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KUFRI MANIK: A RED- SKINNED BIOFORTIFIED POTATO VARIETY

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ABSTRACT: Kufri Manik is a medium maturing, main season, nutrient-rich table potato variety suitable for cultivation in Eastern plains. It is a clonal selection from the cross between Kufri Arun × CP3192. Its plants are tall with field resistance to late blight. The variety produces attractive, deep red, round shaped tubers with medium eyes and yellow flesh. Kufri Manik is nutrient-dense variety by virtue of high anthocyanin (68 mg/100g FW), phenols (71 mg/100g FW), Zinc (33 ppm), Iron (30 ppm) as compared to red skin control varieties like Kufri Lalima and Kufri Lalit. It is fertilizer responsive and can yield 23-25 t/ha under optimum agronomical practices. Kufri Manik has performed well in multi-location trials conducted under AICRP on Potato and has been recommended for cultivation in eastern plains (Bihar, Orissa, West Bengal, Assam and Eastern Uttar Pradesh).

KEYWORDS: Potato, biofortification, yield, late blight, Kufri Manik, Eastern plains

INTRODUCTION

Potato is the third most consumed food crop globally after wheat and rice. Potato yields more dry matter, well-balanced protein and more calories per unit area of land and time than other major food crops. Potatoes have the highest overall nutrient-to-price ratio than other vegetables and are a major staple food worldwide (Drewnowski, 2013). But being the staple food, still, there is a need to improve the nutritional quality of the most consumed non-grain food crop i.e. 'Potato'. According to the nutritional profile, potatoes are a good source of carbohydrates, protein, minerals, dietary fibres, as well as vitamin C, B6, K, Fe and folate (Robertson *et al*., 2018). Potatoes can deliver additional nutrients and dietary fibres if cooked without peeling. To boost the nutritional value, biofortification has emerged as an upcoming approach with enormous potential. Anthocyanin and carotenoid pigments impart colour to the crop. The accumulation of carotenoids renders white, cream, and yellow whereas anthocyanin pigments produce red, purple, and blue potatoes. Potatoes also constitute significant levels of micro-nutrients *viz*., iron and zinc content (Burgos *et al.,* 2007) in the broad genetic resources that can be introgressed through selection and varietal development.

The cultivation of potatoes is stretched to different agroclimatic zones of India. Mostly white/yellow fleshed potatoes were preferred by the people but coloured potatoes nowadays have a rising demand by consumers due to its enhanced nutrient characteristics and this choice also varies from region to region. In Eastern plains, some stretches of North Eastern states and Jammu and Kashmir, red-skinned potatoes are preferred; purple-black or purple skinned varieties are popular in some pockets of

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Himachal Pradesh and North Eastern regions. Some coloured genotypes, especially red and purple skinned and fleshed (Luthra *et al*., 2020; Dalamu *et al*., 2023) advanced clones have been developed by CPRI Shimla. Considering consumer orientation to nutrient-dense potatoes in addition to other major objectives for developing a variety the present investigation reports development of nutrient-rich biofortified variety Kufri Manik for Eastern plains.

BACKGROUND

Kufri Manik (PS/06-88) was developed at ICAR-Central Potato Research Institute, Regional Station, Patna from the cross Kufri Arun × CP3192 in 2005. The female parent Kufri Arun is a medium maturing table potato variety suitable for cultivation in north Indian plains (Luthra *et al*., 2006). Its plants are tall (80-85 cm) and bear red, ovoid tubers, shallow to medium eyes and creamy-light yellow flesh with good keeping quality. The male parent CP3192 (var. 27/40) is an exotic genotype from Peru. The plants are erect and produce medium to large-sized, light red round compressed tubers with medium-deep eyes and yellow cream flesh. The hybridisation was carried out in the year 2005 at ICAR-CPRS, Kufri, Himachal Pradesh. Pedigree details of Kufri Manik are detailed in Fig 1.

