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Nitrogen source fertilization for nutrient profiling of Royal Delicious apples in temperate ecosystem

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ABSTRACT

The investigations were conducted at Denwari, Rohru in Shimla district, Himachal Pradesh to compare the effects of various sources of nitrogen on leaf and soil nutrient status of Royal Delicious apple and to find out an alternate source of nitrogen for the substitution for CAN (calcium ammonium nitrate) which was recommended for Himachal Pradesh. Soil application of five sources of N viz urea, calcium nitrate, NPK (19:19:19) + urea, NPK (12:32:16) + urea and calcium ammonium nitrate at the three levels (840, 700 and 560 g N/tree) was tried and compared to get best nitrogen source and level of application. The results indicated that highest leaf N content was recorded with the treatment of urea at 840 g N/tree whereas highest P and K contents were recorded with NPK (19:19:19) + urea at 560 g N/tree. Leaf Ca, Mg and micronutrients viz Fe, Cu, Zn and Mn concentrations were also quantified significantly by different soil N fertilization in similar trend. Soil pH decreased with combination treatment of NPK (12:32:16) + urea. However organic carbon and soil N, Fe, Cu and Mn increased with urea and soil P and K increased with NPK (12:32:16) + urea and calcium ammonium nitrate respectively.

Keywords: CAN; fertilization; Royal Delicious; soil application; soil fertility indicators

INTRODUCTION

Optimal mineral nutrition has an important role to play for growth, development and yield of apple trees. In order to ensure a regular crop application of manures and fertilizers is a common orcharding practice. However N, P and K are the commonly deficient nutrients occurring in apple orchards. The orchards on undulating topography result in considerable loss of nutrient elements through runoff and slow unchecked leaching. Thus not digging the soil throughout the spread of trees may be limiting the absorption of optimal amounts of manurial ingredients in the root feeding zone. This imposes limitations on the efficacy of soil application of fertilizers. The application of nitrogenous fertilizer is of paramount importance in addition to phosphorus and potassium fertilizers. Nitrogen is a major element required by all plants; adequate nitrogen is essential for tree growth, leaf cover, blossom formation, fruit set and fruit size all of which combine to determine crop yield (Mengel et al 2001). Nitrogen is often more limiting factor influencing plant growth than any other nutrient.

Application of nitrogen to apple every year has a direct effect on growth, yield and fruit quality. The efficient use of nitrogen fertilizers to increase crop yield is an important goal in all agricultural systems (Dong et al 2005). Nitrogen is required for the initial growth of deciduous trees in the spring during cell division (Bi et al 2003). Initial growth of fruit trees in spring is supported by remobilization of N reserves and there is positive relationship between spring growth and the amount of N reserves for many species and varieties (Dong et al 2005). Many workers have shown that fertilization of fruit trees with nitrogen fertilizer increases fruit set, vegetative growth and yield in Starking Delicious apple trees (Klein et al 1989), in Fuji apples (Dong et al 2005) and in two cultivars of apple namely Idared and Jonagold (Swierczynski et al 2007). Calcium ammonium nitrate (CAN) is presently recommended for apple orcharding. But due to scarcity and non-availability it has led to the search for other easily available alternative sources based on field experiments. Therefore the present study was focused and planned with the objective to find out the response of plants to N soil fertilizer inputs on growth, nutrient profiling, fruit set, yield and quality of fruits.

MATERIAL and METHODS

The present investigations were carried out in a private orchard at Denwari, Shimla, Himachal Pradesh during 2015 and 2016. The trees of uniform age group (28-year old) were spaced at 6 x 6 m in northsouth row orientation. The cultivar Royal Delicious was raised on the crab apple, *Malus sylvestris* (L) Mill seedling rootstock. Thus there was a tree density of 277 trees/ha trained with the modified central leader system. The experimental orchard was located at an altitude of 2419 m amsl between coordinates of 31°14'44.71'' North latitude and 77°54'23.05'' East longitude. The climate of area is typically temperate. The annual rainfall ranged between 800-1300 mm. The predominant soil at the site was texturally sandy loam with an average particle size distribution for the surface 15 cm soil depth of 59.9 per cent sand, 20.6 per cent silt and 18.8 per cent clay. Water holding capacity (WHC) and moisture content at field capacity (M_cF_c) at 15-30 cm depth were 64.80 and 22.10 per cent respectively. The soil used for experiment was towards neutral (pH 6.51) in reaction with 1.52 per cent soil organic carbon (SOC).

