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INFLUENCE OF TREE AGE ON VEGETATIVE GROWTH, LEAF NUTRIENT CONTENT AND YIELD OF KINNOW TREES

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Abstract

The tree age affects vegetative growth of trees, yield and quality of fruits to a great extent. The current research to explore the influence of age of Kinnow trees on plant growth, fertility and productivity has been worked out in subtropical mountainous region of Punjab. It was observed that there was significant influence of tree age on the vegetative parameters studied and the annual increment in the various vegetative parameters like trunk girth, tree height, tree spread, tree canopy volume, trunk cross sectional area and leaf area was decreased with the increase in age from 5 to 25 years, though at varied rate. The macronutrients (N, P, K, Ca, Mg and S) content in the leaves was significantly increased with the increase in age of trees from 5 to 25 years while the micronutrients (Fe, Zn, Mn, Cu and B) content was significantly decreased with increasing age of trees. The fruit yield was significantly increased with increase in age of trees and the maximum fruit yield (1314.75 fruits per tree and 196.74 kg per tree) were recorded in 25-year-old trees followed by trees of 20 years age (1241.79 fruits per tree and 188.59 kg/ tree) whereas, minimum fruit yield (219.69 fruits per tree and 37.62 kg per tree) were recorded in 5-year-old trees.

Key words **:** Trunk girth, vegetative growth, trunk cross sectional area, fruit yield.

Introduction

The major citrus producing countries are confined to tropical and subtropical part of world. India is one of the big producers and exporter of citrus fruits with 1.255 x 10^7 MT production of citrus fruits from an area of 1.003 x 10^6 Ha area (2017-18) which accounts for approximately 13% of total fruit production and 15.4% the total area under fruit crops. Among various citrus species, mandarin is leading in terms of area and production followed by sweet oranges which is primarily the Mosambi. The major Mandarin growing areas in India are Punjab (highest), Madhya Pradesh, Andhra Pradesh, Maharashtra, Rajasthan, Assam, etc. The major Sweet Orange (Mosambi) growing states are Maharashtra, Uttar Pradesh, Odisha, Punjab, Rajasthan, Madhya Pradesh, Kerala, Himachal Pradesh, etc. In the recent 10 years, citrus production has significantly increased due to greater income associated with its cultivation (Singh *et al.,* 2020).

At present, the most of the trees are at high productive stage so the productivity is being expected to rise in coming years as well. The tree age affects vegetative growth of trees, yield and quality of fruits to a great extent. The canopy volume, leaf area and fruit yield were observed to be increased gradually with the increase in trunk cross-sectional area and which in turn reported to be increased with age of trees (Dalal and Brar, 2012; Liu *et al.,* 2016). The fruit yield is function of photosynthetic activities and bearing surface of trees so, increases with the tree age till the final maturity after which trees start to lose their productivity. The highest fruit yield was estimated in the trees aged between 5-15 years in comparison to trees with age less than 5 years and more than 15 years in guava (Sharma and Kumawat, 2019). Thus, result confirmed the productive age of guava as 5-15 years. Similarly, citrus and other fruit trees are also having a productive stage and beyond that age the production gradually decreases.

The productivity of trees significantly influenced by leaf nutrient contents which varies with the age of trees. In 11 years old 'Newhall' and 'Skagg's Bonanza' navel orange trees, Sheng *et al.,* (2009) reported that Ca, Mn, and K concentrations in leaves were found relatively

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constant whereas concentrations of Mg, B, Fe, and Zn showed variations throughout the fruit growth and development. Ratio of N and Ca was increased whereas, P and K was decreased in leaves of 'Nanguo' pear as age increased from 1 to 10 years (Liu *et al.,* 2016). Macro nutrients like nitrogen, phosphorus, calcium and magnesium content was found greater in the leaf samples of 15 years old trees followed by 10 and 5 years old 'Kinnow' trees, whereas tree age was found to have non-significant effect on micronutrients (El-Sayed, 2018). Macro nutrients (N, P, K) level in 'Kinnow' leaves was observed higher in old orchards as compared to young orchards (Khalid *et al.,* 2018). Thus, the tree age has substantial influence over vegetative growth, truck growth, leaf nutrient status and productivity of trees. The current research is being presented to explore the influence of age of Kinnow trees on plant growth, fertility and productivity.

