Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(6): 533-537
Received: 01-09-2019
Accepted: 04-10-2019

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High yielding Kodo millet variety 'GAK-3' for cultivation in hilly region of Gujarat

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Abstract
The kodo millet culture 'DK-127' is a pure line selection from the germplasm accession. The culture 'DK-127' was found superior for grain yield by 27.50% over local check variety 'GK-2' and 31.14% over National check variety 'GPUK-3' under hilly/ tribal area of Middle Gujarat. The culture 'DK-127' is resistant to Shoot fly and Head smut. The culture matures in 105-110 days. It endows with the special attributes of easy threshability, synchronised maturity and non-lodging growth habit. This culture is moderately resistant to major diseases to Head smut (%) and moderately resistant to major pest like shoot fly as compared with local check GK-2 and national check GPUK-3. It is rich in protein (8.83%) and lowest in TSS (3.26%) as compared to other released kodo millet varieties. The proposed culture 'DK-127' was found to have good nutritional properties as comparable to the checks under food quality studies. Hence, DK-127 a kodo millet culture has been released as a new variety GAK-3 (Gujarat Anand Kodra-3) during the year 2017 for cultivation during *kharif* as rainfed in Gujarat Agro-climatic Zone- I, II & III *i.e.* Hilly/Tribal little millet growing region of Gujarat.

Keywords: Kodo millet, high yielding variety, yield attributing characters, nutritional quality

Introduction
Kodo millet (*Paspalum scrobiculatum* L.), is a tropical small millet indigenous to India (De Wet *et al.*, 1983) [6] and grown for its grain and fodder. It is a traditional, long duration, hardy and drought resistant crop cultivated (Bondale, 1994 and Singh, 1994) [3]. The area under kodo millet cultivation is witnessing a declining trend in the post- green revolution period due to predominance of the major ce- reals 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, thrust to grow millets is given due to their nutri- tional superiority as compared to the major cereals. Kodo mil- let has been reported to have higher free radical quenching po- tential when compared to other millets (Hegde and Chandra, 2005) [8]. Besides, it provides low priced protein, minerals and vitamins in form of sustainable food (Yadava and Jain, 2006) [15]. Growing health consciousness among the consumers also cre- ates demand for this type of nutri-cereals which are anti- diabetic and anti-oxidant in nature (Chandrasekara and Shahidi, 2011) [4]. Hence, technological intervention in this crop is essential to boost the production on a profitable scale. Kodo millet is predominantly grown as a pure crop and yields high net returns as compared to other dry land crops owing to its high unit area productivity and market price of the produce in addition to its fodder value. Besides the food crops *viz*., rice, wheat, maize, sorghum and pearl millet, there are other food and feed crops grown in the country. Among the other crops, hill millets figure prominently which include finger millet (ragi, nagli), little millet (vari, kutki), kodo millet (kodra), foxtail millet (kang), proso millet (cheena) and barnyard millet (banti). The kodo millet (*Paspalum scrobiculatum* L.) having chromosome no. 2n=2x=40 is a highly drought resistant crop and coarsest of all food grains. It is a minor grain crop in India and an important crop in the Deccan plateau. It is an important food grain crop in the tribal areas and very popular among the tribal farmers with their food habit and sometimes as a medicinal purpose.

It is commonly known as 'Kodra' in Gujarati, Marathi and Punjabi, 'Kodo' in Bengali, 'Kodon' in Hindi, 'Harka' in Kannada, 'Kodua' in Oriya, 'Varagu' in Tamil and 'Arikelu (Arika)' in Telugu is indigenous cereal of India. It is grown in Southern Rajasthan and Maharashtra for at least 3,000 years (De Wet *et al.*, 1983) [6]. In India, the crop is cultivated in an area of 224 thousand hectares with annual production of 73 thousand tones. The productivity of kodo millet is 312 kg/ha (Anon., 2017) [1]. Madhya Pradesh rank first in area of kodo millet, which shares about 60% of its total area of country. Other major states growing kodra are Maharashtra, Tamil Nadu, Chhattisgarh, Andhra Pradesh, Karnataka and Gujarat. In India,

Kodra occupies an area of 9.08 lakh ha with an annual production of 3.11 lakh tones and average productivity of 342 kg/ha. Among the small millets, productivity per unit area is highest in kodo millet (Anon., 2018) [2].

