# OPTIMIZING CROP GEOMETRY IN KUFRI CHIPSONA-3 AND KUFRI HIMSONA FOR HIGHER GRADE TUBER YIELD AND QUALITY

Parveen Kumar[1], BP Singh[2], Rajeev Kumar[3], KS Sandhu[4], Dinesh Kumar[5], SK Pandey[2] and SV Singh[3]

ABSTRACT: A field study was conducted at Central Potato Research Institute Campus, Modipuram, India during 2008-2010 with two processing varieties Kufri Himsona and Kufri Chipsona-3 in main plot and five crop geometry treatments (67.5 × 20, 67.5 × 22.5, 67.5 × 25, 67.5 × 27.5 and 67.5 × 30 cm). Growth traits, processing grade tuber number and yield and processing quality parameters were not influenced by crop geometry. Tuber number/plant, percent processing grade tuber and average processing grade tuber weight steadily increased with increased intra-row spacing from 22 to 30 cm. Net returns (₹ 126,000/ha) and B:C ratio (2.69) was highest at 67.5 × 30 cm crop geometry. Processing grade tuber number and yield, net returns, B:C ratio was higher for cv. Kufri Chipsona-3 than Kufri Himsona. Tuber number/plant, tuber dry matter and chip yield was higher and oil per cent in chips were lower in cv. Kufri Himsona compared to Kufri Chipsona-3. Tuber dry matter yield, chip colour score and glucose content were statistically similar in both the cultivars. Study suggests that cvs Kufri Chipsona-3 and Kufri Himsona may be raised at 67.5 × 30 cm crop geometry for higher tuber yield, net returns and better processing quality.

KEYWORDS: Chip colour, chip yield, crop geometry, intra-row spacing, Kufri Chipsona-3, Kufri Himsona, net returns, specific gravity, tuber yield

## INTRODUCTION

Processing of potatoes into chips and French fries has increased tremendously in India in last one decade mainly due to availability of processing varieties along with their production and storage technologies. An estimated 3.3 million t of potatoes were processed by organized and unorganized sectors in India during 2013-14 (Singh *et al.*, 2014), which is almost 3.4 times higher compared to 0.97 million t potato processed during 2005-06 (Rana and Pandey, 2007). This tremendous growth in potato processing in India has largely been made possible by the predominant processing variety Kufri Chipsona-1. Agronomic practices may vary depending upon the end use of potatoes. For processing, more large and uniform sized potatoes in the produce is desired by the processing industry. Processing of potatoes into chips requires certain minimum quality attributes that include round to oblong tubers (> 45 mm) with shallow eyes and low peeling losses for higher recovery of finished product. The tubers need to have 20% or more dry matter with glucose content as low as possible (preferably below 35 mg/100 g fresh tuber weight) to yield crisp and light colored chips (Marwaha, 1997 and Gould, 1999). A number of factors influence potato yield and potato size distribution which include spacing (inter-row or intra-row), nutrient management, water management, seed size, cultivar, geographic location and climatic conditions.

[1]ICAR-Central Soil Salinity Research Institute, Karnal–132 001, Haryana, India.
 Email: pkumarcssri@gmail.com
[2]ICAR-Central Potato Research Institute, Shimla–171 001, Himachal Pradesh, India.
[3]ICAR-Central Potato Research Institute Campus, Modipuram–250 110, Uttar Pradesh, India.
[4]Khalsa College, Amritsar-143001, Punjab, India.
[5]ICAR-Directorate of Wheat Research, Karnal – 132 001, Haryana, India.

The extent of yield and tuber size response to intra-row spacing varies among cultivars (Arsenault *et al.,* 2001). Total yields in some cultivars increase with closer spacing, while in others without any significant difference. Variation in intra-row spacing can also affect tuber size distribution (Kumar *et al.,* 2012). For any given potato cultivar, information on intra-row spacing is required to optimize yields of marketable size tubers (Handerson *et al.,* 1992). There is also evidence of reduced tuber specific gravity and higher incidence of hollow heart at wider intra-row spacing; however no effect of intra-row spacing on chip colour has been observed (Zebarth *et al.,* 2006; Kumar *et al.,* 2012). The objective of this experiment was to study the effect of crop geometry (intra-row spacing) on tuber yield (processing grade and total), processing quality and economics of Indian potato processing cultivars Kufri Chipsona-3 and Kufri Himsona.

