Indian Journal of Agronomy **60** (1): 139–144 (March 2015)

Research Paper

Effect of tuber planting depth on yield, quality and profitability of potato (*Solanum tuberosum*) processing varieties

P. KUMAR[1], SUKHWINDER SINGH[2], RAJEEV KUMAR[3], S. RAWAL[4] AND B.P. SINGH[5]

ICAR-Central Potato Research Institute, Regional Station, Modipuram, Uttar Pradesh 250 110

Received : October 2014; Revised accepted : January 2015

ABSTRACT

A field experiment was conducted during 2009–10 and 2010–11 at Central Potato Research Institute, Regional Station, Modipuram, Uttar Pradesh, to evaluate the effect of 3 planting depths (10, 15 and 20 cm) on 2 potato (*Solanum tuberosum* L.) processing varieties, 'Kufri Frysona' and 'Kufri Chipsona 1'. In both the processing varieties, final plant emergence and growth traits (plant height, stem and leaf number/plant) decreased significantly at 20 cm depth of planting. Increase in tuber planting depth increased the depth of tuber setting. 'Kufri Frysona' tubers were found little deeper (by 1 cm) than 'Kufri Chipsona 1'. Maximum processing grade (French fry and chip grade) and total tuber number were realized at 10 cm planting depth. The lowest number and yield of green tuber recorded at 20 cm depth of planting. The maximum french fry-grade tuber yield was recorded at 10 cm depth of planting in cv. 'Kufri Frysona', whereas it was the highest at 15 cm planting depth in 'Kufri Chipsona 1'; however, total tuber yield was the maximum at 10 cm depth of planting in both the varieties. Total tuber yield was significantly higher in 'Kufri Frysona' than 'Kufri Chipsona 1' at 10 cm planting depth only. Highest net returns and benefit: cost ratio were recorded at 10 cm planting depth and decreased with the increase in planting depth. Similarly, 'Kufri Frysona' recorded higher net returns and benefit: cost ratio than 'Kufri Chipsona 1', under shallower depths of planting (10 cm and 15 cm). French fry colour was observed best at 10 cm seed tuber depth of planting. Medium size (50–60 g) seed tuber of processing varieties, 'Kufri Chipsona 1' and 'Kufri Frysona' may be planted at 10 cm depth of planting for realizing higher processing grade (French fry + chip grade) and total tuber yields, maximum net returns and benefit: cost ratio along with best fry quality.

Key words : French fry grade tuber, Fry colour, Green tuber, Planting-depth, Potato, Tuber yield

Processing of potatoes is gaining momentum at faster pace in India since last decade (Rana, 2010) because of development of processing varieties and standardization of their production and storage technologies (Kumar *et al.,* 2011). Chips and French fries are 2 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 convenience food of people of all age groups. Processing of potatoes into French fry requires certain minimum quality attributes that include oblong to long non-green tubers (preferably more than 75 mm size) with shallow eyes, low glucose content (< 35 mg/100 g fresh tuber weight) and more than 20% tuber dry matter for crispy and light-coloured French fries (Kumar *et al.,* 2012). The industry is using 'Kufri Chipsona 1' from Indian potato varieties in absence of suitable specialized variety for French fries. The variety 'Kufri Chipsona 1' has lower percentage of French fry-grade tubers, therefore variety 'Kufri Frysona' was developed during 2009 with higher percentage of French fry grade tubers and superior fry quality (Singh *et al.,* 2010).

Proportion of field green tubers has always been a serious concern, as these are considered unfit for human consumption because of higher levels of glycoalkaloids (Friedman, 2006). Presence of green tubers in the produce reduces total marketable yield and farm profits. Field greening aspect is of great importance when potato crop is raised specially for French fry industry, as French fry-grade tubers are more susceptible to field greening because of their large size (> 75 mm). When tuber growth exceed the soil volume of the surrounding hill, tuber greening may occur. Green tubers being not fit for processing require additional manpower for removal from

