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KUFRI FRYOM: A NEW HIGH YIELDING FRENCH FRY POTATO VARIETY

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ABSTRACT: Kufri FryoM is a medium maturing, high yielding main season French fry potato variety suitable for cultivation in North-West and Central Indian plains. It is a clonal selection from a cross between Kufri Chipsona-1 × MP/92-35. It has semi-compact, vigorous, medium-tall plants and produces attractive white cream, oblong tubers with shallow eyes and white flesh. It possesses 20% tuber dry matter content and low reducing sugars (50-90 mg/100 g fresh weight) which results into crispy French fries of very good quality in taste, texture and colour. It produces >80% process grade tuber yield and is capable of yielding 35-40 t/ha under optimum agronomical practices. The new variety Kufri FryoM yields higher than the existing indigenous processing varieties Kufri Frysona and Kufri Chipsona-1. It possesses field resistance to late blight disease and resistance to potato virus Y. The variety has very good keeping quality with over 10 week dormancy period and it can be processed even after 7-8 months of storage with CIPC application at 10-12° C temperature.

KEYWORDS: Kufri FryoM, potato, variety, high yield, French fries, late blight, keeping quality

INTRODUCTION

Frozen French fries are the most popular processed product of potato throughout the world. Frozen prepared or preserved potatoes including French fries amounted to $12.8 billion in global export sales for 2019. Belgium (24.8%), Netherlands (21.9%), USA (14.7%), Canada (11.3%) and France (4.8%) constitute about 75-78% of total export business in the world (Anonymous, 2020). Since 2015, fastest growing exporters of frozen prepared or preserved potatoes are Turkey (526%), India (228%), Poland (61.2%) and Belgium (60%). In India, the domestic demand for processed potato products has also increased considerably during last two decades. Several indigenous and multinational entrepreneurs have established chips, French fries and flakes units in India and new manufacturers are coming up in the field of diversified potato and potato-based products including starch manufacturing. Rising global demand coupled with concerted efforts for development of new indigenous potato varieties for processing and contract farming has transformed India from an importer of French fries to a potential exporter in just over a decade. Among potato based processed products, French fries have higher (>11.6%) annual compound growth rate (ACGR) than other potato based products (Singh *et al*., 2014). Currently, total French fry production in India is around 1, 10,000 tonnes and out of it about 25,000 tonnes are exported to different countries. Existing French fry companies are also doubling their capacities; therefore, in coming time, India is going to be one of the fast-emerging nations

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not only for domestic consumption but also a very competitive exporter for overseas markets (Gupta *et al*., 2020a). To keep pace with rising demand, the development of high yielding new processing potato varieties and their adoption in different agro-ecologies is essential.

Processing of potatoes into French fries requires certain quality attributes and mainly include oblong to long-oval tubers of preferably more than 75 mm size with shallow eyes to yield desirable long sticks of international standard with minimum peeling losses. Tubers need to have 20% or more dry matter with reducing sugars content below 200 mg/100 g fresh tuber weight so as to yield crisp and light coloured French fries (Gupta *et al*., 2020). Presently Kufri Frysona is the only Indian popular variety for making French fries, when grown in northern and central plains. It has medium to late maturity with moderate to high productivity (Singh *et al*., 2010). Although Kufri Frysona is being grown and has been adopted by the processor but there has been a demand of an alternate high yielding variety with a relatively shorter maturity period. Therefore, efforts were directed to meet the above demand and as result a new potato variety Kufri FryoM (MP/4-578) was developed and released in 2020 for North-West and Central Indian plains. Adoption of new potato variety Kufri FryoM by the potato growers will increase their farm productivity and income, thus improving their livelihood besides better sustenance of French fry industry in the country.

MATERIAL AND METHODS

Evaluation and testing of hybrid

Advanced stage hybrid MP/4-578 named as Kufri FryoM originated from hybridization of cross Kufri Chipsona-1 × MP/92-35 attempted in 2004 at Kufri (31° 1'N 77° 3'E; 2501 m above msl) in the mid- hills of Himanchal Pradesh. Seedlings and subsequent clonal generations were raised and evaluated at the Central Potato Research Institute (CPRI), Regional Station, Modipuram, Meerut, UP (29 °4' N and 77° 46' E; 237 above msl) as per procedure described by Luthra *et al*., (2020). The pedigree of Kufri FryoM has been described in **Fig. 1**. The female parent Kufri Chipsona-1 an indigenous processing variety produces white cream ovoid, shallow eyed tubers with cream flesh and possessed resistance to late blight, whereas male parent MP/92-35 an indigenous advanced stage clone produces white-cream ovoid tubers with medium-deep eyes and white-cream flesh.

