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Full Research Article

Effect of Nitrogen Sources on Yield, Fruit Quality and Nutritional Status of Apple (*Malus×Domestica* Borkh.)

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Abstract

A trial was conducted in a private orchard at Matiyana (Shimla), India (during December, 2014 to December, 2015) to find out the alternate to calcium ammonium nitrate for nitrogen application to apple trees. Different nitrogen containing fertilizers (sources of nitrogen) alone or in combination were used as treatments and applied in split doses to the experimental trees. Different nitrogen sources significantly influenced fruiting, yield, fruit quality and leaf nutrient contents of apple. Trees subjected to calcium nitrate+urea treatment exhibited significantly higher fruit set (23.96%), yield (5.20 kg tree^{-1}) as well as yield efficiency (0.183 kg cm^{-2} trunk cross sectional area (TCSA) and lower fruit drop (13.06%). The treatment (calcium nitrate+urea) significantly improved fruit weight (179.67 g), total soluble solids content (13.10 °B), total sugars (9.99%) and reducing sugars content (7.15%). Similarly, significantly higher leaf N (2.86%), K (1.93%) and Mg (0.44%) contents were recorded in trees subjected to calcium nitrate+urea treatment, whereas, leaf P (0.28%) and Ca (1.58%) were observed highest in trees treated with combination of di-ammonium phosphate and calcium nitrate and calcium nitrate, respectively. With respect to various observations recorded, calcium nitrate+urea treatment was either superior or statistically at par with calcium ammonium nitrate (control), thus calcium nitrate+urea was proved to be most suitable alternate to calcium ammonium nitrate for supplying nitrogen to the apple trees.

1. Introduction

Apple is a predominant fruit crop of North Western Himalayan region of the country and ranks first in area and production among the temperate fruits. At present, the crop is being cultivated in the country at 0.31 m ha area with an annual production of 2.50 mt (Anonymous, 2014a). In Himachal Pradesh, apple has emerged as a leading cash crop amongst fruit crops. It has revolutionized the socio economic condition of farmers of the state as about 0.2 m families (Anonymous, 2014b) are involved in its cultivation and accounts for 49% area and 88% production of total fruits. In recent years, productivity and quality of fruits has become primary concern of growers and researchers. Plant nutrition is one of the major factors influencing the productivity and fruit quality of apple. Nutrition plays an important role in improving productivity and quality of fruits. Nitrogen is one of the most important nutrients required by the plants as it is a major constitute of protein, nucleotides as well as chlorophyll (Marchner, 1995). Nitrogen supply of apple trees affects tree growth, flower bud formation, yield and fruit quality, particularly size and colour of fruits (Raese et al., 2007). For supplying nitrogen to apple trees, calcium ammonium nitrate (CAN) has been the most widely used fertilizer in Himachal Pradesh (Verma and Chauhan, 2013) and considered good source of nitrogen as it contains equal amounts of fast acting nitrate-nitrogen and long lasting ammonium-nitrogen beside 8% calcium content. Recently manufacturing of CAN in the country has been stopped and its unavailability led to search for most suitable alternate source of nitrogen for apple trees.