The clone PS/06-88 successfully passed through seedling and initial clonal generations and it was evaluated in a preliminary yield trial (PYT), two confirmatory yield trials during 2009-2010, 2010-2011, and 2011-2012 at ICAR-CPRS, Patna, Bihar. Based on superior performance advanced clone PS/06-88 was introduced in AICRP (Potato) for mult-location testing. In AICRP (Potato), advanced clone PS/06-88 was evaluated in multi-locations replicated trials (2013-2014 & 2014-2015) at four locations, i.e. Bhubneshwar, Faizabad, Jorhat and Patna and on-farm trials (2015-16) at five locations namely Dholi, Faizabad, Jorhat, Kalyani and Patna; and (2017-18) at six locations *viz*., Bhubneshwar, Dholi, Faizabad, Jorhat, Kalyani and Patna in Eastern plains. The advanced clone PS/06-88 was recommended for release in the 36th AICRP (Potato) group meeting held during September 08-11, 2018 at SDAU, Sardarkrushinagar, Gujarat. Subsequently, advanced clone PS/06-88 has been notified as variety Kufri Manik by Central Sub-Committee on Crop Standards Notification and Release of Varieties for Horticultural Crops, Ministry of Agriculture, Department of Agriculture and Co-operation, Government of India, New Delhi vide gazette notification S.O. No. 4272 (E) dated 1st April 2021.

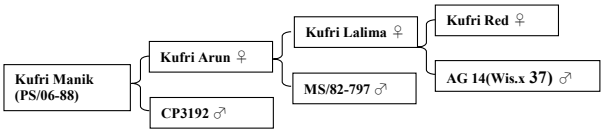

Fig. 1. Pedigree of Kufri Manik

VARIETAL DESCRIPTION

Plants: Tall, canopy semi-compact, stem medium thick, predominantly green, wings highly developed and straight.

Foliage: Grey-green, leaves close, leaflet width narrow, leaflets ovate, leaflet coalescence absent, rachis green, midrib green.

Flower: Flowering medium, inflorescence medium-sized, floral stalk green, floral stalk-pedicle articulation clearly visible and located above the middle, calyx green, corolla red-violet, corolla shape semi-stellate, anther orange, anther cone normally developed, styler length longer than stamen column and stigma bi-lobed.

Tubers: Tubers (8-10), deep red, round tuber, medium eyes, eyebrows normal, flesh yellow (Fig. 2), texture waxy.

Sprout

Red-purple, spherical, pubescence at the sprout base is weak

DNA Fingerprint of advanced potato hybrid, PS/06-88 with STU and STIIKA markers (ABI 3500 Genetic analyzer)

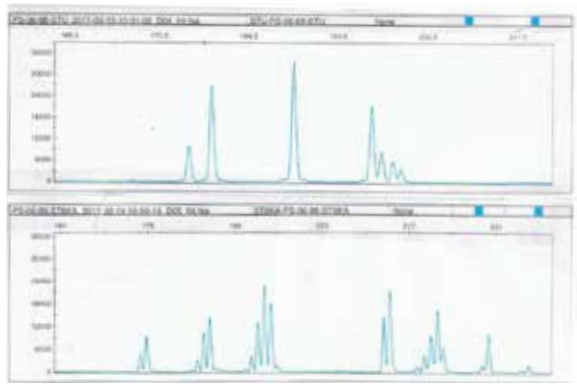

Fig. 2. Kufri Manik: Leaf, Inflorescence, tubers, sprout and DNA fingerprint profile

YIELD PERFORMANCE

Station trials: In station trials at Patna during three consecutive years, i.e. 2009-10, 2010-11 and 2011-12, advanced clone PS/06-88 consistently out-yielded the controls Kufri Arun and Kufri Lalima at 75 days (**Table 1**). On an average, PS/06-88 (27.50 t/ha) yielded 20 and 24% higher total tuber yield as compared to controls Kufri Arun (22.92 t/ha) and Kufri Lalima (22.12 t/ha).

Multi-location testing in AICRP (Potato): In AICRP (Potato) advanced clone PS/06-88 was evaluated in multi-locations replicated trials (2013-2014 to 2014-2015) and two on-farm trials (2015-16 and 2017-18) in Eastern plains.