The clone MP/4-578 was in seedling stage in 2004-05, the five-hill plot in 2005-06, 30 hill plot in 2006-07, multiple-row trial in 2007-08 and in replicated yield trials during 2008-12 at Modipuram. Based on its consistently superior performance over control varieties in yield trials, MP/4-578 was introduced in AICRP in year 2012 for multi-location testing across the country. This advanced stage hybrid had also gone through industrial evaluation and testing during 2012-13. During 2014-18 it was evaluated at 16 locations in three regions i.e. North-Western (4 locations *viz*., Hisar, Jalandhar, Modipuram and Pantnagar), Central (6 locations namely Chhindwara, Deesa, Gwalior, Kanpur, Kota and Raipur) and Eastern plains (6 locations

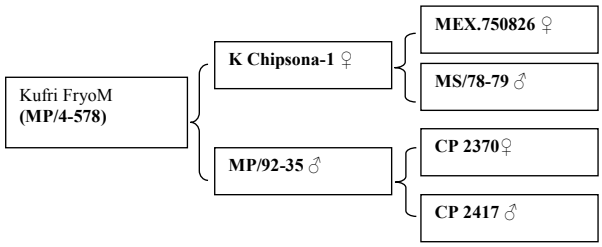


Fig. 1. Pedigree of Kufri FryoM

viz., Bhubaneshwar, Dholi, Faizabad, Jorhat, Kalyani and Patna) in multi-location replicated, on-farm and advanced varietal trails under AICRP.

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 matter content of the sample was estimated when the weight of the sample reached to a constant level.

French fries: For French fry colour score, 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 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. 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 glucose solution (9.00 g/l) after every twenty samples.

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 overall performance, the advanced hybrid MP/4-578 was recommended for release in North Indian plains by '36th AICRP on Potato Group Meeting' held during 08-11 September, 2018 at SDAU, Sardar Krushinar, Gujarat. This hybrid was named as potato variety Kufri FryoM, released and notified by the 'Central Sub-Committee on Crop Standards Notification and Release of Varieties for Horticultural Crops, Ministry of Agriculture and Farmer Welfare, Department of Agriculture and Co-operation, Government of India, New Delhi vide Communication No.3-69/2018-SD/lVdated 28th October, 2020'.

Varietal description

Salient morphological attributes of variety Kufri FryoM are described below for identification purpose.

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

Foliage: Grey green, leaves intermediate, leaf width medium, leaflets ovate lanceolate, leaflet coalescence absent, anthocyanin in rachis and midrib.

Flower: Flowering medium, inflorescence medium, floral stalk green, floral stalk-pedicle articulation clearly visible and located above the middle, calyx green, corolla red-violet, corolla shape pentagonal, anther yellow, anther cone normal, style longer than stamen column and stigma bi-lobed.

Tubers: Tubers (8-10), oblong, skin white-cream, eyes shallow, eyebrows normal, flesh white, texture mealy.

Sprout: Red-purple, cylindrical, pubescence at sprout base weak.

DNA finger printing: Fingerprint of hybrid, MP/04-578 was generated using 2 SSR markers viz., STU and STIKA using genetic analyzer, ABI 3500. The fingerprints are clearly unique and do not match to any of the existing indigenous varieties (**Fig-2**).

RESULTS AND DISCUSSION

Yield performance in primary screening: In replicated trials at Modipuram, during

