

Influence of calcium dose and time of application on tuber yield and processing quality of potato (*Solanum tuberosum*)

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ABSTRACT

A field experiment was conducted during 2008-2010 at CPRI Campus, Modipuram, Meerut to study the effect of calcium on quality and productivity of three potato varieties. Results indicated that cvs Kufri Bahar and Kufri Sindhuri recorded 12% improvement in the marketable tuber yields with 200 kg Ca/ha in two splits. Processing cv. Kufri Chipsona-3, also tended to improve processing grade yield with this treatment without showing any statistical significance. All the three cultivars observed significant enhancement of specific gravity with moderate calcium application. Chip colour score of processing cv. Kufri Chipsona-3 improved distinctly with moderate Ca level of 100 kg Ca/ha (2.16) over control (2.70) at harvest time. Glucose content in Kufri Chipsona-3 also exhibited similar trend consistently as it declined with Ca nutrition. No internal and external defects were observed in any treatment under study during both the years. Moderate calcium application (200 kg/ha) in two equal splits i.e. at planting and 20-25 days after planting during earthing operation as gypsum may be advised to potato growers for mitigating abiotic stress of higher temperatures under field conditions to attain better tuber productivity and post harvest quality.

Key words: Potato, gypsum treatment, application time, tuber yield, chip colour score, glucose content

Current scenario of threatened food security due to climate change and decrease in cultivable land under food crops requires growing of potatoes under abiotic stresses particularly of heat, in Indo-gangetic plains and in non-traditional potato growing areas of the country such as Maharashtra, Karnataka, Andaman & Nicobar Islands etc. Higher temperatures induce development of lanky potato plants with thin and long stems, smaller leaves probably due to reduced cell division, long stolons, increased length and number of inter-nodes, inhibition of tuber development and reduced partitioning of photosynthates towards sink leading to poor canopy cover and ultimately, the yields (Kumar

et al., 2003). Hence, mitigation of heat stress through balanced plant nutrition would be a proper crop management strategy for potatoes, apart from breeding the heat tolerant varieties. The work of Palta (1996) and Tawfik *et al.* (1996) indicated towards possible role of calcium in mitigating heat stress of potato crop variety Russet Burbank and its positive effect on tuber yields under such environment. This nutrient is required for cell elongation, cell division and stabilization of newly synthesized cell wall and membrane. The lower concentration of calcium in cytoplasm is important for functioning of calmodulin for activation of certain enzymes like Ca-ATPase, nucleotide phosphodiesterase etc. It

is also found in mitochondria for the activity of enzymes like glutamate dehydrogenase. It is evident now that response of plant tissue for abiotic stress is mediated now by passive influx of Ca^{++} from apoplast of cytosol and it thus plays as a physiological transducer in abiotic stresses (Mengel and Kirkby, 2001). Reports of work by Palta and Kleinhenz (2003) indicated that increasing root zone Ca improved plant growth and yield by improving the mean tuber size and weight. Apart from this, calcium nutrition may also affect potato tuber quality. Higher incidence of physiological stresses like heat or water results in poor tuber quality, which further leads to economic losses for potato growers and application of calcium in potato crop increases tuber calcium content and thus can improve tuber quality (Silva *et al.*, 1991). One more dimension of calcium nutrition in potato is clear that genetic variations exist in this crop regarding tuber calcium accumulation (Brown *et al.*, 2012). This investigation was taken up to study the influence of calcium basically on quality of potatoes and productivity and to standardize its dose along with application time for table purpose and processing potato cultivars.