The results of the replicated trials in Eastern plains Bhubneshwar (BHN), Faizabad (FZB), Jorhat (JRH) and Patna (PAT) during 2013-14 & 2014-15 at 75 days showed superiority of PS/06-88 (20.01 t/ha) for total tuber yield over Kufri Lalima (19.17 t/ha) and Kufri Arun (18.42 t/ha) by a margin of 4

Table 1. Performance of PS/06-88 at Patna in station trials during 2009-2012

Genotype	Total tuber yield (t/ha) at 75 days				% yield increase over control varieties
	2009-10	2010-11	2011-12	Average	
PS/06-88	25.09	27.94	29.46	27.50	
Kufri Arun	19.25	26.36	23.15	22.92	19.98
Kufri Lalima	-	-	22.12	22.12	24.32
CD (0.05)	1.38	1.89	1.48		

Table 2. Total tuber yield (t/ha) of PS/06-88 in replicated trials at 75 days

Genotype	2013-14					2014-15					Overall Mean
	BHN	FZB	JRH	PAT	Mean	BHN	FZB	JRH	PAT	Mean	
PS/06-88	13.89	15.47	21.30	29.94	20.15	17.05	27.67	13.07	21.71	19.87	20.01
Kufri Lalima	15.33	14.47	19.91	24.43	18.54	23.29	25.50	15.48	14.97	19.81	19.17
Kufri Arun	8.93	15.00	17.69	25.3	16.73	21.85	27.00	14.72	16.88	20.11	18.42
CD (0.05)	Y = 0.68, L= 0.96, Y × L =1.36, G = 0.83, Y × G =1.17, L × G =1.67, Y × L × G =2.35										

and 9% respectively at 75 days (**Table 2**). At 90 days, PS/06-88 yielded equal total tuber yield (23 t/ha) with control Kufri Lalima (23 t/ha), however it has an advantage of 3% over Kufri Arun (22 t/ha) (**Table 3**). Marketable tuber yield (t/ha) of PS/06-88 was observed 17.08 t/ha while controls Kufri Lalima and Kufri Arun yielded at par (16.94 t/ha and 16.79 t/ha, respectively) at 75 days maturity. At 90 days, PS/06-88 yielded at par marketable yield (19.34 t/ha) than the controls Kufri Lalima (19.75 t/ha) and Kufri Arun (19.28 t/ha). PS/06-88 produced nearly 86% marketable yield at both 75 and 90 days crop durations.

During third year, in on-farm replicated trials, pooled analysis of five locations (Dholi, Faizabad, Jorhat, Kalyani and Patna), PS/06-88 (18.22 t/ha) out yielded Kufri Lalit (16.89 t/ha) by a margin of 9% at 75 days, while at 90 days, PS/06-88 (23.72 t/ha) out yielded Kufri Lalit (22.93 t/ha) by a margin of 3% (**Table 4**). PS/06-88 produced nearly 80 and 83% marketable tuber yield at 75 and 90 days, respectively. PS/06-88 also possessed high tuber dry matter of 20% as compared to 19% in Kufri Lalit at 90 days.

The on-farm trials during 2017-18 were conducted at **s**ix centres in Eastern plains i.e Bhubneshwar, Dholi, Faizabad, Jorhat, Kalyani and Patna, where PS/06-88 out yielded the controls Kufri Lalit and Kufri Lalima, at all centres, except Kalyani at both 75 and 90 days harvesting (**Table 5** and **Table 6**). On an average, PS/06-88 (20.50 t/ha), out yielded the control Kufri Lalima (19.19 t/

Table 3. Total tuber yield (t/ha) of PS/06-88 in replicated trials at 90 days

Genotype	2013-14					2014-15					Overall mean
	BHN	FZB	JRH	PAT	Mean	BHN	FZB	JRH	PAT	Mean	
PS/06-88	13.19	19.83	22.78	32.99	22.20	17.04	32.67	17.50	24.73	22.98	22.59
Kufri Lalima	14.19	17.81	20.97	31.29	21.06	23.43	30.57	20.83	21.58	24.10	22.59
Kufri Arun	9.48	19.86	18.98	30.28	19.65	21.99	32.50	18.23	23.53	24.06	21.86
CD (0.05)	Y =0.57, L= 0.80, Y × L =1.13, G = NS, Y × G =0.98, L × G =1.39, Y × L × G =1.97										