In Gujarat, small millets other than finger millet is cultivated in an area of 9281 hectare with an average productivity of 1415 kg/ha. Not with standing low contribution of these crops to the national food baskets, small millets offer enormous advantages such as early maturity, wide adaptation and high nutritive value of both grain and fodder. They are grown on diverse soils in the area with wide difference for thermo and photoperiod. These unique qualities have made them as choice crop to rainfed, tribal and hill agriculture where options of crops are limited. Besides this now a day awareness regarding nutrition is increased which also increased the demand of hill millets. The productivity of other hill millets except finger millet, is low due to poor soil fertility and age-old cultivation methods. Small millets area in the country has come down substantially in the last two decades and is likely to go down further in coming years; particularly in other small millets except finger millet. (Gautam and Kaushik, 1981) [7].

However, small millets are raised on lands where no other crop worth mentioning can give a reasonable quantity of nutritionally balanced grain and valuable straw yields. It is good source of protein, very rich in carbohydrate, fat, mineral and vitamins and should be considered as essential food for nutritional security (Patil *et al*, 2019) [11]. Hence, these crops need attention of scientists, developmental agencies, processors, nutritionists and policy makers in order to not only sustain the production but also to enhance demand so that millet farmers can be benefited. The variety Gujarat kodra-1 released during 1996 and then variety Gujarat kodra-2 was identified during 2006. In view of this, Hill Millet Research Station, AAU, Dahod and Hill Millet Research Station, NAU, Waghai combinely worked and selected this genotype through pure line selection from the collection of local land races. Considering present need, early maturing, multi tillering, high yielding with diseases and pest resistance with good nutritional qualities new genotype 'Gujarat Anand Kodra-3' was developed. This variety is developed with the aim to medium maturing bold seed variety with resistance to insect-pests and diseases.

Material and Methods

The kodomillet culture DK-127 was evolved at Hill Millet Research Station, Dahod under Anand Agricultural University, Anand and proposed for release as Gujarat Anand Kodra - 3 (GAK-3) during the year 2017. This variety has been developed through pure line selection from locally collected germplasm of Hilly regions of Rewa district of Madhya Pradesh during 2009 and maintained with code No. RK-286 at Hill Millet Research Station, AAU, Dahod from 2010. It is a pure line selection from the germplasm accession. Single plant with desirable traits and high yield with medium maturing and moderately resistant to blast and grain smut disease was selected from the germplasm accession and was forwarded as single plant to progeny rows. The promising culture was evaluated over six years with checks at Dahod and Waghai locations starting from 2010 to 2015, on farm trials during *kharif* 2016-17 in farmer's field of Dahod and Dangs districts. Besides, the reaction of the cultures against important pest and disease was screened and as per the standard procedures the grain qualities were analyzed.

Results and Discussion

The evaluation of Large Scale Varietal Trials data under state level experiments of the culture DK-127 from the station trials at Hill Millet Research Station, Dahod are presented in Table-1. The culture DK-127 was tested in station trials at Dahod from 2010-11 to 2015-16. This culture DK-127 recorded an average grain yield of 2457 kg/ha where as the check GK-2 recorded 1927 kg/ha and GPUK-3 recorded 1782 kg/ha grain yield, which is 27.50 and 31.15 per cent increased yield over check GK-2 and GPUK-3, respectively. The overall performance of culture DK-127 in farmer's field trial at various villages of Dangs, recorded an average grain yield of 934 kg/ha, which was 27.42 percent higher over the check variety GK-2 (733 kg/ha).

Morphological characters

The morphological characters of the culture DK-127 are preferable by the farmers as compared to local check GK-2 and comparisons of various morphological characters are presented in Table-2. The culture DK-127 has more number of tillers per plant (3.4) as compared to local check GK-2 (3.1). The plant type is erect and non-lodging with non-shattering grain panicle and milling recovery of 53.4%. The culture DK-127 matures in 106 days and attains 50 per cent flowering in 70-72 days after sowing which is earlier than the local check GK-2 and grouped in to medium duration. It has an erect plant habit with 65 cm to 71 cm plant height. The panicle is dense with panicle length 6.3 cm. Grain weight of 1000 fully developed grains is also good in the culture DK-127 (7.2 g). The undecorticated grain colored noted is attractive and decorticated grain colour is clean white while, brown seed colour with ellipsoidal shape on maturity (Table 2).

