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Research Note

CKMV 1: A Short duration, high yielding, drought tolerant, non lodging kodomillet variety suitable for rainfed cultivation in India

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Abstract
A high yielding and early maturing kodo millet variety CKMV 1 was developed at the Centre of Excellence in Millets, Tamil Nadu Agricultural University, Athiyandal by pure line selection from DPS 63/58. It recorded an average grain yield of 2813 kg/ha and 6967 kg/ha of straw under rainfed conditions in all India trials, which was 14, 28, 34 and 16 per cent higher over the check varieties RK 390-25 (2465kg/ha), RBK-155 (2196kg/ha), GPUK-3 (2103kg/ha) and TNAU 86 (2420kg/ha), respectively. All India Coordinated trials were conducted in three years during *kharif*, 2017 to *kharif*, 2019. This variety has registered 18 and 16 per cent increased grain yield over the qualifying varieties KMV 546 and KMV 547, respectively in All India Coordinated trials. This variety has registered 22, 27, 23 and 10 per cent increased straw yield over the check varieties RK 390-25, RBK-155, GPUK3 and TNAU 86, respectively in All India Coordinated trials. This variety has registered 7 and 8 per cent increased fodder yield over the qualifying varieties KMV 546 and KMV 547, respectively in All India Coordinated trials. Being an early duration variety with 106-110 days of maturity, it is the best choice for rainfed sowing. It is a profusely tillering and non-lodging variety and is highly suitable for rainfed cultivation in India. The panicle is long, compact and grains are arranged in irregular rows. The grains are bold and dark brown in colour and nutritionally superior with high protein (8.5%) and Iron (3.8 mg/100g) of rice. The introduction of this high yielding, short duration and drought tolerant culture with nutritionally rich grains will fulfil the needs of the dry land, hill area and tribal farming tracts of India, where Kodomillet is grown predominantly under the rainfed situation.

Keywords: Kodo millet, CKMV 1, rainfed sowing, short duration, high yielder, non lodging

Small millets are resilient to climatic uncertainties and highly suitable for rainfed cultivation due to their shorter growth period, C4 means of photosynthesis and ability to yield even in marginal environments and low input agriculture (Himasree *et al.,* 2017). Kodo millet is a traditional, long duration, hardy and drought resistant crop

(Bondale, 1994). The area under kodo millet cultivation is witnessing a declining trend in the post-green revolution period due to predominance of the major cereals such as rice and wheat. However, an intensified drive to increase the acreage of small millets is important because millets still contribute to the regional food security of the dry and marginal lands, where major cereal crops fail to yield. Nowadays, the thrust to grow millets is given due to their nutritional superiority as compared to the major cereals. Small millets offer enormous advantages such as early maturity, wide adaptation and high nutritive value of both grain and straw fodder apart from their low contribution to the national food basket. They are grown on diverse soils in the area with a wide difference for thermo and photoperiods. These unique qualities have made them as choice crops to rainfed, tribal and hill agriculture, where options of crops are limited. Besides these advantages, nowadays awareness regarding nutrition has increased which also increased the demand of small millet. The productivity of other small millets except for finger millet, is low due to poor soil fertility and age-old cultivation methods. The small millets area in the country has come down substantially and is likely to go down further in coming years; particularly in other small millets except for finger millet. (Gautam and Kaushik, 1981). Kodo millet is grown in upland rice regions in India, Indonesia, Philippines, Thailand and Vietnam, and also in Bangladesh and Myanmar. At present kodo millet is cultivated in an area of 0.20 m ha with a production of 0.084 m t. In India, it is cultivated over an area of 1.96 lakh ha with a total production of about 0.84 lakh tonnes and with a productivity of 429 kg/ha during the year 2015-16. In India it is grown in Rajasthan, Uttar Pradesh, Tamil Nadu, West Bengal, Madhya Pradesh and Andhra Pradesh (Prabhakar *et al.,* 2017). The grain of this millet is easily preserved and proves as a good famine reserve. It is the poor man's food and the crop is very drought resistant. Only well matured grains should be dehusked and used for food. Husk and immature grains are poisonous. This millet is considered safer for consumption as the grains get old. This millet is grown mostly as rain-fed crop, though in some areas under irrigated conditions also. Kodo millet is recognized by three races: *regularis*, *irregularis*, and *variabilis*. To date, no anti-nutrients from kodo millet have been reported. Kodo millet among all millets has the highest free radical quenching potential, thus possessing good antioxidant properties (Taylor and Emmambux, 2008).

