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Fertilizer management of potato *(Solanum tuberosum)* variety *Kufri Frysona* for higher yield, good fry quality, profitability and storability

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Abstract

The field experiment was conducted at Modipuram (India) in split-plot design having three potato varieties in main plot and four fertilizer management treatments in sub-plot with three replications. Fertilizer management treatments did not influence the growth parameters as well as graded tuber number except French fry grade (FFG), which was maximum at 270 N+80 P_2O_5+150 K_2O kg/ha. French fry grade tuber numbers were statistically similar between *Kufri Surya* and *Kufri Frysona* but lower in *Kufri Chipsona-1*. Over varieties, different fertilizer management treatments did not show any significant change in tuber yield recorded under different size categories. Among varieties, FFG tuber yield were at par between *Kufri Frysona* (13.7 t/ha) and *Kufri Surya* (15.6 t/ha) but significantly higher than *Kufri Chipsona-1* (8.8 t/ha). Across potato varieties, tuber specific gravity was recorded significantly higher in treatment F_1 (1.083) than F_3 (1.081) and F_4 (1.081), where N and K rates was higher by 25%; other processing quality traits *viz*. tuber dry matter content, French fry colour and glucose content did not vary significantly due to different fertilizer management treatments. *Kufri Frysona* recorded maximum tuber specific gravity (1.087) and dry matter content (23.8%) which was significantly higher than *Kufri Chipsona-1* and *Kufri Surya*. During long-term storage, the fry colour was in acceptable range in F_1 and F_3 treatment for *Kufri Frysona* at all dates of storage (upto 165 days). The glucose levels were less than 35 mg/100 g fresh weight in all the fertilizer management treatments and after all the dates of storage for *Kufri Frysona*. Across varieties, net income and benefit cost ratio were statistically higher under fertility regime F_1 (270 N+ 80 P_2O_5 + 150 K_2O kg/ha, where all NPK was applied through soil application). Among varieties, *Kufri Frysona* had highest net returns as well as B:C followed by *Kufri Chipsona-1* and lowest in *Kufri Surya*. To realize higher French fry grade tuber yield, maximum profits and acceptable fry quality at harvest and during long-term storage the newly developed French fry variety *Kufri Frysona* may be grown with fertilizer dose of 270 N [N135 (planting) + N135 (earthing)] + 80 P_2O_5 + 150 K_2O kg/ha as soil application.

Key words: *Kufri Frysona*, potato, fertilizer management, french fry grade, fry colour, glucose content, net returns, storage

Processing of potatoes is gaining momentum at faster pace in India since last decade (Pandey and Sarkar 2005) because of development of processing varieties, and standardization of their production and storage technologies (Kumar *et al.*, 2011). Chips and French fries are two of the major processed products of potatoes in India. Unlike the popularity of chips among children

