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Effect of graded levels of NPK on growth and leaf nutrient content of apple (*Malus* × *domestica*) nursery plants

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ABSTRACT

An experiment was conducted during 2017–18 to study the effect of different N, P and K doses on vegetative growth and leaf nutrient content of apple nursery plants of cultivar Starking Delicious and to find out the optimum dose of nutrients for production of healthy planting material for Merton 793 rootstock. The experiment was laid out in a randomized block design comprising 12 combinations of N, P_2O_5 and K_2O {3 levels of N (12, 15 and 18 g/m^2 nursery bed), 2 levels of P (3 and 6 g/m^2 nursery bed) and 2 levels of K (4.5 and 9 g/m^2 nursery bed)}, *Jeevamrut* and control. The results revealed that maximum linear growth of plant, number of leaves, leaf area, length of main root, total root length, fresh and dry weight of roots, leaf P, Mg and Ca contents were recorded in the plants fertilized with NPK @18:6:4.5 g/m^2. However, radial growth of plant, internodal length, fresh and dry weight of shoots, total biomass, leaf N and K were highest in the plants treated with NPK @18:6:9 g/m^2 nursery bed. NPK @18:6:4.5 g/m^2 nursery bed and NPK @18:6:9 g/m^2 nursery bed were found statistically at par with each other with respect to plant growth and leaf nutrients. Thus, nursery bed with 18.0 g N, 6.0 g P and 4.5 g K per m^2 was found most suitable for production of quality nursery plants of apple plantlets on Merton 793 clonal rootstock.

Keywords: Correlation, Growth response, NPK, Nursery, Rootstock, Starking Delicious

Apple (*Malus* × *domestica* Borkh.) is the most economical fruit crop in temperate regions of India. In past few decades, apple production in the country has seen an outward trend due to introduction of new colouring strains and low chilling varieties leading to a substantial increase in demand of nursery plants. Besides, a large number of orchards have completed their economical life and need replanting. Thus, demand of planting material is increasing every year but paucity of genuine and quality planting material is the major hindrance in area expansion and replanting. Weak plants with poor root system in the nursery become susceptible to insects-pests and diseases and fail to attain desired plant size required for transplanting to the orchards. Therefore, quality of apple nursery plants is of paramount importance and can be ensured by adopting proper nursery management practices.

Balanced application of nutrients (NPK) is a major factor which plays an important role in production of healthy and high grade planting material by influencing the growth of plants. The quantity of nutrients applied to the soil affects the amount of organic carbon in the soil and nutrient availability to the plants (Skwarylo-Bednarz and Krzepilko 2009). Presently, nurserymen apply only FYM and nitrogenous fertilizers to nursery plants. Non-application of phosphorus and potash fertilizers is resulting in nutrient imbalance and poor growth of nursery plants. Starking Delicious is a predominant variety and about 75% apple plantations in the State are under this variety. A semi-vigorous clonal rootstock, Merton 793 has resistance to apple replant problem. It is adaptable to wider soil and climatic conditions. Keeping in view the importance of NPK in production of strong and healthy planting material, the present study was undertaken to find out the optimum dose of NPK for production of high grade planting material of apple on clonal rootstocks.

MATERIALS AND METHODS

The study was carried out during 2017–18 on grafted nursery plants of apple cv. Starking Delicious raised on one-year old 'Merton 793' clonal rootstock in Department of Fruit Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. There were 14 different treatment combinations comprising N, P_2O_5 and K_2O including, NPK @12:3:4.5 g/m^2 (T_1) , NPK @12:3:9 g/m^2 (T_2), NPK @12:6:4.5 g/m^2 (T_3) , NPK @12:6:9 g/m^2 (T_4), NPK @15:3:4.5 g/m^2 (T_5), NPK @15:3:9 g/m^2 (T_6), NPK @15:6:4.5 g/m^2 (T_7), NPK @15:6:9 g/m^2 (T_8),

