling temperature as well as depriving the crop of the benefits of residual soil moisture. The newly released variety VL *Mandua* 378 showed mean maturity duration of 114 days in SVTs conducted over 5 locations from 2015 to 2017 (Table 1). Interestingly, VL *Mandua* 378 showed mean maturity duration of 110 days in AICRP-SM IVT trials conducted over 18 locations in the year 2014. Thus, being a medium duration variety, VL *Mandua* 378 suitably fits into the prevalent cropping system of Himalayan region and can be sown after onset of monsoon in the month of June and harvested by the first week of October, thereby ensuring timely sowing of successive *Rabi* crops.

In terms of grain quality (Table 4), VL *Mandua* 378 has higher calcium (361 mg/100 g) and protein content (7.2%) in comparison to the check VL *Mandua* 352 (345 mg/100g and 6.3%) and VL *Mandua* 324 (294 mg/100 g and 6.6%), respectively. In addition, Iron content was also higher in VL*Mandua* 378 (4.5 mg/100 g) in comparison to check VL *Mandua* 352 (3.9 mg/100 g) and VL *Mandua* 324 (2.8 mg/100 g).

VL *Mandua*378 is characterized by dark copper colour grains (Figure 2) with average test weight of 2.79 g. The plants and leaves are green in appearance and nodes are non-pigmented. The growth habit is erect and the leaves are characterised with blade pubescence. The ear heads are semi compact with high grain density and long fingers (7.4 cm). The detailed descriptor of the variety is presented in Table 5.

Frontline demonstrations (FLDs) were conducted during *kharif* 2021-22 crop seasons. In FLDs, VL *Mandua* 378 recorded grain yield of 1,803 which was 27.06% higher than 1,419 kg/ha of the local farmer's variety. These demonstrations were conducted in Almora district of Uttarakhand with 45 farmers. Farmers' response to this variety has been positive and they are very enthusiastic for this variety which led to high farmer to farmer exchange of seed of the variety. The economics of finger millet production under frontline demonstrations were estimated and results have been presented in Table 6. Finger millet variety VL *Mandua*378 recorded higher Benefit: Cost (B:C) ratio of 1.14 in demonstration plots than of 0.65 in farmers' plot.

Considering the consistent superior performance of the

culture VL *Mandua* 378 as compared to the checks for grain yield, and preferable grain quality traits coupled with the nutritional superiority specificallyhigher calcium and iron content than the check variety VL 324, VL *Mandua* 78 was released by State Varietal Release Committee Uttarakhand in 2020 and subsequently, it was notified by the Central Sub-Committee on Crop Standards and Release for Agricultural Crops of Varieties vide notification number S.O.500 (E); dated January 29, 2021. The specific area of adaptation of this variety is the rainfed organic condition of Uttarakhand hills. In view of the high yield potential, blast resistance and superior grain quality (high calcium and iron) with check varieties, VL *Mandua* 378 was released as finger millet variety suitable for rainfed and organic ecology of hills. This would fulfil the long felt needs of the farmers of hilly areas of Uttarakhand, where finger millet is predominantly grown under rainfed condition. The large scale demonstration of the variety and its value added products will enhance its adoption rate by the farmers along with consumer acceptability.

