International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2020; 8(1): 2126-2130

Received: 16-11-2019
Accepted: 18-12-2019

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Assessing fruit quality of high density apple cv. red velox by application of different levels of N, P and K under temperate conditions of Kashmir valley

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DOI: https://doi.org/10.22271/chemi.2020.v8.i1af.8583

Abstract
The present study was conducted at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus Srinagar at High Density Apple Block of Division of Fruit Science for two consecutive years 2017-2018 and 2018-2019 with an objective to observe the influence of different levels and combinations of nitrogen, phosphorous and potassium on quality parameters of High Density Apple cv. Red velox. The results of the study revealed that the apple fruit quality viz., SSC, sugars, reducing and non-reducing sugars were significantly influenced with highest levels of phosphorus and potassium (*i.e.* P_3 and K_3) coupled with N_2 level of nitrogen during 2017 and 2018 respectively when nutrients were applied in combination. Maximum soluble solids content (14.31, 15.04; 14.26, 14.87 and 14.23, 14.82 ^{0}Brix), total sugars (9.685, 9.897; 9.444, 9.646 and 9.472, 9.687%), reducing sugars (6.937, 7.015; 6.985, 7.047 and 7.005, 7.067%), non-reducing sugars (2.492, 2.632; 2.366, 2.479 and 2.371, 2.473%) was obtained in N_2 level of nitrogen coupled with highest level of P and K i.e., P_3 and K_3. Among the interaction effects, the treatment combination of $N_2P_3K_3$recorded maximum SSC (14.50, 15.19 ^{0}Brix), total sugars (9.810, 10.05%), reducing sugars (7.20, 7.39%) and non-reducing sugars (2.61, 2.73%) resulted in significant increase in quality attributes of High Density Apple cv. Red velox.

Keywords: Apple, high density planting, nitrogen, phosphorus, potassium, and quality attributes

Introduction
Apple (*Malus domestica* Borkh) is an important member of family Rosaceae and is widely cultivated in temperate regions of the world. The state of Jammu and Kashmir is bestowed with a particularly well suited climate for production of temperate fruits like Pear, Peach, Plum, Almond particularly Apple. Apple is the principal fruit crop of Jammu and Kashmir, accounting for 48.14 per cent of area and 77.26 per cent of total fruit production. It occupies an area of 16, 2971hectares with a total production of 18, 51,723 Metric tonnes and productivity of 12.16 t/ha (Anonymous, 2019) [1].

Providing adequate nutrition is the outmost concern for enhancing the yield as well as quality of apple. High density planting is one of the advanced techniques that have proven significantly good in increasing not only the productivity per unit area but also in improving the fruit quality (Singh, 2005) [13]. It has been observed that fertilizer requirements in high density arrangements are greater when compared to conventional planting. The effect of closer planting on fruit quality is mainly marked by the changes in quantity and quality of intercepted light and the partitioning of assimilate between vegetative and reproductive shoots (Policarpo *et al*. 2006) [9]. With proper nutrient management, this phenomenon could be balanced and hence will be helpful in improvement of fruit quality. With the increase in the plant and fruit number per unit area in dense planting, the nutrient management becomes the first and most important consideration. Therefore, nutrient management is essential for optimum plant growth, development and for increasing the fruit quality (Singh and Singh, 2007) [15].

Nitrogen, phosphorus and potassium are key elements required by the apple tree for various important functions like growth of tissues, formation of amino acids and proteins, chlorophyll development, water uptake, transpiration, manufacture and translocation of sugars and starches, and quality of fruit. The amount of nitrogen, phosphorus and potassium required by plants is of great significance in fruit cultivation. A small change in nitrogen, phosphorus and potassium content in tissue has a great effect on growth, yield and quality of apple trees.

Optimizing the NPK fertilizer doses is necessary to achieve optimal yield potential. Keeping this in view, the study was undertaken to find out the optimization of quality attributes of High Density Apple cv. Red velox by application of different levels and combinations of N, P and K under temperate conditions of Kashmir Valley.