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NPK @18:3:4.5 g/m^2 (T_9), NPK @18:3:9 g/m^2 (T_{10}), NPK @18:6:4.5 g/m^2 (T_{11}), NPK @18:6:9 g/m^2 (T_{12}), *Jeevamrut* drenching (10%) at fortnight intervals (T_{13}) and Control (T_{14}). Each treatment was replicated thrice. Ten plants in each replication (total 30 plants) in each treatment were treated. N, P_2O_5 and K_2O were applied through urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. Full dose of SSP (P_2O_5) and MOP (K_2O) was applied after the preparation of beds before the planting of stock during the month of January. Urea (N) was applied in two split doses. The first half dose was applied at the time of transplanting of stock and the remaining half at the onset of monsoon. Uniform cultural practices were adopted in each treatment including application of FYM @8 kg/m^2 bed. *Jeevamrut* was prepared by mixing cow dung (1 kg), cow urine (1 litre), gram flour (200 g), jaggery (200 g) and virgin soil (100 g); and making the final volume 20 litre with the tap water. After mixing the component and making the final volume, it was allowed to ferment for 7 days. During the process of fermentation, the solution was stirred clockwise regularly thrice a day. Well prepared *Jeevamrut* was diluted 10 times and applied fortnightly as soil drench to each assigned bed right from the start of the experiment until the plants were uprooted. Fresh *Jeevamrut* was prepared for each application and applied @10 litre/ m^2 nursery bed area.

Linear and radial growth of the plant was measured with measuring tape and digital vernier calipers, respectively at the end of season. To calculate the internodal length, height of the scion portion of the plant was divided by the number of nodes on the plant. The leaf area was measured with the help of an Automatic Leaf Area Meter (Licor Model–3100). To determine the fresh weight of shoots and roots, after uprooting the plants at the end of season, shoot and root portion was separated and cut into small pieces. The fresh weight of shoot and root segments was then recorded separately on electronic balance. To record the dry weight, the root and shoot segments were dried in an oven at 65±5°C until a constant weight was obtained. The length of the main roots was measured with the help of measuring tape. Total root length was measured with the help of root length scanner (Comair root length scanner). Total plant biomass was obtained by adding the dry weight of shoots and roots.

To determine the leaf nutrient content, from each experimental plot leaf samples with petioles were collected from the middle part of the plant during the first week of August and composite sample of individual replication was prepared. Leaf samples were brought directly to the laboratory and washed thoroughly first under tap water, followed by 0.1 N HCl and distilled water as suggested by Chapman (1964). The samples were then dried first by spreading on filter paper sheets and subsequently in paper bags by putting in hot air oven at 65±5°C for 48 h. The dried samples were crushed, ground and stored in butter paper bags for digestion. The digestion of dried leaf sample (1 g) for the estimation of nitrogen was carried out in concentrated H_2SO_4 in the presence of a digestion mixture comprising potassium sulphate (400 parts), copper sulphate (20 parts), mercuric oxide (3 parts) and selenium powder (1 part). For the estimation of P, K, Ca and Mg, the samples (0.5 g) were digested in di-acid mixture of HNO_3 and $HClO_4$ in the ratio 4:1 (Piper 1966). Nitrogen was determined by micro-Kjeldhal's method and phosphorus by vanado molybdate phosphoric yellow colour method (Jackson 1973). Potassium, calcium and magnesium were determined on atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

Effect of NPK on plant growth: The growth of grafted apple nursery plants was found to increase significantly with increasing doses of NPK (Table 1). The maximum linear growth (187.42 cm) and number of leaves per plant (56.0) were recorded in plants fertilized with NPK @18:6:4.5 g/ m^2 (T_{11}) and this treatment was significantly superior to all other treatments except NPK @18:3:4.5 g/m^2 (T_9), NPK @18:3:9 g/m^2 (T_{10}) and NPK @18:6:9 g/m^2 (T_{12}). The maximum annual increase in radial growth of rootstock (5.18 mm) and scion (6.66 mm) was exhibited by plants subjected to T_{12} which was statistically at par with T_9 and T_{11}. Similarly, highest internodal length (3.84 cm) was recorded in T_{12} and increased significantly with increasing doses of NPK. Maximum leaf area (24.77 cm^2) was recorded in T_{11} treatment which was statistically at par with T_{10}. Similarly, plants treated with T_{11} treatment had maximum length of main roots (1.34 m) and total root length (18.35 m). This treatment was statistically at par with NPK @15:6:4.5 g/m^2 (T_7) and T_{12} treatment with respect to length of main root but significantly superior to all other treatments with respect to total root length. Maximum fresh weight (140.52 g) and dry weight (71.42 g) of shoots was recorded in T_{12} which was statistically at par with T_{11}. However, maximum fresh weight of roots (72.08 g), dry weight of roots (38.67 g) and total biomass of plant (107.97 g) were observed in T_{11} which was significantly higher than treatments with lower doses of NPK and control.

