



Effect of calcium and magnesium nutrition on vegetative growth and tuber yield of potato (*Solanum tuberosum*)

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ARTICLE INFO	ABSTRACT
Received : 23 May 2023 Revised : 25 September 2023 Accepted : 09 October 2023 Available online: 02 February 2024 Key Words: Calcium Nitrate Growth Magnesium Sulfate Potato Tuber Yield	A field experiment was conducted to investigate the effect of calcium nitrate and magnesium sulfate on the growth and tuber yield in potato (<i>Solanum tuberosum</i> L.). Experiment was carried out in split-plot design comprising of nine calcium nitrate and magnesium sulfate treatments i.e. T ₁ - Ca(NO ₃) ₂ @ 0.5%, T ₂ - Ca(NO ₃) ₂ @ 1%, T ₃ - Ca(NO ₃) ₂ @ 2%, T ₄ - MgSO ₄ @ 0.5%, T ₅ - MgSO ₄ @ 1%, T ₆ - MgSO ₄ @ 2%, T ₇ - Ca(NO ₃) ₂ @ 1% + MgSO ₄ @ 1%, T ₈ - Ca(NO ₃) ₂ @ 2% + MgSO ₄ @ 2%, T ₉ - Control on two potato varieties i.e. Kufri Jyoti and Kufri Chandramukhi. Data collected on different parameters were analyzed using CPCS1 software. Among all the calcium nitrate and magnesium sulfate treatments, application of Ca(NO ₃) ₂ @ 2% + MgSO ₄ @ 2% was found to be the best for most of the parameters studied and between the varieties Kufri Jyoti was found highly significant for the different parameters under study. Hence it can be concluded that commercial cultivation of potato in the central region of Punjab can be successfully supplemented with application of Ca (NO ₃) ₂ + MgSO ₄ and variety Kufri Jyoti.

Introduction

Potato (*Solanum tuberosum* L.) is a widely grown tuber crop all over the world. It belongs to the family Solanaceae and had originated in Peru, South America. It is the fifth most important crop around the world after wheat, corn, rice and sugarcane (Mann, 2011). Next to cereals, potato is the only crop which could supplement the need for the food of the country (Das, 2000). It is a tetraploid crop containing all essential food ingredients, which are required to maintain proper health and considered to be the main source of starch and carbohydrates. Potato is the balanced food containing less energy but considered to be the rich source of starch, vitamin C, folate, vitamin B6, and antioxidants such as flavonoids, phenolic acids, carotenoids and a substantial amount of protein (Mehdi *et al.* 2008). The average composition of potato tuber per 100g edible portion is 79.25g moisture, 2.05g protein,

0.09g fat, 17.49g carbohydrates, 77 kcal energy, 12mg calcium, 57mg phosphorus, 0.81mg iron, 24µg carotene, 0.081mg thiamine, 0.032mg riboflavin, and 19.7mg vitamin-C. Potato cultivation is highly cost-intensive due to many dependencies on fertilizers as reported by Nandekar *et al.* (2006) that nutritional requirement increases with a higher bulking rate as in potato. Production of potato is also affected by certain nutritional deficiencies when cultivated on sandy soils which are low in certain nutrients such as calcium and magnesium. Potatoes are more sensitive to calcium deficiency than many other crops because calcium as an essential macronutrient plays a great role in maintaining cell wall and cell membrane structure in the potato. Calcium performs this function of maintenance by stable linking the polar head groups and pectic acid fractions of the cell wall by stable reversible

linkages. So supplement the crop with calcium is beneficial in commercial production of potato. Simmons *et al.* (1988) reported that calcium treatments increased the yield of prime sized tubers along with an increase in periderm calcium concentration. Whereas, Locascio *et al.* (1992) reported that tuber yields were increased from 29.8 to 31.6 tons per hectare with the application of calcium-based fertilizers. Adequate amounts of calcium help in improving skin color of red potatoes. Deficient supply of calcium can result in abnormal growth like hollow heart and internal brown spot. It has been reported that the incidence of necrosis and internal rust spot is also reduced by calcium (Clarkson, 1984). An adequate supply of calcium increases potato's resistance to soft rot during storage and have also potential to increase the seed potatoes performance. Another important nutrient element in potato cultivation is magnesium as in some cases it has been found that severe magnesium deficiency can reduce the yield of tubers up to 15%. Foliar sprays of magnesium can be very effective during dry conditions of soil which can otherwise restrict the uptake. Uptake of magnesium is dependent upon the exchange capacity of the soil and its balance with other cations like potassium. The high concentration of potassium can also cause magnesium deficiency; in such cases the foliar application of magnesium is also recommended. With severe susceptibility to magnesium deficiency, it is essential to include magnesium in the balanced fertilizer programs. Application of calcium in potato has been reported to reduce the input of fungicides, decrease internal necrosis, increase yield, storage life, tuber weight, size, and quality. Calcium also promotes plant growth and root development as it plays part in cell division and root elongation (Iiyama *et al.* 1994). During the stress, calcium helps the plants in resisting them or to adapt the stress by inducing the signal chain (Kudla *et al.* 2010).