2. Materials and Methods

Present investigations were carried out during December, 2014 to December, 2015 in a private orchard at Matiana (Shimla), India, situated at an elevation of 2,444 meter above MSL (Mean Sea Level) with latitude of 31°13´0´´ N and longitude of 77°25´0´´ E. Five years old trees of apple cv. Oregon Spur grafted on MM 111 rootstock which were uniform in growth and vigour were selected for the studies. The experiment was laid out in a Randomized Block Design with 10 nitrogen sources as treatments viz., Calcium nitrate (T_1), Urea (T_2), Calcium nitrate+urea (T_3), NPK mixture 12:32:16 and calcium nitrate (T_4), NPK mixture 12:32:16 and urea (T_5), Di-ammonium phosphate (DAP) and calcium nitrate (T_6), Di-ammonium phosphate (DAP) and urea (T_7), NPK mixture 12:32:16 and calcium nitrate+urea (T_8), Di-ammonium phosphate (DAP) and calcium nitrate+urea (T_9) and calcium ammonium nitrate (CAN)/control (T_{10}). The treatments were replicated thrice and uniform cultural practices were followed for each experimental tree during the entire course of study to keep the plants in a good health. The quantity of fertilizers applied under each treatment was based on recommended dose i.e. N (350 g tree^{-1}), P (175 g tree^{-1}) and K (350 g tree^{-1}) for 5-year-old trees and calculated as per the nitrogen contained by the respective fertilizer. Under the treatments, where DAP and NPK mixture 12:32:16 were used, the quantity of these fertilizers to be applied was calculated to fulfill the recommended dose of phosphorus and the quantity of N thus applied through these fertilizers was also calculated and remaining dose of nitrogen was applied through calcium nitrate or urea or mixture of both these fertilizer as per the treatment. Under calcium nitrate+urea treatments, quantity of both fertilizers was calculated for 50% of recommended nitrogen and requisite quantity of the fertilizers was mixed before application. In treatments where complex fertilizers were not taken as source of nitrogen, recommended dose of P and K was applied to the experimental trees through single super phosphate and muriate of potash, respectively. The NPK mixture 12:32:16 and Di-ammonium phosphate (DAP) were applied during the month of February along with P and K fertilizers. Whereas, calcium nitrate, urea, calcium nitrate+urea and calcium ammonium nitrate were applied in two equal split doses, first half dose 15 days before flowering and remaining half dose 15 days after flowering. The fertilizers were broadcasted under the spread of tree in entire basin area, 30 cm away from the tree trunk.

After harvest, fruits obtained from each tree were weighed for calculation of yield tree^{-1}. Ten fruits from yield of each tree were randomly taken for physico-chemical analysis and analysis was done as per the standard procedure (A.O.A.C., 2000). The data generated from the investigations was computed, and analyzed in accordance with procedures outlined by (Gomez and Gomez, 1983).

3. Results and Discussion

3.1. Fruiting and yield

The perusal of data presented in Table 1 reveals that different nitrogen sources exerted significant influence on fruit set, fruit drop, yield and yield efficiency of apple. The highest fruit set (23.96%) and lowest fruit drop (13.06%) was recorded in trees fertilized with calcium nitrate+urea (T_3). With respect to fruit set, T_3 treatment was statistically at par with T_1 and T_{10} whereas, with respect to fruit drop it was statistically at par with T_1, T_2, T_4 and T_{10}. The lowest fruit set (14.42%) and highest fruit drop (20.83%) was observed under treatment di-ammonium phosphate and urea (T_7). Among all the treatments under study, highest fruit yield (5.20 kg tree^{-1}) and yield efficiency (0.183 kg cm^{-2} TCSA) were obtained in trees fertilized with calcium nitrate+urea (T_3). Treatment T_3 was statistically at par with T_1 (calcium nitrate) and significantly superior to other treatments with respect to fruit yield, however, with respect to yield efficiency, it was statistically at par with T_1 (calcium nitrate), T_2 (urea) and T_{10} (calcium ammonium nitrate/control). The lowest fruit yield (3.16 kg tree^{-1}) and yield efficiency (0.130 kg cm^{-2} TCSA) were recorded under di-ammonium phosphate and urea treatment (T_7). Significantly higher fruit set and lower fruit drop with the combined application of calcium nitrate+urea

Table 1: Effect of nitrogen sources on fruiting and yield of apple cv. Oregon Spur

Treatments	Fruit set (%)	Fruit drop (%)	Yield (kg-tree^{-1})	Yield efficiency (kg cm^{-2} TCSA*)
T_1: Calcium nitrate	23.05	14.34	4.98	0.18
T_2: Urea	19.98	15.70	4.31	0.16
T_3: Calcium nitrate+urea	23.96	13.06	5.20	0.18
T_4: NPK mixture 12:32:16 and calcium nitrate	22.10	16.44	3.73	0.14
T_5: NPK mixture 12:32:16 and urea	20.96	17.76	4.23	0.15
T_6: Di-ammonium phosphate and calcium nitrate	17.89	19.76	3.41	0.13
T_7: Di-ammonium phosphate and urea	14.42	20.83	3.16	0.13
T_8: NPK mixture 12:32:16 and calcium nitrate+urea	18.74	18.12	4.44	0.15
T_9: Di-ammonium phosphate and calcium nitrate+urea	16.85	17.83	4.29	0.15
T_{10}: Calcium ammonium nitrate/ control	22.37	14.75	4.76	0.16
SEm±	0.596	1.306	0.098	0.008
CD (p=0.05)	1.76	3.87	0.29	0.02