## MATERIAL AND METHODS

The field experiment was conducted on well drained 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 split-plot design with three replications. The treatments consisted of two processing varieties Kufri Himsona and Kufri Chipsona-3 in main plot and five crop geometry treatments (67.5 × 20, 67.5 × 22.5, 67.5 × 25, 67.5 × 27.5 and 67.5 × 30 cm) as sub-plot. The soil (0-15 cm) of the experimental field was neutral pH (6.9), low organic carbon content (0.32%) and low alkaline $KMnO_4$-N (158.4 kg/ha), high Olsen's (0.5 $M$ $NaHCO_3$ extractable) P (80.0 kg/ha) and medium 1N ammonium acetate extractable K (150.7 kg/ha). Half dose of 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 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 18 and 23 October during 2008 and 2009, respectively. Well-sprouted seed tubers (about 60 g weight and 40-45 mm seed size) were planted in plots of 4.05 × 4.0 m size. The experimental crop was raised under assured irrigation by the furrow method. Dehaulming was done manually at 110 and 120 days after planting (DAP) for Kufri Chipsona-3 and Kufri Himsona, respectively. The harvesting was done two weeks later after skin setting.

Observations on growth parameters, such as stem number, plant height and compound leaf number were recorded at 60 DAP. Total and processing-grade tuber yield and number were recorded at harvest, tubers of >45 mm in diameter were considered as processing-grade. To calculate net tuber yield, seed tuber used was deducted from the total tuber yield. To estimate tuber dry matter content five processing grade tubers from each plot were chopped into fine pieces and 50 g sample was oven dried at 80°C till constant weight was achieved (Kumar *et al.,* 2007). Tuber specific gravity was measured by the Hydrometer method by taking 3.632 kg of processing grade potato tubers from each plot (Gould, 1999). Five processing grade tubers were selected randomly from each plot and used for estimating the chip colour score. Potato chips were prepared in laboratory which involved peeling the tubers in abrasive peeler, slicing into 1.75 mm thick slices with an automatic slicer, washing and drying on paper towel. Dried slices were fried in refined sunflower oil in a thermostatically controlled deep fat fryer at 180°C till bubbling stopped. Fried chips

were then evaluated for chip colour on a scale of 1-10, subjectively with the help of colour cards (Ezekiel *et al.,* 2003), where 1 denotes a highly acceptable colour, 10 denotes a dark brown and unacceptable colour, and chips with colour range of up to 3.0 were considered acceptable. The glucose content in potato tubers was quantified using YSI Biochemistry analyzer as described by Sowokinos (1978). Chip yield and oil content of the chips were calculated by linear regression equations (Gould, 1999) as below.

Percent chip yield = 16.39544 + 0.748377 X*

Oil percentage of flat chips = 59.10894 - 0.96768 X

Oil percentage of wavy chips = 53.06224 - 0.73989 X

*Where X represents tuber dry matter content (%)

Net returns generated by the crop were calculated as the difference between gross returns (GR) and cost of cultivation (CoC). Gross returns were calculated by taking the price of the processing-grade potato tubers as ₹ 6000/t (price paid by the processors to their contract growers during those years) and the price for non-processing grade potato tubers

as ₹ 3000/t (the prevailing market price for that quality of potato tubers). CoC includes the costs of all inputs, such as seed potatoes, fertilizer, pesticides, labour and capital. Benefit cost ratio (B:C) indicates the returns one gets after investing one rupee. It was calculated by dividing the gross returns with costs of cultivation.