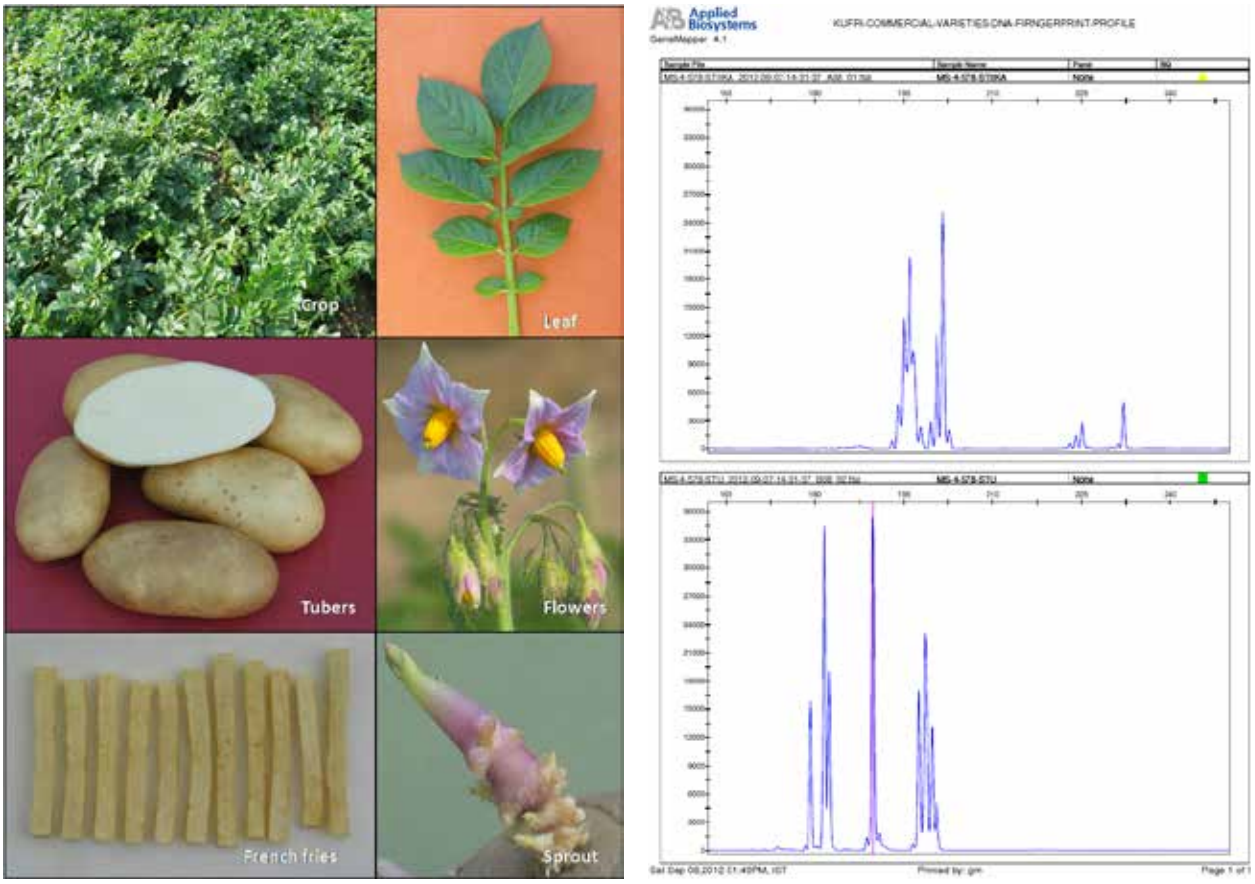


Fig. 2 Morphological features and DNA fingerprint profile of Kufri FryoM

2010-12, MP/4-578 produced higher total tuber yield (38.0 t/ha) as compared to control Kufri Frysona (33.5 t/ha) at 90 days and showed advantage of 14, 14 and 9% higher process, French fry grade and total tuber yields, respectively over control Kufri Frysona (**Table 1**). At Jalandhar, the hybrid had markedly higher process grade tuber yield (30.0 t/ha) than Kufri Frysona (25.3 t/ha) with yield advantage of 18 %, 33% and 11% for process & French fry grade and total tuber yield than Kufri Frysona at 100 days(**Table 2**). Quality parameters were in acceptable range at both the locations.

Yield performance in multi-location AICRP trials

Hybrid MP/4-578 was evaluated for four years at 16 locations (2014-18) across all regions of country, however, hybrid performed well in North-West and Central plains. The results are described below-

First year replicated AICRP trials (2014-15): Hybrid MP/4-578 recorded higher total tuber yield than Kufri Frysona in North-Western (Hisar, Jalandhar, Modipuram, Pantnagar) and Central plains (Deesa, Chhindwara and Raipur). It had significantly higher total tuber yield at Hisar, Deesa and Raipur **(Table 3)**. Mean total tuber yield of MP/4-578 (34.2 t/ha) over different locations of north-western plains and central plains was significantly higher than Kufri Frysona (31.7 t/ha).

Hybrid MP/4-578 also produced higher process grade tuber yield than Kufri Frysona in north-western (Hisar, Jalandhar, Modipuram, Pantnagar) and central plains (Deesa, Chhindwara and Raipur). It had significantly higher total tuber yield at Hisar and Modipuram, Deesa and Raipur **(Table 3)**. Mean process grade tuber yield of hybrid MP/4-578 (25.3 t/ha) over different locations of north-western plains and central plains was significantly higher than Kufri Frysona ((22.2 t/ha). It had acceptable mean tuber dry matter content (19.7%), French fry colour (3.6) and reducing sugars (153.1 mg/100 g fresh weight). **(Table 3 & 4).**

Table 1: Mean yield and quality parameters of MP/4-578 at Modipuram at 90 days (2010-12)

Genotypes	Tuber yield (t/ha)*			PGY (%)	Mean values of processing quality parameters		
	PGY	FFGY	TTY		Tuber dry matter (%)	Glucose (mg/100 g fresh weight)	French fry colour*
MP/04-578	33.9	11.3	38.3	88.3	20.1	32.5	4.8
Kufri Frysona	29.6	10.4	33.5	88.1	22.1	38.0	3.9
% increase over control	14	14	9				

*PGY: Process grade yield; FFGY: French fry grade yield; TTY: Total tuber yield, ** French fry colour score on a scale of 1-10, where up to 4 is acceptable for French fry making

Table 2: Mean yield and quality parameters of MP/04-578 at Jalandhar at 100 days (2010-12)

Genotypes	Tuber yield (t/ha)*			PGY (%)	Processing quality parameters		
	PGY	FFGY	TTY		Tuber dry matter (%)	Reducing sugars (mg/100 g fresh weight)	French fry colour**
MP/04-578	30.0	20.2	37.5	80.1	20.3	75.1	2.1
Kufri Frysona	25.3	15.2	33.8	75.2	21.1	55.5	2.2
% increase over control	18	33	11				

**PGY: Process grade yield; FFGY: French fry grade yield; TTY: Total tuber yield,* **French fry colour score on a scale of 1-10, where up to 4 is acceptable for French fry making

Table 3: Tuber yield and tuber dry matter content of hybrid MP/04-578 in replicated trials in AICRP at 90 days (2014-15)

Region	Location	Total tuber yield (t/ha)		Process grade tuber yield (t/ha)		Tuber dry matter content (%)	
		MP/4-578	Kufri Frysona	MP/4-578	Kufri Frysona	MP/4-578	Kufri Frysona
North-western plains	Hisar	30.1	26.0	24.0	21.5	19.0	18.3
	Jalandhar	35.8	34.7	22.0	21.2	20.5	21.7
	Modipuram	34.4	33.6	27.5	24.5	19.0	21.9
	Pantnagar	30.2	30.0	26.0	25.9	20.2	19.1
Central plains	Deesa	39.7	36.7	32.9	25.6	19.6	21.5
	Chhindwara	43.7	42.5	30.6	29.6	18.7	19.5
	Raipur	25.6	18.6	14.2	7.4	20.8	21.0
	Mean	34.2	31.7	25.3	22.2	19.7	20.4
% increase over controls			7.8		13.8		
	CD 0.05	Variety:0.96	Variety × location: 2.90	Variety: 0.85	Variety × location: 2.67	Variety: 0.29	Variety × locations: 0.93