The increase in plant growth with the increasing doses of NPK may be attributed to the fact that applied minerals helped in building-up of nutrient reserves in the soil which were then extracted by the plant root system and used in the metabolic processes with the advancement of plant growth. Better availability of mineral nutrients and accumulation of dry matter by the plants in their tissues could have activated the physiological processes for rapid absorption and utilization of nutrients for the primary metabolic process. N combines with C, H, O and S to form amino acids which are the building blocks of proteins. Amino acids are essential in forming protoplasm, the site of cell division, thus promotes plant growth. P is required in large quantity in young cells where metabolism and cell division is rapid. Though 'K' is not a part of any vital organic compound, as an enzyme activator K regulates metabolism and thus promotes growth besides imparting resistance against drought and diseases. According to Pavlikova *et al.* (2012)

Table 1 Effect of graded levels of NPK on growth of grafted nursery plants of apple cv. Starking Delicious

Treatment	Linear growth (cm)	Increase in diameter (mm)		Number of leaves	Internodal length (cm)	Leaf area (cm^2)	Length of main roots (m)	Total root length (m)	Fresh weight of shoots (g)	Dry weight of shoots (g)	Fresh weight of roots (g)	Dry weight of roots (g)	Total plant biomass (g)
		Rootstock	Scion										
T_1 : NPK @12:3:4.5 g/m^2 nursery bed	160.40	3.23	5.72	42.33	3.52	22.83	0.98	9.46	105.23	52.34	48.83	25.83	78.17
T_2 : NPK @12:3:9 g/m^2 nursery bed	163.23	3.31	5.69	44.00	3.56	22.90	0.99	10.55	110.28	55.19	52.42	29.83	85.02
T_3 : NPK @12:6:4.5 g/m^2 nursery bed	165.50	3.19	4.99	44.00	3.58	21.92	1.14	10.82	111.51	56.82	58.58	33.68	90.50
T_4 : NPK @12:6:9 g/m^2 nursery bed	166.75	2.61	5.23	45.00	3.62	22.32	1.14	10.63	112.28	57.40	58.00	33.75	91.15
T_5 : NPK @15:3:4.5 g/m^2 nursery bed	169.02	4.35	5.68	46.00	3.67	22.62	1.15	9.70	113.63	60.58	53.50	30.50	91.08
T_6 : NPK @15:3:9 g/m^2 nursery bed	172.25	4.21	5.87	46.33	3.70	21.19	1.14	9.50	125.65	61.65	53.50	31.66	93.31
T_7 : NPK @15:6:4.5 g/m^2 nursery bed	176.75	4.51	5.61	46.67	3.73	20.34	1.31	12.53	129.13	62.58	64.94	36.32	98.90
T_8 : NPK @15:6:9 g/m^2 nursery bed	181.25	4.50	6.16	47.67	3.74	21.67	1.26	12.93	129.73	63.39	60.17	36.06	99.45
T_9 : NPK @18:3:4.5 g/m^2 nursery bed	186.27	4.66	5.42	51.33	3.79	22.10	1.11	11.17	130.01	65.88	53.50	35.14	101.02
T_{10} : NPK @18:3:9 g/m^2 nursery bed	186.80	4.43	5.84	55.00	3.78	24.68	1.06	11.62	134.18	66.47	53.50	35.86	102.33
T_{11} : NPK @18:6:4.5 g/m^2 nursery bed	187.42	4.93	5.96	56.00	3.80	24.77	1.34	18.35	136.99	69.30	72.08	38.67	107.97
T_{12} : NPK @18:6:9 g/m^2 nursery bed	186.93	5.18	6.66	52.00	3.84	22.09	1.32	14.05	140.52	71.42	65.21	36.19	107.60
T_{13} : Jeevamrut (10%)	174.40	3.93	6.31	50.00	3.71	20.58	1.20	11.49	128.24	69.15	53.42	31.75	100.90
T_{14} : Control	157.87	2.14	4.96	41.00	3.45	20.06	0.97	7.83	101.15	50.92	43.58	23.40	74.32
$CD_{0.05}$	9.93	0.57	0.85	4.70	0.14	1.54	0.05	1.03	6.51	8.85	6.03	4.42	10.11