The data for each year were subjected to analysis of variance. Since the trend was similar in both years; therefore, the data were pooled and analyzed with the statistical software IRRISTAT (IRRI, 1999)

## RESULTS AND DISCUSSION

### Growth parameters

Across potato varieties growth traits (plant height, stem number and leaf number per plant) were not influenced significantly due to varied crop geometry treatments **(Table 1)**. Kumar *et al.* (2004a) also reported non-significant differences for the plant height; stem number as well as leaf number in processing cultivars Kufri Chipsona-1

**Table 1. Effect of crop geometry and variety on growth and graded tuber number of potato (data pooled over 2 years).**

| Treatments | Plant height | Stem number/ plant | Leaf number/ plant | Tuber number (thousand/ha) | | | Tuber number/ plant |
|---|---|---|---|---|---|---|---|
| | | | | Processing grade (>45 mm) | Small (<45 mm) | Total | |
| Crop geometry (cm) | | | | | | | |
| 67.5 × 20 | 58.9 | 6.31 | 59.0 | 329.3 | 410.9 | 740.2 | 11.2 |
| 67.5 × 22.5 | 58.1 | 6.68 | 60.9 | 340.3 | 372.7 | 713.0 | 12.1 |
| 67.5 × 25 | 57.5 | 6.74 | 52.0 | 331.0 | 358.4 | 689.4 | 13.0 |
| 67.5 × 27.5 | 56.6 | 7.07 | 59.2 | 329.5 | 331.1 | 660.6 | 13.7 |
| 67.5 × 30 | 55.8 | 6.41 | 60.6 | 324.7 | 305.2 | 629.9 | 14.3 |
| Variety | | | | | | | |
| Kufri Himsona | 54.9 | 6.67 | 55.4 | 298.3 | 449.9 | 748.2 | 13.8 |
| Kufri Chipsona-3 | 59.9 | 6.61 | 61.3 | 363.6 | 261.4 | 625.1 | 11.6 |
| CD (0.05) | | | | | | | |
| Crop geometry (CG) | NS | NS | NS | NS | 44.4 | 71.2 | 1.2 |
| Variety (V) | 1.8 | NS | NS | 43.4 | 59.0 | 75.3 | 1.3 |
| CG × V | NS | NS | NS | NS | NS | NS | NS |

and Kufri Chipsona-2 under different crop geometry treatments with similar conditions. Between varieties, plant height and leaf number/plant was higher in Kufri Chipsona-3, whereas, stem number was statistically similar for both the potato cultivars. Variation in growth may be ascribed to the variation in genetic makeup of the varieties (Kumar *et al.,* 2004b; Sharma and Singh, 2010).

## Tuber number

Processing grade tuber number remained unaffected due to crop geometry treatments; however, small and total tuber numbers were higher under narrower crop geometry and steadily decreased with widening of intra-row spacing from 20 to 30 cm **(Table 1)**. Higher plant population (Long *et al.,* 2004) and lower individual (average) tuber weight (Zebarth *et al.*, 2006) at closer intra-row spacing may have led to higher number of small and total tubers. Contrary to total tuber number, average tuber number per plant steadily increased with wider intra-row spacing because of reduced competition for resources between the plants.

Between varieties, processing grade tuber number was higher in Kufri Chipsona-3 than Kufri Himsona, whereas, small as well as total tuber number were significantly higher in cv. Kufri Himsona than Kufri Chipsona-3. This can be ascribed to lower average tuber number per plant in Kufri Chipsona-3 (11.6) compared to Kufri Himsona (13.8). Differences among the varieties for the number of tubers per unit area can also be attributed to the varied growth behaviour of plants on account of genotypic variability (Sharma and Singh, 2010).