Kodo millet is a good candidate for diversifyng dietary patterns and to cope up with the global threat of malnutrition and climate change. It can able to grow in adverse environment and contains high-quality protein and anti-oxidant properties . The glutelin is the most abundant protein in Kodo millet (Sudharshana *et al.,* 1988) which is a good substitute for wheat gluten. Hence, it is a good replacement for wheat for those who have wheat gluten sensitivity. India is extremely rich in kodo millet genetic variability and a variety of land races. The improved varieties are developed in the recent past in many national institutes in India. On account of these advantages, kodo millet can therefore be exploited for use in value added nutritive health foods. Further, in view of the growing importance of kodo millet as nutritious food, there is a need to enhance genetic yield potential and evolve a new high yielding variety with early duration in kodo millet growing states of India. The low productivity in a farmers field in kodo millet can be increased by adopting a new high yielding agronomical desirable variety. With the objective to develop short duration, nutritionally superior, lodging resistant and suitable for rainfed drylands of India, the CKMV 1 was developed to fulfil the needs of the dry land, hill area and tribal farming tracts of India where Kodomillet is grown predominantly under rainfed situation.

The kodo millet culture, TNPsc 262 (KMV 545) was evolved at ICAR- AICRP on Small Millets, Centre of Excellence in Millets, Athiyandal, Tamil Nadu Agricultural University and released as CKMV 1. The variety was developed by pure line selection from DPS 63/58 germplasm accession. Elite single plants with desirable traits which contribute toward high grain yield were selected and harvested individually. The selected single plants were grown in progeny rows and the performance was estimated. The promising culture was evaluated and tested in station trials during 2015-19 with check varieties CO 3, TNAU 86 and GPUK 3 at Athiyandal during 2015 to 2019. On Farm trials were conducted at six locations of Tamil Nadu during the main rainy season of 2019. Among the different stabilized lines evaluated in station trials, the culture CKMV 1 (KMV 545) was observed to be superior than the checks. The culture was also nominated to the All India Coordinated Research Project on Small Millets. It was further evaluated in multi location trials in All India Coordinated trials conducted over three years from 2017-2020 at Andhra Pradesh, Chhattisgarh, Gujarat, Jharkhand, Karnataka, Telangana, Madhya Pradesh and Tamil Nadu following Randomized Complete Block Design with three replications under rainfed condition.

The genomic DNA was extracted from two-weeks-old seedlings by using the standard Cetyl Trimethyl Ammonium Bromide (CTAB) procedure. Extracted DNA quantity was checked using the Bio Spectrometer, kinetic (Eppendorf Germany) based on the absorbance at 260 nm. Agarose gel (0.8%) was used to check the quality of extracted DNA and the amplified products were visualized using a Bio-Rad gel documentation system.

The DNA samples were diluted to a working concentration of 25 ng/µL for the Polymerase Chain Reaction (PCR) amplification. The PCR (Eppendorf, Hamburg, Germany) reactions were performed to a total volume of 10µL reaction mixtures containing 1 µL of enomic DNA as a template, 7 µL of 1X Master Mix diluted from

smARTPrime Master mix-Red (2X), 1µL of the primer pairs (Forward and Reverse) and 1 µL of Milli-Q water. The PCR profile consisted of Initial denaturation at 94˚C for 7 minutes, followed by 35 cycles of amplification at 94˚C for 30 seconds of subsequent denaturation, 60˚C for 30 seconds for annealing of primers to the template and 72˚C for 45 seconds for an extension. The cycle was terminated after a final extension phase at 72°C for 7 minutes. The PCR amplicons were resolved in 3% agarose gel prepared using 1x TBE buffer at 120 V for 3 h. A Bio-Rad gel documentation system was used to visualize the resolved amplified products.

The overall mean performance of kodo millet pre culture KMV 545 in Station trails and On Farm trails is presented in **Table 1**. The culture KMV 545 was tested in Station trials from 2015 to 2019 which recorded an average grain yield of 2688 kg/ha and straw yield of 3915 kg/ha, whereas the checks CO 3 and TNAU 86 recorded an average grain yield of 2145 and 2320 kg/ha and straw yield of 3300 and 3505 kg/ha, respectively. It recorded 2613 kg/ha of grain and 4011 kg/ha of straw yield which was 26.7 and 21.5 per cent increase over the check CO 3 and 18.7 and 12.8 per cent increase over the check TNAU 86, respectively. Similar mean performance of KMV 545 was also observed in On Farm Trails conducted at six locations. The recorded grain yield mean was 2613 kg/ha and straw yield was 4011 kg/ha, respectively which was 26.7, 18.7 and 26.0 per cent increased grain yield over the check varieties CO 3, TNAU 86 and GPUK 3, respectively, based on the mean grain yield performance of All India Coordinated Varietal Trials (**Table 2**) conducted at eight states in India under rainfed condition.

