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KUFRI SANGAM: A HIGH YIELDING DUAL PURPOSE POTATO VARIETY FOR TABLE AND PROCESSING

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ABSTRACT: Kufri Sangam is a medium maturing, main season high yielding dual purpose potato variety suitable for cultivation in northern plains (for table use) and central plains (for processing and table use). It is a clonal selection from a cross between Kufri Himsona × Kufri Pukhraj. It has compact, vigorous and medium-tall plants. It produces attractive white-cream, ovoid tubers with shallow eyes and cream flesh. It possesses 18-20% tuber dry matter, low reducing sugars (<150mg/100 g fresh weight), mealy texture, very good taste. It produces >90 marketable and >80% processing grade tuber yield and is capable of yielding 35-40 t/ha under optimum agronomical practices. Kufri Sangam yields higher than the presently grown popular table variety Kufri Bahar and processing varieties viz., Kufri Chipsona-3 and Kufri Frysona. Kufri Sangam is moderately resistant to late blight and has excellent keeping quality under country storage conditions with over 10 weeks dormancy period.

KEYWORDS: Potato, Kufri Sangam, dual purpose variety, high yield, late blight resistance, keeping quality, northern and central plains

INTRODUCTION

Potato is the third most important food crop in the world after rice and wheat. There has been phenomenal growth in production and productivity of potato in India. Besides best management practices, the key for sustaining higher production and productivity lies in superior genotypes and diversified utilization. During last two decades focus has been to develop varieties with higher yield, resistant to diseases along with superior quality and storability traits. To meet the demand of burgeoning population, India would be requiring about 125 million tones of potato in the year 2050 (Singh *et al* 2014). The demand for processed potato products from last two decades in the country has increased many fold and several Indian and multinational entrepreneurs have established chips, French fries and flakes making units and several companies are coming-up in the field of diversified potato and potato based products including starch manufacturing (Gupta *et al* 2020a). Potatoes' having multiple traits to suit fresh market consumption as well as for processing market are the most sought after objectives of now a day's breeding programme. To get the right combination of characteristics in one variety takes a large investment in time and resources. The sincere effort directed in this regards enabled identification of Kufri Sangam having high yield, quality, storability and disease resistance to late blight than to existing varieties like Kufri Bahar (table variety) and Kufri Chipsona-3 and Kufri Frysona (processing varieties).

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MATERIAL AND METHODS

Advanced stage hybrid MP/6-39 christened as Kufri Sangam originated from hybridization of cross between Kufri Himsona × Kufri Pukhraj (Fig. 1). The hybridization was done in 2006 at Kufri (32°N 77°E; 2501 m above MSL) in the hills. The pedigree of MP/6-39 is described in figure-1. The female parent Kufri Himsona is an indigenous processing variety produces white-cream ovoid, shallow eyed tubers with cream flesh and possessed resistance to late blight; whereas male parent Kufri Pukhraj an indigenous popular table potato variety produces yellow, ovoid tubers with shallow eyes and light yellow flesh.

The seedling and subsequent clonal stages were raised and evaluated (Gupta *et al*., 2020) at ICAR-Central Potato Research Institute, Campus, Modipuram, Meerut (29° N and 77.7° E; 300 masl). The clone MP/6-39 was in seedling stage in 2006-07, the five-hill plot in 2007-08, 30 hill plot in 2008-09, multiple-row trial in 2009-10 and in replicated yield trials during 2010-2011 to 2014-2015 at Modipuram, Jalandhar, Amirgarh, Indore and Burdhwan. Based on consistently superior performance over control varieties in replicated yield trials, the hybrid was introduced in All India Coordinated Research Project on Potato (AICRP on Potato) in 2015 for multi-location testing across the country and also evaluation and testing of hybrid at industrial conditions during 2015-16. In multi-location initial varietal trial (IVT)/advanced varietal trial (AVT) during 2015-2016 to 2018-2019, the hybrid was evaluated at 17 locations in four regions, however, MP/6-39 performed well in North (4 locations-Hisar, Jalandhar, Modipuram and Pantnagar) and Central plains (6 locations-Chhindwara, Deesa, Gwalior, Kanpur, Kota, Raipur) of the country.

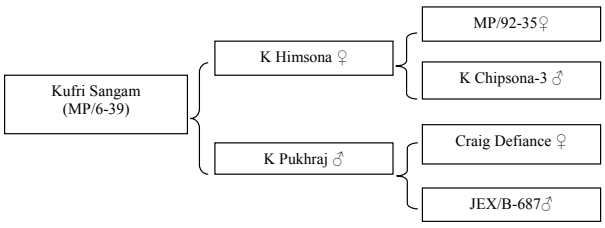


Fig. 1. Pedigree of Kufri Sangam

Estimation of quality parameters

Tuber dry matter: Samples of 5 randomly drawn tubers were used for dry matter estimation. The tubers were chopped into small pieces. The chopped pieces were mixed properly and 50g sample of each variety in 3 replications was kept in oven at 80° C for 72 hours (Gupta *et al*., 2015).The final dry content of the sample was estimated when the weight of the sample reached to a constant level.