nitrogen application increased the levels of cytokinins and increased concentration of endogenous cytokinins as well as the enhanced content of free amino acids (glutamic acid, aspartic acid and asparagine) results in better distribution patterns of nutrients and provides improved conditions for plant growth. Findings of present study are in conformity with Prado *et al.* (2009) who reported that fertilization with N, P and K @918, 184, 876 mg/dm^3 of substratum significantly improved the growth of sweet orange nursery plants. Pathak and Dhawan (2010) recorded an increase in plant biomass in apple with increasing doses of N and P.

Effect of NPK on leaf nutrient content: Leaf nutrient content of grafted apple nursery plants (Table 2) were significantly affected by different NPK doses. Leaf N, P and K content increased with increasing doses of NPK. Leaf Ca and Mg content increased with increasing doses of N and P but decreased with increasing doses of K. Maximum N content (2.47%) was recorded in plants fertilized with T_{12} which was statistically at par with T_8, T_9, T_{10} and T_{11} treatments. Maximum leaf P content (0.30%) was exhibited by nursery plants subjected to T_{11} which was statistically at par with T_{12}. Leaf K (1.88%) was recorded maximum under T_{12} treatment which was significantly higher than those of NPK @12:3:4.5 g/m^2 (T_1), NPK @12:6:4.5 g/m^2 (T_3), *Jeevamrut* drenching (10%) at fortnight intervals (T_{13}) and control (T_{14}). Maximum leaf Ca (1.53%) and Mg (0.35%) content was observed in T_{11} which was statistically at par with treatments T_8, T_9, T_{10} and T_{12}.

The increase in leaf N content with the increasing doses of NPK may be due to high mobility of N and its efficient translocation under abundant supply from root to the leaves which could have accounted for its enhanced accumulation in the leaves. The increase in phosphorus content was due to enhanced phosphorus activity that mobilizes sparingly the available nutrient sources and ectozymes resulting in improved phosphate uptake. The increase in leaf K content following increased application of NPK could be due to the fact that higher levels of soil potassium application create concentration gradient between potassium ion concentration inside the root and soil solution, which ultimately results in increased uptake of potassium by plant. The increase in leaf Ca and Mg content with increasing doses of N and P could be due to the fact that leaf calcium normally shows a direct positive relationship with leaf nitrogen concentration. However, decrease in leaf Ca and Mg content with increasing dose of K may be attributed to inverse relationship between availability of K in soil and leaf Ca or Mg content as K ions compete with Ca and Mg ions for same binding site in the absorption process. The results of present investigation are corroborated by Singh *et al.* (2006), who reported that leaf nutrient accumulation was greatest when NPK was applied at higher rates to apple plants. Prado *et al.* (2009) fertilized grafted nursery plants of 'Valencia' sweet orange with different N, P and K levels and recorded greater accumulation of these nutrients in the aerial parts with higher dose of N, P and K @918, 184, 876 mg/dm^3 of substratum. Nabi *et al.* (2018) recorded significantly higher leaf N, Ca and Mg content in high density plantations of apple with the higher application of N (105 g), P_2O_5 (35 g) and K_2O (150 g) per plant.

Correlation studies: The perusal of data presented in Table 3 shows that there was a positive and significant correlation of leaf N, P, K, Ca and Mg content with growth characteristics of grafted nursery plants of apple. It is clear from the data that leaf N, P and K content were positively and highly correlated with linear plant growth, radial growth of stock, internodal length, number of leaves, length of main roots, total root length, fresh and dry weight of shoots and

Table 2 Effect of NPK doses on leaf nutrient content of grafted nursery plants of apple cv. Starking Delicious