The experiment was arranged in randomized block design (RBD) with four replicates and three trees per treatment selected for each season. Different levels of NPK fertilizers in RBD factorial matrix included urea alone, calcium nitrate alone, NPK (19:19:19) along with urea, NPK (12:32:16) along with urea and CAN alone. NPK fertilizer sources referred were adjusted with urea (46% N), calcium ammonium nitrate (CAN, 25% N), calcium nitrate (15.5% N), water soluble NPK (19:19:19) and NPK (12:32:16). Three levels of N fertilizers 840 g/tree (120% RDF), 700 g/tree (100% RDF) and 560 g/tree (80% RDF) of the blanket recommended dose of fertilizers (RDF) (70:35:70) were adjusted. The NPK mixture NPK (19:19:19) and NPK (12:32:16) were applied during the month of December along with P and K fertilizers. Urea, calcium nitrate and CAN were applied in two equal splits. The half dose of N along with farmyard manure (FYM) was applied fifteen days before flowering and the remaining half dose one month after flowering 30 cm away from the tree trunk as broadcast application. Besides the fertilization management was conducted as foliar boric acid (1%, w/w) at pink bud stage, $CaCl_2$ (1%, w/w) at fruit set to pea nut stage (20 mm fruit diameter) and the last stage of fruit growth (1-2 sprays at walnut stage to fruit about 80-90% of final size stage). Usually farmers supplemented only the soil fertilization with 20 kg FYM, 2.8 kg CAN, 2.2 kg SSP and 1.15 kg MoP as per 10-year old tree age basis in the middle of winter months.

The pollinizer cultivars Golden Delicious and Tydeman's Early Worcester in Royal Delicious orchards (main variety: pollinizer variety) as an alternate tree in each main variety was maintained. The phenological observations in relation to beginning of the flowering the full bloom to end of flowering in main and pollinizer trees were carried out. Flowering period was observed to last for 17-19 days. The flowering period of the pollinizing cultivars fully coincided with the main cultivars. Trees were trained in the modified central leader system and standard cultural practices for apple were applied to achieve a manageable uniform size, a balance between growth and regular yields and to allow proper penetration of light and spray to the tree centre. The trees received routine horticultural care in accordance with the scientific principles for commercial fruit production including the framework of fertilization, weeds control, the optimal operations for plant protection and irrigation. The field was irrigated each season from mid April to October. Flood irrigation was generally supplemented in July-August during hot and dry weather. It was recognized that in addition to the climatic variation the sites differed with respect to soil which was subsequently considered to be a very important factor for the potential productivity of the orchards.

The soil differences at each site within the orchard were also assessed. The baseline soil samples weighed up to 1 kg were collected at 15-30 cm depth of the surface soil using an auger of 10 cm diameter in the rhizosphere of common vetch. The soil samples were air-dried in the shade, ground to pass through 2 mm sieve and stored in plastic bags with four replicate cores. Soil characteristics of apple orchards were based on texture characteristics including water holding capacity (Keen-Raczkowski Box method) (Piper 1966), bulk density (Chopra and Kanwar 1976), porosity, pH, EC, SOC, initial available N, $NaHCO_3$-extractable P, K and DTPA extractable micronutrient cations viz Zn, Mn, Fe and Cu.

The chemical properties of soils were determined according to standard methods. Soil pH and EC were measured in 1:2.5 soil-water suspensions. Soil organic carbon (SOC) was analyzed according to Walkey and Black (1934), available N using alkaline potassium permanganate method (Subbiah and Asija 1956), P (0.5 M $NaHCO_3$ extractable) by Olsen et al (1954) and 1N neutral ammonium acetate extractable K estimated by flame photometry (Merwin and Peach 1950). Meso-nutrients (exchangeable Ca and Mg) were determined according to ammonium acetate method (Black 1965). DTPA extractable Fe, Cu, Zn and Mn were buffered at pH 7.3 ± 0.05 according to Lindsay and Norvell (1978) and then analyzed using atomic absorption spectrophotometer model-4141.