Materials and Methods

The present study was worked out in the private orchards situated in Block Bhunga, District Hoshiarpur, Punjab during the year 2017-2020. Five orchards of Kinnow mandarin of different age groups (5, 10, 15, 20 and 25 years) having similar cultural and management practices were selected. A single factor experiments where study materials were subjected to randomized block design with five tree ages as treatments and three replications. In this experiment, vegetative growth parameters of trees were recorded along with the leaf nutrient analysis to find out annual increment in the vegetative growth influenced by the tree age. The percent annual increment in vegetative growth parameters was estimated by using observations of two successive years and the formula given below:

Nitrogen was determined by using micro Kjeldhal while other macro-nutrients (P, K, Ca, Mg and S) and micro-nutrients (Zn, Fe, Mn, Cu, B and Mo) were estimated by Inductively Coupled Plasma Spectrophotometer (ICP). The amount of each nutrient in the samples was calculated as: Nutrient content (ppm) = ICP value of nutrient x Dilution factor; Where, dilution factor = Volume made / Weight of sample taken. Further, macro nutrients were expressed into percentage and calculated as below: Macro nutrient (%) = Value in ppm / 10000. The yield characteristics from experimental trees were recorded in the month of January 2019.

Results and Discussion

Vegetative growth characteristics

The observations on vegetative growth parameters confirmed significant effect of tree age on annual increment in trunk girth, tree height, tree spread, tree canopy volume, trunk cross sectional area and leaf area (Table 1). The maximum annual increment in trunk girth, tree height, tree spread, canopy volume, trunk cross-sectional area and leaf area was recorded in 5-year-old trees (12.61%, 12.81%, 17.38%, 55.37%, 26.78% and 5.74%, respectively) followed by 10 year (8.62%, 10.28%, 15.21%, 46.05%, 17.97% and 2.23%, respectively), 15 year (5.06%, 7.30%, 12.84%, 35.02%, 10.39% and 1.36%, respectively) and 20 year (3.00%, 6.09%, 11.24%, 32.41%, 6.10% and 0.80%, respectively) old trees while the minimum increment was found in 25-year-old trees (1.34%, 4.78%, 8.66%, 23.82%, 2.70% and 0.64%, respectively). It was also observed that annual increment in these parameters was decreased with the increase in age from 5 to 25 years, though at varied rate.

Biomass difference among trees can be attributed to CO_2 assimilation during photosynthesis (Gonzalez-Mas *et al.,* 2009). However, the distribution of these photosynthates is dependent on the competition existing between vegetative growth and reproductive development. The flowering and fruiting in citrus depends on supply of photosynthates during flower bud differentiation, fruit set and fruit development thus, acts as major sink for carbohydrates (Jover *et al.,* 2012) which might be associated to poor annual increment trunk girth and plant height or vegetative growth in the citrus trees of older age (Martinez-Cuenca *et al.,* 2016). The gradual increase in canopy volume of Kinnow trees might be associated with the increase in trunk cross-sectional area and maximum could be at highest trunk cross-sectional area of 'Kinnow' mandarin trees (Dalal and Brar, 2012) and can be correlated with finding of current research as the maximum trunk cross-sectional area was recorded in the 25 year old trees.

The greater increment in TCSA in the tree with younger age might be associated with the hormonal function and can be described on the basis of physiological mechanism. The activity of auxins has greater significance in determining the radial growth of tree trunk and distribution of auxins (IAA) activities had correlation with the secondary cambial growth (Funada *et al.,* 2001) which is synthesised more actively in young stems (Uggla *et al.,* 1998). However, even in the old aged trees, there is possibility of radial growth as long as there is production of new leaves and is related to hormonal activities. This can be further correlated as the improvement in sapwood area in the trunk below crown to sustain the increasing leaves production (Sumida *et al.,* 2013). The older trees further maintain their crown and foliage through repeated

Table 1: Effect of tree age on growth rate of vegetative parameters of 'Kinnow' mandarin tree.

Tree age (years)	Trunk girth (cm)			Tree height (cm)			Tree spread (m)		
	Year (2018)	Year (2019)	Annual increment (%)	Year (2018)	Year (2019)	Annual increment (%)	Year (2018)	Year (2019)	Annual increment (%)
5	30.30	34.12	12.61[a]	2.81	3.17	12.81[a]	3.05	3.58	17.38[a]
10	53.60	58.22	8.62[b]	3.60	3.97	10.28[b]	3.88	4.47	15.21[b]
15	56.67	59.54	5.06[c]	3.97	4.26	7.30[c]	4.44	5.01	12.84[c]
20	66.60	68.60	3.00[d]	4.60	4.88	6.09[d]	5.07	5.64	11.24[c]
25	69.48	70.41	1.34[e]	5.23	5.48	4.78[e]	5.31	5.77	8.66[d]
Mean	55.33	58.18	6.13	4.04	4.35	8.25	4.35	4.89	13.07
CD ($p \leq 0.05$)			1.37			1.06			1.90
SE(m)±			0.41			0.32			0.57
Tree age (years)	**Tree canopy volume (m^3)**			**Trunk cross-sectional area (cm^2)**			**Leaf area (cm^2)**		
	Year (2018)	**Year (2019)**	**Annual increment (%)**	**Year (2018)**	**Year (2019)**	**Annual increment (%)**	**Year (2018)**	**Year (2019)**	**Annual increment (%)**
5	13.69	21.27	55.37[a]	73.03	92.59	26.78[a]	9.75	10.31	5.74[a]
10	28.47	41.58	46.05[b]	228.53	269.60	17.97[b]	12.56	12.84	2.23[b]
15	47.57	64.23	35.02[c]	255.46	281.99	10.39[c]	13.97	14.16	1.36[c]
20	53.51	70.85	32.41[c]	352.83	374.34	6.10[d]	14.92	15.04	0.80[d]
25	77.15	95.53	23.82[d]	384.00	394.35	2.70[e]	15.53	15.63	0.64[d]
Mean	44.08	58.69	38.53	258.77	282.57	12.79	13.35	13.60	2.16
CD ($p \leq 0.05$)			4.14			2.61			0.27
SE(m)±			1.25			0.79			0.08