MATERIALS AND METHODS

The study was conducted for two consecutive years during 2008-09 and 2009-10 at Central Potato Research Institute Campus, Modipuram, Meerut ($29^{\circ} 4' \text{ N}$, $77^{\circ} 46' \text{ E}$, 237 m above mean sea level). Soil of the experimental site was well-drained and sandy loam (Typic Ustochrept) in texture. Chemical analysis of top 15 cm soil layer exhibited neutral pH (7.05), lower organic carbon content (0.26%) and potassium permanganate extractable nitrogen (163.5 kg/ha), high Olsen's (0.5 M NaHCO_3 extractable) phosphorus (52.6 kg/ha) and medium exchangeable potassium (147.6 kg/ha). The experiment was laid out in split plot design having three replications. Three varieties (Kufri Bahar, Kufri Sindhuri and Kufri Chipsona-3) were kept in main plot, while five calcium rate (kg/ha) \times time of application (0, 100 as basal, 100 in two equal splits at planting and earthing up, 200 as basal and 200 in two equal splits at planting and earthing up) were in sub-plots. The source of calcium was gypsum and recommended packages of practices for the cultivars were applied for successful raising of

potato crop. Planting was done on 24th and 21st of October in first and second year, respectively. Well-sprouted seed tubers (about 40-45 mm seed size) were planted manually in experimental plots (18 m²) and the crop was furrow irrigated to avoid the moisture stress. Recommended dose of phosphorus (80 kg/ha) as di-ammonium phosphate and potash (100 kg K_2O /ha for Kufri Bahar and Kufri Sindhuri and 150 kg K_2O /ha for Kufri Chipsona-3) as muriate of potash were applied at the time of planting. Whereas, half recommended dose of nitrogen (90 kg N/ha for Kufri Bahar and Kufri Sindhuri and 135 kg N/ha for Kufri Chipsona-3) was applied as calcium ammonium nitrate at planting and remaining half dose of nitrogen (90 kg N/ha for Kufri Bahar and Kufri Sindhuri and 135 kg N/ha for Kufri Chipsona-3) was side dressed through urea twenty-five days after planting during inter-cultivation and earthing operation (Kumar *et al.*, 2014). Dehaulming of the experimental crop was done after 110 days and harvesting was done 10 days later after skin setting.

Plant stand was monitored up to 30 days and observations on growth parameters, such as plant height, stem number and compound leaf number were recorded from three randomly selected potato plants from each plot at 50 days. Likewise, leaf area index (LAI) was observed using Ceptometer (Accu PAR model LP-80) at 50 days while crop canopy temperature was taken up by infra-red thermometer (Fluke model 572) at 85 days. Senescence was visually recorded at 95 and 105 days on a scale of 1-5, where one was fully senescent and five was fully green. At harvest, grading was done manually and for ware cultivars (Kufri Bahar and Kufri Sindhuri) tuber of >20 mm were considered as marketable and in case of *cv.* Kufri Chipsona-3, marketable (process grade) grade was >45 mm (Kumar *et al.*, 2014). Total and marketable grade tuber number and yield were recorded from the whole produce of the net plot. Tuber specific gravity was measured by the hydrometer method (Gould, 1999), and five marketable grade tubers were drawn randomly from each plot and used for determining the processing quality attributes *viz.* chip colour score (Ezekiel *et al.*, 2003), tuber dry matter content (oven drying at 80°C till constant weight) and glucose content (Biochemistry analyzer, YSI model 2700). All data collected

during the course of experimentation was analyzed on annual basis and pooled analysis has been done as well using statistical software IRRISTAT (IRRI, 1999).