Materials and Methods

The experiment was carried out at High Density Apple Block Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar during two consecutive years 2017-18 and 2018-19. The experiment was laid out in a factorial randomized block design with three replications and 64 treatment combinations containing four levels of nitrogen (0,105,140,175g/tree) four levels of phosphorous (0, 43, 57, 71g/tree) and four levels of potassium (0, 187, 250, 312 g/tree)during the first year and 0, 146, 194, 243 g N/tree,0,60,80,100gP/tree and 0,263,350,438 g K/tree during the second year of experimentation. First half of the nitrogen was applied on 21 days before expected bloom and second half after fruit set while as full dose of phosphorus and half dose of potassium was applied 21 days before expected bloom and another half dose of potassium after fruit set. The results were obtained from ten randomly selected fruits from each observational plant at edible ripe stage. Soluble solid content (^{0}Brix) was determined by using Zeis hand refractometer Reducing sugar and total sugars were determined by "Dubois method" (Sadasivam and Manickam, 1996) [10]. The non-reducing sugars were calculated by subtracting values of reducing sugars from values of total sugars and multiplying by factor 0.95. The data analysis was carried out using the OPSTAT software (1998).

Table 1: Treatment combination details

T_1: $N_0P_0K_0$ (Control)	T_{17}: $N_1P_0K_0$
T_2: $N_0P_0K_1$	T_{18}: $N_1P_0K_1$
T_3: $N_0P_0K_2$	T_{19}: $N_1P_0K_2$
T_4: $N_0P_0K_3$	T_{20}: $N_1P_0K_3$
T_5: $N_0P_1K_0$	T_{21}: $N_1P_1K_0$
T_6: $N_0P_1K_1$	T_{22}: $N_1P_1K_1$
T_7: $N_0P_1K_2$	T_{23}: $N_1P_1K_2$
T_8: $N_0P_1K_3$	T_{24}: $N_1P_1K_3$
T_9: $N_0P_2K_0$	T_{25}: $N_1P_2K_0$
T_{10}: $N_0P_2K_1$	T_{26}: $N_1P_2K_1$
T_{11}: $N_0P_2K_2$	T_{27}: $N_1P_2K_2$
T_{12}: $N_0P_2K_3$	T_{28}: $N_1P_2K_3$
T_{13}: $N_0P_3K_0$	T_{29}: $N_1P_3K_0$
T_{14}: 4dx$N_0P_3K_1$	T_{30}: $N_1P_3K_1$
T_{15}: $N_0P_3K_2$	T_{31}: $N_1P_3K_2$
T_{16}: $N_0P_3K_3$	T_{32}: $N_1P_3K_3$
T_{33}: $N_2P_0K_0$	T_{49}: $N_3P_0K_0$
T_{34}: $N_2P_0K_1$	T_{50}: $N_3P_0K_1$
T_{35}: $N_2P_0K_2$	T_{51}: $N_3P_0K_2$
T_{36}: $N_2P_0K_3$	T_{52}: $N_3P_0K_3$
T_{37}: $N_2P_1K_0$	T_{53}: $N_3P_1K_0$
T_{38}: $N_2P_1K_1$	T_{54}: $N_3P_1K_1$
T_{39}: $N_2P_1K_2$	T_{55}: $N_3P_1K_2$
T_{40}: $N_2P_1K_3$	T_{56}: $N_3P_1K_3$
T_{41}: $N_2P_2K_0$	T_{57}: $N_3P_2K_0$
T_{42}: $N_2P_2K_1$	T_{58}: $N_3P_2K_1$
T_{43}: $N_2P_2K_2$	T_{59}: $N_3P_2K_2$
T_{44}: $N_2P_2K_3$	T_{60}: $N_3P_2K_3$
T_{45}: $N_2P_3K_0$	T_{61}: $N_3P_3K_0$
T_{46}: $N_2P_3K_1$	T_{62}: $N_3P_3K_1$
T_{47}: $N_2P_3K_2$	T_{63}: $N_3P_3K_2$
T_{48}: $N_2P_3K_3$	T_{64}: $N_3P_3K_3$