Material and Methods

A field experiment was conducted to study the effect of calcium nitrate and magnesium sulfate on growth, tuber yield and late blight (*Phytophthora infestans*) incidence in potato (*Solanum tuberosum* L.). The experiment was laid out during rabi 2017-18 under irrigated condition, at the research farm of Lovely Professional University Phagwara. The experiment

was carried out in split plot design with three replications. The experiments had eighteen treatment combinations comprised of nine calcium and magnesium levels i.e. Ca (NO₃)₂ @ 0.5% (T₁), Ca (NO₃)₂ @ 1% (T₂), Ca (NO₃)₂ @ 2% (T₃), MgSO₄ @ 0.5% (T₄), MgSO₄ @ 1% (T₅), MgSO₄ @ 2% (T₆), Ca (NO₃)₂ @ 1% + MgSO₄ @ 1% (T₇), Ca (NO₃)₂ @ 2% + MgSO₄ @ 2% (T₈), control (T₉) and two varieties i.e. Kufri Jyoti (V₁) and Kufri Chandramukhi (V₂). Sprouted seed tubers of potato were dipped before planting in the solution of Dithane M-45 @ 2.5 gm/litre for 20 minutes in a tray to avoid any internal and external fungal infection. Potato seed tubers were taken out 9 days before planting from the cold storage and kept in the shed to accelerate the sprouting of the tubers. The treated tubers were planted on ridges of 60 cm apart with a spacing of 20 cm. The calcium and magnesium water-soluble forms i.e. calcium nitrate and magnesium sulfate were applied as a foliar spray with first spray at 40 DAS followed by two sprays at an interval of 10 days. Different growth and yield attributes were recorded at specific time.

Results and Discussion

Plant height: The plant height was measured in centimetre from ground level to the top of the plant at 75 DAS. Plant height was measured through a centimetre scale and recorded. Five uniform plants were randomly selected and tagged to record the observation. Among the different treatments, calcium nitrate treatments had a more pronounced influence on the plant height as compared to magnesium sulfate treatments. However, combined calcium nitrate and magnesium sulfate treatments i.e. T₇ and T₈ produced significantly taller plants over the alone calcium and magnesium treatments. The highest plant height was observed in T₇ (43.65 cm) i.e. combination of Ca (NO₃)₂ @ 1% + MgSO₄ @ 1%, which was significantly at par with T₈ (43.10 cm) i.e. Ca (NO₃)₂ @ 2% + MgSO₄ @ 2%. Whereas, the shortest plants (28.60 cm) were produced under the T₉ (control) (table1). Among the varieties, V₁ (Kufri Jyoti) resulted in the maximum plant height (36.45cm) in comparison to V₂ (Kufri Chandramukhi) (34.50cm) which showed a 5.65% increase in height over the latter. Significant results were also observed for plant height among the interaction between treatments and varieties.

Interaction between them showed that V₁T₇ i.e. Kufri Jyoti sprayed with Ca (NO₃)₂ @ 1% + MgSO₄ @ 1% performed better and resulted in the highest plant height (47.67cm) and found to be significantly at par with V₁T₈ (Kufri Jyoti sprayed with Ca (NO₃)₂ @ 2% + MgSO₄ @ 2%). Likewise, V₂T₈ (Kufri Chandramukhi sprayed with Ca (NO₃)₂ @ 2% + MgSO₄ @ 2%) was at par with V₂T₇ (Kufri Chandramukhi sprayed with Ca (NO₃)₂ @ 1% + MgSO₄ @ 1%) and V₁T₂ (Kufri Jyoti sprayed with Ca (NO₃)₂ @ 1%). Similarly, V₁T₃ was at par with V₂T₂ and V₂T₃. However, V₁T₉ i.e. (Kufri Jyoti under control) resulted in the lowest plant height (27.27 cm). The higher plant height might be due to better nutrient absorption and higher rates of photosynthesis. Seifu (2017) observed a significant interaction between calcium nutrients and potato varieties for plant height and noticed that due to the application of CaNO₃ and CaCl₂ at 15 g per plant resulted in 45% higher plant height than the control. The difference in plant height among the varieties may be attributed to genetic differences which are in accordance with the finding of Verma *et al.* (2013) and Gupta *et al.* (2017).

Number of leaves per plant: Leaves are associated with the interception and utilization of solar radiation and consequently effect dry matter accumulation and ultimately the tuber yield. The significant effect of treatments, varieties, and interaction between treatments and varieties on the number of leaves per plant. Among the different treatments, the lowest number of leaves per plant was observed under control (37.23), whereas the highest number of leaves per plant (44.85) was achieved by T₇ i.e. Ca (NO₃)₂ @ 1% + MgSO₄ @ 1% which was significantly similar to T₈ i.e. Ca (NO₃)₂ @ 2% + MgSO₄ @ 2% (44.73). However, Ca (NO₃)₂ @ 0.5% i.e. T₁ and MgSO₄ @ 0.5% i.e. T₄ produced a significantly lower number of leaves per plant and were significantly at par with one another (table1). The significant parity was also observed among the T₂, T₅, and T₆ treatments combinations which were significantly lower than the T₃ treatment. Among the varieties, V₁ (Kufri Jyoti) resulted in the maximum number of leaves per plant (43.52) in comparison to V₂ (Kufri Chandramukhi) (39.94) which showed 8.96% increase in the number of leaves per plant over the latter. Significant results were also observed for a number of leaves per plant among the

interaction between treatments and varieties. Interaction between different treatments and varieties showed that V₁T₇ i.e. Kufri Jyoti sprayed with Ca (NO₃)₂ @ 1% + MgSO₄ @ 1% each performs better and resulted in the highest number of leaves per plant (47.27) and found significantly at par with V₁T₈ (47.20) i.e. Kufri Jyoti sprayed with Ca (NO₃)₂ @ 2% + MgSO₄ @ 2%. Treatment V₁T₂ was also found significantly at par with V₁T₃, V₁T₅, V₁T₆, and V₂T₃. However, V₁T₉ i.e. Kufri Jyoti under control resulted in the lowest number of leaves per plant (36.60). Kufri Jyoti variety sprayed with Ca (NO₃)₂ @ 1% + MgSO₄ @ 1% resulted in 29.15% increment in the number of leaves over the growth in control. The varietal difference for number of leaves per plant may be due to the differences in height of the plant as number of leaves per plant increases with increase in plant height which can be seen from higher plant height in Kufri Jyoti as reported by Jatav *et al.* (2017).