RESULTS AND DISCUSSION

Growth and physiological parameters

The emergence of crop and plant stand was similar among all treatments during both the years and not affected by calcium treatments as well. Kufri Chipsona-3 recorded lower emergence (89.2%) in comparison to Cv. Kufri Sindhuri (96.0%) in first year. Plant height, compound leaf number/plant and stem number/plant were not affected by calcium nutrition, but genotypic variations resulted in better plant height in Kufri Chipsona-3 (53.9 cm) and Kufri Sindhuri (53.5 cm) over Kufri Bahar (47.7 cm). Kufri Chipsona-3 also recorded significantly better stem and compound leaf number over other varieties (Table 1). Pooled analysis revealed that leaf area index (LAI) was not influenced at moderate Ca level (100 kg/ha), but declined markedly at highest dose of 200 kg Ca/ha among all the cultivars. Kufri Chipsona-3 recorded better LAI (1.93) over both of the varieties. The experimental findings of El-Beltagy *et al.* (2002) in potato also advocated that Ca promoted growth parameters like stem length, number of leaves and leaf fresh weight only up to a certain level, which declined at further higher levels of Ca. Crop canopy temperature was neither influenced due to Ca treatments nor due to cultivars. Senescence recorded at 95 and 105 days exhibited variations among the cultivars. Higher senescence was observed for Kufri Bahar in comparison to Kufri Chipsona-3 and Kufri Sindhuri at both the stage of observation in both the years. Pooled results of Kufri Bahar at 105 days exhibited its tendency to remain vigorous with moderate Ca dose of 100 Kg, however rest of the cultivars were not influenced as far as senescence is concerned (Table 2). Growth parameters are basically governed by genetic makeup of a genotype and supply of nutrients from the soil, so calcium levels did not influence these traits as crop was not facing any type of deficiencies of either macro or micro nutrients. However, calcium is known to provide cell membrane thermo-stability and counter abiotic stresses; that is why variety Kufri Bahar tended

to remain vigorous even in later phase of growth. This had support from investigations carried out by Tawfik *et al.* (1996) under in-vitro conditions.

Graded tuber number and yield

Marketable, small, as well as total tuber numbers were not significantly affected in any cultivar due to different calcium rate and its time of application during both the crop seasons and in pooled means. Kumar *et al.* (2007) also inferred with two potato cultivars namely Kufri Ashoka and Kufri Surya grown under heat stress that supplemental Ca did not influence tuber number, but the mean tuber weight increased distinctly. Marked differences were found among cultivars with respect to this parameter. Kufri Sindhuri recorded highest and significantly better marketable (553700), total (1100800) and small (546900) tuber number in comparison to Cv. Kufri Chipsona-3 and Kufri Bahar (Table 3). Kufri Bahar recorded significantly higher marketable tuber yield (33.7 t/ha) in 2008-09 with moderate Ca nutrition (100 kg/ha) over control (26.9 t/ha), while having highest of it with treatment of 200 kg/ha in two splits (37.4 t/ha). This improvement was not visible in second year, however the pooled analysis again reflected similar trend where 200 and 100 kg Ca/ha observed 12 and 9% improvement in the marketable tuber yield over control treatment. Marketable tuber yield tended to improve in Kufri Sindhuri with 200 kg Ca/ha in two splits in first year, and 100 kg Ca/ha in two splits and 200 kg Ca/ha in two splits during 2009-10. Pooled analysis for this cultivar exhibited that 200 kg Ca/ha in two splits significantly improved this parameter (12%) over control. In Kufri Chipsona-3, marketable tuber yield tended to improve with 200 kg Ca/ha in two splits during 2008-09 and in pooled analysis without showing any statistical significance. In case of cultivars, the pooled means values revealed that Kufri Chipsona-3 (37.4 t/ha) had significantly higher marketable yield over Kufri Sindhuri (35.2 t/ha), which were significantly higher over Kufri Bahar (32.9 t/ha). Treatment effect was not visible across the cultivars for small grade tuber yields, but among varieties Kufri Sindhuri (7.89 t/ha) had highest small tuber yield over Kufri Chipsona-3 (5.23 t/ha) and Kufri Bahar (3.89 t/ha), both of these also differed statistically among themselves (Table 4).