Results and Discussion

In the present investigation combination of different levels of nitrogen, phosphorus and potassium showed improvement in fruit quality of apple Perusal of data presented in Table 2, 3, 4 and 5 revealed that the quality attributes of apple were significantly influenced by the increasing levels of applied nutrients. Among the all treatment combinations, $N_2P_3K_3$ recorded maximum SSC (14.67and 15.50 ^{0}Brix) which was significantly higher than other N×P×K treatment combinations followed by $N_2P_3K_2$ (14.61 and 15.46^{0}Brix) and the minimum value (13.40 and 14.05 ^{0}Brix) was recorded in $N_0P_0K_0$ during 2017 and 2018 respectively. Maximum total sugars (9.810 and 10.05%) and reducing sugar (7.200 and 7.395%) were recorded with combination treatment $N_2P_3K_3$ (followed by $N_2P_3K_2$ minimum total sugars (9.170 and 9.300%) and reducing sugars (6.740 and 6.857%) were recorded with $N_3P_0K_0$ during both of the experimental years. However,maximum non-reducing sugars was recorded with combination treatment $N_2P_3K_3$ (2.615 and 2.900%) followed by $N_2P_3K_2$ (2.590 and 2.875%) whereas minimum results was recorded with $N_3P_0K_0$ (2.122 and 2.330%).Quality parameters in terms of SSC, total sugars, reducing and non-reducing sugars seems to be improved by application of different nutrient combinations. High rates of nitrogen fertilizer decreased soluble solids (Nava *et al.*, 2008) [7]. Increasing rates of phosphorus and potassium increase the concentration of soluble solids in the apple flesh (Nava *et al.*, 2008) [7]. This might be due to the fact that optimum nitrogen increases the availability of assimilates and higher dose cause excessive vegetative growth which requires most of the metabolites while little was left for storage in the fruit. Nitrogen stimulates the functioning of number of enzymes in the physiological processes, which might have improved the total soluble solid content of the fruits. The finding in line with those of El- Gazzar (2000), Nava *et al.* (2008) [3, 7] and Imam and Brifkany (2010) [5]. The highest improvement in total soluble solids was observed in higher levels of phosphorus and potassium. It may be due to the role of phosphorus and potassium in enhancing rate of hydrolysis of polysaccharides into mono-saccharides. This increase in SSS is also due to role of potassium in translocation of sugars into the fruit (Sobulo and Olorunda, 1977) [12]. These findings are also in confirmation with Singh *et al*., (2006) [14] who recorded highest juice percentage, TSS, and highest reducing sugar with 125% of recommended dose in pomegranate. The effect of nitrogen level N_2 on total sugars was found to be most significant due to maximum photosynthates produced in this treatment (Stamper *et al.* (2003), Hudina *et al.* (2002) [4], Naiema (2003) [8] and Sharma *et al.* (2014) [11]. The useful effect of phosphorus on quality parameters like sugars was due to the fact that it increased the efficiency of metabolic and physiological processes of plants and thus improved the chemical quality of apple fruits. Highest percentages of total sugars were registered in potassium level K_3. This may be attributed to the increased rate of hydrolysis of polysaccharides to monosaccharides by potassium fertilization. Potassium is widely regarded as element required to improve quality of fruits and in this study it is established that the application of potassium is necessary in fruit orchard to harvest good quality crop. Similar results were reported by Stamper *et al.* (2002) [4] in apple. Singh *et al*. (2009) also found phosphorus along with nitrogen at lower level coupled with high level of potassium to directly influence all the physico- chemical fruit characters in apple cv. Red delicious.

Table 2: Influence of different levels and combinations of N, P and K on soluble solids content (^{0}brix) of apple cv. Red velox.