For plant analysis of macro and micronutrient contents the leaf samples were taken from the middle part of the 1-year old shoots all around the periphery of the tree at 150 days from full bloom to harvest (DFFBH) for Royal Delicious. The samples were collected between mid July and August from the middle pair of leaflets from the middle of the current season's growth. The represented sample size of 100 pairs of leaflets from the randomly selected trees was tested within the block. Sampling and the preparation for chemical analysis were carried out according to Chapman (1964). The digestion of leaf samples (1 g) for the estimation of total N was carried out in concentrated H_2SO_4 containing a digestion mixture of potassium sulphate (400 parts), $CuSO_4$ (20 parts) and selenium powder (1 part). For the estimation of P, K and B the samples (0.5 g) were digested in diacid mixture (HNO_4:$HClO_4$) in the ratio of 4:1 (Piper 1966). Total leaf N was determined using a nitrogen auto-analyzer, Kjeltech Foss Tecator model 2300 (FOSS, Denmark) and P by the phosphor vanado molybdate method (Jackson 1973). K concentration was determined by atomic emission spectroscopy whereas micronutrients were quantified on atomic absorption spectroscopy model-4141.

Statistical analyses of the data were carried out using general linear model of the standard errors of the mean. The mean values for the respective parameters were the differences between the means of different treatments and were compared by the least significant difference (LSD) tested at probability value p= 0.05 wherever the results were significant; therefore a separate analysis of variance was conducted on each harvest period.

RESULTS and DISCUSSION

Foliar nutrients

To interpret the results of traditional chemical analysis of plant tissue for the assessment of the nutritional status of plants the methods of critical level and sufficiency range are used frequently (Serra et al 2012). In the present study N fertilization sources had a significant effect on the amount of leaf nutrient macro, meso and micronutrient concentrations of the trees (Tables 1, 2). Small but significant differences were observed among N fertilizers for leaf N, P, K, Ca, Mg and micronutrient concentration. Urea application resulted in maximum (2.45%) leaf N content followed by CAN, calcium nitrate and NPK (12:32:16) + urea. Leaf N was recorded highest in urea (840 g N/tree) application due to increase in N supply which rendered more available N for uptake and also due to enhanced accumulation in leaves as a result of efficient translocation under high supply from roots to other parts (Singh 1992). Similarly maximum leaf P (0.29%) was recorded in conjoint NPK (19:19:19) + urea application which was statistically similar to NPK (12:32:16) + urea, urea and CAN recording 0.27, 0.23 and 0.20 per cent respectively.

Among nitrogen levels maximum (0.25%) and minimum (0.21%) available P was recorded in 560 g and 840 g N/tree respectively. Maximum leaf K (1.61%) was also recorded in NPK (19:19:19) + urea treatment combination followed by NPK (12:32:16) + urea and calcium nitrate application. Leaf Ca, Mg and micronutrient concentrations viz Fe, Cu, Zn and Mn were also quantified significantly by different soil N fertilization in similar trend. The higher leaf Ca content with the application of calcium nitrate and calcium ammonium nitrate can be ascribed to adequate quantity of Ca in the fertilizer input.

The present findings are in line with those of Greene and Smith (1979) who recorded increase in leaf Ca content of Yorking apple with soil application of calcium nitrate in comparison to ammonium sulphate. Increase in leaf Ca content with the application of calcium nitrate has also been reported by Raese (1996)

Table 1. Leaf macronutrients concentration (dry matter basis) at various soil N formulations in Royal Delicious apple

Fertilizer	N (%)				P (%)				K (%)				Ca (%)				Mg (%)			
	840	700	560	Mean	840	700	560	Mean	840	700	560	Mean	840	700	560	Mean	840	700	560	Mean
Urea	2.52	2.43	2.42	2.45	0.20	0.23	0.25	0.23	1.27	1.29	1.35	1.30	1.38	1.33	1.30	1.34	0.43	0.39	0.32	0.38
Calcium nitrate	2.42	2.31	2.28	2.34	0.17	0.21	0.19	0.19	1.36	1.40	1.41	1.39	1.64	1.59	1.51	1.58	0.37	0.28	0.31	0.32
NPK_1 + urea	2.28	2.25	2.22	2.25	0.26	0.29	0.32	0.29	1.58	1.61	1.64	1.61	1.40	1.36	1.33	1.36	0.26	0.34	0.28	0.29
NPK_2 + urea	2.37	2.31	2.29	2.32	0.25	0.27	0.30	0.27	1.51	1.52	1.58	1.54	1.49	1.55	1.42	1.49	0.36	0.32	0.35	0.34
CAN	2.47	2.40	2.37	2.42	0.19	0.22	0.20	0.20	1.32	1.35	1.38	1.35	1.60	1.53	1.46	1.53	0.33	0.22	0.26	0.27
Mean	2.41	2.34	2.31		0.21	0.24	0.25		1.41	1.44	1.47		1.50	1.47	1.40		0.35	0.31	0.30	
$LSD_{0.05}$																				
T				0.03				0.02				0.02				0.02				0.02
R				0.02				0.01				0.01				0.02				0.02
T × R				0.06				N/S				0.03				0.04				0.04