Table 1. Effect of calcium rate and application time on growth and physiological traits of potato cultivars

[illegible]

Table 2. Effect of calcium rate and application time on growth and physiological traits of potato cultivars

Calcium rate and time (kg ha ⁻¹)	LAI at 50 d			Canopy temperature (°C) at 85 d			Senescence* at 95 d			Senescence* at 105 d		
	2008-09			2008-09			2008-09			2008-09		
	2009-10	Pooled		2009-10	Pooled		2009-10	Pooled		2009-10	Pooled	
Kufri Bahar												
T ₁ = Control (0 Ca)	1.61	3.33	2.47	22.5	14.7	18.6	3.00	2.50	2.75	2.33	2.50	2.41
T ₂ = 100 as basal	1.40	1.88	1.64	22.0	16.4	19.2	2.83	2.66	2.75	2.50	2.83	2.66
T ₃ = 100 in two splits	1.40	2.11	1.75	22.0	16.4	19.2	3.40	2.83	3.11	2.66	2.50	2.58
T ₄ = 200 as basal	1.58	1.79	1.68	23.5	16.1	19.8	3.77	2.66	3.21	2.83	2.66	2.75
T ₅ = 200 in two splits	1.82	1.90	1.86	22.3	16.5	19.4	3.67	3.00	3.33	3.16	3.00	3.08
Mean	1.56	2.20	1.88	22.5	16.0	19.2	3.33	2.73	3.03	2.70	2.70	2.69
Kufri Sindhuri												
T ₁ = Control (0 Ca)	1.74	1.76	1.75	22.0	16.2	19.1	4.53	3.73	4.13	3.83	3.13	3.48
T ₂ = 100 as basal	1.53	1.58	1.56	22.5	16.7	19.6	3.83	3.83	3.83	3.50	3.20	3.35
T ₃ = 100 in two splits	1.98	1.69	1.83	21.9	16.5	19.2	4.53	3.40	3.96	3.50	2.96	3.23
T ₄ = 200 as basal	1.58	1.33	1.45	22.1	16.8	19.5	3.66	3.53	3.60	3.50	3.13	3.31
T ₅ = 200 in two splits	1.72	1.66	1.69	21.5	16.8	19.2	4.80	3.66	4.23	3.83	2.96	3.40
Mean	1.71	1.60	1.66	22.0	16.6	19.3	4.27	3.63	3.95	3.63	3.08	3.35
Kufri Chipsona-3												
T ₁ = Control (0 Ca)	1.64	2.28	1.96	22.3	16.2	19.3	4.80	3.76	4.28	3.83	2.93	3.38
T ₂ = 100 as basal	2.13	2.10	2.12	21.6	16.4	19.0	4.50	3.76	4.13	4.00	2.46	3.23
T ₃ = 100 in two splits	1.56	2.07	1.82	22.0	16.3	19.2	4.66	3.23	3.95	4.00	2.83	3.41
T ₄ = 200 as basal	1.49	2.12	1.80	21.8	15.9	18.9	4.46	3.33	3.90	3.67	2.63	3.15
T ₅ = 200 in two splits	1.67	2.22	1.95	22.0	16.3	19.1	4.60	3.16	3.88	4.00	2.40	3.20
Mean	1.70	2.16	1.93	21.9	16.2	19.1	4.61	3.45	4.03	3.90	2.65	3.30
CD (P = 0.05) Variety	NS	NS	0.19	NS	NS	NS	0.83	NS	0.25	1.02	NS	0.22
Treatment	NS	NS	0.24	NS	NS	NS	NS	0.41	NS	0.24	0.41	NS

*On a scale of 1-5, where 1 is fully senescent and 5 is fully green

Table 3. Effect of calcium rate and application time on graded tuber number of potato cultivars