[1]**Corresponding author Email:** pkumarcssri@gmail.com
[1]Principal Scientist (Agronomy), Central Soil Salinity Research Institute, Karnal, Haryana 132 001; [2]Senior Scientist, Central Potato Research Station, Jalandhar, Punjab 144 003; [3]Research Fellow; [4]Principal Scientist, Central Potato Research Institute Campus, Modipuram, Meerut, Uttar Pradesh 250 110; [5]Director, Central Potato Research Institute, Shimla, Himachal Pradesh 171 001

processing chain. To reduce percentage of green tubers, accurate planting depth of seed potatoes is of great importance. Optimum depth of planting should be such that, crop produce should have minimum green tubers and soil mechanical resistance should not delay plant emergence and development. Each variety's unique growth characteristic requires adjustments in management techniques to minimize field-tuber greening without decreasing yield (Bohl *et al.*, 2011). The planting depth in a ridge will influence the level of tubers in the ridge; deeper planting will, in principle, restrict the number of green potatoes. Though information is available on depth of planting in different parts of the world, this aspect has got much attention of potato workers neither for table nor for processing varieties in India. Hence this study was carried out determine the effect of seed tuber planting depth on plant emergence, growth, graded tuber yield, field greening and fry quality of cvs 'Kufri Frysona' and 'Kufri Chipsona 1'.

MATERIALS AND METHODS

The field experiment was conducted during 2009–10 and 2010–11 at Central Potato Research Institute Campus, Modipuram, (29° 4' N, 77° 46', E, 237 m above mean sealevel) to evaluate the effect of 3 seed tuber planting depth (10, 15 and 20 cm from top of ridge to top of seed tuber, Fig. 1.) with 2 processing varieties 'Kufri Frysona' and 'Kufri Chipsona 1' in randomized block design with 4 replications. Soil of the experimental site was well drained and sandy loam (Typic Ustochrept). The soil (0–15 cm) was neutral in reaction (pH 7.05), low organic carbon content (0.35%) and low alkaline $KMnO_4$-N (167.4 kg/ha), high Olsen's (0.5 M $NaHCO_3$ extractable) P (52.6 kg/ha) and medium 1 N ammonium acetate-extractable K (146.8 kg/ha). Half N (135.0 kg/ha), full P (52.4 kg/ha) and full K (99.6 kg/ha) were applied at the time of planting. The remaining half N (135.0 kg/ha) was applied at the time of hilling (25 days after planting). Nitrogen was applied

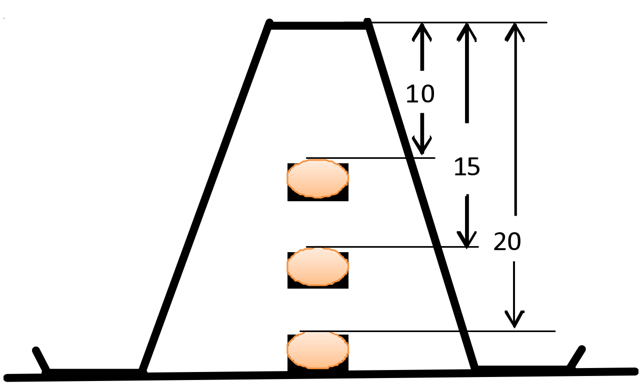

Fig. 1. Three levels of planting depths (10, 15 and 20 cm) measured from the top of ridge to the top of seed tubers

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 24 October during 2009 and 2010 respectively. Well-sprouted seed tubers (50–60 g weight and 40–45 mm size) were planted with in plots of 2.7 m × 2 m size. A collared pipe (Fig. 2) was developed for planting of seed tubers at desired depth. This tool consisted of 75 mm diameter and 100 mm long mild steel pipe. One side of pipe was provided with a collar made up of mild steel sheet of thickness 2 mm. Ridges and furrows were made at spacing of 67.5 cm with tractor-operated mould-board type ridge-maker. Tubers were placed at spacing of 25 cm by first vertically inserting collared pipe manually into the ridge from top and then removing soil (from inside the pipe) to desired depth with an auger of diameter 50 mm. Seed tubers after placing on their longitudinal axis were covered with soil and pipe was pulled out. 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, viz. plant height, stem number and compound leaf number, were recorded from 5 random potato plants from each plot at 45 days after planting (DAP). Dehaulming was done manually at 120 DAP and harvesting was done 2 weeks later after skin setting. Tubers were harvested manually with hand hoe. Depth from top of the ridge to the upper surface of uppermost and the lower surface of lowermost tuber was measured in each plant using 25 mm × 25 mm section steel pipe of length 100 cm and scale of size 30 cm. Produce was graded manually into 3 categories, i.e. French fry grade (FFG) tubers (> 75 mm in length), chip grade (CG) tubers (45–75 mm) and non-processing grade or small tubers (< 45 mm). Tubers with any amount of green surface were also separated out as field green tubers. Five 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 cm × 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. To calculate economic variables the price of the French fry and chip grade potato tubers was taken as ₹5,000/t (price paid by the processors to their contract