Table 2: Effect of tree age on leaf nutrient content in 'Kinnow' mandarin trees.

Tree age (years)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	B (ppm)
5	2.22[c]	0.11[c]	1.22[c]	2.90[d]	0.32[d]	0.26[b]	118.23[b]	76.11[a]	80.98[a]	12.31[b]	98.62[a]
10	2.28[c]	0.13[b]	1.31[bc]	3.47[c]	0.34[d]	0.26[b]	129.77[a]	67.03[b]	67.42[b]	13.68[a]	86.01[b]
15	2.55[b]	0.13[b]	1.61[a]	4.60[a]	0.48[a]	0.29[a]	105.97[c]	53.71[c]	52.76[c]	10.23[c]	77.94[c]
20	2.67[ab]	0.14[ab]	1.66[a]	4.82[a]	0.44[b]	0.30[a]	91.25[d]	42.86[d]	40.00[d]	8.34[e]	60.81[e]
25	2.78[a]	0.15[a]	1.42[b]	4.10[b]	0.39[c]	0.30[a]	83.45[d]	35.76[e]	32.84[e]	9.06[d]	67.34[d]
Mean	2.50	0.13	1.44	3.98	0.39	0.28	105.73	55.09	54.80	10.72	78.14
CD ($p \leq 0.05$)	0.20	0.01	0.15	0.24	0.03	0.02	8.67	5.67	6.02	0.62	4.84
SE(m)	0.06	0.003	0.04	0.07	0.008	0.005	2.62	1.71	1.82	0.19	1.46
SE(d)	0.09	0.005	0.06	0.10	0.012	0.008	3.70	2.42	2.57	0.27	2.07
CV	4.22	4.22	5.29	3.15	3.65	3.25	4.29	5.39	5.75	3.04	3.24

formation and death of epicormic shoots (Ishi *et al.,* 2002) and maintain stem wood production (Sillett *et al.,* 2010).

A strong correlation has been established for leaf area with TCSA and gradual increase in leaf area might be associated with the increase in trunk cross-sectional area and maximum leaf area was reported at highest trunk cross-sectional area in 'Kinnow' mandarin trees (Dalal and Brar, 2012). The diameter of trunk shows more tapering within the crown than below the crown which results in gradual increase in leaves biomass downward from the treetop and the amount of leaves above a point on trunk is proportional to the trunk cross section area (Sumida *et al.,* 2010). However, no significant effect of tree age on leaf area was reported in 'Newhall' navel orange by El-Sayed (2018).

Leaf nutrients status of Kinnow trees of different ages

The data related to macronutrients (N, P, K, Ca, Mg and S) content in the leaves table 2 was significantly affected by tree age. In general, an increasing trend in the macronutrients content was observed with the increase in age of trees from 5 to 25 years. The maximum nitrogen (N) and phosphorus (P) content was recorded in the leaves of 25-year-old trees (2.78% and 0.15%,

Table 3: Effect of tree age on average fruit yield of 'Kinnow' mandarin.

Tree age (years)	Number of fruits per tree	Average fruit yield (kg/tree)
5	219.69[e]	37.62[d]
10	773.48[d]	126.05[c]
15	940.65[c]	147.37[b]
20	1241.79[b]	188.59[a]
25	1314.75[a]	196.74[a]
Mean	898.07	139.27
CD ($p \leq 0.05$)	68.29	9.96
SE(m)±	20.62	3.01
SE(d)	29.16	4.25
CV	3.98	3.74

respectively) and was found at par with 20-year-old trees (2.67% and 0.14%, respectively). Leaves of 5-year-old trees had minimum nitrogen and phosphorus content (2.22% and 0.11%, respectively) and it was significantly lower than the other age groups. Potassium (K) content was found maximum in the leaves of 20-year-old trees (1.66%) which was significantly higher than the other age groups; however, it was found at par with 15-year-old trees (1.61%). Minimum leaf potassium content was observed in 5-year-old trees (1.22%) which was significantly lower than the other age groups but was at par with the 10-year-old trees (1.31%).