Table 4: French fry colour score and reducing sugars of hybrid MP/04-578 in replicated trials in AICRP at 90 Days (2014-15)

Location	French fry colour		Reducing sugars (mg/100 g FW)	
	MP/4-578	Kufri Frysona	MP/4-578	Kufri Frysona
Hisar	3.5	4.5	154.7	148.9
Modipuram	4.5	4.4	199.5	169.5
Deesa	2.9	3.0	105.1	111.6
Mean	3.6	4.0	153.1	143.3

**French fry colour score on a scale of 1-10, where up to 4 is acceptable for French fry making

First year on-farm AICRP trial (2015-16): Hybrid MP/4-578 produced a higher total tuber yield than Kufri Frysona at Hisar, Modipuram and Chhindwara **(Table 5).** In north-western plains and central plains, hybrid MP/4-578 had comparable mean total tuber yield (25.2 t/ha) as compared to Kufri Frysona (26.4 t/ha). However, it attained higher process grade tuber yield than Kufri Frysona at Modipuram (north-western plains), and Deesa and Chhindwara (central plains). Mean process grade tuber yield of hybrid MP/4-578

Table 5: Tuber yield and tuber dry matter content of MP/04-578 in AICRP trials at 90 days (2015-16)

Region	Location	Total tuber yield (t/ha)		Process grade tuber yield (t/ha)		Tuber dry matter content (%)	
		MP/4-578	Kufri Frysona	MP/4-578	Kufri Frysona	MP/4-578	Kufri Frysona
North-western plains	Hisar	26.5	25.8	21.4	22.2	18.6	19.3
	Modipuram	32.1	27.5	25.6	20.7	19.1	20.7
Central plains	Deesa	31.2	40.6	18.7	18.1	22.0	22.8
	Chhindwara	29.2	25.8	20.4	18.0	18.8	18.9
	Raipur	18.3	22.7	7.4	10.6	21.8	21.6
	Kota	14.1	15.7	12.0	14.3	24.5	20.0
	Mean	25.2	26.4	18.8	18.4	20.8	20.6
% Yield increase		-	-	-	-	-	-
	CD 0.05		NS		NS		NS

(18.8 t/ha) over different locations of north-western and central plains was higher than Kufri Frysona (18.4 t/ha). Hybrid MP/4-578 (**Table 5 & 6**) recorded acceptable mean tuber dry matter content (20.8%), French fry colour (3.5) and reducing sugars (144.6 mg/100 g fresh weight).

Second year on-farm AICRP trial (2016-17): Hybrid MP/4-578 produced significantly higher total tuber yield **(Table 7)** than Kufri Frysona at Hisar, Modipuram and Pantnagar (north-western plains) and at Kanpur, Chhindwara and Gwalior (central plains). Mean total tuber yield of the hybrid (35.6 t/ha) over different locations of north-western and central plains was significantly higher than control Kufri Frysona (31.6 t/ha). Hybrid MP/4-578 also had significantly higher process grade tuber yield than Kufri Frysona at Hisar, Modipuram and Pantnagar (north-western plains) and at Kanpur and Chhindwara (central plains). Mean process grade tuber yield of the hybrid (30.3 t/ha) over different locations of north-western and central plains was higher than Kufri Frysona (26.1 t/ha). Hybrid MP/4-578 recorded acceptable mean tuber dry matter content (19.4%), French fry colour score (2.9) and reducing sugars (144.5 mg/100 g fresh weight) **(Table 7 & 8)** in multi-location trials.

Advanced varietal AICRP trials (2017-18): In north-western plains, hybrid MP/4-578 had significantly higher (9%) mean total tuber yield (39.4 t/ha) than Kufri Frysona (35.2 t/ha). It recorded significantly higher total tuber yield at Hisar, while statistically at par yield at Modipuram and Pantnagar **(Table 9)**. Hybrid MP/4-578 also produced significantly higher (21%) mean process grade tuber yield than Kufri Frysona. It attained significantly higher process grade

Table 6: Processing quality attributes of MP/04-578 in AICRP trials at 90 days (2015-16)

Location	French fry colour *		Reducing sugars	
	MP/4-578	Kufri Frysona	MP/4-578	Kufri Frysona
Chhindwara	3.5	5.0	174.3	160.8
Gwalior	2.0	2.3	91.2	79.4
Modipuram	5.0	4.8	168.4	145.7
Mean	3.5	4.0	144.6	128.6

*French fry colour score on a scale of 1-10, where up to 4 is acceptable for French fry making

Table 7: Tuber yield and tuber dry matter content of MP/04-578 in AICRP trials at 90 days (2016-17)