Fig. 2. Planting of seed tubers at different depth levels. 1, Positioning of collared pipe over the ridge; 2, inserting collared pipe into the ridge; 3, removing soil with auger and measuring depth of soil inside the pipe with scale; and 4, placing seed at longitudinal axis at desired depth after which tuber is covered with soil and pipe is pulled out gently

growers during those years) and the price for small-size potato tubers was taken as ₹3,000/t (the prevailing market price for that quality of potato tubers). Green tubers were considered as non-marketable. Data of each character collected from the experiments were statistically analyzed using standard procedures of variance analysis with the help of statistical software CROPSTAT 7.2 (IRRI, 2009). Critical difference (CD) values at P=0.05 were used to determine the significance of differences between means.

RESULTS AND DISCUSSION

Emergence and growth traits

Final tuber emergence was the maximum (98.9%) with 10 cm depth of planting and decreased with increased planting depth; however, the decrease was statistically significant only between 10 and 20 cm depth of planting (Table 1). Both the processing varieties had statistically similar emergence percentage. Taylor and Ten Broeck (1988) also observed that soil volume and mechanical resistance of soil affect sprout growth. Rapid emergence allows plants to capture solar radiation early, which is important for optimizing final tuber yield and dry-matter content (Firman and Allen, 1989). Plant height was similar at 10 cm and 15 cm depth of planting, but it reduced significantly when depth of planting was increased to 20 cm. Stem and compound leaf number/plant were maximum at 10 cm planting depth and decreased with increasing planting depth; however the reduction was significant only between 10 cm and 20 cm. 'Kufri Frysona' had longer plants, whereas 'Kufri Chipsona 1' had higher stem and compound leaf number/plant.

Depth of tuber setting and graded tuber number

The depth of tuber setting increased by increasing depth of planting in both the processing varieties (Table 1). Depth of tuber set also increased with depth of planting. Across processing varieties, the range of tuber setting varied from 1.10 to 14.12 cm under 10 cm depth of planting and from 3.54 to 20.4 cm under 20 cm depth of planting. Bohl and Love (1999) also observed that deeper planting significantly increased the distance from the top of the hill to the uppermost tuber, but the increase in tuber depth was not equal to the deeper planting depth of the seed piece. The closer setting of tubers near the top of the ridges can be attributed to the short stolons length in both the processing varieties compared to table-purpose varieties. Both the processing varieties had almost similar tuber setting behaviour with respect to depth from the top of the ridges, but 'Kufri Frysona' tubers were found little deeper (by 1 cm) than 'Kufri Chipsona 1'.

Maximum French fry grade tuber number (FFGTN) was recorded with 10 cm depth of planting, which reduced with the increased depths of planting; however, significant differences were observed between 10 and 20 cm only

(Table 1). Interaction between planting depth and processing varieties was also significant for this parameter, as the maximum FFGTN was recorded at 15 cm depth of planting in 'Kufri Chipsona 1', whereas, in 'Kufri Frysona', it was the highest at 10 cm planting depth. Across depth of planting, 'Kufri Frysona' had significantly higher FFGTN than 'Kufri Chipsona 1' (Table 1), but interaction data indicated that this was true only at 10 cm depth of planting and both the processing varieties had statistically similar FFGTN at 15 and 20 cm depth of planting (Table 2). Chip-grade tuber number (CGTN) was the maximum at 20 cm (175.2 thousand/ha) followed by 10 cm and the lowest at 15 cm planting depth. Between varieties, 'Kufri Chipsona 1' had significantly higher CGTN than 'Kufri Frysona' (Table 1). Green tubers which are considered non-marketable were statistically higher at shallow depth of plantings (10 cm and 15 cm) than 20 cm. Between varieties 'Kufri Chipsona 1' had slightly higher number of green tubers than 'Kufri Frysona' because the length of stolons is comparatively shorter in 'Kufri Chipsona 1' than 'Kufri Frysona' (*personal observation*). Bohl and Love (2005) also reported similar results. Total tuber number/ha and tuber number/plant or hill were significantly higher at 10 cm planting depth than 15 and 20 cm. The number of tubers/hill became smaller, as the depth of planting increased. Across depth of planting, cv. 'Kufri Frysona' had statistically lower total tuber number/ha than 'Kufri Chipsona 1' (Table 1). Lower tuber number/plant is considered desirable for processing cultivars, as it helps in increasing the proportion of processing-grade tubers in total produce, which increases the profits of the farmers on one hand and reduces the operational cost of the processing industries because of lower peeling losses and better appearance of the finished products.