Table 4. Total and marketable tuber yield (t/ha) of PS/06-88 in on-farm trials (2015-16) at 75 and 90 days (Dholi, Faizabad, Jorhat, Kalyani and Patna)

Genotype	75 Days			90 days		
	Total yield (t/ha)	Marketable yield (t/ha)	Tuber dry matter %	Total yield (t/ha)	Marketable yield (t/ha)	Tuber dry matter %
PS/06-88	18.22	14.52	18.03	23.72	19.64	19.90
Kufri Lalit	16.89	13.60	18.62	22.93	19.52	18.99
CD (0.05)	N/A	N/A	N/A	N/A	N/A	N/A

Table 5. Total tuber yield (t/ha) of PS/06-88 (2017-18) in Eastern plains at 75 days in on-farm trials

Genotypes	75 days						
	BHN	DHL	FZB	JRH	KAL	PAT	Mean
PS/06-88	19.51	21.70	29.50	11.61	14.00	26.65	20.50
Kufri Lalima	16.19	14.00	26.20	11.61	25.01	22.11	19.19
Kufri Lalit	17.26	15.28	28.49	10.66	27.30	22.74	20.29
CD (0.05)	Location= 0.82; Genotype = 0.93; Location × Genotype= 2.47						

Table 6. Total tuber yield (t/ha) of PS/06-88 (2017-18) in Eastern plains at 90 days in on-farm trials

Genotypes	90 days						
	BHN	DHL	FZB	JRH	KAL	PAT	Mean
PS/06-88	19.35	24.97	36.81	13.08	22.05	28.49	24.13
Kufri Lalima	15.46	16.3	30.82	12.12	28.38	23.73	21.14
Kufri Lalit	17.32	18.45	34.79	10.79	31.28	24.91	22.92
CD (0.05)	Location= 0.83; Genotype = 0.95; Location × Genotype= 2.50						

ha) and Kufri Lalit (20.29 t/ha) by margin of 7 and 1% at 75 days. The advanced clone PS/06-88 (24.13 t/ha) showd superiority by margin of 14 and 5% over Kufri Lalima (21.14 t/ha) and Kufri Lalit (22.92 t/ha) respectively at 90 days.

Overall performance of PS/06-88 in AICRP (Potato): Based on pooled mean of four years ie 2013-14, 2014-15, 2015-16 and 2017-18, PS/06-88 (19.69 t/ha) yielded 3 and 7% high total tuber yield than control Kufri Lalima (19.18 t/ha) and Kufri Lalit (18.46 t/ha) at 75 days (**Table 7**). However, at 90 days PS/06-88 (22.76 t/ha) yielded 3 and 2% high total tuber yield than control Kufri Lalima (22.10 t/ha) and Kufri Lalit (22.39 t/ha).

Tuber dry matter

The mean tuber dry matter content of PS/06-88 (**Table 8**) was 18 and 20%, respectively at 75 and 90 days as compared to Kufri Lalima (18 and 19 %) and Kufri Lalit (18 and 19%).

Keeping quality

At Patna, Kufri Manik showed extremely longer tuber dormancy (> 6 weeks) as no sprouting was observerd till 75 days of storage under ambient conditions. The total weight loss due to rottage and physiological reason was comparatively lower in PS/06-88 (23%) as compared to Kufri Lalima (27%) and Kufri Lalit (28%) after 75 days of on-farm storage (**Table 9**).

Table 7. Total tuber yield (t/ha) of PS/06-88 over years under AICRP (Potato)

Years	Total tuber yield (t/ha)		
	PS/06-88	Kufri Lalima	Kufri Lalit
	75 days		
2013-14	20.15	18.54	16.73
2014-15	19.87	19.81	20.11
2015-16	18.22	-	16.69
2017-18	20.5	19.19	20.29
Mean	19.69	19.18	18.46
% yield increase over control varieteis		2.63	6.66
	90 days		
2013-14	20.20	21.06	19.65
2014-15	22.98	24.1	24.06
2015-16	23.72	-	22.93
2017-18	24.13	21.14	22.92
Mean	22.76	22.10	22.39
% yield increase over control varieteis		2.98	1.64