and teenagers, freshly fried French fries are most common convenient food of people of all age groups. Huge growth potential in the French fries sector from 0.06 million tons during 2010 to 0.35 million tons in 2025 and 5.4 million tons in 2050 (Singh *et al.*, 2014) attracted some Indian companies to undertake French fry production venture, but soon they felt handicapped due to non-availability of sufficient quantities of good size French fry quality potatoes. Processing of potatoes into French fry requires certain minimum quality attributes that include oblong to long tubers (preferably more than 75 mm size) with shallow eyes, low peeling losses, low glucose content (< 35 mg/100 g fresh tuber weight) and more than 20% tuber dry matter for crispy and light colored French fries (Marwaha, 1997; Gould, 1999). The industry was using Kufri Chipsona-1 and Kufri Surya as raw material from Indian potato varieties in absence of suitable specialized variety for French fries (Singh *et al.*, 2010). The variety *Kufri Chipsona-1* suffers from lower percentage of French fry grade tubers and tubers of *Kufri Surya* have relatively lower solids content. Taking cognizance of raw material paucity by French fry industry, Central Potato Research Institute, Shimla (HP) developed the variety *Kufri Frysona* having higher percentage of French fry grade tubers and superior processing quality (Singh *et al.*, 2010). However, besides the cultivar, French fry grades as well as total tuber yield are influenced by cultural management and environmental factors. The nutrients N and K have been implicated in the tuber bulking and thus can play an important role in manipulating tuber size. N management especially rate and time of application affect the crop growth period and tuber size distribution (Morena *et al.*, 1994). Already the fertilizer dose of 270 N+80 P_2O_5 + 150 K_2O kg/ha has been found suitable to get maximum chip grade tuber yield (> 45 mm) in Chipsona varieties (Kumar *et al.*, 2007a, 2007b). Since the tuber size requirement is bigger in case of potatoes destined for French fries making *vis-a-vis* chipping potatoes and, secondly it was observed that the crop growth period was relatively longer in *Kufri Frysona* (>110 days) as compared to other Indian processing varieties. Thus, fertilizer management (especially N and K) can be explored as one of the strategies to increase the FFG tuber yield. Therefore this experiment was conducted to study the higher doses of N & K (over and above the already standardized dose of 270 N: 80 P_2O_5:150 K_2O kg/ha for chipping varieties) on French fry grade tuber yield of *Kufri Frysona*. The varieties *Kufri Chipsona-1* and *Kufri Surya* were also included as control varieties to generate the academic information on the influence of higher doses of N & K on French fry quality at harvest and during storage.

Materials and Methods

The field experiment was conducted on sandy loam soil (Typic Ustochrept) during 2008-2010 at Central Potato Research Institute Campus, Modipuram, India (29° 4' N, 77° 46' E, 237 m above mean sea level) in a split-plot design with three replications. The main plot treatments consisted of three potato varieties with long tubers (*Kufri Frysona, Kufri Chipsona-1* and *Kufri Surya*), while sub-plot consisted of four fertilizer management treatments (F_1 = 270 N [N_{135} (planting) + N_{135} (earthing)] + 80 P_2O_5 + 150 K_2O kg/ha, recommended dose for *Kufri Chipsona-1*, soil application; F_2 = 270 N [N_{126} (planting) + N_{126} (earthing) + 2 foliar spray (2% urea) at 60 and 80 days after planting] + 80 P_2O_5 + 150 K_2O kg/ha, soil and foliar application; F_3 = 338 N [N_{169} (planting) + N_{169} (earthing)] + 80 P_2O_5 + 188 K_2O kg/ha, 25% higher N and K, soil application; F_4 = 338 N [N_{160} (planting) + N_{160} (earthing) + 2 foliar spray (2 % urea) at 60 and 80 days after planting] + 80 P_2O_5 + 188 K_2O kg/ha, 25% higher N and K, soil and foliar application). The inter-row spacing was kept 67.5 cm with intra-row spacing of 25 cm. Chemical analysis of the soil (0-15 cm) showed neutral pH (7.05), low organic carbon content (0.31%) and low alkaline $KMnO_4$-N (157.4 kg/ha), high Olsen's (0.5 M $NaHCO_3$ extractable) P (55.6 kg/ha) and medium 1 N ammonium acetate extractable K (146.8 kg/ha). Half N (as per treatment), full P and full K (as per treatment) were applied at the time of planting as band placement. The remaining half N (as per treatment) was applied in soil at the time of earthing up (25 days after planting) as band placement. In two treatments (F_2 and F_4), foliar spray of urea (2%) was also done at 60 and