Graded and total tuber yield

Both the processing varieties behaved differently under different planting depth for French fry-grade tuber yield (FFGTY), chip-grade tuber yield (CGTY) and total tuber yield (TTY). 'Kufri Chipsona 1' recorded the highest FFGTY at 15 cm depth of planting, whereas 'Kufri Frysona' recorded at 10 cm. Bohl and Love (2005) also reported that U.S. No. 1 (large size) yield of cv. 'Shurchip' was significantly higher when planted at a 15 cm depth compared to 5 cm or 10 cm, and the percentage of green tubers was significantly reduced. 'Kufri Frysona' had statistically higher FFGTY than 'Kufri Chipsona 1' only at 10 cm depth of planting. In rest of the planting depths, the FFGTY were statistically at par between both the varieties (Table 2). 'Kufri Frysona' showed the highest CGTY at 20 cm depth of planting, whereas 'Kufri Chipsona 1' at 10 cm. 'Kufri Chipsona 1' had statistically higher CGTY than 'Kufri Frysona' only at 10 cm planting depth; in rest of the planting depths (15 and 20 cm) the CGTY was statistically similar between both the processing cultivars (Table 2). Total tuber yield in 'Kufri Chipsona 1' decreased with the increased depth of planting, but the decrease in TTY was insignificant (Table 3); however, in case of 'Kufri Frysona' statistically higher TTY was recorded with 10 cm depth of planting followed by 15 cm and statistically lowest with 20 cm depth of planting. Like 'Kufri Chipsona 1', no significant differences in tuber yield resulting from the 2 planting depths (5 cm or 10 cm) have been reported even though plants began to emerge sooner from the shallower planting depth (Bohl and Love, 2005). In contrary to our finding, Pavek and Thornton (2009) observed decline in

Table 1. Effect of seed tuber planting depth on growth traits and graded and average tuber number of processing varieties (Pooled data of 2 years)

Treatment	Emergence (%)	Plant height (cm)	Stem number/ plant	Leaf number/ plant	Depth of tuber set (cm)		Tuber number (thousands/ha)				Tuber number/ plant
					From top	From bottom	French fry grade (>75 mm)	Chip grade (45–75 mm)	Green	Total	
Planting depth (cm)											
10	98.9	51.0	4.38	45.3	1.10	14.12	130.9	154.3	56.8	567.9	9.69
15	93.8	52.5	3.88	41.5	1.90	17.26	111.1	125.9	51.9	498.8	8.97
20	92.7	44.7	3.33	35.1	3.54	20.40	87.7	175.2	32.1	458.0	8.34
SEm±	1.7	2.0	0.30	1.9	-	-	6.6	8.0	3.5	21.0	0.22
CD (P=0.05)	5.3	6.2	0.95	6.1	-	-	20.7	25.1	11.1	66.2	0.70
Varieties											
'Kufri Chipsona 1'	93.7	47.1	4.22	42.8	2.18	16.71	90.5	176.2	50.2	543.2	9.78
'Kufri Frysona'	96.5	51.7	3.50	38.5	2.18	17.81	129.2	127.6	43.6	473.3	8.28
SEm±	1.4	1.6	0.25	1.6	-	-	5.4	6.5	2.9	17.2	0.18
CD (P=0.05)	NS	NS	NS	NS	-	-	17.0	20.6	NS	54.3	0.57

marketable yield when seed pieces were planted at shallow depth (10 cm) as compared to planting in deeper soil layers. This was mainly attributed to the presence of more green tubers in shallow planting. However, Bohl and Love (2005) reported yield reductions in deeper planting depths because of delays in plant emergence and development, and a likely increase in soil volume that harvesters would have to lift. Green tuber yield was statistically same at 10 cm and 15 cm depth of planting; however, it was significantly lower at deeper planting at 20 cm. Yield of field-green tubers of 'Russet Burbank' cannot be reduced by planting seed pieces at 23 cm compared with 15 cm, whereas with deep planting, total yield was reduced (Bohl *et al.* 2011).