## Tuber yield

Processing grade tuber yield, processing grade per cent, total and net tuber yield were marginally higher between varieties at wider intra-row spacing's (22.5 to 30 cm) compared to 67.5 × 20 cm crop geometry (**Table 2** and **Fig. 1**). This result has finding carry a lot of practical significance since seed cost is reduced by 33.5% by planting these varieties at 67.5 × 30 cm crop geometry

**Table 2. Effect of crop geometry and variety on graded tuber yield and economics of potato (data pooled over 2 years).**

| Treatments | Plant density@ | Seed rate (t/ha) | Tuber yield (t/ha) | | | | Thousand ₹/ha | | | B: C ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | PG[a] (>45 mm) | Small (<45 mm) | Total | Net | CoC[b] | Gross returns | Net returns | |
| Crop geometry (cm) | | | | | | | | | | |
| 67.5 × 20 | 74.2 | 4.45 | 28.4 | 8.27 | 36.6 | 32.2 | 89.5 | 194.9 | 105.4 | 2.18 |
| 67.5 × 22.5 | 65.8 | 3.95 | 30.0 | 7.25 | 37.2 | 33.3 | 84.5 | 201.6 | 117.1 | 2.39 |
| 67.5 × 25 | 59.3 | 3.56 | 30.0 | 7.56 | 37.5 | 34.0 | 80.6 | 202.4 | 121.8 | 2.51 |
| 67.5 × 27.5 | 53.8 | 3.23 | 28.7 | 7.49 | 37.2 | 34.0 | 77.3 | 194.5 | 117.2 | 2.52 |
| 67.5 × 30 | 49.4 | 2.96 | 30.0 | 6.88 | 36.9 | 33.9 | 74.6 | 200.6 | 126.0 | 2.69 |
| Variety | | | | | | | | | | |
| Kufri Himsona | 60.5 | 3.63 | 25.6 | 8.82 | 34.4 | 30.8 | 81.3 | 180.1 | 98.8 | 2.22 |
| Kufri Chipsona-3 | 60.5 | 3.63 | 33.6 | 6.16 | 39.7 | 36.1 | 81.3 | 219.8 | 138.5 | 2.70 |
| CD (0.05) | | | | | | | | | | |
| Crop geometry (CG) | - | - | NS | 1.22 | NS | NS | - | - | 10.0 | 0.22 |
| Variety (V) | - | - | 3.3 | 0.59 | 3.1 | 3.6 | - | - | 10.1 | 0.26 |
| CG × V | - | - | NS | NS | NS | NS | - | - | NS | NS |

@ = thousand plants/ ha; a = Processing grade; b = Cost of cultivation

Parveen Kumar, BP Singh, Rajeev Kumar, KS Sandhu, Dinesh Kumar, SK Pandey and SV Singh
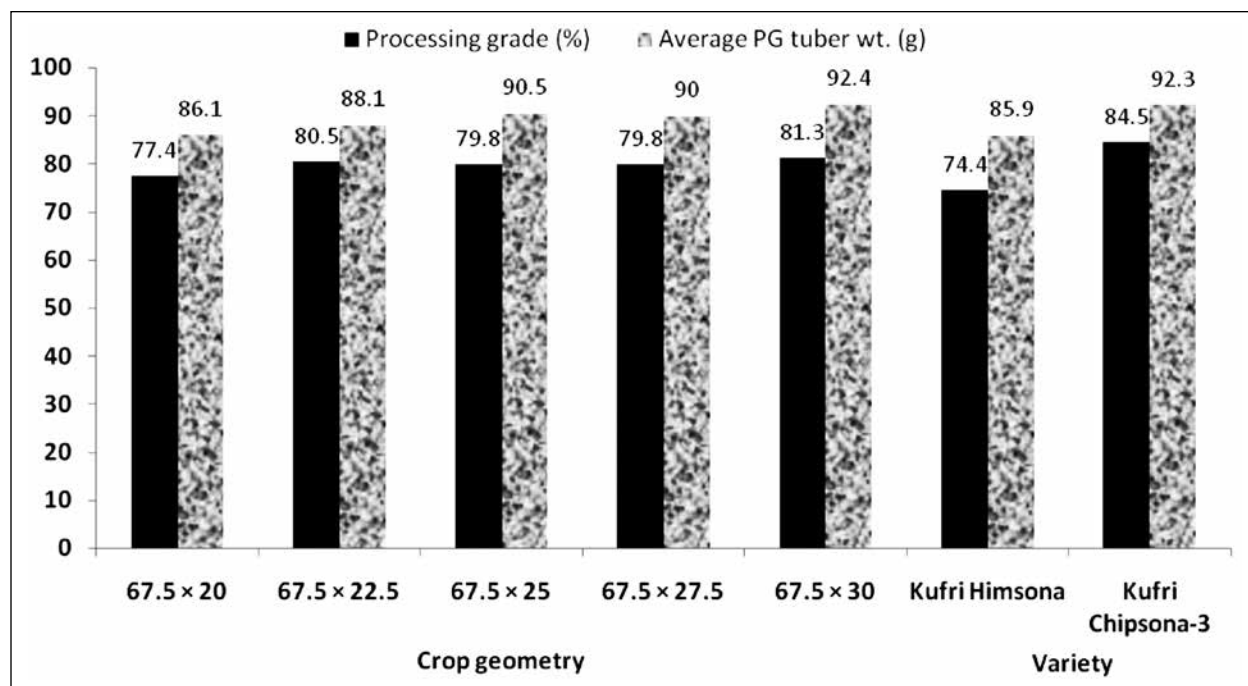


