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IMPACT OF FOLIAR FEEDING OF $Ca(NO_3)_2$ ON PLANT GROWTH AND LEAF NUTRIENTS OF STRAWBERRY (*Fragaria* × *ananassa* Duch.) cv. WINTER DAWN

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ABSTRACT : The objective of present investigation was to compare the effect of foliar application of $Ca(NO_3)_2$ (0.2, 0.4, 0.6, 0.8 percent) applied at 60, 75 and 90 days after transplanting (DAT) on vegetative growth and leaf nutrients content with the control (water spray) of strawberry cultivar 'Winter Dawn'. The experiment was laid out in Randomized Block Design (RBD) and replicated four times. Triple applications of $Ca(NO_3)_2$ at different concentrations improved plant growth related parameters viz. plant spread (N-S, 202.0 to 223.8 mm and E-W, 213.3 to 230.3 mm), number of leaves/plant (21.6 to 29.8), crown length (23.6 to 26.1 mm), crown diameter (28.7 to 35.2 mm), plant fresh weight (22.5 to 33.4g), plant dry weight (7.5 to 10.6g), root fresh weight (3.6 to 5.1g), root dry weight (1.47 to 2.12g), root length (120.7 to 174.0 mm), leaf area index (0.45 to 0.6) and leaf chlorophyll content (45.6 to 53.5) over the control (193.1 mm, 196.4 mm, 19.5, 22.1 mm, 26.9 mm, 20.3 g, 7.1 g, 3.4 g, 1.43 g, 117.9 mm, 0.42 and 44.5, respectively). Foliar feeding with Ca compounds also considerably enhanced leaf N, P, K, Ca, Mg, Cu, Zn, Fe and Mn content and the values ranged from 2.31 to 2.40%, 0.23 to 0.26%, 1.14 to 1.32%, 0.85 to 1.02%, 0.51 to 0.76%, 17.5 to 25.4 ppm, 27.4 to 38.4 ppm, 83.7 to 107.4 ppm and 53.5 to 55.3 ppm, respectively. It is concluded that triple sprays of $Ca(NO_3)_2$ @ 0.4 per cent appreciably enhanced vegetative growth characters and substantially leaf N and Ca contents over the control.

Keywords : *Strawberry, $Ca(NO_3)_2$, vegetative growth, leaf nutrients content.*

Strawberry (*Fragaria* × *ananassa* Duch.) is a cross between two octaploid species, Fragaria × chiloensis Duch. and Fragaria × virginiana Duch., belongs to family Rosaceae (Bowling, 5). It is a temperate fruit crop, but can be successfully cultivated under sub-tropical and tropical areas of the world. A substantial upsurge in an area under strawberry cultivation in sub-tropical regions of India especially Northern parts of the country is noticed due to higher remunerative returns and shorter growing season. Strawberry is a non-climacteric fruit, widely appreciated for its bright red colour, juicy texture, tantalizing flavour and delicious taste. It is a rich source of vitamin C, vitamin E, β-carotene, phenolic compounds and anthocyanin pigments which are highly beneficial for human health (Hancock, 14; Hakkinen and Torronen, 13; Ayala-Zavala *et al.,* 3; Riyaphan *et al.,* 20).

Calcium is an essential component of plant cell wall as it imparts rigidity to the cell wall by cross-linking the pectin chains of middle lamella (Glenn *et al.,* 12). It is also associated with activating certain signal pathways during plant growth, development and responses to environmental changes (Easterwood, 8; Dastjerdy *et al.,* 6). In addition, Ca^{+2} ions play a crucial role in cell division and maintenance of cell integrity (Elad and Kirschner, 9; Frecon, 10). Moreover in strawberry, localized deficiency of Ca causes leaf tip-burning physiological disorder (Mason and Guttridge, 17). Calcium ion is considered immobile in the plant system; therefore, its application through soil is not very effective. In addition, Dastjerdy *et al.* (6) emphasised that calcium is directly related to nutrient uptake by plants.