Reaction to pest and diseases

The grain smut are the major diseases and the genotype 'DK-127' revealed moderately resistant to diseases (Table-3) when sown in normal growing *kharif* season. Similarly, the proposed culture DK-127 showed resistant to pest like shoot fly (Table 4)

Nutritional quality

The culture 'DK-127' nutritionally better which possessed high protein (8.83%) and ash (3.80%) good amount of fiber, carbohydrates and minerals with less amount of Phenol content (0.369%) as compared with the checks (Table-5). Similarly, Chaudhari *et al.* (2012) [5] also reported superior nutritional quality of little millet variety 'GV-2' and Patil *et al.* (2017 and 2018) [12, 13, 14] in variety ' GN-8' and 'GNV-3'.

Considering the superior performance of the culture 'DK-127' over the check varieties namely GK-2 and GPUK-3, the culture released as a new variety GAK-3 (Gujarat Anand Kodra-3) for large scale cultivation in south and middle Gujarat during 2017-2018. (Jon *et al.* 2005 and Intwala *et al.* 2017) [10, 9]. The DNA finger printing as well as field view is given in Fig.1 and 2.

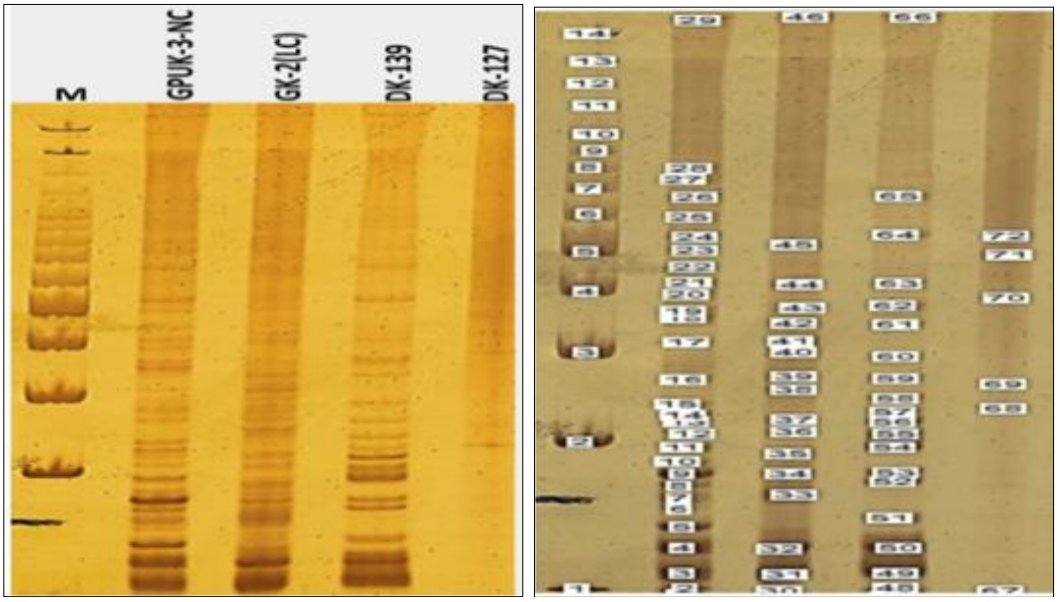

Fig 1: DNA fingerprinting profile of Kodo millet (*Paspalum scrobiculatum*) generated by AFLP marker

Fig 2: Field view of GAK-3

The salient features of the Kodo millet variety 'GAK-3' are given as below.

- The culture DK-127 was found superior for grain yield by 27.50% over local check GK-2 and 31.14% over National check GPUK-3 under hilly/ tribal area of Gujarat.
- The culture DK-127 is resistant to insect-pest and disease ie. Resistant to shoot fly and Head smut.
- The proposed culture DK-127 was found to have good nutritional properties comparable to the checks under study.

Table 1: Comparative performance of Kodo millet culture 'DK-127' over 2010 to 2015

Experiment and Year	Location at AAU, Anand	Grain yield (kg/ha)			CD at 5%	CV%
		DK-127	GK-2 (LC)	GPUK-3 (NC)		
PET- 2010	Dahod	3779 *	2263	-	917	16.76
SSVT- 2011	Dahod	1612	1454	-	550	20.48
SSVT- 2012	Dahod	3498 *#	2517	2586	569	12.51
LSVT- 2013	Dahod	1588 *#	1156	951	286	14.65
LSVT- 2014	Dahod	1189	1506	1329	261	11.79
LSVT- 2015	Dahod	3074 #	2663	2263	428	9.90
Average of Dahod M (6 yrs)		2457	1927	1782		
% Increase over local check GK-2			27.50			
Average of Dahod M_1 (4 yrs)		2337				
% Increase over national check GPUK-3				31.14		