*Fig. 1. Effect of crop geometry and variety on processing grade and average processing grade tuber weight of potato (data pooled over 2 years).*

rather than at 67.5 × 20 cm spacing, which is the normal practice. Non-processing grade or small tuber number decreased linearly in response to the wider intra-row spacing being lowest at 67.5 × 30 cm crop geometry (20.2%) which is less than 67.5 × 20 cm spacing. Average processing grade tuber weight, also responded positively to wider intra-row spacing and was highest at 67.5 × 30 cm crop geometry (92.4 g) than intra-row spacing of 67.5 × 20 cm (86.1 g). Zebarth *et al.* (2006) also reported that under wider intra-row spacing mean tuber weight increased. Similarly, Long *et al.* (2004) also reported higher proportion of small tubers (<5.1 cm) at narrow (20 cm) spacing than wider seed piece spacing (33 cm). The path coefficient between the stem number per square meter and tuber weight showed negative relationship (Morena *et al.,* 1994).

Across crop geometry treatments, tuber yield and tuber size distribution varied significantly between cultivars. Except small tubers, cv. Kufri Chipsona-3 at 110 days, produced significantly higher processing (31%), total (15.4%) and net tuber yield (17.2%) than cv. Kufri Himsona at 120 days (**Table 2**). Similarly, per cent processing grade tuber yield and average tuber weight was higher with cv. Kufri Chipsona-3 (84.5% and 92.3 g) than Kufri Himsona (74.4% and 85.9 g), respectively (**Fig. 1**). More large sized tubers (>45 mm) produced by Kufri Chipsona-3 might have contributed to higher processing grade and total tuber yield. Such a response indicated that tuber size distribution was affected by the genotype and reflected the edge of Kufri Chipsona-3 over Kufri Himsona with respect to processing grade as well total number of tubers (Sharma and Singh, 2010). Kumar *et al.* (2004a) also reported similar results between processing varieties Kufri Chipsona-1 and Kufri Chipsona-2 under similar climatic and edaphic conditions.

156

## Processing quality

Tuber specific gravity and dry matter content directly influence the chip yield, while chips colour score decides the consumer acceptance. A chip colour of < 3 and reducing sugars < 100 mg/100 g fresh tuber weight or glucose content of < 35 mg/100 g fresh tuber weight are considered ideal and acceptable by the chipping industry (Gould, 1999; Sowokinos, 1978). In the present study all the processing attributes studied namely tuber specific gravity, tuber dry matter content, dry matter/tuber, dry matter yield, chip colour score, glucose content, chip yield as well as oil content did not vary significantly in different crop geometry treatments, but were in the acceptable range **(Table 3)**. Kumar *et al.* (2012) also reported that processing traits remained uninfluenced due to intra-row spacing treatments for French fry cv. Kufri Frysona.