Calcium rate and time (kg ha ⁻¹)	Tuber number (thousand ha ⁻¹)								
	Marketable			Small			Total		
	2008-09	2009-10	Pooled	2008-09	2009-10	Pooled	2008-09	2009-10	Pooled
Kufri Bahar									
T ₁ = Control (0 Ca)	323.6	427.8	375.7	220.8	204.4	324.3	557.5	632.2	700.0
T ₂ = 100 as basal	291.7	406.9	349.3	302.8	195.8	354.7	605.0	602.8	704.2
T ₃ = 100 in two splits	337.5	400.0	368.7	156.9	213.9	278.5	508.1	613.9	647.2
T ₄ = 200 as basal	387.5	418.0	348.7	179.2	206.9	298.6	579.2	625.0	701.3
T ₅ = 200 in two splits	254.2	448.6	381.4	258.3	202.8	353.5	527.5	651.4	404.7
Mean	318.9	420.3	365.5	223.6	204.8	321.9	555.4	625.0	631.5
Kufri Sindhuri									
T ₁ = Control (0 Ca)	535.8	623.6	579.7	465.3	420.8	544.4	1007.8	1044.4	1124.7
T ₂ = 100 as basal	501.4	584.7	543.0	534.7	440.3	559.7	1044.2	1025.0	1102.8
T ₃ = 100 in two splits	508.9	616.6	562.7	536.1	413.9	576.4	1050.8	1030.6	1139.2
T ₄ = 200 as basal	495.8	562.50	529.2	450.8	380.6	506.7	951.7	943.0	1035.8
T ₅ = 200 in two splits	494.4	613.9	554.2	480.6	441.7	547.2	981.7	1055.6	1101.4
Mean	507.3	600.3	553.7	493.5	419.4	546.9	1007.2	1019.7	1100.8
Kufri Chipsona-3									
T ₁ = Control (0 Ca)	355.6	460.3	407.9	209.7	306.9	335.0	580.0	767.2	742.9
T ₂ = 100 as basal	340.3	455.5	397.9	359.7	253.0	407.6	711.7	708.1	805.5
T ₃ = 100 in two splits	297.2	440.3	368.8	226.4	313.9	333.3	541.9	754.2	702.0
T ₄ = 200 as basal	381.9	447.2	414.6	261.1	240.3	345.2	650.3	687.5	768.7
T ₅ = 200 in two splits	377.8	486.1	431.9	204.7	223.6	354.4	600.8	709.7	777.3
Mean	350.6	457.9	404.2	252.3	267.6	355.1	616.9	725.4	759.3
CD (P = 0.05) Variety	137.8	66.9	40.1	146.7	95.1	48.7	74.4	85.2	56.1
Treatment	NS	NS	NS	NS	NS	NS	NS	NS	NS

Total tuber yield tended to improve some-time across the cultivars because of better productivity of larger grade. Kufri Bahar had significantly higher total tuber yield with 200 kg Ca/ha (27.7%) in two split and 100 kg Ca/ha (22.1%) over control in first crop season. Although, pooled means were non-significant for this cultivar, but 8.4 and 7.3% higher yield were recorded with 200 kg Ca/ha and 100 kg Ca/ha treatment. Kufri Sindhuri exhibited no difference due to Ca nutrition. The processing variety Kufri Chipsona-3 had significantly better total tuber productivity with 200 kg Ca/ha (14.4%) in two split in first year when compared to control. But this effect was not visible in second year and pooled mean. As far as genotypes are concerned highest total tuber yield was observed in Kufri Sindhuri (43.0 t/ha) followed by Kufri Chipsona-3 (40.3 t/ha) and Kufri Bahar (36.9 t/ha), which also differed statistically among themselves (Table 4).

Higher concentration of Ca in root zone helps plant at cellular level in mitigating abiotic stress of heat due to better cell membrane thermostability and thus assisting cell in its proper functioning (Tawfic *et al.*, 1996). The year 2008-09 was warmer by 1.7 and 1.5 °C for mean maximum and minimum temperatures during crop season in comparison to second year and is evident from Figure 1. Calcium has also probable role in hormonal mechanism of tuberization signals in potato crop, which accelerate quick tuberization and bulking of initial tubers (Palta and Kleinhenz, 2003). Similar results of better bulking of larger grade tubers, which improved marketable yield without improving total tuber yield, have also been reported by Simmons *et al.* (1988).