Leaf Area (cm²): Leaf area influences the interception and utilization of solar radiation of crop canopies and consequently dry matter accumulation and ultimately the tuber yield. The results of the leaf area per plant (cm²) for different treatments, varieties, and interaction between treatments and varieties were found to be significantly significant ($p < 0.05$) and presented in Table 1. Among the different calcium nitrate and magnesium sulfate treatments, T₈ (Ca (NO₃)₂ @ 2% + MgSO₄ @ 2%) lead to the largest leaf area (147.13 cm²) which is significantly superior over all the treatments whereas, T₉ (control) resulted in smallest leaf area (122.95 cm²). Among the varieties, V₂ (Kufri Chandramukhi) resulted in the largest leaf area (146.52 cm²) in comparison to V₁ (Kufri Jyoti) (124.18 cm²) that showed 17.99 % increase in the leaf area over latter (table1). Significant results were also observed for leaf area among the interaction between treatments and varieties. Interaction between different treatments and varieties showed that V₂T₈ i.e. Kufri Chandramukhi sprayed with Ca (NO₃)₂ @ 2% + MgSO₄ @ 2% performs better and resulted in largest Leaf area (160.21 cm²) and found to be significant over all other treatment combinations. However, V₁T₉ i.e. (Kufri Jyoti under control) resulted in the smallest leaf area (109.18 cm²). Calcium helps in increase in the leaf area due to its role in cellular division and cell elongation. It

also has a role in the process of photosynthesis and increases the accumulation of carbohydrates, thereby improving the vegetative growth of plants (Kafi *et al.* 2003). Similarly, magnesium helps in the formation of the chlorophyll molecule which further contributes pigments such as carotene, xanthophyll and is responsible for activation of a number of enzymes and coenzymes which further contribute to carbohydrate metabolism and consequently increases the vegetative growth as reported by Rehm (2008) and Alhatib (2007). The highest leaf area of variety Kufri Chandramukhi might be due to its inherent genetic makeup. The varietal difference for leaf area has also been reported by Raj *et al.* (2016).

Number of branches per plant: Results revealed that calcium nitrate and magnesium sulfate treatments had a non-significant effect on the number of branches per plant. However, numerically the highest value of number of branches per plant (5.00) was achieved under treatment T₁ i.e. Ca (NO₃)₂ @ 0.5% while the lowest value (4.28) was achieved under the T₂ i.e. Ca(NO₃)₂ @ 1 % treatment. The two varietal treatments exerted significant influence on the number of branches per plant. Kufri Jyoti obtained the maximum number of branches (5.38) as compared to the Kufri Chandramukhi variety (4.09) (table1). Data among the different interaction combinations showed non- significant results for the number of branches per plant. However, the highest value (5.65) for number of branches per plant in the interaction combination was achieved under V₁T₆ (Kufri Jyoti sprayed with MgSO₄ @ 2%) and the lowest value (3.36) was achieved by V₂T₃ (Kufri Chandramukhi sprayed with Ca (NO₃)₂ @ 2%) interaction combination. The number of branches per plant was not affected by the application of calcium nitrate and magnesium sulfate treatments because the calcium has more impact on apical dominance, which inhibits the growth of lateral branches as reported by Ravichandran *et al.* (2015). The differences among the variety for number of branches per plant may be due to inherent and genetic characters of cultivars and better adaptability to prevailing environmental conditions. Present findings were in accordance with that of Preetham *et al.* (2018).

Fresh weight of shoots (g/plant): Significant results were recorded in different treatments and data

reveals that fresh weight of shoots ranged from 130.13 g/plant to 189.72 g/plant. Among the different calcium nitrate and magnesium sulfate treatments, T₈ (Ca (NO₃)₂ @ 2% + MgSO₄ @ 2%) lead to the maximum fresh weight of shoots (189.72 g/plant), which is significantly superior over all the treatments. The lowest 130.13g/plant fresh weight of shoots was recorded in T₉ (control). Among the varieties, V₁ (Kufri Jyoti) resulted in maximum fresh weight of shoots (160.77g/plant) in comparison to V₂ (Kufri Chandramukhi) (149.44 g/plant) that showed 7.58% increase in fresh weight of shoots over the latter. Significant results were also observed for the fresh weight of shoots among the interaction between calcium, magnesium treatments and varieties (table1). Interaction between different treatments and varieties showed that V₁T₈ i.e. Kufri Jyoti sprayed with Ca (NO₃)₂ @ 2% + MgSO₄ @ 2% performs better and resulted in highest fresh weight of shoots (194.53g/plant) and found to be significant over all other treatment combinations. However, MgSO₄ @ 1% i.e. T₅ in V₁ produced a significantly lower fresh weight of foliage (152.43 g/plant) followed by V₁ T₄ (Kufri Jyoti sprayed with MgSO₄ @ 0.5%), V₁T₁ (Kufri Jyoti sprayed with Ca (NO₃)₂ @ 0.5%) and V₂T₂ (Kufri Chandramukhi sprayed with Ca (NO₃)₂ @ 1%) and these interaction combinations are also significantly at par with each other. The lowest fresh weight of foliage (122.60 g/plant) was recorded in V₂ T₉ i.e. (Kufri Chandramukhi under control). The significant parity was also observed among the interaction combinations of V₂ T₆, V₂ T₅, V₂ T₃, and V₂ T₁. These findings are supported by Chowdhury (2017), who observed a significant increase in fresh weight of shoots upon applying different doses of calcium and magnesium in potato. The higher fresh weight of shoots might be due to increased membrane integrity and the role of calcium and magnesium in decreasing the losses due to various biotic and abiotic stress by Seifu (2017).