In the modern perspective, a significant work has been carried out to study the role of post-harvest application of calcium in the form of calcium chloride and calcium nitrate. However, the systematic work on the pre-harvest foliar application of calcium has not been done in such a depth. Therefore, the present experiment was mainly designed to record the effect of different $Ca(NO_3)_2$ concentrations through foliar applications at significant intervals during the growing

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season of strawberries on vegetative growth characteristics and leaf nutrients content, as the overall health of the plant affect the fruit yield and quality directly or indirectly.

MATERIALS AND METHODS

Experimental procedure

The experiment was carried out at PFDC, Department of Soil and Water Engineering, COAE, Punjab Agricultural University, Ludhiana. The experimental site was situated at 30°54'41" N latitudes and 75º49'06'' E longitudes and 244 m above the mean sea level. The objective of the study was to elucidate the effect of $Ca(NO_3)_2$ (0.2, 0.4, 0.6 and 0.8 per cent) applied at 60, 75 and 90 DAT (days after strawberry seedlings transplanting) through foliar feedings on vegetative growth parameters and leaf nutrients status in 'Winter Dawn' cultivar. The control plants were sprayed with water and Tween-20 was added as surfactant in all treatments including the control. Strawberry runners were transplanted on raised plots at a distance of 30 × 30 cm during the IInd fortnight of October and nearly 130 plants/replication were transplanted on raised beds. The plants were fertigated through drip irrigation and N:P:K applied in split doses at 4-6 days interval during different growth and development stages.

Determination of plant growth parameters:

Five plants/replication were randomly selected and used to estimate the vegetative growth parameters, after the final fruit picking in IInd fortnight of March. Plant spread in terms of East-West and North-South, petiole length and root length was measured with the help of meter-scale, whereas, crown length and crown diameter with digital vernier's calliper and values were expressed in 'mm'. Number of leaves/plant was counted from selected plants after the final fruit picking. Leaf chlorophyll (Chl) content was measured from selected plants using the SPAD-502 meter (Spectrum Technologies, Inc., Plainfield, IL, USA). SPAD measurements were taken from three different areas/leaf so that major veins did not interfere with the measurement. The randomly selected plants were uprooted and washed to remove all the soil particles and weighed for fresh weight (g) thereafter, these were dried in a micro oven at 70°C till constant dry biomass was obtained. Root fresh weight of strawberries was estimated after extrication of roots from plants and root length of the plants was measured with meter scale. Dry weight of roots was also estimated by following the same procedure as adopted for the calculation of dry plant weight. The plant and root weight both on fresh and dry basis was measured with an electronic weighing balance. Leaf area index (LAI) was recorded by using leaf area meter.

Estimation of leaf nutrients content

Twenty-five fully expanded mature leaves were collected from each treatment. Leaf samples were thoroughly washed with distilled water, subsequently with 0.1N HCl and finally rinsed with the double distilled water. Leaf samples were dried in the shade for 4 hours and finally in an oven at 60°C for 72 hours. The dried samples were ground in the Willey Mill fitted with all components of stainless steel to pass through 40 mesh sieves. These ground samples were stored in butter paper bags and used for leaf nutrients analysis. Before analysis, ground leaf samples were again oven dried for 24 hours at 60°C. Leaf N content was estimated by using Kjeldhal's method (AOAC, 2) and the results were expressed in percentage on dry weight basis. Total P content was estimated by following vanado-molybdate phosphoric yellow colour method (Koeing and Johnson, 16) and leaf K content with the help of flame photometer. Leaf Calcium (Ca), Magnesium (Mg), Zinc (Zn), Iron (Fe), Copper (Cu) and Manganese (Mn) were determined by using Atomic Absorption Spectrophotometer method as described by Bradfield and Spencer (4) and the results were expressed on dry weight basis.

Soil properties

The soil physical and chemical properties of the experimental site were; soil texture was sandy loam, pH 7.5, EC 0.18 (dSm^{-1}), organic carbon (OC) 0.33%, available N 135.1 kg/ha, available P 14.7 kg/ha and available K 169.8 kg/ha.

Experimental design and analysis

The experiment was laid out in the Randomized block design (RBD) and treatments were replicated four times. The data were pooled and analysed for the variance by using the statistical computer software CPCS 1 and differences between the means were analysed in all pairwise comparison by LSD at 0.05% level of significance.