Chip yield determines the profit, whereas oil content of chips affects both the economics of their production and the quality of chips (especially texture). Any agronomic intervention which reduces the oil content in chips is desirable (Kumar *et al.*, 2007). The results of our study have shown that, the mean tuber specific gravity, tuber dry matter content, dry matter/tuber, chip yield were significantly higher and oil uptake lower in chips in cv Kuri Himasona than in Kufri Chipsona-3. Chip colour score and glucose content were statistically similar in both the cultivars. Dry matter yield was also statistically similar between both the varieties as lower tuber yield in Kufri Himsona compared to Kufri Chipsona-3 was compensated by higher tuber matter content of Kufri Himsona **(Table 3)**. Significant variation in tuber dry matter as well tuber specific gravity (Sandhu *et al.*, 2012) and non-significant change in chip colour and glucose level among processing cultivars has already been reported (Kumar *et al.*, 2004a; Kumar *et al.*, 2007).

## Economics

Cost of cultivation decreased linearly with wider intra-row spacing and it was about 20% lower at 67.5 × 30 cm than 67.5

Table 3. Effect of crop geometry and variety on processing quality of potato (data pooled over 2 years).

| Treatments | Specific gravity | Tuber dry matter (%) | Dry matter/ tuber (g) | Dry matter yield (t/ha) | Chip colour score | Glucose (mg/100 g FW) | Chip yield (%) | Oil per cent in chips | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Flat | wavy |
| Crop geometry (cm) | | | | | | | | | |
| 67.5 × 20 | 1.090 | 24.1 | 20.7 | 8.83 | 2.43 | 7.45 | 34.4 | 35.8 | 35.2 |
| 67.5 × 22.5 | 1.090 | 23.6 | 20.8 | 8.78 | 2.34 | 8.45 | 34.1 | 36.3 | 35.6 |
| 67.5 × 25 | 1.091 | 24.0 | 21.7 | 9.00 | 2.30 | 8.31 | 34.1 | 35.9 | 35.3 |
| 67.5 × 27.5 | 1.091 | 24.2 | 21.1 | 8.99 | 2.09 | 9.87 | 34.5 | 35.7 | 35.2 |
| 67.5 × 30 | 1.090 | 23.5 | 21.7 | 8.67 | 2.11 | 8.38 | 34.0 | 36.4 | 35.7 |
| Variety | | | | | | | | | |
| Kufri Himsona | 1.095 | 25.6 | 22.0 | 8.81 | 2.40 | 10.31 | 35.5 | 34.3 | 34.1 |
| Kufri Chipsona-3 | 1.086 | 22.2 | 20.5 | 8.82 | 2.11 | 6.68 | 33.0 | 37.6 | 36.6 |
| CD (0.05) | | | | | | | | | |
| Crop geometry (CG) | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Variety (V) | 0.001 | 1.8 | 1.3 | NS | NS | NS | 2.2 | 2.8 | 2.4 |
| CG × V | NS | NS | NS | NS | NS | NS | NS | NS | NS |

× 20 cm spacing, mainly because of reduced seed rate. All the wider intra-row spacing treatments being statistically at par with each other gave significantly higher net returns than 67.5 × 20 cm. However, numerically highest net returns (₹ 126,040/ha) and B:C ratio (2.69) was observed with 67.5 × 30 cm spacing **(Table 2)**. This might be due to the commutative effect of low cost of cultivation (seed rate) and slightly higher processing grade as well as total tuber yield under wider intra-row spacing than narrow intra-row spacing of 67.5 × 20 cm. Conley *et al.* (2001) also linked the higher net crop value under wider spacing to higher marketable tuber yield (113 to >284 g).

Across crop geometry treatments, cv. Kufri Chipsona-3 (₹ 128,500/ha and 2.70) had significantly higher net returns and B:C ratio, respectively, than Kufri Himsona (₹ 98,800/ha and 2.22) because of its higher processing grade and total tuber yield **(Table 2)**. Kumar *et al.* (2007) also reported that variation in economic variables of processing varieties under similar conditions. Likewise, higher net crop value was noticed in var. Atlantic as compared to Russet Burbank, Goldrush, Russet Norkotah, Dark Red Norland and Snowden because of higher yield of large size tubers (Conley *et al.*, 2001).