Processing quality parameters

Critical perusal of data given in Table 5 indicated that Ca application had influenced

Table 4. Effect of calcium rate and application time on graded tuber yield of potato cultivars

Calcium rate and time (kg ha ⁻¹)	Tuber yield (tones ha ⁻¹)								
	Marketable			Small			Total		
	2008-09	2009-10	Pooled	2008-09	2009-10	Pooled	2008-09	2009-10	Pooled
Kufri Bahar									
T ₁ = Control (0 Ca)	26.9	35.8	31.3	4.87	3.92	4.39	33.4	39.7	35.7
T ₂ = 100 as basal	33.7	34.6	34.1	4.84	3.55	4.20	40.8	38.1	38.3
T ₃ = 100 in two splits	29.9	32.6	31.2	3.72	3.58	3.65	35.4	36.1	34.9
T ₄ = 200 as basal	33.5	32.1	32.8	4.04	3.61	3.82	39.5	35.7	36.6
T ₅ = 200 in two splits	37.4	32.9	35.2	3.38	3.78	3.38	42.7	36.7	38.7
Mean	32.3	33.6	32.9	4.17	3.69	3.89	38.4	37.3	36.9
Kufri Sindhuri									
T ₁ = Control (0 Ca)	36.2	33.8	35.0	8.74	9.36	9.05	45.8	43.1	44.0
T ₂ = 100 as basal	33.1	34.3	33.7	9.19	6.67	7.93	43.0	41.0	41.6
T ₃ = 100 in two splits	35.2	38.8	37.0	10.13	6.28	8.20	45.9	45.1	45.2
T ₄ = 200 as basal	34.4	29.7	32.1	8.30	6.33	7.32	43.1	36.0	39.4
T ₅ = 200 in two splits	38.1	37.9	38.0	6.91	7.03	6.97	46.1	44.9	45.0
Mean	35.4	34.9	35.2	8.65	7.13	7.89	44.8	42.0	43.0
Kufri Chipsona-3									
T ₁ = Control (0 Ca)	31.3	41.0	36.1	4.78	4.44	4.61	37.8	45.4	40.8
T ₂ = 100 as basal	32.3	36.5	34.4	6.27	5.75	6.01	40.1	42.2	40.4
T ₃ = 100 in two splits	29.5	37.2	33.3	6.56	5.50	6.03	38.3	42.7	39.4
T ₄ = 200 as basal	30.7	38.6	44.7	5.16	4.47	4.81	37.6	43.1	39.5
T ₅ = 200 in two splits	34.0	39.4	36.7	5.24	4.14	4.69	43.2	43.6	41.4
Mean	31.5	37.5	37.0	5.60	4.86	5.23	39.4	43.4	40.3
CD (P = 0.05) Variety	3.11	NS	1.80	2.01	2.50	1.01	1.16	3.53	1.93
Treatment	3.09	NS	2.33	NS	NS	NS	3.00	NS	NS

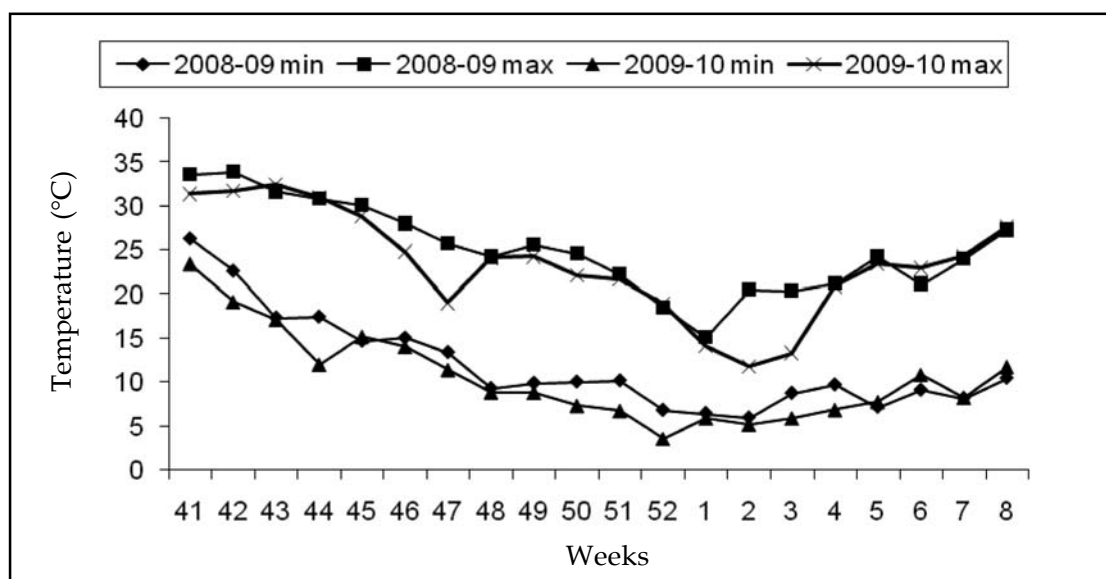
**Fig. 1.** Minimum and maximum temperature during potato crop season of 2008-9 and 2009-10