Dry weight of shoots (g/plant): Significant results were recorded in different treatments for dry weight of shoots. Among the different treatments, T₈ (Ca (NO₃)₂ @ 2% + MgSO₄ @ 2%) lead to the maximum dry weight of shoots (32.90 g/plant). The significantly parity was observed in treatment T₁ i.e. Ca (NO₃)₂ @ 0.5%, T₄ i.e. MgSO₄ @ 0.5%, T₅ i.e. MgSO₄ @ 1% and T₆ i.e. MgSO₄ @ 2%. However,

Table 1 Effect of calcium and magnesium nutrition on vegetative growth of potato

Treatments	Plant Height (cm)		Number of leaves per plant		Leaf area (cm ²)		No. of branches per plant		Fresh weight of shoots (g/plant)		Dry weight of shoots (g/plant)	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
T₁ Ca(NO₃)₂ @ 0.5%	32.70	32.10	42.07	39.43	122.91	142.64	5.45	4.55	150.87	144.57	22.70	22.09
T₂ Ca(NO₃)₂ @ 1%	38.47	35.63	41.87	40.23	126.48	144.22	4.84	3.72	160.63	150.47	25.66	24.44
T₃ Ca(NO₃)₂ @ 2%	36.80	36.20	44.70	40.70	125.70	145.22	5.41	3.36	155.87	146.57	27.14	25.83
T₄ MgSO₄ @ 0.5%	30.67	30.30	41.37	37.90	119.90	142.19	5.25	4.41	149.47	138.67	21.89	20.74
T₅ MgSO₄ @ 1%	33.40	33.37	45.67	39.07	119.87	148.34	5.40	4.33	152.43	143.27	23.09	21.28
T₆ MgSO₄ @ 2%	33.53	34.67	44.90	39.53	124.58	140.28	5.65	3.59	154.57	143.33	24.18	22.20
T₇ Ca(NO₃)₂ 1%+ MgSO₄ @ 1%	47.67	39.63	47.27	42.43	134.91	158.89	5.63	4.09	190.93	170.63	32.72	29.21
T₈ Ca(NO₃)₂ 2%+MgSO₄ @ 2%	47.53	38.67	47.20	42.27	134.05	160.21	5.30	4.49	194.53	184.90	33.78	32.02
T₉ Control	27.27	29.93	36.60	37.87	109.18	136.72	5.49	4.27	137.67	122.60	17.23	13.09
Factors	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)
Varieties	1.088	0.166	1.893	0.289	4.82	0.736	0.93	0.142	1.647	0.251	1.699	0.259
Treatments	0.896	0.310	1.774	0.613	8.79	3.037	N/A	0.331	1.190	0.411	1.106	0.382
Varieties x Treatments	1.502	0.498	2.863	0.867	N/A	2.207	N/A	0.426	2.053	0.754	1.971	0.778

the minimum (15.16 g/plant) dry weight of shoots was observed in T₉ (control). Among the varieties, V₁ (Kufri Jyoti) resulted in maximum dry weight of shoots (25.38 g/plant) in comparison to V₂ (Kufri Chandramukhi) (23.43 g/plant) that showed a difference of 8.32% among both (table1). Significant results were also observed for dry weight of shoots among the interaction between treatments and varieties. Interaction between different treatments and varieties showed that V₁T₈ i.e. Kufri Jyoti sprayed with Ca (NO₃)₂ @ 2% + MgSO₄ @ 2% performs better and resulted in highest dry weight (33.78 g/plant) and found to be at par with V₁T₇ (Kufri Jyoti sprayed with Ca (NO₃)₂ @ 1% + MgSO₄ @ 1%) and V₂T₈ (Kufri Chandramukhi sprayed with Ca (NO₃)₂ @ 2% + MgSO₄ @ 2%). Application of Ca (NO₃)₂ @ 1% and 2% to the variety Kufri Jyoti resulted in significantly similar production of the dry weight of shoots as achieved under variety Kufri Chandramukhi due to the application of Ca (NO₃)₂ @ 2% (V₂T₃). However, V₂T₉ i.e. (Kufri Chandramukhi under control) resulted in the lowest dry weight of shoots (13.09 g/plant). These findings are also in harmony with (Beltagy *et al.* 2002) and El-Zohiri and Asfour (2009) who revealed that Ca²⁺ fertilization increased the dry weight of the potato plant compared with control. Higher genetic potential promoted more photosynthesis and accumulation of dry matter and hence the drier weight of shoots per plant was recorded in variety Kufri Jyoti followed by Kufri Chandramukhi. Similar findings have been reported by Jatav *et al.* (2017).