This culture had registered 14, 28, 34 and 16 per cent increased grain yield over the check varieties RK 390-25, RBK-155, GPUK3 and TNAU 86, respectively in All India Coordinated trials over three years. It had registered 18 and 16 per cent increased grain yield over the qualifying varieties KMV 546 and KMV 547, respectively, in All India Coordinated trials. At the same time, it registered 22, 27, 23 and 10 per cent increased straw yield over the

Table 1. Performance of Kodomillet culture KMV 545 (TNPsc 262) in State Trials (2015 -2019)

S. No.	Name of the trial	Number of trials	Grain yield (kg/ha)				Straw yield (kg/ha)			
			KMV 545	CO 3	TNAU 86	GPUK 3	KMV 545	CO 3	TNAU 86	GPUK 3
1	Station trial	4	2688	2145	2320	2110	3915	3300	3505	3388
2	On farm trial	6	2613	2038	2145	2097	4011	3220	3516	3285
Total number of trials/mean		10	2651	2092	2233	2104	3963	3260	3511	3337
Per cent increase over			-	26.7	18.7	26.0	-	21.5	12.8	18.7

Table 2. Summary grain yield data of coordinated varietal trials (2017-20)

Details	Year of testing	Number of trials/ locations	KMV 545	Checks				Qualifing variety	
				RK 390-25	RBK-155	GPUK-3	TNAU 86	KMV 546 (RPS 520)	KMV 547 (RPS 694)
Mean yield (kg/ha)	2017-18	8	2992	2455	-	2103	2410	2458	2578
	2018-19	8	2314	2328	2196	-	2137	2328	2274
	2019-20	11	3046	2573	-	-	2633	-	-
	Weighted mean		2813	2465	2196	2103	2420	2393	2426
Percentage increase or decrease over the checks & qualifying varieties	2017-18	8	-	22	-	42	24	22	16
	2018-19	8	-	-0.6	5	-	8	-0.6	2
	2019-20	11	-	18	-	-	16	-	-
	Weighted mean		-	14	28	34	16	18	16
Frequency in the top three group (pooled for three years)	2017-18	8	5	0	-	1	1	1	3
	2018-19	8	2	2	0	3	3	1	-
	2019-20	11	7	0	-	2	0	-	-
	Pooled		14	2	0	6	4	-	-
All India Rank	2017-18	8	2nd	6	-	8	7	5	4
	2018-19	8	6th	5	10	8	11	4	9
	2019-20	11	2nd	11	-	9	10	-	-

check varieties RK 390-25, RBK-155, GPUK3 and TNAU 86, respectively in All India Coordinated trials. Also, this culture had registered 7 and 8 per cent increased straw yield over the qualifying varieties KMV 546 and KMV 547, respectively in All India Coordinated trials during 2017-2020.

Brown spot, leaf blight, banded blight and head smut are the major disease and the culture KMV 545 was moderately resistant to brown spot and leaf blight and highly resistant to leaf blight and banded blight in All India Coordinated Trials conducted across 11 hot spot locations. The per cent damage due to brown spot in CKMV 1 was low (disease score 2.7) and it fell in the resistant reaction (R) category with the checks RK 390-25 (1.3), GPUK 3(2.5), RBK 155(3.0) and TNAU 86(2.2) (**Table 3**). The per cent damage due to leaf blight in CKMV 1 was low (4.0) and was grouped in the same scale category of Resistant (R) under natural conditions. Similarly, there was no major incidence of pest infection (**Table 4**).

In terms of grain quality, CKMV 1 has higher iron (3.8 mg/100g of rice) content in comparison to the check varieties TNAU 86 (3.1mg/100 g) and GPUK 3 (3.4 mg/100 g). In addition, the protein content (8.5 g/100 g) in CKMV 1 was higher when compared with check varieties TNAU 86 (8.4 g/100 g) and GPUK 3 (8.2 g/100 g) (**Table 5**). The culture KMV 545 is characterized by non pigmented leaf sheath, leaf juncture, inter node and leaf blade. The growth habit is erect and the leaves are erect and non pigmented. The peduncle is medium in length with a compact panicle. The spikelet arrangement on rachis is in irregular rows. The variety is having bold, dark brown grain colour and oval grain shape and big size. The detailed morphological characters of CKMV 1 are presented in **Table 6**. Among the thirty maize SSR markers used only two markers *viz.,* bnlg 1937 and bnlg 589 distinguished the newly released variety TNPSc 176 (ALT1) and culture TNPSc 262 (KMV 545). The varieties TNPSc 176 and TNPSc 262 recorded the amplicon size of 190 and 200 base pairs, respectively, for the SSR primer bnlg1937. Whereas, other varieties