Note: * Significantly superior over GK-2 (LC), # Significantly superior over GPUK-3 (NC), M: Mean of grain yield of DK-127 over 6 years, M_1: Corresponding mean of grain yield of DK-127 over 4 years

Table 2: Ancillary observations recorded for the genotype 'DK-127' at Dahod

Sr. No.	Characters	DK-127 (Range)	GK-2 (Range)	GPUK-3 (Range)
1	Plant height (cm.)	67.7 (64.7-71)	61.2 (58.7-64.1)	65.5 (60.5-71)
2	No. of Productive tillers/ plant	3.4 (3.1-3.5)	3.1 (2.9-3.3)	2.8 (2.6-3.0)
3	Days to 50% flowering	71 (70.3-72)	73 (72.5-74.1)	73 (72.7-74)
4	Maturity days	106 (105-106.7)	108 (107.3-109)	108 (107.5-109)
5	Plant type	Erect	Erect	Erect
6	Foliage	Green	Green	Green
7	Lodging	Non-lodging	Non-lodging	Non-lodging
8	Shattering	Non-shattering	Non-shattering	Non-shattering
9	Grain colour	Brown	Brown	Brown
10	Grain shape	Ellipsoidal	Ellipsoidal	Ellipsoidal
11.	Milling recovery %	53.4	51.5	52.7
12	1000 Grain weight (g)	7.2 (7.1-7.3)	7.3 (7.2-7.4)	6.6 (6.3-6.8)

Table 3: Reaction of DK-127 against Head smut of Kodra at Dahod. (Pooled of three years - 2013, 2014 and 2015)

Sr. No.	Name of culture	2014		2015		Pooled
		Disease Incidence (%)	Disease Reaction	Disease Incidence (%)	Disease Reaction	
1.	DK-127	2.86	MR	2.28	MR	2.57
2.	GK-2 (Local Check)	3.51	MR	2.90	MR	3.21
3.	GPUK-3 (National Check)	1.79	MR	1.76	MR	1.78

PDI = {No. of smut infected plants/ Total number of plants observed} × 100

Numerical rating/ grade for Head smut:

Head smut incidence (%)	Reaction
0	Highly resistant (HR)
Up to 1.0	Resistant (R)
1.1 to 5.0	Moderately resistant (MR)
5.1 to 10.0	Moderately Susceptible (MS)
10.1 to 20.0	Susceptible (S)
> 20.0	Highly susceptible (HS)

***** The disease rating was recorded by adopting the methodology suggested by Nagaraja, *et al*. (2007). Compedium of small millet diseases. Project coordinating cell, AICRP on Small Millet, Banglore pp 65.

Table 4: Reaction of DK-127 against Shoot fly of Kodra at Dahod (Pooled of two years - 2014 and 2015)

Sr. No.	Name of culture	2014		2015		Pooled
		Dead Heart (%)	Reaction	Dead Heart (%)	Reaction	
1.	DK-127	3.51	HR	2.91	HR	3.21
2.	GK-2 (Local Check)	3.53	HR	2.93	HR	3.23
3.	GPUK-3 (National Check)	2.91	HR	2.34	HR	2.63

Numerical rating/ grade for Shoot fly:

Dead heart (%)	Reaction
0 to 5.0	Highly resistant (HR)
5.1 to 10.0	Resistant (R)
10.1 to 15.0	Moderately resistant (MR)
15.1 to 20.0	Moderately Susceptible (MS)
20.1 to 30.0	Susceptible (S)
> 30.0	Highly susceptible (HS)

* The pest rating was recorded by adopting the methodology suggested by Maithi, *et al*. (1988). Screening of little millet germplasm against little millet shoot fly damage. Millet Newsl 7.

Table 5: Nutritional value of culture DK-127 as compared to checks (per 100 g.)

Name of Culture	Moisture %	TSS %	Phenol %		Oil %	Protein %	Ash %	Crude Fiber %	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
			Seed	Seed coat								
DK-127	6.50	3.26	0.369	0.821	3.07	8.83	3.80	17.56	25.50	18.50	17.50	5.25
GK-2	6.22	3.34	0.410	0.892	3.72	8.17	3.55	16.90	28.00	17.50	19.00	5.00
GPUK-3	6.17	3.32	0.374	0.890	3.51	7.95	3.56	17.63	32.00	22.00	20.00	5.25

Source: Bio-chemical analysis of cultures was done by Biochemistry Department, BACA, AAU, Anand

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