Region	Location	Total tuber yield (t/ha)		Process grade tuber yield (t/ha)		Tuber dry matter content (%)	
		MP/4-578	Kufri Frysona	MP/4-578	Kufri Frysona	MP/4-578	Kufri Frysona
North-western plains	Hisar	39.8	34.3	36.2	30.2	20.0	21.0
	Modipuram	39.2	34.5	31.2	23.4	18.0	18.8
	Pantnagar	31.2	26.4	30.7	25.8	17.3	16.4
Central plains	Kanpur	30.7	27.6	27.5	24.6	20.0	21.0
	Chhindwara	34.5	30.8	32.5	29.2	18.7	18.6
	Gwalior	38.2	36.2	23.7	23.1	22.3	20.1
	Mean	35.6	31.6	30.3	26.1	19.4	19.3
% Yield increase			12.5		16.3		
CD 0.05			1.37		1.52		1.52

Table 8: Processing quality attributes of MP/04-578 in AICRP trials at 90 days (2016-17)

Region	Location	French fry colour		Reducing sugars	
		MP/4-578	Kufri Frysona	MP/4-578	Kufri Frysona
North-western plains	Hisar	2.0	4.5	112.4	148.9
	Modipuram	2.4	4.8	120.9	109.7
	Pantnagar	3.3	2.3	-	-
Central plains	Chhindwara	3.4	3.6	-	-
	Gwalior	2.3	2.8	108.5	120.7
	Kanpur	4.0	2.5	236.2	110.4
Mean		2.9	3.4	144.5	122.4

Table 9: Tuber yield of MP/04-578 in AICRP trials at 90 days (2017-18)

Region	Location	Total tuber yield (t/ha)			Process grade tuber yield (t/ha)		
		MP/4-578	Kufri Chipsona-1	Kufri Frysona	MP/4-578	Kufri Chipsona-1	Kufri Frysona
North-western plains	Hisar	38.9	28.7	30.8	35.0	25.5	27.6
	Jalandhar	29.5	32.0	31.3	12.8	13.6	13.6
	Modipuram	49.7	44.8	46.4	26.7	21.4	20.5
	Mean	39.4	35.2	36.2	24.8	20.2	20.6
	% Yield increase		12.0	8.8		23.0	20.8
	CD 0.05	Variety: 2.6; Location × Variety: 4.51			Variety: 2.49; Location × Variety: 4.32		
Central plains	Chhindwara	42.4	36.9	41.2	31.8	27.7	30.9
	Deesa	34.1	34.4	39.2	25.1	14.9	22.0
	Gwalior	29.6	26.1	29.7	24.4	19.9	23.5
	Kanpur	35.8	32.8	25.5	19.2	26.4	18.7
	Kota	23.5	20.8	17.7	21.3	18.8	15.8
	Raipur	20.3	11.4	15.3	19.7	12.0	14.5
	Mean	31.0	27.1	28.1	23.6	20.0	20.9
	%Yield increase		14.3	10.3		18.2	12.9
	CD 0.05	Variety: 1.53; Location × Variety: 3.75			Variety: 1.08; Location × Variety: 2.65		

tuber yield at Hisar and Modipuram and comparable yield at Pantnagar. The hybrid possessed acceptable mean tuber dry matter content (20.8%), French fry colour score (3.1) and reducing sugars (165.2 mg/100 g fresh tuber weight) in this region **(Table 9 & 10)**.

In central plains, hybrid MP/4-578 recorded significantly (10%) higher mean total tuber yield (31.0 t/ha) over control Kufri Frysona (28.0 t/ha). It had significantly higher total tuber yield at Kanpur, Kota and Raipur, while remaining at par at Chhindwara and Gwalior **(Table 9)**. It also produced significantly higher (13%) mean process grade tuber yield (24.0 t/ha) over Kufri Frysona (21.0 t/ha). Significantly higher process grade tuber yield was observed at Deesa, Kota and Raipur, whereas it was at par at Chhindwara, Gwalior and Kanpur. Hybrid MP/4-578 had acceptable mean tuber dry matter content (20.7%), French fry colour score (2.5) and reducing sugars (114.2 mg/ per 100 g fresh weight) in this zone **(Table 9 &11)**.

Table 10: Processing quality attributes of MP/04-578 at 90 days in North- western plains (2017-18)

Genotypes	HIS*	JAL*	MDP*	Mean
	Tuber dry matter content (%)			
MP/4-578	20.08	22.38	20.07	20.84
Kufri Chipsona-1	20.20	24.00	21.07	21.75
Kufri Frysona	19.97	23.38	21.70	21.68
Mean	20.13	23.17	20.74	
CD 0.05	Location=0.45; Genotype =0.52; Location × Genotype= 0.89			
	French fry colour score			
MP/4-578	3.0	2.4	4.0	3.1
Kufri Chipsona-1	1.0	1.6	3.4	2.0
Kufri Frysona	3.2	2.2	4.8	3.4
Mean	2.4	2.1	4.1	
	Reducing sugars (mg/100g Fresh weight)			
MP/4-578	112.0	232.7	151.0	165.2
Kufri Chipsona-1	130.0	98.3	117.0	115.1
Kufri Frysona	134.0	297.3	148.0	193.1
Mean	125.3	209.4	138.7	

*HIS: Hisar, JAL: Jalandhar, MDP: Modipuram

Table 11: Processing quality attributes of MP/04-578 in Central plains (2017-18)