80 days after planting (DAP) with the view to extend the maturity period to have higher French fry grade tuber number and yield. Nitrogen was applied through calcium ammonium nitrate at the time of planting and through urea at hilling. Phosphorus and potash were applied through diammonium phosphate and muriate of potash, respectively. The experimental crop was planted on 22 and 24th October during 2008 and 2009, respectively. Well-sprouted seed tubers (50-60 g seed weight, about 40-45 mm seed size) were planted in plots of 4.05×4 m size. The experimental crop was raised under assured irrigation using the furrow method. The plant stand was monitored up to 30 days; whereas observations on growth parameters, such as plant height, stem number and compound leaf number were recorded from five randomly selected potato plants from each plot at 50 DAP. Leaf area index (LAI) was also recorded with the help of Ceptometer (AccuPAR model LP-80) at 50 DAP. Dehaulming was done manually at 120 DAP and harvesting was done two weeks later after skin setting. Total, French fry grade (> 75 mm), chip grade (45-75 mm) and small (< 45 mm) tuber number and yield were recorded at harvest from the whole produce of the plot. To estimate tuber dry matter content five French fry grade tubers from each plot were chopped in fine pieces and 50 g sample was oven dried at 80°C till constant weight was achieved (Kumar *et al.*, 2007a). Tuber specific gravity was measured by the Hydrometer method by taking 3.632 kg of French fry grade potato tubers from each plot (Gould, 1999). The price of the French fry grade and chip grade potato tubers of processing varieties *Kufri Frysona* and *Kufri Chipsona-1* were taken as Rs. 6000 and Rs. 5000/t, respectively (price paid by the processors to their contract growers during those years). While in case of *Kufri Surya* price of Rs. 4000/t was taken for French fry as well as chip grade (market price during those years) since the quality of potatoes with respect to dry matter or specific gravity was not suitable for French fry making. Price of Rs. 3000/t was taken for small potato tubers of all varieties tested in the study (the prevailing market price), for calculating the economic variables.

At harvest five French fry size tubers were selected randomly from each plot and used for determining French fry colour score. Potato fries were prepared at laboratory scale which involved peeling of tubers in abrasive peeler, cutting into 1×1 cm thick French fries using manual French fry cutter, washing and drying on paper towel. Dried fries were then fried in refined sunflower oil in a thermostatically controlled deep fat fryer at 180 °C till 5 min. Fries were evaluated for fry colour on a scale of 1-10, subjectively with the help of colour cards (Ezekiel *et al.*, 2003), where scale 1 represents white fries, free from any browning and of highly acceptable colour while 10 is brown and unacceptable colour. The fries with colour range of 1 to 3 were considered acceptable. The glucose content in potato tubers was quantified using YSI Biochemistry analyzer as described by Sowokinos (1978). Data of each character collected from the experiments were statistically analyzed using standard procedures of variance analysis with the help of statistical software IRRISTAT (IRRI, 1999).

After proper curing 75 French fry grade tubers from each treatment as composite pooled sample (25 tuber/replication) were kept in plastic trays in cold chamber at 10-12°C for long term storage study. The fogging of the sprout suppressant CIPC was done to check the sprouting in tubers. Nine tubers were drawn at periodical interval and were analyzed for fry colour (3 without blanching and 3 with blanching) and 3 for glucose estimation. Blanching was done as per standard protocol of the French fry industry where French fries are dipped in hot water (72°C) for 10 minutes, then frozen at –20°C for one week and par fried of 1 minute. Final frying was done for 2.5 minutes.

Results and Discussion

Plant emergence and growth

Different fertilizer management treatments failed to produce significant variation for final emergence count as well as among all the growth parameters recorded (Table 1). Similarly effect of cultivars was not significant on growth parameters except plant height and leaf number per plant. *Kufri Frysona* recorded significantly taller

plants as compared to *Kufri Chipsona-1* followed by *Kufri Surya*. *Kufri Chipsona-1* had significantly higher number of leaves per plant than *Kufri Surya*. Differences in plant height and leaf number per plant between processing cultivars have also earlier been reported by Kumar *et al.*, (2007a, 2007b and 2008).

Potato tuber Number

Across the varieties, there was no significant variation in chip grade, small and total tuber yield except French fry grade tuber yield under different fertilizer management treatments (Table 1). Maximum French fry grade tuber number was recorded when recommended dose of fertilizer for processing cultivars (F_1) was used through soil application. Among F_2, F_3 and F_4 the *French fry* grade tuber number was lower in treatments (F_2 and F_4) where foliar spray of urea was done during mid-season of the crop, however, the differences were non-significant compared to soil application. Kumar *et al.*, (2012) also reported that processing grade (>45 mm) as well as total tuber yield of *Kufri Chipsona-1* did not increase significantly due to increased fertilization beyond 100% recommended dose.