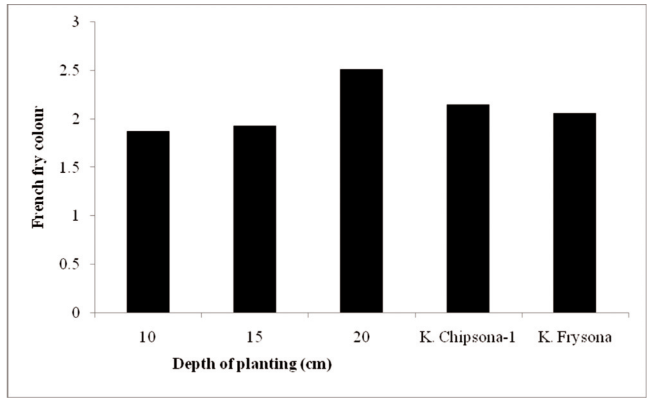

Fig. 3. Effect of depth of planting on french fry colour of processing varieties

French fry colour

Lowest French fry colour (FFC) was recorded with 10 cm depth of planting which increased slowly with increased planting depth, however remained in acceptable limit (<3) of the processing industries (Fig. 3). 'Kufri Frysona' had slightly better FFC than 'Kufri Chipsona 1', however, it was statistically insignificant.

Economics

In 'Kufri Chipsona 1', the net returns were the highest with 10 cm planting depth followed by 20 and 15 cm depth of planting, the differences between 10 and 20 were non-significant. But in case of 'Kufri Frysona', statistically higher returns were recorded with 10 cm depth of planting and increasing depth of planting to 15 or 20 cm led to significant decline in net returns. Between varieties net returns were statistically higher for 'Kufri Frysona' than 'Kufri Chipsona 1' with 10 cm depth of planting; however at 15 cm depth of planting the net returns were statistically similar for both the processing varieties but at 20 cm depth of planting the net returns were statistically higher with 'Kufri Chipsona 1' than 'Kufri Frysona'. In contrast to our findings, Pavek and Thornton (2009) reported decline in gross income when seed pieces were planted at shallow

Table 2. Interaction effect of seed tuber planting depth and processing varieties on French fry-grade (FFG) tuber number and graded tuber yield (Pooled data)

Planting depth (cm)	FFG tuber number (thousand/ha)			FFG tuber yield (t/ha)			Chip grade tuber yield (t/ha)		
	'Kufri Chipsona 1'	'Kufri Frysona'	Mean	'Kufri Chipsona 1'	'Kufri Frysona'	Mean	'Kufri Chipsona 1'	'Kufri Frysona'	Mean
10	79.0	182.7	130.9	12.59	26.47	19.53	16.62	8.91	12.77
15	106.2	116.0	111.1	15.83	20.32	18.07	11.93	8.57	10.25
20	86.4	88.9	87.7	12.91	12.52	12.72	15.38	13.11	14.24
Mean	90.2	129.2	-	13.78	19.77	-	14.64	10.20	-
SEm±	PD=6.6; V=5.4; PD×V=9.3			PD=1.02; V=0.83; PD × V=1.44			PD=0.84; V=0.69; PD × V=1.20		
CD (P=0.05)	PD=20.7; V=17.0; PD×V=29.4			PD=3.20; V=2.62; PD × V=4.54			PD=2.66; V=2.18; PD × V=3.78		

Table 3. Interaction effect of seed tuber planting depth and varieties on total and green tuber yield, and economic variables (Pooled data)