Table 5. Effect of calcium rate and application time on tuber dry matter content and quality traits of potato cultivars

Calcium rate and time (kg ha ⁻¹)	Tuber dry matter content (%)			Specific gravity			Chip colour score*			Glucose (mg 100 ⁻¹ g FW)		
	2008-09	2009-10	Pooled	2008-09	2009-10	Pooled	2008-09	2009-10	Pooled	2008-09	2009-10	Pooled
Kufri Bahar												
T ₁ = Control (0 Ca)	20.0	19.9	19.9	1.076	1.071	1.073	4.33	6.10	5.21	36.9	174.1	105.5
T ₂ = 100 as basal	20.8	20.6	20.7	1.081	1.070	1.075	5.96	5.06	5.51	67.0	164.5	115.7
T ₃ = 100 in two splits	23.3	19.5	21.4	1.078	1.073	1.075	5.03	5.10	5.06	98.9	82.1	90.5
T ₄ = 200 as basal	21.2	18.8	20.0	1.083	1.073	1.078	4.80	6.00	5.40	126.2	116.2	121.2
T ₅ = 200 in two splits	21.9	21.6	21.7	1.080	1.070	1.075	4.93	6.16	5.55	49.9	119.9	84.9
Mean	21.4	20.1	20.7	1.080	1.071	1.075	5.01	5.68	5.34	75.8	131.4	103.5
Kufri Sindhuuri												
T ₁ = Control (0 Ca)	24.9	21.1	22.9	1.092	1.081	1.086	4.00	5.30	4.65	44.2	96.9	70.6
T ₂ = 100 as basal	23.0	22.8	22.9	1.096	1.081	1.088	3.66	5.10	4.39	24.1	76.4	50.2
T ₃ = 100 in two splits	25.9	21.9	23.9	1.099	1.083	1.091	4.10	5.63	4.87	40.9	105.2	73.0
T ₄ = 200 as basal	24.5	21.2	22.8	1.097	1.084	1.090	5.03	5.93	5.48	65.9	91.1	78.5
T ₅ = 200 in two splits	24.7	22.7	23.7	1.097	1.078	1.087	4.86	6.20	5.53	41.0	101.7	71.4
Mean	24.6	21.9	23.2	1.096	1.081	1.088	4.33	5.63	4.98	43.2	94.3	68.7
Kufri Chipsona-3												
T ₁ = Control (0 Ca)	25.4	24.7	25.0	1.095	1.088	1.091	2.43	2.96	2.70	31.2	18.9	25.1
T ₂ = 100 as basal	24.8	23.6	24.2	1.095	1.088	1.091	1.26	3.06	2.16	1.62	17.8	9.7
T ₃ = 100 in two splits	24.2	23.2	23.7	1.094	1.088	1.092	3.10	3.00	3.05	4.50	12.2	8.4
T ₄ = 200 as basal	24.3	22.9	23.6	1.095	1.087	1.093	2.60	3.26	2.93	1.37	28.9	15.2
T ₅ = 200 in two splits	25.6	20.6	23.1	1.093	1.086	1.089	1.60	2.50	2.05	2.50	8.10	5.3
Mean	24.8	22.9	23.9	1.094	1.087	1.091	2.20	2.96	2.58	8.25	17.9	12.7
CD (P = 0.05) Variety	1.74	2.45	0.80	0.003	0.003	0.001	0.28	0.67	0.28	17.9	66.1	18.2
Treatment	NS	2.18	NS	0.002	NS	0.001	0.29	NS	0.36	13.2	NS	NS