Table 8. Mean tuber dry matter content (%) of PS/06-88 in AICRP trials

Genotypes	75 days					90 days				
	2013-14	2014-15	2015-16	2017-18	Mean	2013-14	2014-15	2015-16	2017-18	Mean
PS/06-88	18.25	17.38	18.03	19.82	18.37	19.15	18.51	19.9	21.09	19.66
Kufri Lalima	16.88	17.74		19.80	18.14	18.09	18.18		20.66	18.98
Kufri Lalit	19.00	17.55	18.62	18.16	18.33	18.15	17.67	18.99	19.27	18.52

Table 9. Storage behaviour of PS/06-88 at 75 day of storage at Patna (pooled 2016-17 and 2017-18)

Genotypes	Dormancy (<or> than 6 weeks)	Sprouting (%) at		Weight loss (%)			
		6 weeks storage	75 days of storage	Sprouting	Rottage	Physiological	Total
PS/06-88	> 6 weeks	0.00	0.00	0.00	10.49	12.57	23.06
Kufri Lalima	> 6 weeks	0.00	0.00	0.00	16.08	10.95	27.03
Kufri Lalit	> 6 weeks	0.00	0.00	0.00	14.28	13.55	27.83

Retention of tuber colour

Nearly 50% of potato acreage and production are contributed by Eastern plains region of India. Red-skinned varieties are typically preferred by customers in this area (Dalamu *et al*., 2019). Anthocyanin pigmentation in the tuber periderm and peripheral cortex imparts colour to red potatoes. Tuber appearance is key for fresh potato marketing. Storage conditions affect physical, chemical, and nutritional qualities of potatoes. Smooth skinned red tubers are susceptible to poor retention of skin colours. PS/06-88 has better tuber skin colour retention (Fig. 3) compared to Kufri Lalit and Kufri Lalima after 4 months of cold storage.

Nutritional values

The average analysis of nutritional components (**Table 10**) revealed the excellence of PS/06-88 for anthocyanin content (68 mg/100 g FW; fresh weight) in tuber flesh as compared to Kufri Lalima (32) and Kufri Lalit (41). The average phenol content was reported to be 71 mg/100g FW in tuber flesh of PS/06-88 compared to 27 in Kufri Lalima and 36 in Kufri Lalit. Potatoes have, in general, relatively low levels of zinc and iron. However, higher consumption quantity and better bioavailability render it as an excellent source of these minerals compared to cereal and legume crops (Burlingame *et al*., 2009). Micronutrient content ie zinc was

Table 10. Nutritional status of PS/06-88 (mean of 2018 & 2019)

Genotypes	Anthocyanin (mg/100 g FW)	Total Phenolics (mg/100g FW)	Zn (ppm)*	Fe (ppm)	Cu (ppm)	Mn (ppm)
PS/06-88	68	71.00	32.54	30.19	7.95	27.48
Kufri Lalima	32	27.16	14.17	22.97	7.11	21.20
Kufri Lalit	41	36.23	21.00	23.97	9.26	15.75

*ppm: parts per million on dry weight basis

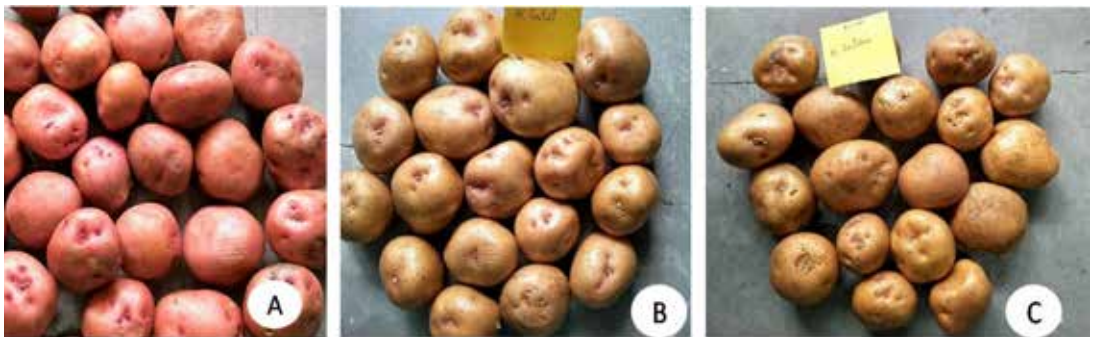

Fig. 3 Tubers of Kufri Manik (A) and control varieties Kufri Lalit (B) and Kufri Lalima (C) after 4 months of cold storage 4 degree Celsius