Across fertilizer management treatments, among varieties, French fry grade tuber numbers were statistically similar between *Kufri Surya* and *Kufri Frysona* but statistically lower in *Kufri Chipsona-1*. However, chip grade, small as well as total tuber numbers were maximum in *Kufri Chipsona-1* than other varieties tested (Table 1). This variation in tuber setting among varieties may be ascribed to their genetic makeup (Horton, 1987).

Potato tuber yield

Across varieties, different fertilizer management treatments did not show significant change in tuber yield recorded under different size categories. But, French fry grade tuber yield

Table 1. Effect of fertilizer management and varieties on growth and graded tuber number of potato (mean of two years).

Treatment	Emergence (%)	Stems/ plant	Plant height	Leaves/ plant	LAI	Tuber number (thousand/ha)			
						French fry grade (>75 mm)	Chip grade (45-75 mm)	Small (<45 mm)	Total
Fertilizer management[a]									
F_1	95.8	3.94	55.7	44.3	1.88	101.2	202.3	168.2	471.7
F_2	96.2	3.89	54.2	42.7	2.04	83.2	220.2	163.4	466.8
F_3	95.4	3.77	54.9	45.2	2.21	89.5	204.8	160.0	454.3
F_4	96.2	3.92	54.5	42.9	1.88	84.3	227.6	170.2	482.0
SEm±	0.6	0.20	0.83	1.76	0.22	4.4	10.1	10.4	18.0
CD (0.05)	NS	NS	NS	NS	NS	13.0	NS	NS	NS
Variety									
Kufri Frysona	95.4	3.94	63.3	44.1	2.26	94.9	205.1	168.0	468.0
Kufri Chipsona-1	96.4	3.87	54.0	46.8	1.84	60.8	265.7	198.2	524.7
Kufri Surya	95.9	3.83	47.1	40.4	1.91	112.8	170.5	130.1	413.4
SEm±	0.5	0.20	0.9	1.5	0.17	4.7	5.5	7.7	13.6
CD (0.05)	NS	NS	3.5	6.0	NS	18.4	21.5	30.2	53.2

[a]F_1 = 270 N [N135 (planting) + N_{135} (earthing)] + 80 P_2O_5 + 150 K_2O kg/ha (Recommended dose for processing cultivars; soil application)

F_2 = 270 N [N_{126} (planting) + N_{126} (earthing) + 2 foliar spray (2 % urea) at 60 and 80 days] + 80 P_2O_5 + 150 K_2O kg/ha (Soil and foliar application)

F_3 = 338 N [N_{169} (planting) + N_{169} (earthing)] + 80 P_2O_5 + 188 K_2O kg/ha (25% higher N and K; soil application)

F_4 = 338 N [N_{160} (planting) + N_{160} (earthing) + 2 foliar spray (2 % urea) at 60 and 80 days] + 80 P_2O_5 + 188 K_2O kg/ha (25% higher N and K; soil and foliar application)

decreased in treatments (F_2 and F_4) compared to (F_1 and F_3), where foliar spray of urea was done though the decrease was insignificant. Except chip grade tubers, yield of all others categories was slightly higher in F_1 (Table 2). Nitrogen application at the rate of 270 kg/ha applied in two splits (between planting and tuber initiation) in soil seems to be sufficient to potato crop throughout the growing period leaving no scope for improvement of tuber yield under different categories either by higher rate or by foliar spray of nitrogen. These results corroborate the findings of Kumar *et al.* (2007a); Kumar *et al.*, (2011) and Kumar *et al.* (2012) for similar conditions. It is documented that in North America, Canada and Europe where potatoes meant for processing purposes are grown on large scale, whole of the N is being applied before planting especially on heavy soils where nitrate leaching is not a problem (Love *et al.*, 2005). However, on light soils splitting of the total N application into two equal splits between planting and tuber initiation showed increase in tuber yield (Joern and Vitosh, 1995).