*Trunk cross sectional area (TCSA)

(T_3) may be attributed to quick supply of nitrogen for longer period. Higher leaf nutritional status under this treatment in the present studies might have resulted in retention of developing and competing fruitlets. This higher fruit set and lower fruit drop as well as greater size and weight of fruits under calcium nitrate+urea (T_3) treatment in the present study might have accounted for higher fruit yield and yield efficiency. Wlodek et al. (1977) had also reported an increase in fruit yield of gooseberry cv. 'White Triumph' with combined application of ammonium and nitrate nitrogen as compared to other nitrogen sources. Quast (1983) also had recorded higher fruit set and yield in sweet cherry with the application of nitrogen source containing both nitrate and ammonium forms of nitrogen.

3.2. Fruit quality

The data pertaining to the effect of nitrogen sources on physico-chemical quality characteristics of fruit (Table 2) reveals that had significantly improved the fruit quality of apple. It is clear from the data that trees fertilized with calcium ammonium nitrate (T_{10}) had maximum fruit length (70.12 mm), which was statistically at par with the length of fruits obtained from trees under calcium nitrate+urea (T_3), NPK mixture 12:32:16 and calcium nitrate (T_4) and NPK mixture 12:32:16 and calcium nitrate+urea (T_8). However, maximum fruit diameter (76.81 mm) was recorded in calcium nitrate (T_1) treatment. This treatment was statistically at par with calcium nitrate+urea (T_3) and di-ammonium phosphate and calcium nitrate+urea (T_9) treatments but significantly superior to all other treatments under study. Fruits with highest weight (179.67 g) were produced by the trees fertilized with calcium nitrate+urea (T_3), which was closely followed, by calcium nitrate (T_1) and CAN/control (T_{10}). The minimum fruit length (61.07 mm) was observed in trees treated with NPK mixture 12:32:16 and urea (T_5), whereas, minimum fruit diameter (66.72 mm) and weight (166.67 g) were observed in di-ammonium phosphate and urea (T_7). The greater size and weight of fruit in trees subjected to nitrate or combination of nitrate and ammonium fertilizer treatments may be attributed to quick supply of nutrients for longer period to the growth and development of fruits. The higher leaf nutrient contents under calcium nitrate (T_1) or calcium nitrate+urea (T_3) treatment in the present studies may also have associated with higher size and weight of fruits. Raese (1987), had observed significant increase in fruit weight of Golden Delicious and Gold Spur apples with calcium nitrate in comparison to ammonium sulphate. Saini (2011) also recorded higher fruit size and weight in plum with calcium nitrate application compared to other nitrogen sources.

Table 2: Effect of nitrogen sources on fruit physico-chemical quality characteristics of apple cv. Oregon Spur

Treatments	Fruit size		Fruit wt. (g)	Firmness (kg cm^{-2})	TSS (°B)	Titratable acidity (%)	Total sugars (%)	Reducing sugars (%)
	Length (mm)	Diameter (mm)						
T_1	63.06	76.81	178.00	7.50	12.20	0.48	9.85	6.73
T_2	62.61	70.17	172.67	6.90	11.90	0.50	9.57	6.99
T_3	66.76	74.21	179.67	7.23	13.10	0.46	9.99	7.15
T_4	67.71	71.56	169.33	7.07	11.77	0.50	9.67	7.02
T_5	61.07	70.58	171.67	6.80	10.77	0.48	9.80	6.86
T_6	62.27	67.79	167.67	7.10	11.77	0.45	9.73	6.95
T_7	62.88	66.72	166.67	6.87	10.63	0.51	9.51	6.66
T_8	66.31	71.01	175.33	6.93	11.50	0.47	9.67	7.05
T_9	64.23	72.30	174.00	6.97	11.87	0.49	9.88	6.89
T_{10}	70.12	70.77	176.33	7.23	11.00	0.47	9.94	6.85
SEm±	1.659	1.632	2.539	0.134	0.416	0.018	0.069	0.079
CD (p=0.05)	4.93	4.84	7.54	0.39	1.23	0.02	0.21	0.23