French fries: The tubers were peeled, washed and trimmed to remove defects and cut into sticks of 10 × 10 mm thickness. Sticks of more than 75mm length were selected, excess water was removed from the surface of sticks by dryer and these were continuously fried for five minutes or till the bubbling stopped at 180°C. French fry colour score was measured by using the chip colour cards on a scale of 1-10, where 1 was complete white and 10 was black/brown. French fry colour score up to 4.0 is considered acceptable (Ezekiel *et al*., 2003).

Reducing sugars (mg/100g fresh tuber weight): Three tubers were cut from bud to stem end and 10 g of chopped sample was withdrawn by after proper mixing. Refluxing was done in 80% iso-propanol (50ml). The extract was filtered using whatman filter paper, evaporated until small quantity remained and volume was made to 100ml. Before estimation of reducing sugars, interfering compounds like soluble proteins were removed by precipitating using saturated

potassium oxalate solution and lead acetate solution followed by centrifuging. To the supernatant (0.2 ml) alkaline copper tartarate reagent was added, content was boiled for 10 minutes, cooled and arsenomolybdate reagent (1 ml) was poured. The developed blue colour absorption was measured using spectrophotometer at 620 nm (Nelson, 1944).

Glucose (mg/100g fresh tuber weight): The tubers were washed and peeled, and 200 g sample was drawn and juicerated and juice was collected in a beaker. Juicerator was washed three times with 100ml portions of buffer diluents (sodium phosphate pH 7.2). Quantitatively combined juice was transferred to volumetric flask and volume was made up to the mark. Samples were covered and combined extract was kept in freeze for one hour prior to analysis. Samples were taken out of freezer and allowed to incubate at room temperature for 20 minutes before analysis. Biochemistry analyser (Make: Yellow Springs Instrument Co. Inc., USA, Model: YSI 2900 series) was calibrated with 2.50 g/l glucose standard solution. Linearity of the membrane was checked by injecting the glucose solution (9.00 g/l) and after every twenty samples.

The data were analyzed following standard statistical procedures as described by Gomez and Gomez (1984) using the software Windostat 8.5 (Ameerpet, Hyderabad, India). Based on its performance, the advanced hybrid MP/6-39 was recommended for release in north and central Indian plains by 38th AICRP Potato group meeting held during 03-4 September, 2019 at JNKV, Jabalpur, Madhya Pradesh. The hybrid MP/6-39 has been christened as potato variety Kufri Sangam and it was released and notified by the 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 No.3-69/2018-SD'lVdated 28th October, 2020.**

Varietal description

For identification purpose, the salient morphological attributes (**Fig 2**) of variety Kufri Sangam are described below-

Plant: Medium, plant canopy compact, stem medium thick, predominantly green, wings highly developed and straight.

Foliage: Grey green, leaves large, leaf width medium, leaflets ovate lanceolate, leaflet

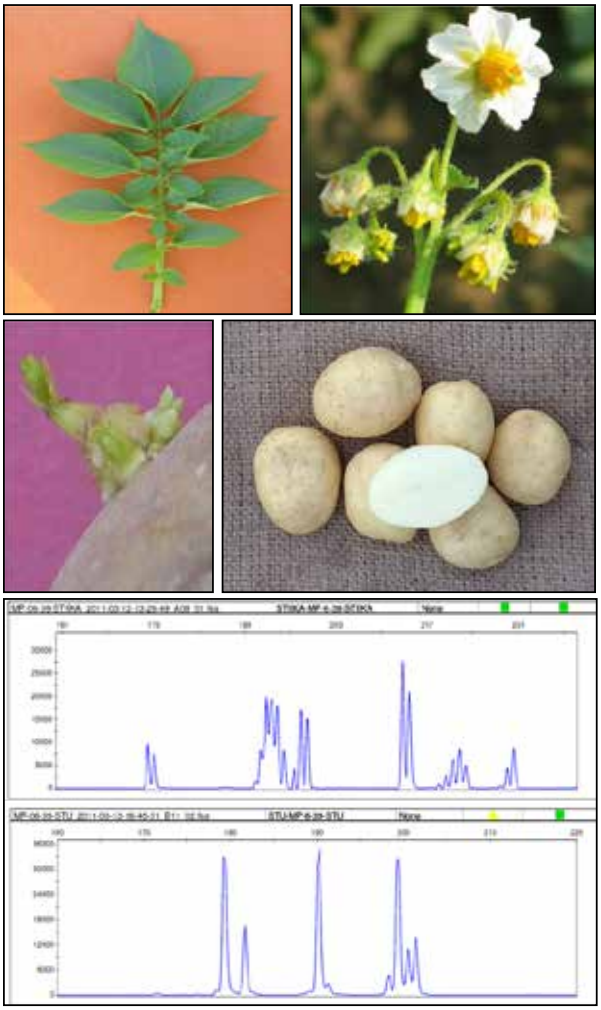


Fig.2 Morphological features and DNA fingerprint profile of Kufri Sangam

coalescence absent, anthocyanin in rachis and midrib not present.