Genotypes	CHN*	DES*	GWL*	KAN*	KTT*	RPR*	Mean
		Tuber dry matter content (%)					
MP/4-578	18.75	19.33	21.93	21.38	22.18	20.68	20.71
Kufri Chipsona-1	18.08	19.40	22.34	20.50	21.80	19.83	20.32
Kufri Frysona	19.15	21.87	23.35	22.23	21.68	19.71	21.33
Mean	18.54	20.83	22.62	20.87	21.96	20.60	
CD 0.05		Location= 0.67; Genotype = 0.55; Location × Genotype= 1.35					
		French fry colour score					
Hybrid/ Variety	CHN*	DES	GWL	KAN			Mean
MP/4-578	1.0	2.4	1.5	5.2			2.5
Kufri Chipsona-1	1.1	1.4	1.4	3.0			1.7
Kufri Frysona	1.0	3.0	2.0	4.0			2.5
Mean	1.0	2.3	1.6	4.1			
		Reducing sugars mg/100g Fresh weight					
MP/4-578	97.7	134.3	84.3	140.3			114.2
Kufri Chipsona-1	70.3	89.9	89.1	120.1			92.4
Kufri Frysona	73.2	108.1	128.5	120.0			107.5
Mean	80.4	110.8	100.6	126.8			

*CHN: Chhindwara, DES: Deesa, GWL: Gwalior, KAN: Kanpur, KTT: Kota and RPR: Raipur

Foliage senescence (%): During 2014-18, hybrid MP/04-578 had higher mean overall foliage senescence (80%) at 90 days at all the locations and crop seasons in comparison to control Kufri Frysona, which had 72% mean foliage senescence (**Table 12**).

Pooled performance of MP/4-578 in AICRP trials:

In north-western plains, hybrid MP/4-578 yielded 10 and 15% higher total and process grade tuber yield (34.5 and 26.5 t/ha) over the control Kufri Frysona (31.4 and 23.0 t/ha), respectively at 90 days **(Table 13)**. The hybrid had acceptable mean tuber dry matter content (20%), French fry colour score (3.7) and reducing sugars (156 mg/100 g fresh weight).

In central plains, Hybrid MP/4-578 yielded 6 and 11% higher total and process grade tuber yield (31.3 and 23.0 t/ha) than Kufri Frysona (26.6 and 20.7 t/ha), respectively at 90 days **(Table 13)**. The hybrid recorded acceptable mean tuber dry matter content (21.0 %), French fry colour score (2.9) and reducing sugars (128 mg/100 g fresh weight)

Overall mean performance in AICRP: Mean values of north-west and central plains revealed that hybrid, MP/4-578 yielded 8 and 13% higher total and process grade tuber yield (32.9 and 24.8 t/ha) as compare to control Kufri Frysona (30.5 and 21.9 t/ha) at 90 days **(Table 13)**. It had acceptable mean tuber dry matter content (20.1%), French fry colour score (3.3) and reducing sugars (142 mg/100 g fresh weight). This hybrid possessed very good storability under ambient storage owing to a longer dormancy period (>6 weeks), lesser rotting, physiological weight loss and total weight loss (11.5%) at 75 days after storage (**Table 13**).

STORAGE BEHAVIOUR

Hybrid MP/04-578 exhibited better keeping quality as compared to control Kufri Frysona during storage at room temperature (**Table 14**). The hybrid was also found suitable for French fry making even after 8 months of long-term storage at 10-12°C with CIPC fogging (**Table 15**).

Industrial Testing

Hybrid MP/4-578 was developed primarily for its use in processing by the French fry industries; therefore, it was evaluated and tested at McCain Foods, Mehsana (Gujarat), Fresh-O-Veg, Indore (Madhya Pradesh) and at Pepsico India Pvt Ltd, Burdwan (West Bengal) during 2012-13. Mean performance (**Table 16**) in processing industry evaluation indicated 20, 23 and 12% superiority of MP/4-578 in process grade, French fry grade and total yield, respectively (40.5, 32.2, 45.4 t/ha) over the control variety K. Frysona (33.6, 26.1, 40.5 t/ha). MP/4-578 has shown ability to produce 90% process grade tubers as compared to

Table 12: Foliage senescence (%) of MP/04-578 at 90 days (2014-15 to 2017-18)

Location	MP/4-578	Kufri Frysona	MP/4-578	Kufri Frysona	MP/4-578	Kufri Frysona
	2014-15		2016-17		2017-18	
Modipuram	60.0	52.6	66.0	50.0	67.0	53.3
Chhindwara	91.3	90.3	83.8	81.5	84.5	83.5
Deesa	100.0	40.0	-	-	72.6	67.6
Kota	-	-	76.0	77.0	81.0	82.0
Raipur	92.0	93.0	90.0	90.0	-	-
Mean	85.8	69.0	79.0	74.6	76.3	71.6

Table 13: Pooled performance of MP/04-578 in AICRP trials at 90 days (pooled over locations*)