## CONCLUSIONS

Study suggested that cvs Kufri Chipsona-3 and Kufri Himsona may be raised at 67.5 × 30 cm crop geometry for higher tuber yield, net returns, benefit cost ratio and better processing quality. This recommendation will cut the cost of cultivation by 20% because of 33.5% less seed rate compared to farmer's practice of 67.5 × 20 cm crop geometry. Cultivation of Kufri Chipsona-3 is more profitable for the farmers being higher yielder, while processing of Kufri Himsona is more remunerative for chip industry for reduced

operational cost due to higher chip yield and less oil in the chips.

## LITERATURE CITED

Arsenault WJ, LeBlanc DA, Tai George CC and Boswall P (2001) Effects of nitrogen application and seed piece spacing on yield and tuber size distribution in eight potato cultivars. *Am J Potato Res* **78**: 301-09

Conley SP, Binuing LK and Connell TR (2001) Effect of cultivar, row spacing and weed management on weed biomass, potato yield and net crop value. *Am J Potato Res* **78**: 31-37

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

Gould WA (1999) Potato production, processing and technology. CTI Publications Inc. Arlington VA, USA: 65-72

Handerson JL, Ojala JC, Harding GW and Musselman EV (1992) Influence of seed placement on Russet Burbank potato yield and grade. *Am Potato J* **69**: 31-38

IRRI (1999) IRRISTAT for windows version 4.0 Biometrics Unit, IRRI, Los Banos, Philippines

Kumar P, Pandey SK, Rawal S, Singh SV and Kumar D (2004a) Optimizing crop geometry of potato cultivars for chipping. *Potato J* **31**: 141-46

Kumar P, Pandey SK, Singh BP, Rawal S, Singh SV and Kumar D (2004b) Fertilizer requirements of chipping potato (*Solanum tuberosum* L.) cultivars in west central plains. *Potato J* **31**: 171-81

Kumar P, Pandey SK, Singh BP, Singh SV and Kumar D (2007) Influence of source and time of potassium application on potato growth, yield, economics and crisp quality. *Potato Res* **50**(1): 1-13

Kumar P, Singh BP, Kumar R, Kumar D, Singh SV, Pandey SK, 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 J* **39**: 88-91

Long CM, Snapp SS, Douches DS and Chase RW (2004) Tuber yield, storability and quality of Michigan cultivars in response to nitrogen management and seed piece spacing. *Am J Potato Res* **81**: 347-57

Marwaha RS (1997) Processing of potatoes: current status, need, future potential and suitability of Indian varieties: A critical appraisal. *J Food Sci and Tech* **34**: 457-71

Morena De la, Guillen A, Garcia Del and Moral LF (1994) Yield development in potatoes as influenced by cultivar and the timing and level of nitrogen fertilization. *Am Potato J* **71**: 165-73

Rana Rajesh K and Pandey SK (2007) Processing quality potatoes in India: an analysis of industry's demand. *Processed Food Industry* **10**(8): 26-35

Sandhu KS, Chinna GS, Marwaha RS, Pandey SK, Kumar P and Singh RK (2012) Effect of staggered planting and dehaulming schedule on yield and processing quality of Potato cultivars in Punjab. *Potato J* **39**: 39-47

Sharma AK and Singh S (2010) Production behaviour of under size seed tubers of Potato under varying plant densities in north-western hills of India. *Potato J* **37**: 131-37

Singh BP, Rana Rajesh K and Govindakrishnan PM (2014) Vision 2050. Central Potato Research Institute, Shimla 171 001 HP: x+26p

Sowokinos JR (1978) Relationship of harvest sucrose content to processing maturity and storage life of potatoes. *Am Potato J* **55**: 333-34

Zebarth BJ, Arsenault WJ and Sanderson JB (2006) Effect of seed piece spacing and nitrogen fertilization on tuber yield, yield components and nitrogen use efficiency parameters to two potato cultivars. *Am J Potato Res* **83**: 289-96