Flower: Flowering medium, inflorescence small, floral stalk green, floral stalk-pedicle articulation clearly visible and located above the middle, calyx green, corolla white, corolla shape pentagonal, anther orange, anther cone normally developed, stylar length longer than stamen column and stigma bi-lobed.

Tubers: Tubers (10-12), ovoid, skin white-cream, eyes shallow, eyebrows normal, flesh cream, texture mealy.

Sprout: Sprout pink, shape spherical, pubescence at sprout base is weak.

RESULTS AND DISCUSSION

Yield performance in yield trials: Advanced stage hybrid MP/6-39 consistently out-yielded the controls Kufri Chipsona-3 at 90 days in replicated yield trials during 2012-2013 to 2014-2015 at Modipuram, (Uttar Pradesh) and Jalandhar (Punjab) and in industrial testing with French fry industry McCain Foods, Mahesana **(**Amirgarh, Gujarat), chips industry Pepsico facility **(**Burdwan, West Bengal) and chip grade potato supplier M/s Fresh-O-Veg (Indore Indore, Madhya Pradesh). MP/6-39 produced higher processing grade (37 t/ha; 28%) and total tuber yield (43 t/ha; 22%) than the best control Kufri Chipsona-3 (29 and 35 t/ha) at 90 days **(Table 1)**. MP/6-39 also showed superiority for processing tuber (39%) and total tuber yield (33%) than the French fry variety Kufri Frysona (27 and 32 t/ha) at 90 days (Gupta *et al*., 2016 and Gupta *et al.,* 2019). It has acceptable chip colour (2.8) and 19% tuber dry matter content **(Table 2)**

Yield performance in AICRP trials: The hybrid MP/6-39 was evaluated for four years in replicated yield (2015-2016) and advanced varietal trials (2016-2017, 2017-2018 and 2018-2019). The results on performance of MP/6-39 are presented below

Initial varietal trial (2015-16): MP/6-39 produced a significantly higher or at par total tuber yield **(Table 3)** than the best control Kufri Chipsona-3 at Hisar, Modipuram (Northern plains), Chhindwara,

Table 1. Yield performance of advanced stage hybrid MS/6-39 during 2012-2013 to 2014-2015 in yield trials

Genotypes	Processing grade yield (t/ha) at 90 days					
	UP*	PNB	GUJ	WB	MP	Mean
MP/6-39	33.4	34.7	43.8	46.3	26.7	37.0
Kufri Chipsona-3	25.1	28.7	36.5	33.1	20.8	28.9
Kufri Frysona	23.7	26.6	29.9	31.2	22.4	26.7
Atlantic	26.2	21.6	35.7	33.5	16.8	26.8
% increase over Kufri Chipsona-3						28.1
Genotypes	Total tuber yield (t/ha) at 90 days					
	UP	PNB	GUJ	WB	MP	Mean
MP/6-39	40.7	39.7	46.7	55.5	31.4	42.8
Kufri Chipsona-3	31.4	36.3	43.1	39.7	24.5	35.0
Kufri Frysona	29.3	33.7	34.1	37.1	26.2	32.1
Atlantic	29.7	25.4	38.1	36.5	19.0	29.7
% increase over Kufri Chipsona-3						22.3

*Modipuram, UP (2012-13 to 2014-15), Jalandhar, Punjab (2013-14 to 2014-15), Burdhwan, WB (2012-2013), Amirgarh, Gujarat and Indore, Madhya Pradesh (2012-13 and 2014-15)

Table 2. Dry matter content and chip colour of advanced processing hybrid during 2012-13 to 2014-2015

Genotype	Tuber dry matter (%)					
	UP*	PNB	GUJ	WB	MP	Mean
MP/6-39	18.6	18.7	18.8	18.2	21.2	19.1
Kufri Chipsona-3	21.6	22.5	22.3	21.0	21.8	21.8
Kufri Frysona	21.2	20.9	22.0	22.0	22.4	21.7
Atlantic	20.3	22.2	19.8	21.1	22.3	21.1
Genotype	French fry colour					
	UP	PNB	GUJ	WB	MP	Mean
MP/6-39	4.7	1.7	1.3	3.3	3.2	2.8
Kufri Chipsona-3	3.8	1.6	1.8	3.3	3.0	2.7
Kufri Frysona	3.2	2.7	1.3	3.0	2.4	2.5
Atlantic	3.4	1.7	1.8	2.8	2.3	2.4

Table 3. Performance of MP/06-39 at 90 days in initial varietal trials (2015-2016)

Region	Locations	Total yield (t/ha)			Processing grade tuber yield (t/ha)		
		MP/6-39	Atlantic	K Chip-3	MP/6-39	Atlantic	K Chip-3
Northern Plains	Hisar	43.1	19.5	25.5	33.0	17.5	21.1
	Modipuram	38.5	24.9	32.2	29.3	21.0	24.3
Central Plains	Chhindwara	36.2	27.0	30.6	25.3	18.9	21.3
	Deesa	34.9	23.1	34.0	29.1	18.0	29.1
	Gwalior	28.8	26.5	29.4	12.0	15.1	10.1
	Kota	13.7	10.9	12.7	11.2	9.7	11.3
	Mean	32.5	22.0	27.4	23.3	16.7	19.5
% Yield increase			48.0	18.7		39.6	19.4
$CD_{0.05}$	-	Variety:1.17 Variety × locations: 3.31			Variety: 0.96 Variety × locations: 2.7		