Year	MP/4-578					Kufri Frysona				
	North-western plains (HIS, JAL, MOD, PNT)*									
	TTY	PGY	DM%	FFC	RS	TTY	PGY	DM	FFC	RS
2014-15	32.6	24.9	19.7	4.0	177.1	31.1	23.3	20.3	4.5	159.2
2015-16	29.3	23.5	18.9	5.0	168.4	26.7	21.5	20.0	4.8	145.7
2016-17	36.7	32.7	18.4	2.5	114.8	31.7	26.5	18.7	3.4	129.3
2017-18	39.4	24.8	20.8	3.1	165.2	36.2	20.6	21.7	3.4	193.1
Mean	34.5	26.5	19.5	3.7	156.4	31.4	23.0	20.2	4.0	156.8
% yield increase						10				
	Central plains (CHN, DES, GWL, KAN, RPR, KTT)*									
2014-15	36.3	25.9	19.7	2.9	105.0	32.6	20.9	20.7	3.0	112.0
2015-16	23.2	14.6	21.8	2.8	132.8	26.2	15.3	20.8	3.7	120.1
2016-17	34.5	27.9	20.3	3.3	160.2	31.5	25.6	19.9	3.7	142.1
2017-18	31.0	23.6	20.7	2.5	114.2	28.1	20.9	21.3	2.5	107.5
Mean	31.3	23.0	20.6	2.9	128.1	29.6	20.7	20.7	3.2	120.4
% yield increase						6	11			
	Pooled over north-west and central plains									
2014-15	34.5	25.4	19.7	3.5	141.1	31.9	22.1	20.5	3.8	135.6
2015-16	26.3	19.1	20.4	3.9	150.6	26.5	18.4	20.4	4.3	132.9
2016-17	35.6	30.3	19.4	2.9	137.5	31.6	26.1	19.3	3.6	135.7
2017-18	35.2	24.2	20.8	2.8	139.7	32.2	20.8	21.5	3.0	150.3
Mean	32.9	24.8	20.1	3.3	142.3	30.5	21.9	20.5	3.6	138.6
% yield increase						8	13			

*HIS-Hisar, JAL-Jalandhar, MOD-Modipuram, PNT-Pantnagar, CHN-Chhindwara, DES-Deesa, GWL-Gwalior, KAN-Kanpur, KTT-Kota, RPR-Raipur
TTY: Total tuber yield/ha, PGY: Process grade tuber yield/ha, DM: Tuber dry mater content (%), FFC: French fry colour score, RS: Reducing sugars mg/100g fresh weight of potato

Table 14: Storage behaviour of MP/04-578 under ambient conditions at Modipuram (2010-11 to 2017-18)

Genotypes	Dormancy	% sprouting		Weight loss in sprouting (%)	Rottage (%)	Physiological weight loss (%)	Total weight loss (%)
		45 days	75 days				
MP/04-578	> 6 weeks	50.6	62.0	0.1	0.2	10.8	11.0
Kufri Frysona	> 6 weeks	34.9	50.8	0.1	0.6	13.4	14.1

Table 15: Performance of MP/04-578 under CIPC long term storage at McCain Foods, Mahesana, Gujarat (2012-13)

Sample Date	Genotypes	USDA Fry Color					Sugar End	Fry Index	Avg. Index	Sugar End
		0	1	2	3	4				
15-06-13	MP/04-578	12	7	1	0	0	0	1.5	-	-
15-06-13	Kufri Frysona	16	2	1	1	0	0	1.4	-	-
22-08-13	MP/04-578	17	3	0	0	0	0	1.2	-	-
22-08-13	Kufri Frysona	19	1	0	0	0	0	1.1	-	-
14-11-13	MP/04-578	19	0	1	0	0	1	1.1	-	-
14-11-13	Kufri Frysona	12	7	1	0	0	0	1.5	1.3	0.5

Table 16: Performance of MP/04-578 in trials with processing industry

Genotypes	Yield (t/ha)*			% PGY	Fry colour (Visual)	Fry colour (USDA)	DM (%)*
	PGY	FFGY	TTY				
McCain Foods, Mehsana, Gujarat (100 days)							
MP/4-578	52.1	38.0	57.6	90.5	1.5	0	20.60
K Frysona	42.4	30.8	50.6	83.9	1.5	0	21.30
CD 0.05	2.5	2.3	2.7				
% Yield increase	23	23	14	8			
Fresh-O-Veg, Indore, Madhya Pradesh (100 days)							
MP/4-578	30.1		32.0	93.9	1.5		22.0
K Frysona	24.3		27.0	90.2	1.8		22.2
CD 0.05	3.0		2.8				
% Yield increase	24		19				
Pepsico India Pvt Ltd, Burdwan, West Bengal (95 days)							
MP/4-578	39.2	26.3	46.5	84.4	2.0		21.1
K Frysona	34.1	21.4	44.0	77.6	2.5		22.8
CD 0.05	2.7	1.9	2.8				
% Yield increase	15	23	6	9			
Mean performance with processing industry (2012-13)							
MP/4-578	40.5	32.2	45.4	89.6	1.7	0.0	21.2
K Frysona	33.6	26.1	40.5	83.9	1.9	0.0	22.1
% Yield increase	20.4	23.2	11.9				
Additional traits at Pepsico India Pvt Ltd, Burdwan, West Bengal (95 days)							
Genotypes	Gross solid (%)	GCD*	DB*	UC*	ID*	ED*	TPoD*
MP/4-578	21.07	0	0	1	1.5	3	5.5
K Frysona	22.77	0	0	0	6.5	5	11.5

*PGY: Process grade yield, FFGY: French fry grade yield, TTY: Total tuber yield, DM: Tuber dry matter content, GCD: Gross Color Defects; DB: Dried Bruise; UC: undesirable Color; ID: Internal Defects; ED: External Defects; TPoD: Total Potato Defects.