Over fertilizer management treatments, French fry grade tuber yield were at par between *Kufri Frysona* (13.7 t/ha) and *Kufri Surya* (15.55 t/ha) but significantly higher than *Kufri Chipsona-1* (8.8 t/ha). Whereas, chip and small grade tuber yield was recorded significantly higher in *Kufri Chipsona-1* than other two varieties (Table 2). Total tuber yield was statistically similar among all the varieties. Kumar *et al.*, (2008) also reported similar results for processing cultivars over different nutrient management options under similar conditions.

Processing quality at harvest and during storage

Tuber specific gravity and dry matter content directly influence the fried product recovery, while fry colour decides the consumer acceptance. Across potato varieties, tuber specific gravity was recorded significantly higher in treatment F_1 (1.083) than F_3 (1.081) and F_4 (1.081), where N and K rates was higher by 25%. It was also observed that foliar application of urea during mid-season (60 and 80 days) resulted in slight decrease, though insignificant in tuber specific gravity as well as dry matter content specially when recommended dose of fertilizer was used in F_1 and F_2 treatments. The decrease in the tuber specific gravity may be attributed to the higher dose of nitrogen and potassium (Westermann *et al.*, 1994b). The reduction in tuber

Table 2. Effect of fertilizer management and varieties on graded tuber yield and processing quality of potato at harvest (mean of two years)

Treatment	Tuber yield (t/ha)				Specific gravity	Tuber dry matter (%)	French fry colour	Glucose (mg/ 100g FW)
	French fry grade (>75 mm)	Chip grade (45-75 mm)	Small (<45 mm)	Total				
Fertilizer management[a]								
F_1	13.45	15.31	4.22	32.98	1.083	21.7	1.75	9.82
F_2	12.23	16.14	3.92	32.28	1.082	21.0	1.71	8.11
F_3	13.07	15.42	3.91	32.40	1.081	21.7	1.69	8.50
F_4	12.00	16.63	3.81	32.43	1.081	21.9	1.93	7.14
SEm±	0.57	0.55	0.25	0.89	0.001	0.55	0.17	1.05
CD (0.05)	NS	NS	NS	NS	0.002	NS	NS	NS
Variety								
Kufri Frysona	13.70	14.95	3.99	32.65	1.087	23.8	1.78	9.21
Kufri Chipsona-1	8.80	19.89	4.79	33.48	1.084	22.5	1.82	5.35
Kufri Surya	15.55	12.77	3.11	31.44	1.073	18.5	1.71	10.60
SEm±	0.92	0.50	0.13	0.89	0.0002	0.42	0.17	1.39
CD (0.05)	3.62	1.95	0.53	NS	0.001	1.67	NS	NS

a = details of treatments given in Table 1

specific gravity or starch content may be because of increased water content to maintain cell turgor pressure against increased negative solute potential. Other processing quality traits *viz.* tuber dry matter content, French fry colour and glucose content did not vary significantly due to different fertilizer management treatments tested (Table 2). There are conflicting reports in the literature on the effect of N and K application on fry colour and reducing sugars content of tubers. Westermann *et al.*, (1994a) reported that N increased or decreased reducing sugars in the apical and stem ends, respectively, while K tended to decrease reducing sugars in both the tuber ends. Kumar *et al.*, (2007a) and Long *et al.*, (2004) did not observe any adverse effect of tested N doses on chip colour and reducing sugars. Whereas, Irritani and Weller (1978) recorded lower concentration of reducing sugars at harvest under optimum N dose.

Over fertilizer management treatments, *Kufri Frysona* recorded maximum tuber specific gravity (1.087) and dry matter content (23.8%) which was significantly higher than *Kufri Chipsona-1* and *Kufri Surya*, which may be ascribed to their genotypic character (Kumar and Kang, 1998). Specific gravity and tuber dry matter content have already been reported to be significantly influenced by nitrogen levels (Kumar *et al.,* 2007a) as well as varieties (Kumar *et al.,* 2007b). French fry colour as well as glucose content did not show significant variation among varieties and was in highly acceptable range (<3 for fry colour and <35 mg/100 g FW for glucose content) (Table 2).

During long-term storage study French fry

Table 3. Effect of fertilizer management on French fry colour of potato varieties during storage at 10-12°C with CIPC.