Deesa, Gwalior and Kota (Central plains) The mean total tuber yield of MP/6-39 (33 t/ha) over different locations of northern plains and central plains were significantly higher (19%) than the best control Kufri Chipsona-3 (27 t/ha). MP/6-39 also produced a significantly higher or at par processing grade tuber yield than the best control Kufri Chipsona-3 at Hisar and Modipuram (Northern plains), Chhindwara, Deesa and Kota (Central plains). The mean processing grade tuber yield of MP/6-39 (23 t/ha) over different locations of northern plains and central plains were significantly higher (19%) than best control Kufri Chipsona-3 (20 t/ha). MP/6-39 has acceptable tuber dry matter content (20%) and 66 % mean foliage maturity **(Table 4, 5).**

Advanced varietal trial-1 (2016-17): MP/6-39 produced a significantly higher or at par total tuber yield **(Table 5)** than the best control Kufri Chipsona-3 at Hisar, Modipuram, Pantnagar (northern plains), Deesa, Gwalior and Kanpur (Central plains). The mean total tuber yield of MP/6-39 (36 t/ha) over different locations of northern plain and Central plain were significantly higher (14%) than the best control Kufri Chipsona-3 (32 t/ha). MP/6-39 also produced a significantly higher or at par processing grade tuber yield than

Table 4. Tuber dry matter (%) and foliage maturity of MP/6-39 at 90 Days (2015-2016)

Region	Locations	Tuber dry matter (%)			Foliage maturity (%)		
		MP/6-39	Atlantic	K Chip-3	MP/6-39	Atlantic	K Chip-3
Northern Plains	Hisar	16.4	19.9	19.9	-	-	-
	Modipuram	18.6	18.8	18.6	70.0	80.0	66.7
Central Plains	Chhindwara	18.6	18.8	18.7	91.8	89.0	87.5
	Deesa	17.8	20.7	20.8	26.7	46.7	40.0
	Gwalior	24.2	18.8	26.7	-	-	-
	Kota	22.2	23.2	21.0	74.0	78.3	76.7
	Mean	19.6	20.0	21.0	65.6	73.5	67.7
$CD_{0.05}$	-	Variety: NS Variety × locations: 1.56			Variety: 3.16 Variety × locations: 7.07		

Table 5. Total tuber yield and processing grade tuber yield at 90 Days in advanced varietal trials-1 (2016-2017)

Region	Locations	Total tuber yield (t/ha)				Processing grade tuber yield (t/ha)			
		MP/6-39	Atlantic	Kufri Chip-3	Kufri Frysona	MP/6-39	Atlantic	Kufri Chip-3	Kufri Frysona
Northern Plains	Hisar	39.7	29.5	37.6	34.3	36.2	27.3	32.8	30.2
	Modipuram	40.0	30.3	38.4	34.5	28.9	26.4	30.8	23.4
	Pantnagar	30.4	28.4	26.2	26.4	29.8	27.9	25.7	25.8
Central Plains	Deesa	29.9	19.9	25.7	22.2	24.4	14.0	13.6	13.6
	Gwalior	37.0	34.5	37.8	36.2	21.5	22.0	26.4	23.1
	Kanpur	38.7	27.9	23.5	27.6	35.5	24.9	22.6	24.6
	Mean	36.0	28.4	31.5	30.2	29.4	23.8	25.3	23.5
Yield increase (%)			26.5	14.0	19.0		23.7	16.1	25.3
		$CD_{0.05}$: 2.64		CV: 9.23		$CD_{0.05}$: 2.86		CV: 12.18	

the best controls Kufri Chipsona-3 at Hisar, Modipuram, Pantnagar (northern plains), Deesa and Kanpur (Central plains). The mean processing grade tuber yield of MP/6-39 (29 t/ha) over different locations of north-western plain and central plain were significantly higher (16%) than Kufri Chipsona-3 (25 t/ha). It is pertinent to mention that MP/6-39 produced higher total (19%) and processing grade (25%) tuber yield over French fry variety Kufri Frysona (30 and 24 t/ha) **(Table 5)**. MP/6-39 has acceptable tuber dry matter content (20%), foliage maturity (66%), French fry colour (3.7) and reducing sugars (138 mg/100g fresh weight of potato) **(Table 6 and 7).**

Advanced varietal trial-2 (2017-2018): MP/6-39 produced higher total tuber yield **(Table 8)** than Kufri Bahar at Modipuram, Pantnagar (northern plains) and Chhindwara, Gwalior Kanpur and Kota (central Plains). The mean total tuber yield of MP/6-39 (41 t/ha) over different locations of northern and central plains was higher (8%) than Kufri Bahar (38 t/ha). MP/6-39 also produced higher marketable tuber yield than Kufri bahar at Modipuram, Pantnagar (northern plains), Chhindwara, Deesa, Gwalior and Kota (Central plains). The mean marketable tuber yield of MP/6-39 (37 t/ha) over different locations of North-Western plains and Central plains was higher (8%) than Kufri Bahar (34 t/ha).The tuber dry matter (20%) of MP/6-