NPK_1= 19:19:19, NPK_2= 12:32:16; 800, 700 and 560= Levels of N g/tree. T= Treatment, R= Rate

Table 2. Leaf micronutrients concentration (ppm, dry matter basis) at various soil N formulations in Royal Delicious apple

Fertilizer	Fe				Cu				Zn				Mn			
	840	700	560	Mean	840	700	560	Mean	840	700	560	Mean	840	700	560	Mean
Urea	119.86	121.18	119.53	120.19	11.92	10.19	7.94	10.02	27.14	23.56	27.21	25.97	55.53	54.10	52.34	53.99
Calcium nitrate	111.10	114.32	120.65	115.36	8.85	7.48	7.34	7.89	33.22	31.20	30.53	31.65	83.75	78.99	77.27	80.00
NPK_1 + urea	124.85	121.31	117.55	121.24	10.07	9.50	8.01	9.19	29.66	26.86	28.23	28.25	59.59	58.43	53.22	57.08
NPK_2 + urea	128.28	125.10	121.28	124.89	10.60	9.81	7.68	9.36	31.18	28.66	29.88	29.91	61.68	59.75	57.37	59.60
CAN	106.50	112.17	119.20	112.62	8.65	7.65	7.30	7.87	34.75	33.02	31.16	32.98	83.77	79.86	75.55	79.73
Mean	118.12	118.82	119.64		10.02	8.93	7.65		31.19	28.66	29.40		68.86	66.23	63.15	
$LSD_{0.05}$																
T				1.44				0.05				1.14				1.32
R				1.12				0.04				0.88				1.02
T × R				2.49				0.09				N/S				2.29

NPK_1= 19:19:19, NPK_2= 12:32:16; 800, 700 and 560= Levels of N g/tree, T= Treatment, R= Rate in apple and pear. Further highest leaf Mg was recorded in urea (840 g N/tree) application may be due to synergetic effect of nitrogen on magnesium (Sud and Bhutani 1992). Leaf Zn, Cu, Fe and Mn increased with the increased N fertilization. This might be due to synergistic effect of N on availability of micronutrient cations and its uptake by the plants.

Soil chemical indicators

The mean values of soil chemical indicators were recorded significantly in variable N soil fertilizer nutrient sources application (Tables 3, 4). There was a significant effect on soil pH and SOC ($P < 0.05$) but differences were very small. Different N sources changed pH of the soil towards acidic environment. Minimum reduction in soil pH was found with calcium nitrate at 560 g N/tree.

The present results are in line with the findings of Malhi et al (2000) who reported that ammonium fertilizers reduced the soil pH as compared to calcium nitrate and urea. Clark et al (1989) also recorded lower soil pH due to N when NH_4^+- N is converted to NO_3^-- N in the soils. Additional acidity is from the presence of anions of NH_4^+ fertilizers. Maximum soil OC build up was observed with the inclusion of urea application into the soil. Among the tested N fertilizer inputs urea application showed maximum available N, NPK (12:32:16) + urea for P, CAN for K, calcium nitrate for exchangeable Ca, NPK (19:19:19) + urea for Mg content. Urea significantly increased the available N content while CAN lowered down it due to the NH_4^+ fixation capacities in the soil. Soil K was significantly increased with CAN (840 g N/tree). The results of present study are in line with those of Xie and Cummings (1995) who also reported increase in soil K with application of nitrogenous fertilizers. Soil Ca and Mg contents were significantly influenced by various sources of nitrogen. The data revealed that calcium nitrate (840 g N/tree) increased the calcium content in soil however magnesium content decreased. These findings are also in line with those of Glenn et al (1987) in apple and Clark et al (1989) in blue berry who reported that calcium nitrate increased Ca content and Mg content decreased with increasing $Ca(NO_3)_2$ that can be attributed to Ca displacement of soil Mg on the cation exchange complex and Mg leach out from root zone. Further DTPA extractable micronutrient cations (Fe, Cu, Zn and Mn) were recorded maximum under urea application (Table 4).