Treatment	Leaf nutrient content (%)				
	N	P	K	Ca	Mg
T_1 : NPK @12:3:4.5 g/m^2 nursery bed	2.22	0.16	1.75	1.39	0.27
T_2 : NPK @12:3:9 g/m^2 nursery bed	2.23	0.16	1.78	1.37	0.24
T_3 : NPK @12:6:4.5 g/m^2 nursery bed	2.24	0.20	1.76	1.43	0.28
T_4 : NPK @12:6:9 g/m^2 nursery bed	2.25	0.21	1.80	1.35	0.26
T_5 : NPK @15:3:4.5 g/m^2 nursery bed	2.28	0.18	1.79	1.45	0.29
T_6 : NPK @15:3:9 g/m^2 nursery bed	2.31	0.18	1.83	1.42	0.28
T_7 : NPK @15:6:4.5 g/m^2 nursery bed	2.34	0.22	1.81	1.46	0.32
T_8 : NPK @15:6:9 g/m^2 nursery bed	2.35	0.21	1.85	1.40	0.30
T_9 : NPK @18:3:4.5 g/m^2 nursery bed	2.38	0.19	1.81	1.50	0.37
T_{10} : NPK @18:3:9 g/m^2 nursery bed	2.41	0.20	1.87	1.47	0.33
T_{11} : NPK @18:6:4.5 g/m^2 nursery bed	2.43	0.30	1.86	1.53	0.35
T_{12} : NPK @18:6:9 g/m^2 nursery bed	2.47	0.29	1.88	1.51	0.32
T_{13} : Jeevamrut (10%)	2.25	0.20	1.70	1.40	0.27
T_{14} : Control	2.03	0.15	1.60	1.28	0.22
$CD_{0.05}$	0.12	0.03	0.11	0.13	0.06

Table 3 Correlations between leaf nutrient contents and plant growth characteristics of grafted nursery plants of apple cv. Starking Delicious

Parameter	Correlation coefficient (r-value)				
	Leaf N	Leaf P	Leaf K	Leaf Ca	Leaf Mg
Linear plant growth	0.915**	0.726**	0.752**	0.830**	0.893**
Radial growth of scion	0.643*	0.533*	0.526NS	0.477NS	0.338NS
Radial growth of stock	0.912**	0.652*	0.773**	0.898**	0.841**
Internodal length	0.941**	0.735**	0.793**	0.853**	0.859**
Number of leaves	0.845**	0.723**	0.664**	0.805**	0.814**
Leaf area	0.504NS	0.341NS	0.577*	0.489NS	0.427NS
Length of main roots	0.688**	0.860**	0.565*	0.641*	0.577*
Total root length	0.746**	0.914**	0.627*	0.715**	0.661*
Fresh shoot weight	0.904**	0.760**	0.736**	0.799**	0.801**
Dry shoot weight	0.843**	0.755**	0.625*	0.785**	0.746**
Fresh root weight	0.737**	0.914**	0.687**	0.696**	0.606*
Dry root weight	0.878**	0.784**	0.819**	0.776**	0.792**
Total biomass	0.905**	0.809**	0.742**	0.825**	0.807**

NS, Non-significant; *Significant at 1% level of significance; **Significant at 5% level of significance.

roots and total plant biomass. Similarly, leaf Ca and Mg content exhibited positive and highly significant correlations with linear plant growth, radial growth of stock, internodal length, number of leaves, total root length, fresh and dry weight of shoots and roots and total plant biomass.

It is inferred from the results of present investigations that application of 18 g N, 6 g P_2O_5 and 4.5 g K_2O/m^2 nursery bed to nursery plants of apple cv. Starking Delicious grafted on Merton 793 rootstock had significantly higher linear growth, number of leaves, fresh and dry weight of roots, total biomass of plant, leaf P and Ca content. Radial growth, internodal length, fresh and dry weight of shoots, leaf N and K content were found highest under treatment comprising 18 g N, 6 g P_2O_5 and 9 g K_2O/m^2 nursery bed, however, this dose of nutrients was statistically at par with 18 g N, 6 g P_2O_5 and 4.5 g K_2O/m^2 nursery bed. Leaf N, P, K, Ca and Mg content had positive and significant correlation with plant growth characteristics. Thus, soil application of 18 g of N, 6 g of P_2O_5 and 4.5 g of K_2O/m^2 nursery bed has been found most effective nutrient dose and can be recommended for the production of quality nursery plants of apple on clonal rootstocks.

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