Table 6. Tuber dry matter (%) and foliage maturity (%) at 90 Days (2016-2017)

Region	Locations	MP/6-39	Atlantic	K Chip-3	K Frysona	MP/6-39	Atlantic	K Chip-3	K Frysona
		Tuber dry matter %				Foliage maturity %			
Northern Plains	Modipuram	18.0	19.1	18.2	18.8	60.0	70.0	50.0	50.0
	Pantnagar	16.9	16.7	16.5	16.4	94.7	95.0	95.0	95.7
Central Plains	Deesa	20.8	19.9	21.8	24.3	80.0	80.0	80.0	80.0
	Gwalior	22.3	23.0	23.3	20.1	-	-	-	-
	Kanpur	-	-	-	-	46.4	63.0	64.1	66.5
	Mean	19.5	19.7	20.0	19.9	70.3	77.0	72.3	73.1
		$CD_{0.05}$: NS		CV: 5.96					

Table 7. Quality attributes at 90 Days (2016-2017)

Locations	French fry colour			Reducing Sugar mg/100 g of fresh weight of the potato		
	MP/6-39	Atlantic	K Chip-3	MP/6-39	Atlantic	K Chip-3
Modipuram	4.2	3.0	4.2	118.9	66.1	124.6
Pantnagar	3.3	2.7	2.7			
Gwalior	3.6	2.7	3.3	157.2	84.8	85.4
Mean	3.7	2.8	3.4	138.1	75.5	105.0

Table 8. Performance of MP/6-39 and popular variety Kufri Bahar at 90 Days in advanced varietal trial-2 (2017-2018)

		MP/6-39				Kufri Bahar			
Region	Location	Foliage Senescence (%)	Total yield (t/ha)	Marketable yield (t/ha)	Tuber dry matter (%)	Foliage Senescence (%)	Total yield (t/ha)	Marketable yield (t/ha)	Tuber dry matter (%)
Northern Plains	Modipuram	65.0	50.8	46.8	17.0	70.0	45.4	40.8	15.9
	Pantnagar	86.0	29.3	27.6		86.7	28.0	26.7	
Central Plains	Chhindwara	84.5	42.4	34.8	19.1	85.3	37.6	30.8	18.7
	Deesa	66.2	41.6	40.6	20.2	78.6	42.6	40.6	18.8
	Gwalior		37.9	37.9	22.7		33.5	33.5	21.0
	Kanpur	16.3	46.3	37.9	19.5	37.8	43.8	38.5	19.5
	Kota	85.2	35.8	33.9	23.1	86.6	31.8	29.3	20.4
Mean		67.2	40.6	37.1	20.3	74.1	37.5	34.3	19.1
Yield increase (%)							8.2	8.0	

39 was higher as compared to Kufri Bahar (19%).

Advanced varietal trial-3 (2018-19): MP/6-39 produced a significantly higher or at par total tuber yield **(Table 9)** than the best control Kufri Chipsona-3 at Hisar, Jalandhar, Modipuram (North-western plain), Deesa, Gwalior, Kanpur, Kota and Raipur (Central plains). The mean total tuber yield of MP/6-39 (39 t/ha) over different locations of north-western plain and central plain were significantly higher (12%) than the best control Kufri Chipsona-3 (35 t/ha).

MP/6-39 also produced a significantly higher or at par processing grade tuber yield **(Table 9)** than the best controls Kufri Chipsona-3 at Hisar, Jalandhar, Modipuram

Table 9. Total tuber yield and processing grade tuber yield at 90 Days (2018-2019)

Region	Locations	Total tuber yield (t/ha)				Processing grade tuber yield (t/ha)			
		MP/6-39	Atlantic	K Chip-3	K Frysona	MP/6-39	Atlantic	K Chip-3	K Frysona
Northern Plains	Hisar	31.3	18.9	30.9	22.4	30.3	18.0	29.2	21.4
	Jalandhar	36.5	35.7	30.3	26.3	31.6	32.7	25.3	22.1
	Modipuram	49.8	31.6	44.3	40.6	41.0	28.5	36.3	34.0
Central Plains	Deesa	43.6	31.2	38.3	39.9	39.1	29.5	33.3	37.9
	Gwalior	48.3	40.1	42.3	44.0	40.8	35.7	35.1	37.2
	Kanpur	41.1	32.7	36.4	36.0	35.5	28.1	30.2	27.7
	Kota	31.6	15.1	26.1	16.5	30.5	14.0	25.1	15.3
	Raipur	27.6	28.8	29.0	22.9	22.0	17.4	16.7	11.3
Mean		38.7	29.3	34.7	31.1	33.9	25.5	28.9	25.9
Yield increase (%)			32.3	11.6	24.6		32.3	11.6	24.6
$CD_{0.05}$			Genotype: 0.83 Location × Genotype: 3.1				Genotype: 0.8 Location × Genotype: 3.0		