RESULTS AND DISCUSSION

Plant Growth

It is cleared from the data mentioned in Table 1 that foliar applications of $Ca(NO_3)_2$ at different concentrations and intervals substantially improved plant spread (N-S, E-W) over the control in strawberry cv. Winter Dawn; however, values for plant spread (E-W) with 0.6 and 0.8% $Ca(NO_3)_2$ were statistically at

Table 1 : Effect of foliar application of $Ca(NO_3)_2$ on plant growth of strawberry.

Treatments	Plant spread (N-S) (mm)	Plant spread (E-W) (mm)	No. of 1eaves/ plant	Petiole length (mm)	Crown length (mm)	Crown diameter (mm)
T_1-$Ca(NO_3)_2$ @0.2 %	214.3[b]	221.0[b]	27.0[b]	52.5	23.4[b]	28.7[c]
T_2-$Ca(NO_3)_2$ @0.4 %	223.8[a]	230.3[a]	29.8[a]	55.5	26.1[a]	35.2[a]
T_3-$Ca(NO_3)_2$ @0.6 %	211.3[b]	215.5[c]	25.3[b]	56.3	23.6[b]	33.4[b]
T_4-$Ca(NO_3)_2$ @0.8 %	202.0[c]	213.3[c]	21.6[c]	55.5	23.6[b]	29.5[c]
T_5-Control (water spray)	193.1[d]	196.4[d]	19.5[c]	53.2	22.1[c]	26.9[d]
$LSD_{0.05}$	3.49	3.29	2.52	N.S.	0.87	1.20

Table 2 : Effect of foliar application of $Ca(NO_3)_2$ on plant and root characters of strawberry *cv* Winter Dawn.

Treatments	Plant fresh weight (g)	Plant dry weight (g)	Root fresh weight (g)	Root dry weight (g)	Root length (mm)	Leaf area index	Chlorophyll (SPAD)
T_1-$Ca(NO_3)_2$ @0.2 %	27.6[b]	8.6[b]	4.7[b]	1.94[b]	169.0[b]	0.48[bc]	53.1[a]
T_2-$Ca(NO_3)_2$ @0.4 %	33.4[a]	10.6[a]	5.1[a]	2.12[a]	174.0[a]	0.60[a]	53.5[a]
T_3-$Ca(NO_3)_2$ @0.6 %	26.9[b]	8.4[b]	4.7[b]	1.86[c]	139.5[c]	0.53[ab]	51.8[a]
T_4-$Ca(NO_3)_2$ @0.8 %	22.5[c]	7.5[c]	3.6[c]	1.47[d]	120.7[d]	0.45[bc]	45.6[b]
T_5-Control (water spray)	20.3[c]	7.1[c]	3.4[d]	1.43[d]	117.9[d]	0.42[c]	44.5[b]
$LSD_{0.05}$	2.18	0.44	0.07	0.06	3.36	0.09	2.47

par with each other. Plant spread was recorded significantly maximum to the tune of 223.8 and 230.3 mm for N-S and EW, respectively with the triple application of $Ca(NO_3)_2$ 0.4% (T_2) as foliar feeding in comparison to other treatments and the values were minimum (193.1 and 196.4 mm, respectively) in the control (T_5). Similarly, higher number of leaves/plant (29.8) were also observed with 0.4% $Ca(NO_3)_2$ (T_2) followed by T_1 (27.0), T_3 (25.3), T_4 (21.6) and the lower (19.5) in the control (T_5). However, T_1 & T_3 and T_4 & T_5 were statistically non-significant with each other. Crown length also showed variability and ranged from 23.4 to 26.1 mm in the strawberry plants sprayed with different concentrations of $Ca(NO_3)_2$ applied at 60, 75 and 90 days after transplanting (DAT) on raised beds during IInd fortnight of October and minimum (22.1 mm) in the control. Likewise, strawberry crown diameter was observed considerably highest (35.2 mm) in T_2 than T_3 (33.4 mm), T_4 (29.5mm), T_1 (28.7mm) and minimum in T_5 (26.9 mm). The impact of foliar application of Ca compounds on the length of petiole for strawberry cv. 'Winter Dawn' was statistically non-significant. This variability in vegetative growth parameters may be due to the fact that calcium plays a vital role in cell division, plant metabolism and maintenance of cell integrity (Elad and Kirschner, 9; Frecon, 10). Maximum values for plant growth parameters were obtained with triple sprays of $Ca(NO_3)_2$ (0.4 %) may be due to availability of all the nutrients in optimum ranges while; higher doses of calcium causes toxicity within the leaf tissue and which in turn leads to imbalance of other nutrients (Dunn and Able, 7).