Table 3. Reaction to major diseases

Disease	Screening condition	Year	Proposed variety	Check				Qualifying variety	
			KMV 545	RK 390-25	GPUK 3	RBK-155	TNAU 86	KMV 546	KMV 547
Brown spot (G) (1-10)	Natural	2017-18	-	-	-	-	-	-	-
		2018-19	2.1	1.6	2.5	3	2.3	3.3	1.8
		2019-20	3.3	1	-	-	2	-	-
		Mean	2.7	1.3	2.5	3	2.2	3.3	1.8
Leaf blight (G)	Natural	2017-18	-	-	-	-	-	-	-
		2018-19	7	3.6	5	7	2	3.7	7.7
		2019-20	1	1	-	-	1	-	-
		Mean	4	2.3	5	7	1.5	3.7	7.7
Banded blight (%)	Natural	2017-18	68	76	-	-	53.3	66.7	72
		2018-19	93.8	95.5	95.3	17.2	92.8	90.8	95
		2019-20	45.9	32.6	-	-	32.8	-	-
		Mean	69.2	68.0	95.3	17.2	59.6	78.7	83.5
Head smut (%)	Natural	2017-18	33.1	9.5	24.0	-	34.2	17.1	24.3
		2018-19	1	2.8	6.1	1.6	1	13.4	14.2
		2019-20	8.8	3.1	-	-	-	-	-
		Mean	14.3	5.1	15.0	1.6	17.6	15.2	19.2

Table 4. Reaction to major pests KMV 545

Pests name	Screening condition	Year	Proposed variety	National Checks				Qualifying variety	
			KMV 545	RK 390-25	GPUK 3	RBK-155	TNAU 86	KMV 546	KMV 547
Shoot fly (%)	Natural	2017-18	5.9	4.1	-	-	7.2	8.2	5.5
		2018-19	12.4	15.2	11.7	11.6	12.2	10	8.3
		2019-20	8.6	7.3	11.2	-	9.8	-	-
		Mean	8.9	8.8	11.4	11.6	9.7	9.1	6.9

Table 5. Grain and quality characteristics of KMV 545

S. No.	Quality characteristics	Proposed variety (KMV 545)	Check 1 TNAU 86	Check 2 GPUK 3
a)	**Nutritional Quality**			
1.	Protein (g/100g)	8.5	8.4	8.2
2.	Carbohydrate(g /100g)	65.3	65.8	67.0
3.	Oil (g/100g)	1.4	1.2	1.5
4.	Crude fiber (g/100g)	9.5	9.4	9.9
5.	Phosphorus (mg/100g)	197	192	191
6.	Iron (mg/100g)	3.8	3.1	3.4
7.	1000 grain weight (g)	5.6	4.7	4.2
8	1000 grain volume (ml)	5.5	5.0	5.3
b)	**Cooking qualities**			
1.	Water uptake (ml)	294	282	267
2.	Cooking time (min)	29	28	26
3.	Initial Volume (ml)	100	100	100
4.	Cooked volume (ml)	320	299	278
5.	Initial weight (g)	100	100	100
6.	Cooked weight (g)	426	403	383
c)	**Sensory evaluation score (1-10 score)**			
1.	Colour& appearance	9.3	9.0	9.0
2.	Flavour	9.1	8.5	8.5
3.	Texture	9.2	90	8.5
4.	Taste	9.6	9.5	9.0
d)	**Fodder characteristics**			
1	Dry matter (%)	20.4	20.2	21.7
2	Crude protein (%)	9.5	9.6	8.4
3	Crude fibre (%)	16.8	17.8	19.0
4	Potassium (%)	2.0	1.7	1.9
5	Phosphorus (%)	0.5	0.6	0.5
6	Mineral matter (%)	2.9	2.9	2.3
e)	**Milling per cent**	55.8	52	49

scored the amplicon size of 193 bp (RK 390-25), 195 bp (TNAU 86), and 205 bp (CO3). The use of SSR marker for fingerprinting small millets was demonstrated earlier by Natesan *et al.* (2020). The varieties TNPSc 176 and TNPSc 262 were differentiated with the allelic size of 160 and 164 base pairs by the maker bnlg 589 compared with the check varieties which showed 164 bp for RK 390-25, 168bp for TNAU 86 and 160 bp for CO3. Hence, TNPSc 176 (ALT1) and culture TNPSc 262 could be differentiated from other check varieties used in this study. Hence, these two markers could be utilized in future for varietal identification and registration of Germplasm with the NPBGR (National Bureau of Plant Genetic Resource and PPV&FRA (Protection of Plant Varieties and Farmers Right Authority).