(north-western plain), Deesa, Gwalior, Kanpur, Kota and Raipur (Central plains). The mean processing grade tuber yield of MP/6-39 (34 t/ha) over different locations of north-western plain and central plain were significantly higher (12%) than Kufri Chipsona-3 (29 t/ha). MP/6-39 has acceptable tuber dry matter content (21%), French fry colour (2.8), reducing sugars (98 mg/100g fresh tuber weight) and 69 % mean foliage maturity **(Table 10 and 11).**

Pooled performance in AICRP during different years and locations

Northern plains: MP/6-39 (39 t/ha and 32 t/ha) yielded 19 and 17% higher total and processing grade tuber yield than the best control Kufri Chipsona-3 (33 t/ha and 28 t/ha), respectively at 90 days **(Table 12).** MP/6-39 has tuber dry matter content (18%), French fry colour (3.2) and reducing sugars (106 mg/100 g fresh tuber weight).

Table 10. Tuber dry matter (%) and foliage maturity (%) at 90 Days (2018-19)

Region	Locations	Tuber dry matter				Foliage maturity (%)			
		MP/6-39	Atlantic	K Chip-3	K Frysona	MP/6-39	Atlantic	K Chip-3	K Frysona
Northern Plains	Hisar	17.2	15.8	19.9	18.8	-	-	-	-
	Jalandhar	19.5	23.9	19.6	20.8	-	-	-	-
	Modipuram	18.6	21.8	20.7	21.0	55.0	60.0	50.0	50.0
Central Plains	Deesa	22.1	23.6	23.9	21.4	71.2	89.6	82.8	77.2
	Gwalior	23.4	22.7	24.1	21.6	-	-	-	-
	Kanpur	19.8	20.1	20.5	21.1	-	-	-	-
	Kota	23.8	21.3	20.6	22.2	80.3	87.7	81.8	84.6
	Raipur	23.8	22.4	22.3	18.1				
	Mean	21.0	21.5	21.5	20.6	68.8	79.1	71.5	70.6
	$CD_{0.05}$	Genotype: 0.25 Location × Genotype: 0.90							

Table 11. Quality attributes (Chip/ French fry colour) at 90 Days (2018-19)

Region	Locations	French fry colour				Reducing Sugar mg/100 g of fresh weight of the potato			
		MP/6-39	Atlantic	K Chip-3	K Frysona	MP/6-39	Atlantic	K Chip-3	K Frysona
Northern Plains	Hisar	2.5	3.0	3.0		84.3	87.1	75.5	
	Jalandhar	1.5	2.3	2.3	2.4	102.3	323.7	231.1	355.7
	Modipuram	4.0	3.0	3.6	4.5	66.7	85.0	90.9	88.2
Central Plains	Deesa	3.0	1.0	2.0	3.0	94.5	127.3	67.9	78.5
	Gwalior	3.0	2.5	3.0		140.5	121.0	89.1	
	Mean	2.8	2.36	2.78	3.3	97.7	148.8	110.9	174.1

Table 12. Performance of MP/6-39 in AICRP trials at 90 days (pooled over location)

Northern Plains												
Stage	MP/6-39			ATL			K. Chip-3			K Frysona		
Trial	TTY	PGY	DM%	TTY	PGY	DM%	TTY	PGY	DM%	TTY	PGY	DM%
IVT*	40.8	31.2	17.5	22.2	19.3	19.4	28.9	22.7	19.3			
AVT1**	36.7	31.6	17.5	29.4	27.2	17.9	34.1	29.8	17.4	31.7	26.5	17.6
AVT3**	39.2	34.3	18.4	28.7	26.4	20.5	35.2	30.3	20.1	29.8	25.8	20.2
Mean	38.9	32.4	17.8	26.8	24.3	19.3	32.7	27.6	18.9	30.8	26.2	18.9
Yield increase (%)				45.3	33.3		19.0	17.3		26.5	23.8	
Central Plains												
IVT*	28.4	19.4	20.7	21.9	15.4	20.4	26.7	18.0	21.8			
AVT1**	35.2	27.1	21.6	23.9	19.5	19.9	29.0	20.9	22.6	28.7	20.4	22.2
AVT3**	38.4	33.6	22.6	29.6	24.9	22.0	34.4	28.1	22.3	31.9	25.9	20.9
Mean	34.0	26.7	21.6	25.1	19.9	20.8	30.0	22.3	22.2	30.3	23.2	21.5
Yield increase (%)				35.4	33.9		13.3	19.8		12.4	15.3	
G Mean	36.5	29.5	19.7	26.0	22.1	20.0	31.4	25.0	20.6	30.5	24.7	20.2
Yield increase (%)				40.5	33.6		16.2	18.3		19.4	19.7	

Northern plains: IVT (Hisar and Modipuram), AVT1 (Hisar, Modipuram and Pantnagar), AVT3 (Hisar, Jalandhar and Modipuram); Central plains: IVT (Chhimdwara, Deesa, Gwalior and Kota), AVT1 (Deesa, Gwalior and Kanpur), AVT3 (Deesa, Gwalior, Kanpur, Kota and Raipur)