It is evident from the data that various nitrogen sources produced significant effect on fruit firmness and total soluble solids content of the fruits. The maximum fruit firmness (7.50 kg cm^{-2}) was observed in trees subjected to calcium nitrate (T_1) application, which was statistically at par with the firmness in fruits obtained from trees treated with calcium nitrate+urea (T_3) and calcium ammonium nitrate/control (T_{10}), however, lowest fruit firmness (6.80 kg cm^{-2}) was recorded in NPK mixture 12:32:16 and urea (T_5) treatment. The maximum total soluble solids content of fruits (13.10 ˚B) was exhibited by the trees under calcium nitrate+urea (T_3) treatment, which was statistically at par with treatments calcium nitrate (T_1), urea (T_2) and di-ammonium phosphate and calcium nitrate+urea (T_9). The lowest total soluble solids content (10.63 °B) was found in the treatment di ammonium phosphate and urea (T_7). The minimum titratable acidity (0.45%) was recorded in the treatment di-ammonium phosphate and calcium nitrate (T_6), which was statistically at par with calcium nitrate+urea (T_3), NPK mixture 12:32:16 and calcium nitrate+urea (T_8)

and calcium ammonium nitrate/control (T_{10}). The maximum titratable acidity (0.51%) was exhibited by the fruits born on trees under treatment di-ammonium phosphate and urea (T_7). Trees subjected to treatment calcium nitrate+urea (T_3) exhibited highest total sugars content (9.99%) and reducing sugars content (7.15%). This treatment was statistically at par with calcium nitrate (T_1), NPK mixture 12:32:16 and urea (T_5), di-ammonium phosphate and calcium nitrate+urea (T_9) and calcium ammonium nitrate/control (T_{10}) with respect to total sugars content but with respect to reducing sugars content, it was statistically at par with urea (T_2), NPK mixture 12:32:16 and calcium nitrate (T_4), di-ammonium phosphate and calcium nitrate (T_6) as well as NPK mixture 12:32:16 and calcium nitrate+urea (T_8). The lowest total sugars content (9.51%) and reducing sugars content (6.66%) were observed in the treatment di-ammonium phosphate and urea (T_7).

The higher fruit firmness in trees subjected to calcium nitrate and calcium ammonium nitrate might be corresponds to higher leaf calcium levels under these treatments in the present studies. This might be due to the fact that these fertilizers contain calcium content along with nitrogen and increase Ca supply to the leaves and fruits. However, higher total soluble solids and sugars content and lowest acidity in fruits born on trees treated with calcium nitrate and combination of calcium nitrate+urea might be attributed to higher N, K and Mg content in the leaves under these treatments in the present study, which could have accounted for higher production and translocation of metabolites to the fruits. Raese (1987) had recorded significant increase in fruit firmness and total soluble solids of apple with calcium nitrate as compared to ammonium sulphate and ammonium nitrate. Similarly, Shukla and Singh (1998) also reported increase in fruit firmness of ber with calcium nitrate. Ganapathy et al. (2011) had recorded significant increase in total soluble solids as well as sugars content and decrease in acidity in banana fruit by applying mixtures of CAN, urea and ammonium sulphate as compared to other nitrogen sources.