Number of small tubers per plant: Among the different treatments, the lowest number of small tubers per plant were achieved by T₈ (1.55) i.e. application of Ca (NO₃)₂ @ 2% + MgSO₄ @ 2%. However, the maximum number of small tubers per plant was found in T₉ (control) that was 3.43. Among the different varieties, the lowest number of small tubers per plant (2.31) was found in V₂ (Kufri Chandramukhi) whereas V₁ (Kufri Jyoti) produced a significantly highest number of small tubers per plant (2.37) (table2). Interaction between different treatments and varieties exhibited significantly significant results for number of small tubers per plant. Among the different interaction combination, the lowest number of small tubers per plant (1.45) was found in V₁T₈ i.e. by the spray of Ca (NO₃)₂ @ 2% + MgSO₄ @ 2% in variety Kufri Jyoti. The significant parity was observed in V₂T₇ (Spray of

Ca (NO₃)₂ + MgSO₄ @ 1% each in variety Kufri Chandramukhi), V₁T₇ (Spray of Ca (NO₃)₂ @ 1% + MgSO₄ @ 1% in variety Kufri Jyoti) and V₁T₁ (Spray of Ca (NO₃)₂ @ 0.5% in variety Kufri Jyoti), V₂T₁ (Spray of Ca (NO₃)₂ @ 0.5% in variety Kufri Chandramukhi). However, the highest number of small tubers per plant was found in V₂T₉ (Kufri Chandramukhi under control) (3.56). The number of small tubers per plant was significantly reduced with the increase in the concentration of magnesium sulfate and calcium nitrate. These results were supported by the findings of Mani *et al.* (2014). According to Preetham *et al.* (2018) and Marwaha *et al.* (2007) the differences in number of small tubers between the varieties might be due to genetic variations and adaptability of the variety to prevailing climatic conditions of the experimental site.

Number of medium tubers per plant: the highest number of medium tubers per plant (5.04) was obtained under T₈ i.e. Ca (NO₃)₂ @ 2% + MgSO₄ @ 2% which was significantly higher than all other treatments except (T₇) i.e. Ca (NO₃)₂ @ 1% + MgSO₄ @ 1% (4.86), which was significantly similar to T₈. However, the lowest number of medium tubers per plant (3.55) was observed under the control T₉ (control). The significant parity was observed among the (T₁) i.e. Ca (NO₃)₂ @ 0.5%, (T₂) i.e. Ca (NO₃)₂ @ 1%, (T₄) i.e. MgSO₄ @ 0.5% and (T₅) i.e. MgSO₄ @ 1% treatment combinations. A progressive increase in the number of medium tubers per plant was reported with increasing concentrations of Ca (NO₃)₂ and MgSO₄. Combined application of CaNO₃ + MgSO₄ has a significantly better effect on the number of medium tubers per plant in comparison to alone application of CaNO₃ and MgSO₄. The number of medium tubers per plant was significantly influenced by the two varieties as Kufri Jyoti (V₁) achieved significantly higher number count (4.30) of the medium tubers per plant over the Kufri Chandramukhi (V₂) (4.09). The interaction effect of different calcium nitrate and magnesium sulfate treatments and varieties on number of medium tubers per plant at the time of harvesting revealed significant differences. Highest count (5.22) was obtained under V₁T₈ (Kufri Jyoti sprayed with Ca (NO₃)₂ @ 2% + MgSO₄ @ 2%) and lowest (3.40) under V₁T₉ (Kufri Jyoti under control). Among the different interaction combinations, the significant parity was observed in V₂T₈ (Kufri Chandramukhi sprayed with Ca (NO₃)₂ @ 2% + MgSO₄ @ 2%)

with V₁T₇ (Kufri Jyoti sprayed with Ca (NO₃)₂ @ 1% + MgSO₄ @ 1%) and V₂T₇ (Kufri Chandramukhi sprayed with Ca (NO₃)₂ @ 1% + MgSO₄ @ 1%). These findings get support from the work of Simmons and Kelling (1988) who reported an improvement in tuber grade by the application of calcium in the sandy soils. The variation in the number of medium tubers of potato genotypes may be due to genotypic and varietal factor. Similar results were reported by Marwaha *et al.* (2007), Khan *et al.* (2018) and Sadawarti *et al.* (2018) that different varieties had significant influence on number of medium tubers per plant.

Number of large tubers per plant: It is clear from the data that the best results in terms of number of large tubers per plant were given by application of Ca (NO₃)₂ @ 2% + MgSO₄ @ 2% (3.54) concentration i.e. in treatment T₈ and was having significantly similarity with treatment T₇ (3.46) i.e. CaNO₃ @ 1% + MgSO₄ @ 1% concentration. The lowest number of large tubers per plant (2.82) was obtained under the control i.e. T₉ which was significantly lower than all other treatments (table 2). However, there was the non-significant difference among all the calcium nitrate treatments i.e. T₁, T₂, and T₃. The number of large tubers per plant was influenced significantly by varietal treatments. Kufri Jyoti (V₁) had given better results by producing a significantly higher number of large tubers per plant (3.39) over the Kufri Chandramukhi (V₂) variety that was recorded 3.14. The interaction effect of treatments and varieties showed that application of calcium nitrate and magnesium sulfate @ 2% each on variety Kufri Jyoti produces a higher number of large sized tubers (3.75) i.e. in V₁T₈. Among the other interaction combinations, the significant parity was observed in V₂T₈ (Kufri Chandramukhi sprayed with Ca (NO₃)₂ @ 2% + MgSO₄ @ 2%), V₂T₇ (Kufri Chandramukhi sprayed with CaNO₃ @ 1% + MgSO₄ @ 1%) and V₁T₇ (Kufri Jyoti sprayed with CaNO₃ @ 1% + MgSO₄ @ 1%). However, the lowest number of large tubers were found in V₂T₉ (Kufri Chandramukhi under control) (2.57). On the support to present findings, Russell (1975) found that the application of magnesium to potato crop resulted in a higher number of large tubers which ultimately enhance the total tuber yield mainly due to the role of magnesium in the transportation of phosphate. On the other side application of

calcium to potato crop enhance the tuberization process as reported by Ozgen *et al.* (2003).