highest in PS/06-88 (33 ppm) in tuber flesh compared to Kufri Lalima (14) and Kufri Lalit (21). Iron content in PS/06-88 (30 ppm) was also more than Kufri Lalima (23 ppm) and Kufri Lalit (24 ppm). Similarly, manganese content was reported highest in PS/06-88 (27 ppm) than Kufri Lalima (21 ppm) and Kufri Lalit (16 ppm). However, Kufri Lalit had highest copper content in tuber flesh (9.26ppm) followed by PS/06-88 (7.95 ppm).

Usage

The new medium maturing variety Kufri Manik is suitable for table potatoes with attractive deep red round tubers having medium eyes and yellow flesh colour. Tubers of this variety seldom exhibit external/ internal defects and are not susceptible to skin damage at harvest. Its tubers are easy to cook (15-20 minutes) and cooked/boiled tubers are free from any kind of discolouration. The variety possesses a pleasant flavour, waxy texture, and good organoleptic taste. Thus, the desirable tuber characters, good keeping, and culinary quality of this clone will favour its acceptance.

Disease

PS/06-88 shown moderate resistance to late blight under field conditions at Patna (Bihar). Further, tubers of this clone seldom exhibit external or internal defects and are not susceptible to skin damage at harvest.

Agronomic management

A regular agronomic programme for medium maturing varieties is required for Kufri Manik. *Planting time*: 25th October to 10th November in Eastern plains. *Seed rate*: 28-30 q/ha. *Seed size*: 40-60 gram *Spacing*: The optimum row to row spacing is 60 cm and plant to plant distance within a row is 20 cm at a planting depth of 10-12 cm. *Fertilizer:* The optimum nitrogen, phosphorus and potassium dose per hectare area for ware potato crop is 150 kg N, 80 kg P2O5 and 100 kg K2O, respectively. Half dose of nitrogen is applied at the time of planting and the remaining 50% N at earthing up. However, nutrient management should be done as per soil test data and regional recommendations. *Weeding and inter-culture*: Pre-emergence herbicide Oxyfluorfen 23.5% EC is to be applied @ 500ml dissolved in 800-1000 litres water per hectare within one week after planting. Earthing-up is done nearly 22-25 days after planting when the crop is 8-12 cm in height. *Irrigation*: Germination, stolon formation and tuber bulking are critical stages for plant moisture requirement. Pre-sowing irrigation is recommended for uniform emergence. Otherwise, first irrigation should be given 4-6 days after planting. Post planting irrigations is recommended at 7-10 days interval in sandy loam soil and 10-12 days in heavy soil. *Plant protection*: For control of leafhoppers and mites, foliar spray of Imidacloprid (200SL) @ 0.03% (3 ml/10 litres of water) or Sulphur 70WP @ 30gm/10 litres of water or Spiromesifen 240SC @ 4ml/10 litres of water at 30-35 days after planting (seed crop only). For the management of other pests like cutworms, white grubs, beetles and leaf eating caterpillars application of Cartap hydrochloride 4G @20 kg/ha during earthing-up. *Late blight*: Although Kufri Manik has field resistance to late blight however, prophylactic spray of Mancozeb or Propineb or Chlorothalonil @ 0.2% (20 gm/10 litres of water) followed by need based application of Cymoxanil + Mancozeb or Dimethomorph + Mancozeb or Fenamidone + Mancozeb @ 0.3% (30 gm/10 litres of water) is recommended.

Adaptability

Kufri Manik has performed well in multi-location trials conducted under AICRP on Potato and has been recommended for

cultivation in eastern plains (Bihar, Orissa, West Bengal, Assam and Eastern Uttar Pradesh.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

ETHICAL STATEMENT

This article does not contain any studies with human participants or animals performed by any of the authors

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