Nitrogen	Phosphorus	Potassium									
		2017-2018					2018-2019				
		K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	P_0	13.40	13.60	13.80	13.90	13.67	14.05	14.12	14.18	14.22	14.14
	P_1	13.60	13.80	13.95	14.00	13.83	14.15	14.18	14.23	14.26	14.20
	P_2	13.85	14.00	14.10	14.15	14.02	14.20	14.24	14.28	14.33	14.26
	P_3	14.00	14.10	14.15	14.20	14.11	14.24	14.30	14.35	14.40	14.32
	Sub Means	13.71	13.87	14.00	14.06	13.91	14.16	14.21	14.26	14.30	14.23
N_1	P_0	14.03	14.05	14.08	14.10	14.06	14.65	14.67	14.69	14.70	14.67
	P_1	14.06	14.09	14.11	14.16	14.10	14.68	14.70	14.73	14.78	14.72
	P_2	14.10	14.12	14.17	14.20	14.14	14.70	14.75	14.85	14.87	14.79
	P_3	14.15	14.18	14.22	14.25	14.20	14.80	14.87	14.90	14.97	14.88
	Sub Means	14.08	14.11	14.14	14.17	14.12	14.70	14.74	14.79	14.83	14.76
N_2	P_0	14.20	14.23	14.25	14.28	14.24	14.85	14.90	14.94	14.97	14.91
	P_1	14.24	14.25	14.30	14.32	14.27	14.92	14.95	14.99	15.03	14.97
	P_2	14.27	14.31	14.35	14.38	14.32	14.98	15.05	15.10	15.17	15.07
	P_3	14.32	14.36	14.42	14.50	14.40	15.10	15.20	15.25	15.29	15.21
	Sub Means	14.25	14.28	14.33	14.37	14.31	14.96	15.02	15.07	15.11	15.04
N_3	P_0	14.10	14.15	14.20	14.25	14.17	14.75	14.80	14.85	14.91	14.82
	P_1	14.18	14.23	14.26	14.28	14.23	14.82	14.87	14.91	14.97	14.89
	P_2	14.25	14.30	14.31	14.35	14.30	14.90	14.95	15.00	15.08	14.98
	P_3	14.30	14.34	14.37	14.44	14.36	15.01	15.10	15.15	15.21	15.10
	Sub Means	14.20	14.25	14.28	14.33	14.27	14.87	14.93	14.97	15.04	14.95
	Potassium	14.06	14.12	14.18	14.23		14.67	14.72	14.77	14.82	
	Phosphorus	14.03	14.10	14.19	14.26		14.66	14.69	14.77	14.87	
		CD ($p \leq 0.05$) Nitrogen (N): 0.07 Phosphorus(P): 0.07 Potassium (K): 0.07 N×P: N.S N×K: N.S K×P: 0.14 N×P×K: 0.29					CD ($p \leq 0.05$) Nitrogen (N): 0.01 Phosphorus(P): 0.01 Potassium (K): 0.01 N×P: N.S N×K: N.S K×P: 0.02 N×P×K: 0.05				

Table 3: Influence of different levels and combinations of N, P and K on total sugars (%) of apple cv. Red velox.