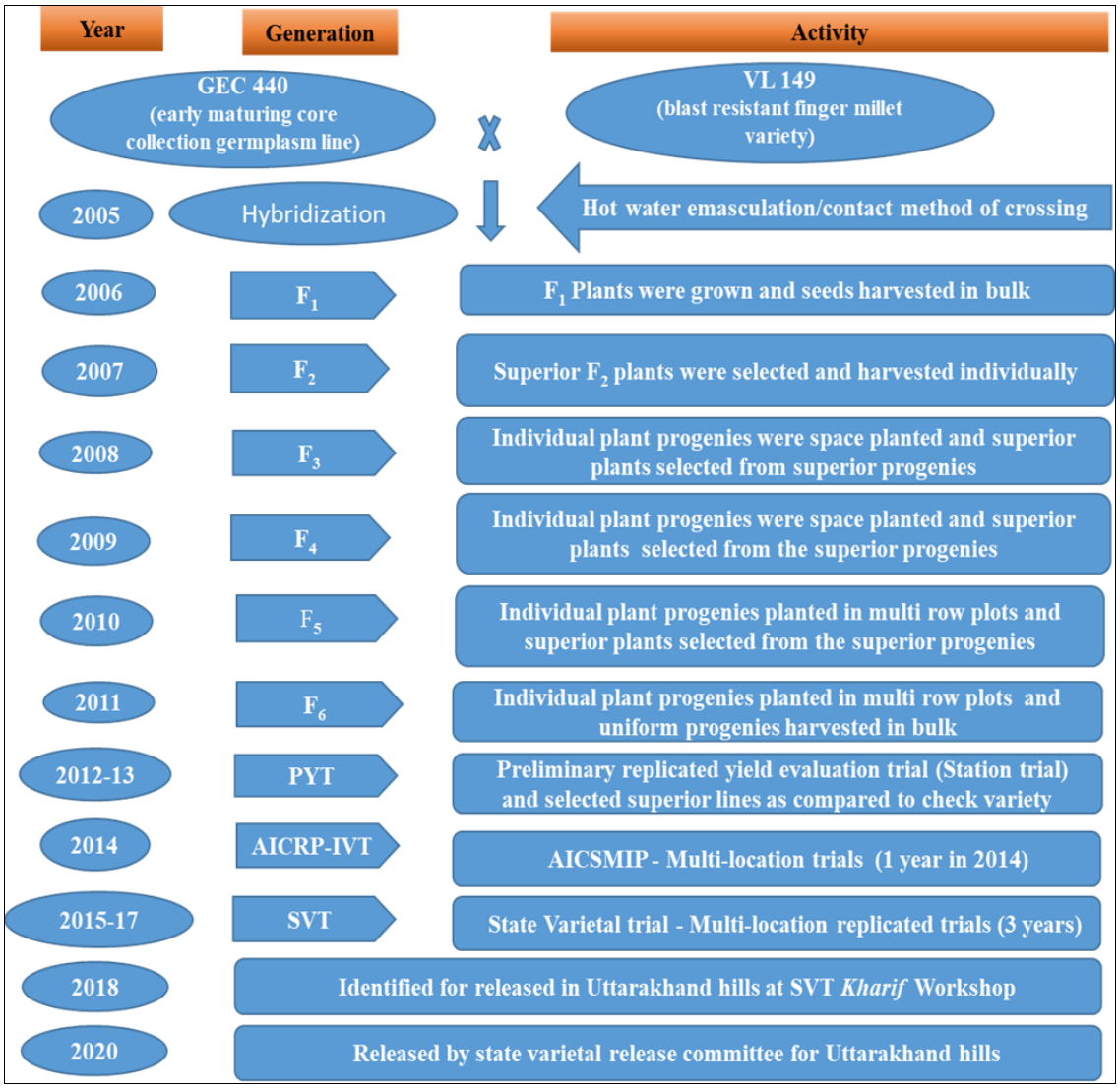

Fig 1: Development of high yielding, medium maturing and blast resistant variety (VL *Mandua* 378) for Uttarakhand Hills

Fig 2: Field view and Seeds of VL *Mandua* 378

Table 1: Performance of VL *Mandua* 378 in comparison to check varieties in state varietal trials (SVT) conducted from the year 2015 to 2017

Name and year of the trials	Number of locations	Name of locations	Grain yield (kg/ha)					% increase over VL *Mandua* 324	% increase over PRM 1	Days to maturity (Days)
			VL *Mandua* 378	VL *Mandua* 324	PRM 1	C.D. at 5%	CV (%)			
SVTs-2015	5	Hawalbagh	2164	1700	1309	4.48	14.96			
		Ranichauri	1696	1632	2105	1.53	4.55			
		Thal	1398	1007	810	1.21	7.71			
		Majhera	1871	1409	1311	6.11	19.86			
		Chinyalisaur	792	400	604	1.30	11.86			
		Mean	1585	1212	1228	-	-	30.78	29.08	112
SVTs-2016	4	Hawalbagh	3213	2939	2612	5.05	10.19			
		Ranichauri	987	495	495	0.07	0.47			
		Thal	2104	1165	1165	1.90	8.82			
		Majhera	830	905	905	2.23	17.18			
		Mean	1784	1376	1295	-	-	28.30	63.55	115
SVTs-2017	3	Hawalbagh	2825	2104	939	3.18	9.10			
		Thal	1807	1552	1068	5.41	20.90			
		Majhera	3853	2079	1227	7.63	18.18			
		Mean	2828	1912	1078	-	-	47.90	162.0	117
Pooled mean of SVTs			2096	1557	1230			34.56	70.33	114.70