Central plains: MP/6-39 (34 t/ha and 27 t/ha) yielded 12 and 15% higher total and processing tuber yields than the best control Kufri Frysona (30 t/ha and 23 t/ha), respectively at 90 days crop duration **(Table 12).** MP/6-39 has acceptable tuber dry matter content (22 %), French fry colour (3.3) and reducing sugars (137 mg/100 g fresh tuber weight)

***Mean performance MP/4-578 in AICRP trials (Pooled over northern and central plains)*:** MP/6-39 (37 t/ha and 30 t/ha) yielded 16 and 18% higher total and processing grade tuber yields respectively, than the best controls Kufri Chipsona-3 (31 t/ha and 25 t/ha) at 90 days of crop duration **(Table 12).** MP/6-39 has acceptable tuber dry matter content (20%), French fry colour (3.3) and reducing sugars (122 mg/100 g fresh tuber weight) **(Table 13)**.

Keeping Quality

Kufri Sangam has better keeping quality as compared to Kufri Chipsona-3 and Kufri Bahar during storage at room temperature

Table 13. Quality attributes MP/6-39 in AICRP trials at 90 days (pooled over location)

Northern Plains								
Trials	MP/6-39		ATL		Chip-3		K Frysona	
	CC/FFC	RS	CC/FFC	RS	CC/FFC	RS	CC/FFC	RS
AVT1	3.8	118.9	2.9	66.1	3.5	124.6		
AVT3	2.7	93.3	2.8	205.4	3.0	153.3	3.5	355.7
Mean	3.2	106.1	2.8	135.8	3.2	139.0	3.5	355.7
Central Plains								
Trials	FFC	RS	FFC	RS	FFC	RS	FFC	RS
AVT1	3.6	157.2	2.7	84.8	3.3	85.4		
AVT3	3.0	117.5	1.8	124.2	2.5	78.5	3.0	78.5
Mean	3.3	137.4	2.2	104.5	2.9	82.0	3.0	78.5
G Mean	3.25	121.75	2.5	120.15	3.05	110.5	3.25	217.1

TTY: Total tuber yield, PGY: Processing grade tuber yield, DM; Dry mater (%), French fry colour: on 1-10 scale (1 very light colour & 10 very dark).RS: Reducing sugars: mg/100g FTW

Table 14. Storage behavior of MP/6-39 under ambient conditions at Modipuram*

Genotypes	Dormancy period (weeks)	Sprouting (%)		Weight loss (%)			
		45 days	75 days	Sprouts	Rottage	Physiological	Total
MP/6-39	>10 week	0.0	8.2	0.0	3.4	7.8	11.2
Kufri Chipsona-3	>6 weeks	70.0	96.6	0.5	2.0	11.7	14.3
Kufri Bahar	>6 weeks	69.9	86.7	0.5	0.8	11.8	13.1

*Four years means (2015-2016 to 2018-2019)

(Table 14). Kufri Sangam has long dormancy (>10 Week), less physiological weight loss (8%) and total weight loss (11%) as compared to popular variety Kufri Bahar (12 and 13%) and Kufri Chipsona-3 (12 and 14%) after 75 days storage under ambient conditions.

Industrial Testing of hybrid

To see suitability of MP/6-39 to provide the raw material for French fries industry, industrial testing was done at McCain Foods, Mahesana (2015-16). MP/6-39 produced significantly high total and processing grade tuber yield than Kufri Frysona and Kennebec. The results **(Table 15)** of MP/6-39 with 49 and 46 t/ha total and processing grade tuber yield showed 32% and 31% yield superiority over the French fry variety Kufri Frysonsa (38 and 36t/ha). The advanced hybrid MP/6-39 with 49 and 46 t/ha total and processing grade tuber yield showed 23% showed yield superiority over exotic French fry variety

Table. 15 Industrial testing of MP/6-39 with McCain Foods, Mahesana (2015-16)

Genotypes	TTY/ha	PGY/ha >40mm	% PGY	Tuber form index (> 40 mm)	Tuber count per 10 kg	Tuber dry matter %
MP/6-39	49.4	46.4	93.9	0.93	98	20.6
K Frysona	37.5	35.5	94.5	0.93	92	20.2
Kennebec	40.1	37.7	93.9	1.03	75	20.2
$CD_{0.05}$	4.5	6.0	6.6	-	11.0	

Kennebec (40 and 38 t/ha). The variety produced nearly 94% processing grade tuber yield with acceptable (21%) dry matter and comparable processing traits as compared to indigenous and exotic genotypes. The industry remarked MP/6-39 to be with white tuber with good size and good for French fry.

Disease resistance

Kufri Sangam has moderate level of resistance against late blight as it has recorded lower area under disease progress curve (AUDPC) values (290) as compared to check variety Kufri Bahar (750) under artificial epiphytotic conditions during 2013-15 at Modipuram. Similarly on detach leaf method Kufri Sangam showed lesser lesion area (2.95 cm^2) as compared to Kufri Bahar (7.2 $cm^{2)}$.