Variety	Fertilizer management [a]		Days after storage				
			0	45	75	105	165
Kufri Frysona	F_1	WB [b]	1.9	2.9	2.1	2.5	2.3
		B [c]	-	2.5	1.5	1.9	2.3
	F_2	WB [b]	1.6	2.5	2.6	2.1	3.2
		B [c]	-	1.7	2.0	2.0	2.5
	F_3	WB [b]	1.6	2.8	2.0	2.5	2.6
		B [c]	-	2.1	1.8	2.1	2.6
	F_4	WB [b]	2.5	2.4	2.5	3.0	5.0
		B [c]	-	1.5	2.0	2.1	3.2
Kufri Chipsona-1	F_1	WB [b]	2.4	4.5	3.9	4.1	5.0
		B [c]	-	4.1	2.7	3.1	4.3
	F_2	WB [b]	2.7	5.2	3.5	3.5	3.3
		B [c]	-	3.5	2.7	3.4	3.2
	F_3	WB [b]	1.9	6.3	4.4	3.6	4.5
		B [c]	-	2.6	2.9	3.6	3.0
	F_4	WB [b]	2.5	5.2	3.4	3.7	3.7
		B [c]	-	2.3	2.5	3.0	3.0
Kufri Surya	F_1	WB [b]	1.6	3.3	4.1	3.0	3.0
		B [c]	-	3.0	3.0	2.5	2.4
	F_2	WB [b]	1.6	2.0	3.6	3.5	2.9
		B [c]	-	1.2	3.2	2.7	2.5
	F_3	WB [b]	1.9	3.0	2.6	2.5	3.0
		B [c]	-	1.7	2.3	2.0	2.9
	F_4	WB [b]	1.9	3.5	2.9	3.0	3.5
		B [c]	-	2.7	2.3	3.0	3.5

a = details of treatments given in Table 1;

b = without blanching, direct frying for 5 minutes

c = blanching of 10 minutes at 72°C, frozen at -20°C for 1 week, par frying of 1 minute and final frying of 2.5 minutes

colour was estimated both by frying without blanching treatment and with blanching. However, under industrial conditions, blanching is always given to ensure good colour of the fries. The logic behind frying without blanching was to get more clear effect of nutrient application for academic interest. The fry colour was in acceptable range in F_1 and F_3 treatment for Kufri Frysona at all dates of storage (up to 165 days). However, (spraying of urea) in F_2 and F_4 treatment led to increased undesirable fry colour at last date of storage experiment (165 d). In case of *Kufri Chipsona-1* in most of the treatments the fry colour was unacceptable in fries prepared without blanching and colour improved to some extent after blanching. For the variety *Kufri Surya*, the colour was acceptable at all the dates of storage in treatment F_3, but colour was more or less acceptable after blanching in almost all the treatments at different dates of observation. It can be concluded that even at higher doses of N and K, fry colour remains unaffected even after storage in case of variety *Kufri Frysona* (Table 3).

Glucose is the principal contributor to the reducing sugars in potato tuber and has important role in fry colour upon frying through 'Maillard reaction' (Kumar *et al.,* 2004). Higher glucose levels are also related to formation of potentially carcinogenic compound acrylamide upon frying (Kumar *et al.*, 2004). Therefore, lower levels of glucose are desirable in fried potato products. The glucose levels were less than 35 mg/100 g fresh weight in all the treatments and after all the dates of storage in *Kufri Frysona* (Table 4). Though glucose has important role in determining fry colour, but it cannot always be directly correlated, since besides glucose other compositional factors like fructose, sucrose and free amino acids are also involved in determining non-enzymatic colour development in fried potato products. In case of *Kufri Chipsona-1*, glucose content increased to unacceptably higher levels particularly at later dates of storage in F_1, F_2 and F_3 treatments. In case of *Kufri Surya*, glucose levels were in acceptable range in all the treatments at all the dates of observation. The tuber sugar content has also been shown to get influenced by N and K levels, but it is more of an interaction between genotype and treatment (Westermann *et al.,* 1994a). In this study also genotypic related differences were observed especially during storage. However, in case of *Kufri Frysona*, the higher doses of N and K have been found to be suitable with respect to fry colour and glucose content (Table 4).