The application of $Ca(NO_3)_2$ @ 0.4 per cent (T_2) notably increased plant fresh weight and dry weight as compared to other treatments (Table 2). The highest plant weight both on the basis of fresh and dry weight was registered in (T_2) and values were 33.4g and 10.6g, respectively and the lowest (20.3 and 7.1g, respectively) in the control (T_5). Foliar feeding with $Ca(NO_3)_2$ in 'Winter Dawn' strawberry significantly improved root dry and fresh weight over the control; however, T_4 and T_5 were statistically non-significant in terms of root dry weight. Maximum root fresh weight of 5.1g and root dry weight 2.12g were attained in T_2; where $Ca(NO_3)_2$ @ 0.4 per cent was sprayed thrice on strawberry plants and minimum (3.4g and 1.43g, respectively) in the control (T_5). Root length was also obtained highest to the tune of 174.0 mm; wherein,

$Ca(NO_3)_2$ was applied thrice @ 0.4 per cent concentration and the lowest (117.9 mm) in the control. Motamedi *et al.* (18) and Kazemi (15) also confirmed that calcium salts positively influences the vegetative and reproductive growth of strawberry plants.

Leaf area index (LAI) observed maximum (0.60) in T_2 wherein, $Ca(NO_3)_2$ was applied at 0.4 per cent and minimum (0.42) in the control and treatments *viz.,* T_4, T_1 and T_3 were statistically non-significant with each other and the values were 0.45, 0.48, 0.53, respectively. Strawberry leaf chlorophyll content measured with SPAD-502 also exhibited a similar trend as observed for LAI parameter with the application of Ca compounds. It was noted substantially higher (53.5) in T_2, closely followed by 53.1 in T_1 and 51.8 in T_3 than T_4 (45.6) and T_5 (44.5); but T_2, T_1 and T_3 were statistically at par with each other. Calcium ions play a crucial role in activating various signal pathways related to plant growth and development; besides also improve N use efficiency (Easterwood, 8; Dastjerdy *et al.,* 6). The considerable improvement in strawberry plant growth related characters with the foliar application of $Ca(NO_3)_2$ is attributed to the maintenance of optimum level for Ca content; and other macro and micro nutrients without showing any adverse effects on the plant system.

Leaf nutrients content

The results presented in Table 3 reveal that leaf nutrients content was influenced by foliar application of $Ca(NO_3)_2$. However, leaf N, P, Ca, Zn, Fe and Mn contents were within the optimum range as per leaf standards proposed by Anon (1) and the values ranged from 1.9 - 2.8%, 0.25 - 0.4%, 0.7 - 1.7%, 20 - 49 ppm, 60 - 250 ppm and 50 - 200 ppm, respectively. It was observed that leaf K content remained within sub-optimal range, leaf Mg above-optimal range and leaf Cu content beyond the optimal limits as the concentration of $Ca(NO_3)_2$ was increased from 0.2 to 0.8 per cent in the present studies. Leaf N, Ca and Cu content were gradually better at higher $Ca(NO_3)_2$ concentrations. The highest leaf N (2.40%), Ca (1.02%) and Cu (25.4 ppm) content were recorded in T_4; wherein, $Ca(NO_3)_2$ 0.8 % was applied at 60, 75 and 90 DAT and followed by T_3, T_2 and T_1 and minimum (2.26%, 0.82% and 17.2 ppm, respectively) in the control (T_5). Higher leaf N concentrations observed at higher doses of $Ca(NO_3)_2$ is due to more supply of N, which in turn, increased the uptake of other essential nutrients and ultimately had the higher accumulation in leaf tissue. Similar results were also obtained by Singh (21) while studying the effect of calcium nitrate in guava cultivar.