In view of the consistent superior performance of KMV 545 as compared to the checks for grain yield, straw yield, preferable grain quality traits and disease and pest resistance, it was released as CKMV 1 by Central Seed Sub Committee during 2020 for rainfed dry land regions of Andhra Pradesh, Telangana, Chattisgarh, Gujarat, Jharkhand, Karnataka, Madhya Pradesh and Tamil Nadu. This culture was registered in NBPGR as IC 635777 and it was notified by the Central Sub Committee on Crops Standards, Notification and Release of Varieties for Agricultural Crops vide notification during 2021. This would fulfil the needs of the dry land, hill area and tribal farming tracts of India where Kodomillet is grown predominantly under a rainfed situation. Besides, CKMV 1 will also add to kodo millet varietal diversity for rainfed cultivation in India. The descriptors along with DNA fingerprint data would be useful in varietal identification programme, purity maintenance of the variety and also for registering the newly developed variety with NPBGR.

Table 6. Morphological characteristics of Kodo Millet - KMV 545

S. No.	Character	KMV 545	
		Range	Mean
1	Days to 50% flowering	73-77	75
2	Days to maturity	106-114	110
3	Plant height (cm)	72-84	68
4	Number of productive tillers/plant	6-11	8
5	Flag leaf length (cm)	13.1-15.4	14.6
6	Flag leaf width (cm)	1.9-2.3	1.7
7	Length of inflorescence (cm)	6.0-9.2	8.4
8	Number of racemes above thumb	6-11	8
9	Length of longest raceme (cm)	10.8-12.6	11.4
10	Grain yield per plant (g)	18-32	24.2
11	Straw yield per plant (g)	21-35	26.3
12	Harvest index	0.32-0.37	0.35
13	1000 grain weight (g)	4.9-6.1	5.9
14	Plant habit	Erect	-
15	Plant pigmentation at flowering	Absent	-
16	Culm branching	High	-
17	Degree of lodging at maturity	Low	-
18	Inflorescence compactness	Compact	-
19	Grain arrangement in inflorescence	Irregular	-
20	Shattering of inflorescence	Absent	-
21	Grain colour	Dark Brown	-
22	Grain shape	Oval	-
23	Grain size	Bold	-
24	Milling percentage	55.8	-

REFERENCES

Bondale, K. V. 1994. Status of small millets in India. In National seminar on ragi and small millets, held during January (pp. 6-7).

Gautam, R. C. and Kaushik, S. K. 1981. Improved technology for millets [cultural practices, India]. Indian Farming (India).

Himasree, B., Chandrika, V., Sarala, N.V. and Prasanthi, A. 2017. Evaluation of remunerative foxtail millet (*Setaria italica* L.) based intercropping systems under late sown conditions. Bulletin of Environment, Pharmacology and Life Sciences Bull. Env. Pharmacol. *Life Sci.,* 6 Special issue **(3):** 306-308.

Natesan, S., Venugopalan, G., Selvamani, S. B. and Angamuthu, N. 2020. Characterization of little millet (*Panicum sumatrense*) varieties using morphological descriptors and SSR based DNA fingerprinting. *Journal of Phytology,* **12:** 29-34. [Cross Ref]

Prabhakar, Prabhu, C., Ganiger, Boraiah B., Sujata Bhat, Nandini C., Kiran, Tippeswamy, V. and Manjunath, H. A. 2017. Improved production technology for kodo millet. Technical Bulletin, ICAR-AICRP Small Millets, Bangalore.

Sudharshana, L., Monteiro, P. V. and Ramachandra, G. 1988. Studies on the proteins of kodo millet (*Paspalum scrobiculatum*). *Journal of the Science of Food and Agriculture*, **42(4):** 315-323. [Cross Ref]

Taylor, J. R. and Emmambux, M.N. 2008. Gluten-free foods and beverages from millets. In Gluten-free cereal products and beverages (pp. 119-V). Academic Press. [Cross Ref]