Kufri Frysona (84%). The hybrid possessed >21% tuber dry matter, 1.5 French fry colour score and other quality traits comparable to control Kufri Frysona. French fries made from French fry grade tubers of hybrid MP/4-578 were excellent and met the standards of all required quality traits.

Disease resistance

Late blight: Hybrid, MP/04-578 was evaluated for two years under natural epiphytotic conditions at Kufri for late blight resistance. The plant foliage was found to be field resistant (AUDPC 158) to all races of late blight (*Phytophthora infestans*) compared to best control Kufri Chipsona-1 (AUDPC 213) and other indigenous and exotic processing controls

Potato Virus Y: Potato Virus Y (PVY, Potyvirus) is the most damaging potato virus that causes severe yield reduction up to 80% alone or in combination of other viruses. Breeding PVY resistant cultivars through introgression of resistance (Ry) gene is the best strategy to overcome this problem. The Ry_{adg} gene derived from *Solanum tuberosum*

ssp *andigena* provides extreme resistance to PVY. The hybrid possesses, Ry_{adg} gene (**Fig 3**) which imparts durable resistance against Potato Virus Y (PVY).



Fig. 3: Presence of R_{yadg}gene (320bp) in hybrid, MP/04-578 (Lane 7)

Agronomic management

Optimum tuber yield of hybrid MP/4-578 could be obtained by adopting a standard agronomical schedule for medium maturing varieties. In north-western and central plains, it could be planted as main crop during 15 October to 5 November when maximum day time temperature falls around 32°C by adopting recommended seed rate of 3.5-4.0 t/ha consisting seed size tubers (40-60 g). This hybrid requires more space, so plant spaced at 20-25 cm in 66 cm rows had optimum tuber size distribution for production of maximum proportion of French fry and process grade tubers. As far as nutrient management is concerned, generally 135 N-40 P_2O_5-100 K_2O kg/ha should be band placed at the time of planting and remaining half dose of 135 kg N/ha should be applied 20-25 days after planting at earthing-up. At Modipuram, nitrogen, phosphorous and potassium levels of 270, 40 and 100 kg/ha, respectively were found optimum for the production of maximum proportion of French fry grade tubers. Nutrient management in other agro-ecologies may differ and thus needs to be fine-tuned. Otherwise, regional recommendations may be followed for optimum productivity of this hybrid. Inter-culture and earthing-up operation is recommended to provide aeration in root zone, improving nitrogen use and controlling second flush of weeds. This is done after 22-25 days of planting when the crop is 8-12 cm in height. Cartap hydrochloride 4G @ 20 kg/ha should be applied during earthing-up for management of cutworms, white grubs, beetles and leaf-eating caterpillars. It will also take care of sucking pest like leafhopper and aphids. In case of seed crop, yellow sticky traps (15 × 30 cm^2 size) may be placed 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 l water) for 10 minutes before planting should be adopted. First spray of imidacloprid (200SL) @ 0.03% (3 ml/10 l water) should be done at 85% of crop emergence. Second spray of thiamethoxam (25 WG) @ 0.05% (5 gm/10 l water) should be carried out 10-15 days after the first spray. Integrated management schedule should be adopted for late blight. Prophylactic spray just at the time of canopy closure should be given with mancozeb or propineb or chlorothalonil @ 0.2% (2 g/l of water). If disease appears then need based application of cymoxanil + mancozeb or dimethomorph + mancozeb or fenamidone + mancozeb @ 0.3% (3 g/l of water) is followed for effective management of late blight. Irrigation is stopped 12-15 days before haulm killing. Crop is harvested 12-15 days after haulm cutting. It is left in the field for 2-3 hours for air drying. Tubers are kept in heaps (1.5m height) for 10-15 days in shade for skin curing. For seed, treatment is done after harvest of seed crop and before cold storage. Seed tubers are washed in clean water and treated with 3% boric acid for 25-30 minutes. Afterwards, tubers are dried in shaded place before storage. Solution once prepared can be used for 20 times dipping. This is effective in management of black scurf and common scab.

Adaptability

Hybrid MP/4-578 named as cv. Kufri FryoM has been recommended for Punjab, Haryana and western Uttar Pradesh (north-western plains), and Madhya Pradesh, Chhattisgarh, Gujarat and Rajasthan (central plains). This variety can provide raw material for processing industry a longer period and can be an apt choice for making French Fries due to its higher yield in shorter growing period, field resistance to late blight, acceptable quality traits, attractive oblong tubers, long tuber dormancy and better shelf life under CIPC storage.

Usage

The new potato variety Kufri FryoM is suitable for the production of raw material for processing into crispy French fries. Variety Kufri FryoM is likely to be preferred by the processors for its white oblong tubers, white flesh, shallow eyes, pleasant flavour, mealy texture and expected lower peeling losses.

CONCLUSION

Kufri FryoM (MP/4-578) has performed well in multi-location trials conducted under AICRP on potato in north and central Indian plains. Therefore, it can be grown successfully for increasing productivity and diversified utilization of potatoes for making French fries in these areas. Kufri FryoM can provide one more alternative genotype to fast-growing processing industry and the potato farmers with white-cream skin oblong tubers, shallow eyes, white flesh, excellent keeping and culinary quality with field resistance to late blight and tolerance to potato virus Y in addition to higher process grade and total tuber yields in comparatively shorter duration.

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