3.3. *Leaf nutrient contents*

Data pertaining to the effect of nitrogen sources on leaf nutrients content (Table 3) shows that various nitrogenous fertilizers significantly influenced the leaf nutrient contents of the plants. The maximum leaf N (2.86%), K (1.93%) and Mg (0.44%) contents were recorded in trees subjected to calcium nitrate+urea (T_3). This treatment was statistically at par with calcium nitrate (T_1), di-ammonium phosphate and calcium nitrate+urea (T_9) and calcium ammonium nitrate/control (T_{10}) with respect to leaf N content and with calcium nitrate (T_1), NPK mixture 12:32:16 and calcium nitrate+urea (T_8), di-ammonium phosphate and calcium nitrate+urea (T_9) and calcium ammonium nitrate/control (T_{10}) with respect to leaf Mg content, whereas, regarding leaf K content, treatment $T_3$was closely followed by T_2 (urea) treatment (1.86%) and both these treatments had significantly higher leaf K content in comparison to NPK mixture 12:32:16 and urea (T_5), di-ammonium phosphate and calcium nitrate (T_6), di-ammonium phosphate and urea (T_7), NPK mixture 12:32:16 and calcium nitrate+urea (T_8), di-ammonium phosphate and calcium nitrate+urea (T_9) and calcium ammonium nitrate/control (T_{10}). The minimum leaf N (2.64%), K (1.42%) and Mg (0.29%) contents were observed in di-ammonium phosphate and calcium nitrate (T_6), calcium ammonium nitrate/control (T_{10}) and di-ammonium phosphate and urea (T_7), respectively. The higher leaf nitrogen content with calcium nitrate+urea application could be due the presence of both slow and fast releasing forms and lower concentration of nitrogen, which might have improved its uptake by the plants and reduced the loss in various forms. The present results are in line with the findings of Romaniuk et al. (1979) in Mclntosh apple.

The maximum leaf phosphorus (0.28%) was accumulated in the leaves of trees treated with di-ammonium phosphate and urea (T_6), which was statistically at par with urea (T_2), di-ammonium phosphate and urea (T_7) and di-ammonium phosphate and calcium nitrate+urea (T_9). The lowest leaf phosphorus (0.23%) was found in trees treated with calcium nitrate (T_1). Trees subjected to calcium nitrate application (T_1) had highest accumulation of leaf calcium content (1.58%), which was significantly higher compared to urea (T_2), NPK mixture 12:32:16 and urea (T_5), di-ammonium phosphate and calcium nitrate (T_6), di-ammonium phosphate and urea (T_7), NPK mixture 12:32:16 and calcium nitrate+urea (T_8) and di-

Table 3: Effect of nitrogen sources on leaf nutritional status of apple cv. Oregon Spur

Treatments	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)
T_1	2.84	0.23	1.82	1.58	0.43
T_2	2.66	0.26	1.86	1.23	0.36
T_3	2.86	0.24	1.93	1.55	0.44
T_4	2.72	0.23	1.78	1.53	0.34
T_5	2.74	0.24	1.66	1.31	0.33
T_6	2.64	0.28	1.53	1.52	0.36
T_7	2.69	0.27	1.56	1.42	0.29
T_8	2.77	0.23	1.47	1.24	0.39
T_9	2.80	0.26	1.43	1.46	0.41
T_{10}	2.82	0.24	1.42	1.56	0.43
SEm±	0.026	0.018	0.026	0.018	0.026
CD (p=0.05)	0.08	0.03	0.08	0.05	0.07

ammonium phosphate and calcium nitrate+urea (T_9) treatments. The lowest leaf calcium content (1.23%) was observed under urea (T_2). The higher leaf Ca content with the application of calcium ammonium nitrate and calcium nitrate might be due to the fact that these fertilizers contain adequate quantity of Ca. The addition of sufficient quantity of Ca to the soil through these fertilizers might have resulted in accumulation in plants. The present findings are in line with those of Green and Smith (1979) in apple and Raese and Staiff (1983) in pear who had also observed higher accumulation of Ca content in leaves with soil application of calcium nitrate than ammonium nitrate. Results of present studies are also in conformity with those of Saini (2011), who had reported higher leaf P content in Santa Rosa plum with di-ammonium phosphate+urea application in comparison to other nitrogen sources.

4. Conclusion

Different nitrogen sources significantly influenced fruiting, yield, fruit quality and leaf nutrient contents of apple. Among various treatments, calcium nitrate+urea (T_3) was either superior most or statistically at par with calcium ammonium nitrate (control) with respect to various observations recorded, thus this treatment (calcium nitrate+urea) was proved to be most suitable substitute of calcium ammonium nitrate for supplying nitrogen to the apple trees.

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