Planting depth (cm)	Total tuber yield (t/ha)			Net returns (₹/ha)			Benefit: cost ratio		
	'Kufri Chipsona 1'	'Kufri Frysona'	Mean	'Kufri Chipsona 1'	'Kufri Frysona'	Mean	'Kufri Chipsona 1'	'Kufri Frysona'	Mean
10	38.77 (3.26)	44.94 (3.77)	41.85 (3.52)	84,950	1,14,276	99,613	2.06	2.43	2.25
15	36.24 (3.09)	37.65 (2.57)	36.95 (2.83)	74,986	83,018	79,002	1.94	2.04	1.99
20	35.41 (1.73)	30.52 (1.70)	32.96 (1.71)	77,638	57,720	67,679	1.97	1.72	1.85
Mean	36.81 (2.69)	37.70 (2.68)	-	79,191	85,004	-	1.99	2.06	-
SEm±	PD=1.29; V=0.34; PD × V=1.80			PD=2578; V=2114; PD × V=3660			PD=0.12; V=0.10; PD × V=0.17		
CD (P=0.05)	PD=4.06; V=NS; PD × V=5.68			PD=8120; V=NS; PD×V=11530			PD=0.38; V=NS; PD×V=0.54		

*Data in parentheses index field green tuber yield depth (10 cm) as compared to planting in deeper soil layers because of higher green tubers in shallow planting. Benefit: cost ratio was statistically similar with all the planting depths in case of 'Kufri Chipsona 1', while in case of 'Kufri Frysona' the benefit: cost ratio decreased with increasing planting depth from 10 cm to 20 cm. 'Kufri Frysona' had higher benefit: cost ratio than 'Kufri Chipsona 1' at 10 cm and 15 cm depth of planting, reverse trend was noted at 20 cm depth.

It is concluded that seed tuber (size 50–60 g or 40–45 mm) of processing varieties, 'Kufri Chipsona 1' and 'Kufri Frysona' should be planted at 10 cm planting depth for realizing higher processing grade (French fry and chip grade) and total tuber yields, maximum net returns and benefit: cost ratio along with best fry quality.

REFERENCES

Bohl, W.H. and Love, S.L. 2005. Effect of planting depth and hilling practices on total, U.S. No.1and field greening tuber yields. *American Journal of Potato Research* **82**: 441–50.

Bohl, W.H. and Love, S.L. 1999. Affects of removing seed pieces and planting depth on potato yield. *Presented at the Idaho Potato Conference* on 20–21, January 1999.

Bohl, W.H., Love, S.L. and Salaiz, T. 2011. Hill shape effect on field-greening tuber yield. *Presented at the Idaho Potato Conference* on 19, January 2011.

Ezekiel, R., Singh, B. and Kumar, D. 2003. A reference chart for Potato chip colour for use in India. *Journal of Indian Potato Association* **30**(3–4): 259–65.

Firman, D.M. and Allen, E.J. 1989. Relationship between light interception, ground cover and leaf area in potatoes. *The Journal of Agricultural Science* **113**(3): 355–59.

Friedman, M. 2006. Potato glycoalkaloids and metabolites: Roles in the plant and in the diet. *Journal of Agricultural Food Chemistry* **54**(23): 8,655–81.

IRRI. 2009. CROPSTAT for windows version 7.2 Crop Research Informatics Laboratory, IRRI, Los Banos, Phillippines.

Kumar, P., Pandey, S.K., Singh, S.V., Singh, B.P., Singh, K., Kumar, D., Rawal, S. and Singh, S. 2011. Effect of growth duration, N application and row spacing on productivity, profitability and processing quality of potato. *Potato Journal* **38**(2): 137–42.

Kumar, P., Singh, B.P., Kumar, R., Kumar, D., Singh, S.V., Pandey, S.K., Singh, S. and Rawal, S. 2012. Standardization of intra-row spacing of cultivar Kufri Frysona for higher French fry grade tuber yield with good fry quality. *Potato Journal* **39**: 88–91.

Pavek, M.J. and Thornton, R. E. 2009. Planting depth influences potato plant morphology and economic value. *American Journal of Potato Research* **86**: 56–67.

Rana, R., K., Pandit, A. and Pandey, N.K. 2010. Demand for processed potato products and processing quality potato tubers in India. *Potato Research* **53:** 181–97.

Singh, S.V., Pandey, S.K., Kumar, D., Marwaha, R.S., Manivel, P., Kumar, P., Singh, B.P. and Bhardwaj, V. 2010. Kufri Frysona: First high yielding potato variety for French fries in India. *Potato Journal* **37:** 103–09.

Taylor, A.G., and C.W. Ten Broeck. 1988. Seedling emergence forces of vegetable crops. *Horticulture Science* **23**(2): 367–69.