Yield of tubers

Yield of Small Tubers (g/plant): The calcium and magnesium treatments had a depressing effect on the yield of small tubers. The lowest and highest yield of small tubers was obtained under the T₈ treatment i.e. CaNO₃ @ 2% + MgSO₄ @ 2% (53.44 g/plant) and T₉ i.e. control (97.39 g/plant), respectively. All the treatments were significantly different from each other except T₁ & T₂ and T₃ & T₄ which were at par with one another. The yield of small tubers followed the decreasing trend when calcium and magnesium treatment concentrations were increased from 1 % to 2 %. The varieties had a significant effect on the yield of small tubers. Variety V₁ i.e. Kufri Jyoti (79.81 g/plant) had the significantly higher yield of small tubers over the V₂ i.e. Kufri Chandramukhi (70.44 g/plant). Among the interaction, the effect of different calcium and magnesium treatments and varieties exhibited significantly significantly results for the yield of small tubers. The lowest yield of small tubers was recorded in V₁T₈ i.e. Kufri Jyoti sprayed with Ca (NO₃)₂ @ 2.0% + MgSO₄ @ 2.0% (52.17 g/plant) and highest yield was found under V₂T₉ i.e. Kufri Chandramukhi control (94.71 g/plant). The significant parity was observed in V₂T₈ i.e. Kufri Chandramukhi sprayed with Ca (NO₃)₂ @ 2.0% + MgSO₄ @ 2.0% (54.71 g/plant), V₁T₈ i.e. Kufri Jyoti sprayed with Ca(NO₃)₂ @ 2.0% + MgSO₄ @ 2.0% (52.17 g/plant) and V₂T₇ i.e. Kufri Chandramukhi sprayed with Ca(NO₃)₂ @ 1% + MgSO₄ @ 1% (57.97 g/plant). According to Arsenault and Christie (2004), the variations between the varieties for small tuber weight were mainly due to reason that the plant height and number of branches may strongly influence the yield of small tubers. This was confirmed by the present findings where Kufri Jyoti had higher plant height and number of branches and hence produced the higher yield of small tubers.

Yield of medium tubers (g/plant): The different calcium and magnesium treatment combinations had exerted significant influence on the weight of the medium tubers. Yield of medium tubers was recorded maximum (173.99 g/plant) in T₈ (Ca (NO₃)₂ @ 2.0% + MgSO₄ @ 2.0%) which was almost double of the T₉ (control) treatment which had the lowest (100.58 g/plant) yield of medium tubers. All the treatment combinations were significantly different from each other. The yield

of medium tubers increased with an increase in the calcium nitrate and magnesium sulfate concentration. Foliar application of calcium nitrate and magnesium sulfate @ 2% was found to be superior over both 0.5% and 1.0% concentration. Data further reveals that the yield of medium tubers was also significantly affected by the two varieties. The yield of medium tubers was significantly higher in V₁ i.e. Kufri Jyoti (147.38 g/plant) as compared to the V₂ i.e. Kufri Chandramukhi (126.79 g/plant) variety. The interaction effects of treatments and varieties showed that application of calcium nitrate and magnesium sulfate @ 2 % each on variety Kufri Jyoti recorded maximum yield of medium tubers (187.75 g/plant) i.e. in interaction combination V₁T₈. However, the lowest yield of medium tubers was recorded in V₂T₉ i.e. Kufri Chandramukhi under control (98.12 g/plant). Among the other interaction combinations, the significant parity was observed in V₁T₃ i.e. Kufri Jyoti sprayed with Ca (NO₃)₂ @ 2% (160.65 g/plant) and V₂T₈ Kufri Chandramukhi sprayed with Ca (NO₃)₂ @ 2.0% + MgSO₄ @ 2.0% (160.22 g/plant) (table 2). This might be due to the fact that the application of calcium nitrate and magnesium sulfate increases the tuber size, weight and number of medium size tubers per plant. Hence the yield of medium tubers was significantly increased with the increase in the concentration of calcium nitrate and magnesium sulfate. These results were supported by the findings of Simmons and Kelling (1987).