Table 4. Effect of fertilizer management on glucose (mg/100 g fresh wt) content of potato varieties during storage at 10-12°C with CIPC.

Variety	Fertilizer management [a]	Days after storage				
		0	45	75	105	165
Kufri Frysona	F_1	11.4	5.0	19.1	17.4	4.8
	F_2	8.0	7.1	11.1	1.5	4.0
	F_3	9.0	6.7	4.4	6.9	13.6
	F_4	8.4	8.9	9.1	5.5	5.6
Kufri Chipsona-1	F_1	6.5	44.0	16.3	43.5	21.1
	F_2	5.6	26.0	27.1	42.3	58.9
	F_3	5.8	11.5	26.0	36.6	49.8
	F_4	3.4	9.2	24.4	25.3	17.4
Kufri Surya	F_1	11.5	8.5	26.0	11.8	4.7
	F_2	10.6	5.5	5.3	17.4	14.0
	F_3	10.7	7.7	11.5	9.1	2.9
	F_4	9.6	21.6	4.2	31.5	22.5

a = details of treatments given in Table 1

Table 5. Effect of fertilizer management and varieties on economics of potato (pooled data of two years)

Treatment	Cost of cultivation ($\times 10^3$ Rs./ha)	Gross returns ($\times 10^3$ Rs./ha)	Net returns ($\times 10^3$ Rs./ha)	Benifit: Cost ratio
Fertilizer management [a]				
F_1	80.0	155.8	75.8	1.95
F_2	80.5	152.3	71.8	1.89
F_3	81.0	153.4	72.4	1.89
F_4	81.5	153.0	71.5	1.88
SEm±	-	-	1.1	0.02
CD (0.05)	-	-	3.2	0.05
Variety				
Kufri Frysona	80.8	168.9	88.1	2.09
Kufri Chipsona-1	80.8	166.6	85.8	2.06
Kufri Surya	80.8	122.6	41.8	1.52
SEm±	-	-	1.1	0.02
CD (0.05)	-	-	4.2	0.07

a = details of treatments given in Table 1

Economic analysis

The adoption of any recommendation depends on its merits in terms of farm profits. Across varieties, net income and benefit cost ratio were statistically higher under fertility regime F_1 because of higher French fry grade tuber yield and lower cost of cultivation due to saving on additional fertilizer dose and expenses on foliar application of N (Table 5). Kumar *et al.,* (2007a) also reported that N dose of 270 kg/ha resulted in highest B:C ratio for processing cultivars *Kufri Chipsona-1* and *Kufri Chipsona-2*. Over fertilizer management treatments, the variety *Kufri Frysona* had highest net returns as well as B:C ratio followed by *Kufri Chipsona-1* and lowest in *Kufri Surya*. The higher returns for *Kufri Frysona* and *Kufri Chipsona-1*, can be ascribed to the higher selling price (Rs. 6000/t for French fry grade and Rs. 5000/t for chip grade) than tuber of *Kufri Surya* (Rs. 4000/t for French fry and chip grade) as due to poor processing quality, the variety *Kufri Surya* was not suitable for making good quality French fries due to lower dry matter content and specific gravity.

Conclusions

Cultivar specific standardization of agronomic practices is always desirable to exploit its full genetic potential with respect to tuber yield, quality and economics. In case of French fry varieties, besides total tuber yield, French fry grade and tuber quality at harvest and during long-term storage are very important attributes for industry. In this study, it has been shown that for north-western plains, the newly developed French fry variety *Kufri Frysona* may be grown with fertilizer dose of 270 N [N_{135} (planting) + N_{135} (earthing)] + 80 P_2O_5 + 150 K_2O kg/ha as soil application to realize higher French fry grade tuber yield, maximum profit and acceptable fry quality at harvest and during long-term storage. The study also validated that the earlier standardized dose of NPK for *Kufri Chipsona-1* holds good for *Kufri Frysona*.

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