Table 3. Soil chemical characteristics at various soil N formulations in Royal Delicious apple

Fertilizer	pH				Soil organic carbon (%)				N (kg/ha)				P (kg/ha)				K (kg/ha)			
	840	700	560	Mean	840	700	560	Mean	840	700	560	Mean	840	700	560	Mean	840	700	560	Mean
Urea	5.56	5.69	5.77	5.67	1.74	1.72	1.70	1.72	413.2	405.5	396.8	405.2	22.0	23.2	20.2	21.8	325.5	316.5	328.3	323.4
Calcium nitrate	5.77	5.86	5.89	5.84	1.53	1.55	1.58	1.55	394.3	391.0	387.0	390.8	22.2	26.0	24.0	24.1	339.5	329.4	286.3	318.4
NPK_1 + urea	5.67	5.70	5.77	5.71	1.64	1.62	1.59	1.62	396.8	393.5	389.8	393.4	27.9	30.1	27.3	28.5	337.7	334.7	325.7	330.0
NPK_2 + urea	5.27	5.59	5.62	5.49	1.60	1.68	1.66	1.65	385.7	382.7	377.4	381.9	30.8	30.3	28.6	29.9	331.9	324.2	333.8	330.0
CAN	5.46	5.48	5.59	5.51	1.56	1.61	1.62	1.60	386.2	375.0	371.4	377.5	24.1	25.9	25.8	25.3	340.9	326.3	333.2	333.7
Mean	5.55	5.66	5.73		1.61	1.64	1.63		395.2	389.5	384.5		25.4	27.1	25.2	335.1	326.2	321.4		
$LSD_{0.05}$																				
T				0.09				0.01				1.59				1.31				9.09
R				0.07				0.01				1.23				1.02				7.05
T × R				0.16				0.03				2.75				NS				15.76

NPK_1 = 19:19:19, NPK_2 = 12:32:16; 800, 700 and 560= Levels of N g/tree, T= Treatment, R= Rate

Table 4. Exchangeable Ca, Mg and DTPA extractable micronutrient cations (ppm) at various soil N formulations in Royal Delicious apple

Fertilizer	Level of N g/tree											
	840	700	560	Mean	840	700	560	Mean	840	700	560	Mean
	Ca				Mg				Fe			
Urea	21.0	23.1	24.4	22.8	23.3	20.8	19.7	21.2	56.9	55.1	50.9	54.3
Calcium nitrate	37.2	34.6	32.4	34.7	20.3	20.6	21.3	20.7	54.0	50.3	48.5	50.9
NPK_1 + urea	30.9	29.0	26.2	28.7	24.4	25.3	22.7	24.1	43.8	42.1	42.3	42.7
NPK_2 + urea	29.5	26.7	25.9	27.3	21.2	23.0	22.6	22.2	45.9	43.5	45.1	44.8
CAN	36.3	34.1	32.1	34.2	19.3	20.1	20.4	19.9	48.4	44.5	39.9	44.3
Mean	31.0	29.5	28.2		21.7	21.9	21.3		49.8	47.1	45.3	
$LSD_{0.05}$												
T				0.42				0.03				0.51
R				0.32				0.02				0.39
T × R				0.72				0.04				0.88
	Cu				Zn				Mn			
Urea	1.52	1.54	1.49	1.52	2.83	2.79	2.78	2.80	42.8	40.1	38.4	40.4
Calcium nitrate	1.43	1.39	1.50	1.44	2.62	2.59	2.56	2.59	41.6	39.8	38.7	40.0
NPK_1 + urea	1.32	1.37	1.36	1.35	3.16	3.17	3.09	3.14	35.7	37.1	34.8	35.8
NPK_2 + urea	1.44	1.33	1.34	1.37	2.83	2.77	2.74	2.78	37.4	36.1	38.3	37.3
CAN	1.44	1.40	1.49	1.44	2.55	2.53	2.52	2.53	40.0	36.8	33.6	36.8
Mean	1.43	1.41	1.44		2.80	2.77	2.74		39.5	38.0	36.7	
$LSD_{0.05}$												
T				0.03				0.03				0.05
R				0.02				0.02				0.04
T × R				0.04				NS				0.09

NPK_1= 19:19:19, NPK_2= 12:32:16, NS= Non-significant, T= Treatment, R= Rate

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