Yield of large tubers (g/plant): It is evident from the data that different calcium nitrate and magnesium sulfate treatments had a significant and positive effect on the weight of large tubers per plant. The highest yield of large tubers (122.32 g/plant) was observed in T₈ i.e. Ca (NO₃)₂ @ 2% + MgSO₄ @ 2% which was significantly at par with T₇ i.e. Ca (NO₃)₂ @ 1% + MgSO₄ @ 1% (117.65 g/plant). Yield of large tubers was the lowest (80.54 g/plant) in T₉ (control). Ca (NO₃)₂ @ 1% (T₂) significantly increased yield of large tubers over the Ca (NO₃)₂ @ 0.5% (T₁), but was at par with T₃ i.e. Ca (NO₃)₂ @ 2%. Among the alone magnesium treatments, increase in large tubers weight was reported with increase in magnesium concentration, but MgSO₄ @ 0.5 (T₄) and 1.0 % (T₅) were significantly at par with one another. Effect of varieties on yield of large tubers had followed the same trend as that of medium and small tubers weight. Kufri Jyoti i.e. V₁ (115.60 g/plant) was significantly superior over the variety

Kufri Chandramukhi i.e. V₂ (97.53 g/plant) in terms of the yield of large tubers. The interaction effect of different calcium and magnesium treatments and varieties on the yield of large tubers at the time of harvesting revealed significant differences. Highest weight (134.78 g/plant) was obtained under V₁T₈ i.e. Kufri Jyoti sprayed with CaNO₃+MgSO₄ @ 2% each and lowest yield (68.26 g/plant) under V₂T₉ (Kufri Chandramukhi under control). Among the other interaction combinations, the significant parity was observed in V₁T₁ i.e. Kufri Jyoti sprayed with CaNO₃ @ 0.5% with V₂T₇ i.e. Kufri Chandramukhi sprayed with CaNO₃ @ 1% + MgSO₄ @ 1% and V₂T₈ i.e. Kufri Chandramukhi sprayed with CaNO₃ @ 2% + MgSO₄ @ 2%. The increase in yield of large tubers might be due to the application of calcium and magnesium nutrition which influences the tuberization by altering the hormonal balance at the stolon tip as reported by Ozgen *et al.* (2003), Ozgen and Palta (2005).

Total tuber yield per plant (g): The highest total tuber yield per plant (321.46 g) was obtained by the foliar application of Ca (NO₃)₂ @ 2% + MgSO₄ @ 2% i.e. in treatment T₈ and found to be significant over all the other treatments. The lowest total tuber yield per plant was obtained from the control i.e. T₉ (249.03 g). Foliar application of Ca (NO₃)₂ @ 2% + MgSO₄ @ 2% (T₈) recorded 14.43% increase over (control) (T₉). Significant variations were observed among the results for different varieties. Kufri Jyoti (V₁) produced the highest total tuber yield per plant (310.21 g) and found significant over other variety (V₂). Minimum total tuber yield per plant (268.65 g) was produced in Kufri Chandramukhi (V₂). Kufri Jyoti resulted in 15.46% increase over Kufri Chandramukhi. Interaction between different treatments and varieties exhibited significantly non-significant results for total tuber yield per plant. However, maximum total tuber yield per plant (344.17 g) was recorded in T₈V₁ i.e. Kufri Jyoti sprayed with Ca (NO₃)₂ @ 2% + MgSO₄ @ 2% and minimum total tuber yield per plant (234.04 g) was recorded in T₉V₂ i.e. when Kufri Chandramukhi grows under control. These results are in conformity to the earlier findings of Hamdi *et al.* (2015) who demonstrated the effect of calcium on the total tuber yield per plant and found that plants treated with a high level of calcium had highest total tuber yield per plant while the least total tuber yield per plant was found in the control plots.

Table 2 Effect of calcium and magnesium nutrition on tuber yield of potato

Treatments	No. of Small Tubers Per Plant (< 25 g)		No. of medium tubers per plant (25 – 50 g)		No. of large tubers per plant (> 50g)		Yield of small tubers (g/plant)		Yield of medium tubers (g/plant)		Yield of large tubers (g/plant)		Total tuber yield per plant (g)		Tuber yield per hectare (q)		Marketable tuber yield per hectare (q/ha)	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
T₁ Ca(NO₃)₂ @ 0.5%	2.50	2.51	4.11	3.80	3.36	3.27	81.45	75.07	133.91	113.70	109.57	97.90	298.33	263.50	239.12	210.83	179.18	155.62
T₂ Ca(NO₃)₂ @ 1%	2.31	2.33	4.16	3.91	3.54	3.20	83.26	75.00	149.78	125.94	127.39	103.12	330.83	279.67	265.21	223.75	203.97	168.58
T₃ Ca(NO₃)₂ @ 2%	2.21	2.23	4.53	4.08	3.31	3.24	78.33	72.03	160.65	131.88	117.39	104.64	327.08	283.83	262.24	227.12	204.61	174.11
T₄ MgSO₄ @ 0.5%	2.70	2.38	3.75	4.03	3.55	3.15	84.71	67.32	117.61	113.84	111.59	89.42	271.30	243.42	231.01	199.18	168.65	149.62
T₅ MgSO₄ @ 1%	2.57	2.27	4.07	3.84	3.18	2.96	90.36	70.73	143.33	119.86	111.96	92.32	317.50	260.17	254.47	208.18	187.95	156.12
T₆ MgSO₄ @ 2%	2.36	2.09	4.36	3.96	3.22	3.16	81.67	66.45	150.94	125.65	111.52	100.36	299.88	258.50	253.37	215.30	193.24	166.37
T₇ Ca(NO₃)₂ 1%+ MgSO₄ @ 1%	1.88	1.77	5.09	4.64	3.50	3.42	66.23	57.97	179.35	151.88	123.41	111.88	338.75	295.96	271.51	236.81	222.79	194.15
T₈ Ca(NO₃)₂ 2%+MgSO₄ @ 2%	1.45	1.65	5.22	4.85	3.75	3.32	52.17	54.71	187.75	160.22	134.78	109.86	344.17	298.75	275.81	239.03	237.38	198.80
T₉ Control	3.30	3.56	3.40	3.69	3.06	2.57	100.07	94.71	103.04	98.12	92.83	68.26	264.01	234.04	217.81	192.18	144.15	122.47
Factors	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)	C.D.	SE(m)
Varieties	0.048	0.007	0.162	0.025	0.169	0.026	1.735	0.265	4.619	0.705	4.812	0.735	13.938	0.575	2.885	0.440	1.516	0.231
Treatments	0.116	0.04	0.177	0.061	0.089	0.031	3.278	1.133	4.634	1.601	4.991	1.725	9.818	2.987	6.950	2.402	5.642	1.95
Varieties x Treatments	0.168	0.022	0.277	0.074	0.171	0.078	4.81	0.794	7.368	2.115	7.884	2.204	N/A	1.724	N/A	1.321	8.059	0.694