Nitrogen	Phosphorus	Potassium									
		2017-2018					2018-2019				
		K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	P_0	9.170	9.200	9.260	9.300	9.232	9.300	9.350	9.380	9.450	9.370
	P_1	9.220	9.270	9.320	9.370	9.295	9.360	9.400	9.470	9.550	9.445
	P_2	9.290	9.330	9.400	9.450	9.367	9.420	9.500	9.580	9.640	9.535
	P_3	9.350	9.410	9.470	9.550	9.445	9.530	9.600	9.690	9.750	9.642
	Sub Means	9.257	9.302	9.362	9.417	9.335	9.402	9.462	9.530	9.597	9.498
N_1	P_0	9.200	9.240	9.300	9.340	9.270	9.400	9.460	9.500	9.580	9.485
	P_1	9.260	9.300	9.360	9.390	9.327	9.480	9.520	9.600	9.650	9.562
	P_2	9.320	9.360	9.420	9.500	9.400	9.540	9.600	9.670	9.760	9.642
	P_3	9.400	9.445	9.520	9.580	9.486	9.650	9.750	9.800	9.860	9.765
	Sub Means	9.295	9.336	9.400	9.452	9.370	9.5175	9.582	9.642	9.712	9.613
N_2	P_0	9.330	9.400	9.470	9.510	9.427	9.580	9.620	9.670	9.720	9.647
	P_1	9.420	9.470	9.530	9.600	9.505	9.640	9.700	9.740	9.790	9.717
	P_2	9.490	9.550	9.630	9.710	9.595	9.700	9.770	9.850	9.900	9.805
	P_3	9.560	9.650	9.720	9.810	9.685	9.770	9.850	9.920	10.05	9.897
	Sub Means	9.450	9.517	9.587	9.657	9.553	9.672	9.735	9.795	9.865	9.766
N_3	P_0	9.040	9.080	9.110	9.160	9.097	9.110	9.160	9.210	9.270	9.187
	P_1	9.090	9.140	9.190	9.220	9.160	9.170	9.230	9.290	9.360	9.262
	P_2	9.150	9.190	9.240	9.280	9.215	9.250	9.300	9.380	9.450	9.345
	P_3	9.200	9.250	9.300	9.350	9.275	9.320	9.400	9.500	9.570	9.447
	Sub Means	9.120	9.165	9.210	9.252	9.186	9.212	9.272	9.345	9.412	9.310
	Potassium	9.256	9.321	9.394	9.472		9.422	9.496	9.581	9.687	
	Phosphorus	9.280	9.330	9.389	9.444		9.450	9.512	9.578	9.646	
		CD ($p \leq 0.05$) Nitrogen (N): 0.16 Phosphorus (P): 0.16 Potassium (K): 0.16 N×P: N.S N×K: 0.33 K×P: N.S N×P×K: 0.66					CD ($p \leq 0.05$) Nitrogen (N): 0.03 Phosphorus (P): 0.03 Potassium (K): 0.03 N×P: N.S N×K: 0.05 K×P: N.S N×P×K: 0.11				

Table 4: Influence of different levels and combinations of N, P and K on reducing sugars (%) of apple cv. Red velox.

Nitrogen	Phosphorus	Potassium									
		2017-2018					2018-2019				
		K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	P_0	6.780	6.805	6.840	6.880	6.826	6.928	6.948	6.965	7.003	6.961
	P_1	6.805	6.855	6.890	6.930	6.870	6.955	6.975	7.010	7.035	6.993
	P_2	6.870	6.900	6.955	6.990	6.928	7.000	7.016	7.050	7.007	7.018
	P_3	6.910	6.965	7.000	7.050	6.981	7.032	7.065	7.090	7.127	7.078
	Sub Means	6.841	6.881	6.921	6.962	6.901	6.978	7.001	7.028	7.043	7.012
N_1	P_0	6.800	6.840	6.865	6.920	6.856	6.810	6.830	6.880	6.930	6.862
	P_1	6.853	6.885	6.915	6.970	6.905	6.830	6.875	6.915	6.930	6.887
	P_2	6.890	6.920	6.985	7.055	6.962	6.890	6.910	6.845	7.010	6.913
	P_3	6.960	7.000	7.060	7.090	7.027	6.930	6.960	7.010	7.050	6.987
	Sub Means	6.875	6.911	6.956	7.008	6.938	6.865	6.893	6.912	6.980	6.912
N_2	P_0	6.830	6.855	6.870	6.900	6.863	6.830	6.887	6.945	6.970	6.908
	P_1	6.870	6.900	6.920	6.955	6.911	6.903	6.945	6.980	7.035	6.965
	P_2	6.900	6.915	6.950	7.010	6.943	6.957	7.008	7.055	7.125	7.036
	P_3	6.940	6.960	7.025	7.200	7.031	7.010	7.075	7.130	7.395	7.152
	Sub Means	6.885	6.907	6.941	7.016	6.937	6.925	6.978	7.027	7.131	7.015
N_3	P_0	6.740	6.760	6.800	6.910	6.802	6.857	6.868	6.922	6.949	6.899
	P_1	6.780	6.800	6.910	6.950	6.860	6.898	6.930	6.964	6.995	6.946
	P_2	6.850	6.930	6.960	6.970	6.927	6.948	6.971	7.015	7.065	6.999
	P_3	6.965	7.000	6.980	6.990	6.983	6.989	7.030	7.058	7.138	7.053
	Sub Means	6.833	6.872	6.912	6.955	6.893	6.923	6.949	6.989	7.036	6.974
	Potassium	6.836	6.886	6.940	7.005		6.907	6.947	6.991	7.067	
	Phosphorus	6.858	6.892	6.932	6.985		6.922	6.955	6.989	7.047	
		CD ($p \leq 0.05$) Nitrogen (N): 0.14 Phosphorus (P): 0.14 Potassium (K): N.S N×P: 0.30 N×K: N.S K×P: N.S N×P×K: 0.60					Nitrogen (N): 0.08 Phosphorus (P): 0.08 Potassium (K): N.S N×P: 0.17 N×K: N.S K×P: N.S N×P×K: 0.35				