*On a scale of 1-10, where 1 is white and 10 is black/brown, and a score up to 3 is considered as acceptable.

tuber dry matter content slightly, as in case of Kufri Bahar, moderate level of 100 kg Ca/ha improved this consistently over the years and in pooled means without statistical significance. Similarly, in Kufri Sindhuri this trend was visible in second crop season and pooled means. However, dry matter content of Kufri Chipsona-3 was not influenced by calcium nutrition, which tended to decline with higher doses. Among cultivars, Kufri Chipsona-3 (23.9%) recorded pooled mean maximum tuber dry matter content at par with Kufri Sindhuri (23.2%), but it was significantly better over Kufri Bahar (20.7%). Likewise, specific gravity, a more sophisticated indicator of tuber dry matter content in Kufri Bahar and Kufri Sindhuri exhibited improvement in all the years and in pooled analysis. Kufri Bahar recorded highest specific gravity (1.078) with 200 kg Ca/ha followed by (1.075) at 100 kg Ca/ha which was significantly better over the control (1.073) in pooled means. Kufri Sindhuri had highest specific gravity (1.091) with 100 kg Ca/ha in two splits followed by 1.088 at 100 kg Ca/ha remaining statistically superior over the control (1.086). Kufri Chipsona-3 also observed highest specific gravity (1.093) at 200 kg Ca/ha significantly better over the control (1.091). As Recovery of the finished/fried products is directly correlated with the tuber dry matter content and more specifically with tuber specific gravity, therefore higher values for these variables are desirable especially for processing purposes (Table 5).

Chip colour score, where 1 is white (most acceptable), 10 is black/brown (not acceptable) and score up to 3 is acceptable, is not much important in ware cultivars like Kufri Bahar and Kufri Sindhuri. But it is second most important character after tuber dry matter content for processing variety Kufri Chipsona-3 and this score improved significantly at moderate Ca level of 100 kg Ca/ha (1.26) in first year and on pooled

basis (2.16) in comparison to control (2.43 & 2.70, respectively), at harvest time. Glucose content (limit : <30 mg/100g fresh tuber weight) measured at harvest time is also very important for processing cultivar Kufri Chipsona-3, unlike the Cv. Kufri Bahar and Kufri Sindhuri as its higher content also downgrade chip colour score due to Maillard reaction (Kumar *et al.*, 2004). The glucose content in Kufri Chipsona-3 consistently declined with Ca application and significantly lower values of 1.62 and 9.7 were recorded at 100 kg Ca/ha in first year and in pooled means as compared to control values of 31.2 and 25.1 mg/100 g FW. The glucose content also tended to decline in second year; however, the mean values were statistically at par (Table 5). Silva *et al.* (1991) observed no impact of calcium application in the form of gypsum (0, 560 and 840 kg Ca/ha) on chip colour and reducing sugars of potato tubers.

Internal and external defects

No internal defects like hollow heart, brown centre, internal brown spots etc. were observed in any treatment under study during 2008-09. External defects like crack, knobbiness etc. was also recorded and it was found that it did not respond to Ca nutrition. Likewise, no internal defects were found in any treatment during second crop season and again external defects did not response to calcium levels. Ozgen *et al.* (2006) worked for internal defects of tubers at Wisconsin and stated that increased application of calcium in root zone enhanced tuber Ca concentration which helped in reduction of tuber defects like Internal brown spots.

Moderate calcium application (200 kg/ha) in two equal splits (at planting and 20-25 days after planting during earthing operation) as gypsum may be advised to potato growers for mitigating abiotic stress of higher temperatures under field conditions to attain better tuber productivity and post harvest quality.

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