Leaf P content was obtained maximum (0.26%) in T_2 and minimum (0.21%) in the control, the values decreased slightly as the concentration of Ca was increased from 0.2 to 0.8 per cent. Similar results were also reported by Dunn and Able (7) while working on 'Selva' strawberries. Leaf K content was registered maximum (1.32%) in T_1, and minimum (1.11%) in the control whereas, it declined gradually as the doses of $Ca(NO_3)_2$ compound was increased from 0.2 to 0.8 per cent. Similar observations were also confirmed by Ganai (11) in apple cv. 'Red Delicious' growing under temperate conditions of India. The decrease in the value for leaf K content is attributed to higher concentration of Ca and N levels when plants were sprayed with 0.8 per cent $Ca(NO_3)_2$ as mentioned in the literature that Ca and N are showing antagonistic with K (Pooja, 19).

Leaf Mg (0.76%) content was significantly enhanced with the application of $Ca(NO_3)_2$ @ 0.6% *i.e.,* T_3 over the other treatments, while the lowest value to the tune of 0.50% was recorded in T_3 (control). Singh (21) also reported that the leaf Mg content in guava was increased, when plants were sprayed with higher doses of calcium compounds. Leaf Zn content decreased as doses of $Ca(NO_3)_2$ was enhanced and maximum (38.4 ppm) was found in T_1 (0.2%) followed by 38.0 ppm in T_2, 30.8 ppm in T_3 and 27.4 ppm in T_4 and minimum (26.9 ppm) in the control. These results

Table 3 : Effect of foliar feeding of $Ca(NO_3)_2$ on leaf nutrients content in strawberry.

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Cu (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)
T_1-$Ca(NO_3)_2$ @0.2 %	2.31^{c}	0.25^{ab}	1.32^{a}	0.85^{c}	0.51^{c}	17.5^{d}	38.4^{a}	83.7^{d}	53.5^{ab}
T_2-$Ca(NO_3)_2$ @0.4 %	2.34^{b}	0.26^{a}	1.24^{b}	0.96^{b}	0.64^{b}	20.8^{c}	38.0^{a}	107.4^{a}	55.3^{a}
T_3-$Ca(NO_3)_2$ @0.6 %	2.36^{b}	0.24^{bc}	1.19^{c}	0.99^{ab}	0.76^{a}	23.1^{b}	30.8^{b}	98.2^{b}	54.7^{ab}
T_4-$Ca(NO_3)_2$ @0.8 %	2.40^{a}	0.23^{c}	1.14^{d}	1.02^{a}	0.62^{b}	25.4^{a}	27.4^{c}	93.8^{c}	53.7^{bc}
T_5-Control (water spray)	2.26^{d}	0.21^{d}	1.11^{d}	0.82^{c}	0.50^{c}	17.2^{d}	26.9^{c}	79.8^{e}	53.1^{c}
$LSD_{0.05}$	0.02	0.01	0.04	0.04	0.04	0.86	1.02	2.15	1.02

are corroborated with the findings of Wooldridge *et al.* (22) and they reported that foliar application of calcium chloride reduces leaf K and Zn content in apples. Maximum leaf Fe (107.4 ppm) content and Mn (55.3 ppm) were registered in the plants sprayed with 0.4% $Ca(NO_3)_2$ (T_2). Minimum leaf Fe and Mn content to the tune of 79.8 ppm and 53.1 ppm, respectively was obtained in the control (T_5). Increased concentration of various nutrients in strawberry leaves with foliar application of $Ca(NO_3)_2$ over the control may be related to the direct role of calcium in the nutrient uptake of plants (Dastjerdy *et al.,* 6).

CONCLUSION

From the present investigation, it is concluded that foliar feeding of $Ca(NO_3)_2$ significantly improved various plant growth parameters and also enhanced leaf macro and micro nutrients content of strawberry cv. Winter Dawn. Foliar application of $Ca(NO_3)_2$ at 0.4 per cent applied during 60, 75 and 90 DAT improved vegetative growth of strawberry as compare to other treatments including the control (water spray).

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