Table 5: Influence of different levels and combinations of N, P and K on non-reducing sugars (%) of apple cv. Red velox.

Nitrogen	Phosphorus	Potassium									
		2017-2018					2018-2019				
		K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	P_0	2.270	2.275	2.299	2.299	2.285	2.348	2.376	2.390	2.403	2.379
	P_1	2.294	2.294	2.308	2.318	2.303	2.379	2.398	2.432	2.451	2.415
	P_2	2.299	2.308	2.322	2.337	2.316	2.394	2.432	2.451	2.460	2.434
	P_3	2.318	2.322	2.346	2.375	2.340	2.403	2.441	2.470	2.480	2.448
	Sub Means	2.295	2.300	2.318	2.332	2.311	2.381	2.411	2.435	2.448	2.419
N_1	P_0	2.280	2.280	2.313	2.318	2.297	2.441	2.460	2.470	2.498	2.467
	P_1	2.286	2.294	2.322	2.327	2.307	2.470	2.512	2.527	2.536	2.511
	P_2	2.308	2.318	2.327	2.337	2.322	2.490	2.517	2.536	2.555	2.524
	P_3	2.318	2.322	2.346	2.365	2.337	2.527	2.565	2.565	2.575	2.558
	Sub Means	2.298	2.303	2.327	2.336	2.316	2.482	2.513	2.524	2.541	2.515
N_2	P_0	2.375	2.417	2.470	2.479	2.435	2.584	2.596	2.617	2.622	2.604
	P_1	2.422	2.441	2.479	2.512	2.463	2.603	2.617	2.622	2.636	2.619
	P_2	2.460	2.503	2.546	2.565	2.518	2.612	2.631	2.655	2..670	2.632
	P_3	2.489	2.555	2.560	2.612	2.554	2.622	2.637	2.670	2.736	2.666
	Sub Means	2.436	2.479	2.513	2.542	2.492	2.605	2.620	2.641	2.664	2.632
N_3	P_0	2.185	2.204	2.218	2.232	2.209	2.140	2.177	2.194	2.204	2.178
	P_1	2.194	2.223	2.242	2.251	2.227	2.156	2.185	2.209	2.256	2.201
	P_2	2.223	2.232	2.251	2.261	2.241	2.186	2.212	2.246	2.265	2.227
	P_3	2.232	2.251	2.261	2.280	2.256	2.214	2.251	2.319	2.327	2.277
	Sub Means	2.208	2.227	2.243	2.256	2.233	2.174	2.206	2.242	2.263	2.221
	Potassium	2.306	2.325	2.349	2.371		2.407	2.436	2.466	2.473	
	Phosphorus	2.309	2.327	2.350	2.366		2.410	2.437	2.460	2.479	
		CD ($p \leq 0.05$) Nitrogen (N): 0.03 Phosphorus (P): 0.03 Potassium (K): 0.03 N×P: 0.04 N×K: 0.04 K×P: 0.04 N×P×K: 0.08					CD ($p \leq 0.05$) Nitrogen (N): 0.02 Phosphorus (P): 0.02 Potassium (K): 0.02 N×P: 0.05 N×K: 0.05 K×P: 0.05 N×P×K: 0.09				

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