Table 2: Grain yield performance of VL *Mandua*378 in comparison to national check varieties in Uttarakhand and at national level under All India IVT coordinated trial in rainfed inorganic conditions during 2014

Locations	Grain yield (kg/ha)			% increase over	
	VL *Mandua*378	VL 352 (C1)	VR 708 (C2)	VL 352 (C1)	VR 708 (C2)
Almora	4869	3477	1067	40.43	356.32
Gaja	3142	3845	1435	-18.29	118.95
Ranichauri	2654	3230	1654	17.84	60.45
Uttarakhand mean	3556	3518	1386	1.08	156.57
National (Mean)	3082	2810	2263	9.68	36.19

Table 3: Reaction of VL *Mandua* 378 to different types blast diseases (range and mean score in % of 9 locations) as recorded in AICRP-SM IVT coordinated trials conducted during *kharif*2014

Genotype	Year	No. of locations	Leaf blast	Neck blast	Finger blast
VL *Mandua*378	2014	9	0.0-4.0 (1.8)	0.0-60.4 (10.3)	0.0-62.4 (11.6)
VL 352 (C1)	2014	9	0.0-4.0 (1.9)	0.0-52.9 (9.7)	0.0-53.1 (10.1)
VR 708 (C2)	2014	9	0.0-5.0 (2.6)	0.0-43.1 (14.4)	2.2-46.0 (15.0)
GPU 45 (C3)	2014	9	0.0-4.4 (2.0)	0.0 -27.5 (5.9)	1.3-26.4 (6.1)

Note: C1, C2 & C3 are the checks.

Table 4: Grain quality parameters of VL *Mandua* 378 in comparison to the check variety VL 352 and VL *Mandua* 324

Quality parameters	VL *Mandua*378	VL 352 (C1)	VL 324 (C2)
Calcium (mg/100 g)	361	345	294
Zinc (mg/100 g)	2.4	2.9	3.0
Iron (mg/100 g)	4.5	3.9	2.8
Protein (%)	7.2	6.3	6.6

Table 5: Distinguishing characteristics of VL *Mandua* 378

Characters	VL *Mandua*378	VL *Mandua* 324	PRM 2
Days to flowering	74	73	81
Days to maturity	114.7	114.3	116.7
Pigmentation on nodes	Absent	Absent	Absent
Pigmentation on panicles	Absent	Absent	Absent
Plant height (cm)	101.1	101.4	107.5
Earhead shape	Semi-compact	Compact	Semi-compact
Earhead length (cm)	7.4	7.5	8.2
Grain colour	Dark copper colour	Brown	Brown
Test weight (g)	2.79	2.13	2.24

Table 6: Performance of VL *Mandua*380 in front line demonstrations

Year	Area (ha)	Demonstration Yield (kg/ha)	Farmers Field Yield (kg/ha)	% increase over farmers field yield	Cost of productions (Rs/ha)		Gross Return (Rs/ha)		Net Return (Rs/ha)		B:C ratio	
					DP	FP	DP	FP	DP	FP	DP	FP
2021	3.6	1803	1419	27.06	21567	19234	43267	29873	24560	12445	1.14	0.65

Note: DP-Demonstration plots; FP- Farmers plots

Conclusion

Thus, VL *Mandua* 378 was released and notified for cultivation under rainfed organic agro-ecology of the Himalayan region owing to its consistently superior performance in terms of grain yield, blast resistance, and quality attributes. Accordingly, VL *Mandua* 378 will augment to finger millet diversity for organic farming in the country as a whole and in the state of Uttarakhand specifically.

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