Tuber yield per hectare (q/ha): Highest yield per hectare (257.42 q/ha) was obtained by the foliar application of $\text{Ca}(\text{NO}_3)_2 @ 2\% + \text{MgSO}_4 @ 2\%$ i.e. in T_8 and found to be significant over all the other treatments. The lowest yield was obtained from the control (T_9) (205 q/ha). Foliar application of $\text{Ca}(\text{NO}_3)_2 @ 2\% + \text{MgSO}_4 @ 2\%$ recorded 25.60% increase over (control) (T_9). Significant variations were observed among the results of different varieties. Kufri Jyoti (V_1) produced the highest tuber yield per hectare (252.28 q/ha) which was significant over other variety (V_2) Kufri Chandramukhi (216.93 q/ha). Kufri Jyoti resulted in 16.29% increase over Kufri Chandramukhi. Interaction between different treatments and varieties exhibited significantly non-significant results for tuber yield per hectare. However, maximum tuber yield per hectare (275.81 q/ha) was recorded in T_8V_1 i.e. Kufri Jyoti sprayed with $\text{Ca}(\text{NO}_3)_2 @ 2\% + \text{MgSO}_4 @ 2\%$ and minimum tuber yield per hectare (192.18 q/ha) were recorded in T_9V_2 i.e. when Kufri Chandramukhi was grown under control. It is apparent that calcium nitrate played an important role in increasing the total yield per hectare followed by magnesium sulfate. Combined application of $\text{Ca}(\text{NO}_3)_2$ and MgSO_4 has more effect on total tuber yield per hectare. On the support to present findings, Seifu (2017) concluded that with the application of calcium nitrate the average tuber yield of potato was increased up to 77% in the tested potato varieties.

Marketable tuber yield (q/ha): The marketable tuber yield had undergone significant influence with both the calcium and magnesium treatments. The lowest marketable tuber yield (133.31 q/ha) was obtained under the control (T_9) which was significantly lower than all other treatments. When calcium and magnesium were sprayed in combination i.e. T_7 and T_8 , they had a more pronounced effect on the marketable tuber yield as compared to their alone application. $\text{Ca}(\text{NO}_3)_2 @ 2\% + \text{MgSO}_4 @ 2\%$ i.e. T_8 had the highest marketable tuber yield (218.09 q/ha) which was slightly higher than T_7 (208.47 q/ha) and was significantly different from all other treatments. There was no significant difference between $\text{Ca}(\text{NO}_3)_2 @ 1\% \& 2\%$ and $\text{Ca}(\text{NO}_3)_2$ and MgSO_4 both @ 0.5 % concentration. Both the varieties were significantly different from one

another indicating a significant influence of the varietal treatments on the marketable tuber yield. Kufri Chandramukhi (V_2) had the marketable tuber yield of 165.09 q/ha which was significantly lower than Kufri Jyoti (V_1) having 193.55 q/ha marketable tuber yield. Interaction between calcium nitrate and magnesium sulfate treatments and varieties exhibited significantly significant results for the marketable tuber yield per hectare. Among the different interaction combinations, the highest marketable tuber yield was recorded in V_1T_8 i.e. Kufri Jyoti sprayed with $\text{Ca}(\text{NO}_3)_2 @ 2\% + \text{MgSO}_4 @ 2\%$ (237.38 q/ha) and least in V_2T_9 i.e. Kufri Chandramukhi under control (122.47 q/ha). The significant parity was observed in V_2T_7 (spray of $\text{Ca}(\text{NO}_3)_2 @ 1\% + \text{MgSO}_4 @ 1\%$ in variety Kufri Chandramukhi) with V_2T_8 (spray of $\text{Ca}(\text{NO}_3)_2 @ 2\% + \text{MgSO}_4 @ 2\%$ in variety Kufri Chandramukhi). The higher marketable yield in variety Kufri Jyoti may be due to the maximum increase in growth attributes and higher yield of medium and large sized tubers. These results were in harmony with the findings of Raj *et al.* (2016).

Conclusion

From the results of the present study following conclusion have been drawn. Calcium nitrate and magnesium sulfate treatments had significantly affected the yield and growth parameters as well as late blight incidence in potato where $\text{Ca}(\text{NO}_3)_2 @ 2\% + \text{MgSO}_4 @ 2\%$ proved to be the most effective treatment among all. it can be concluded that commercial cultivation of potato in the central region of Punjab can be successfully supplemented with application of $\text{Ca}(\text{NO}_3)_2 + \text{MgSO}_4$ and variety Kufri Jyoti.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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