Agronomic management

The optimum tuber yield of Kufri Sangam can be obtained by adopting a standard agronomical schedule for medium maturing varieties. *Planting time:* northern plains (15-25 October) and central plains (5-15 November). *Seed rate:* 35-40 q/ha. *Seed size*: 40-60 g. *Spacing:* Plant spaced at 20-25 cm in 66 cm rows provides optimum tuber size distribution for production of desirable tuber size for the production of ware or processing potatoes. *Fertilizer:* For seed crop, generally 90, 80, 100 kg/ha nitrogen, phosphorous and potassium at the time of planting and remaining 90 kg/ha nitrogen at the time of earthing-up is recommended. At Modipuram, optimum nitrogen (240 kg/ha), phosphorous (40 kg/ha) and potassium (100 kg/ha) dose was worked out for the production of ware or processing potatoes. Nutrient management in other agro-ecologies may differ and thus needs to be fine-tuned or regional recommendation may be followed for optimum productivity of this variety. *Irrigations:* In conventional flood irrigation, first irrigation is given 12-15 days after planting at 2-5% crop emergence. Second irrigation is given 20-25 days just after earthing up. Subsequent irrigations are given as and when required at 10-12 days interval. Crop should not face moisture stress at stolon formation and during tuberization. Stop irrigation about 10-12 days before haulm cutting when 25-30% plants have shown senescence. *Plant Protection Measures:* For management of cutworms, white grubs, beetles and leaf-eating caterpillars, apply cartap hydrochloride 4G @20 kg/ha during earthing-up. It will also take care of sucking pest like leafhopper and aphids. For seed crop, place yellow sticky traps (15 × 30 cm^2 size) just above the canopy height @ 60 traps/ha at equidistance from each other for mass trapping of whiteflies/aphids. Seed treatment with imidacloprid (200SL) @ 0.04% (4 ml/10 lit) for 10 minutes before planting. First spray with imidacloprid (200SL) @ 0.03% (3 ml/10 lit of water) at 85% crop emergence. Second spray with thiamethoxam (25 WG) @ 0.05% (5 gm/10 lit of water) after 10-15 days of the first spray.

Adaptability

Kufri Sangam has been recommended for Punjab, Haryana, Uttar Pradesh, Uttrakhand (northern plains) and Madhya Pradesh, Chhattisgarh, Gujarat, Rajasthan (Central plains). Due to its higher yield, moderate resistance to late blight, acceptable quality traits and attractive ovoid tubers, long dormancy, better shelf life under ambient store conditions, the variety can provide option to long distance transportation of tubers for table or processing use.

Usage

The new potato variety Kufri Sangam is suitable for ware (northern plains) as well as

for production of potatoes for processing into French fries (central plains). Kufri Sangam is likely to be preferred by processors for its white- ovoid tubers with cream flesh and shallow eyes resulting in lower peeling losses. It possesses a pleasant flavour, mealy texture.

CONCLUSIONS

Kufri Sangam has performed well in multi-location trials conducted under AICRP on potato in northern and central Indian plains and therefore can be grown successfully for increasing productivity and utilization of potatoes for table as well as for processing (making French fries) in these areas. Kufri Sangam can provide one more very good alternative to consumer for fresh consumption and also to processing industry from single variety with white-cream skin ovoid tubers, shallow eyes, cream flesh, excellent keeping and culinary quality and moderate resistance to late blight in addition to high marketable/processing and total tuber yields.

LITERATURE CITED

Ezekiel R, Singh B and Kumar D (2003) A reference chart for potato chip colour for use in India. *J Indian Potato Association* (*Potato Journal*) **30**: 259-65

Gomez KA, Gomez AA (1984) Statistical procedures for agricultural research. John. Wiley and Sons, New York, p 680

Gupta VK, Bhardwaj V, Luthra SK, Singh SV, Mehta A, Bandana and Singh BP (2016) Multipurpose advanced potato hybrid MP/6-39 with excellent keeping quality. CPRI Newsletter 63 (January-March) 2016, pp 2-3

Gupta VK, Bhardwaj V, Luthra SK, Singh SV, Mehta A, Bandana and Singh BP (2019) MP/6-39 (IC 0623 446; INGR 17065) an advanced potato hybrid (*Solanum tuberosum*) for processing with excellent keeping quality and high tuber yield. *Indian J Plant Genetic Resources*, 32 (2): 272-273

Gupta VK, Luthra SK and Bhardwaj V (2020) Potato breeding for processing. *In:* Potato science and technology for subtropics (AK Singh *et al*., Eds.), New India Publishing Agency, Pitampura, New Delhi-110034, India, pp 75-96 ISBN 978-93-89571-93-6

Gupta VK and Luthra SK (2020a) Potato processing in India: past, present and future. *In*: Proceedings of Global Potato Conclave: Roadmap for Better World, 28-31 January 2020, Gandhinagar, Gujarat, India, p134

Gupta VK, Luthra SK and Singh BP (2015) Storage behaviour and cooking quality of Indian potato varieties. *Journal of food Science and technology* 52 (8): 4863–4873

Nelson N (1944) A photometric adoption of the Somogyi's method for determination of glucose. *J Biological Chemistry* **153**: 375-80

Singh BP, Rana RK and Govindakrishnan PM (2014) Vision-2050. Central Potato Research Institute, Shimla, India

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