Calcium (Ca) content was also recorded highest in the leaves of 20 year old trees (4.82%) which was found at par with 15 year old trees (4.60%) and the minimum calcium content (2.90%) was found in the leaves of 5 year old trees and it was significantly lower than the other age groups. In case of magnesium (Mg), highest content was found in the leaves of 15-year-old trees (0.48%) followed by 20-year-old trees (0.44%) while the minimum leaf magnesium content was recorded in 5-year-old trees (0.32%) which was found at par with the 10 year old trees (0.34%). The sulphur (S) content in leaves was noticed with lower variation among all the age groups; however, 5 and 10-year-old trees had lowest sulphur content in the leaves (0.26%) whereas, maximum sulphur content was recorded in leaves of 20 and 25-year-old trees (0.30%).

Similar results of lower macronutrients in young trees are also reported by Storey and Treeby (2002) in leaves of young 'Navel' orange trees. Leaf nitrogen and phosphorus increased gradually with the increase in trunk cross-sectional area and were recorded maximum at highest trunk cross-sectional area in 'Kinnow' mandarin as reported by Dalal & Brar (2012). Also, higher macronutrients content was reported in the leaves of older trees as compared to young trees of 'Newhall' navel orange (El-Sayed, 2018) and 'Kinnow' mandarin trees (Khalid *et al.,* 2018). But the results are in contradiction with the findings of Sharma and Kumawat (2019) who found the deficiency of nitrogen and phosphorus in the leaves of more than 15 years old guava trees.

The micronutrients (Fe, Zn, Mn, Cu and B) content in the leaves table 2 was also significantly affected by tree age. In general, a decreasing trend in the micronutrients content was observed with the increase in age of trees from 5 to 25 years. Maximum iron (Fe) content was recorded in the leaves of 10-year-old trees (129.77 ppm) and it was significantly higher in comparison to other age groups while the minimum was observed in leaves of 25 year old trees (83.45 ppm) which was found at par with the 20 year old trees (91.25 ppm). Zinc (Zn) content was found significantly higher in the leaves of 5-year-old trees (76.11 ppm) whereas, in leaves of 25-year-old trees, it was found significantly lowest (35.76 ppm).

In case of manganese (Mn), maximum content in leaves was recorded in 5-year-old trees (80.98 ppm) which was significantly higher than all the other age groups. Significantly lowest manganese content was found in the leaves of 25-year-old trees (32.84 ppm). Copper (Cu) content was recorded significantly higher in the leaves of 10-year-old trees (13.68 ppm) followed by 5-year-old trees (12.31 ppm) while it was minimum in the leaves of 20-year-old trees (8.34 ppm) and it was significantly lower than the other age groups. Similarly, in case of boron (B), highest content was found in the leaves of 5-year-old trees (98.62 ppm) whereas, lowest copper content was found in the leaves of 20-year-old trees (60.81 ppm).It was evident from the data that copper content in leaves differed significantly with each other among all the age groups.

Significantly higher micronutrients content in leaves of young 'Navel' orange trees was also reported by Storey and Treeby (2002). However, El-Sayed (2018) had recorded non-significant effect of tree age on micronutrients level in the leaves of 'Newhall' navel orange trees. It is apparent from the data that the leaves of older trees had higher macronutrients but lower micronutrients content but it was vice versa in case of younger trees. This difference may be due to the variation in mobility of the nutrients in the trees as nitrogen, phosphorus and potassium are known to be phloem mobile, whereas calcium, zinc, manganese and iron are known to be xylem mobile nutrients (Storey and Treeby, 2002). Further, it has been reported that xylem conductivity decreases with increasing tree age which may lead to the better mobility of xylem mobile nutrients in young trees that ultimately resulted higher zinc, manganese and iron content in the leaves of younger trees.

Average fruit yield of Kinnow trees of different age group

The data related to average fruit yield table 3 of Kinnow trees of different age group reveals that number of fruits per tree and fruit yield varied significantly with respect to tree age. It was observed that number of fruits increased with the increase in age from 5 to 25 years. The maximum number of fruits (1314.75) were recorded in 25-year-old trees and these were significantly higher than the other age groups whereas, the minimum number of fruits (219.69) were recorded in 5-year-old trees. Similarly, average fruit yield was recorded to be highest in 25-year-old trees (196.74 kg/tree) followed by 20 year (188.59 kg/tree) and 15-year-old trees (147.37 kg/tree). The lowest fruit yield was recorded in 5-year-old trees (37.62 kg/tree). The increase in fruit yield was due to higher number of fruits in older trees as compared to younger trees. Increased fruit yield with the tree age may be due to increase in bearing surface so the larger trees were more likely to be reproductive and produce more fruits (Minor and Kobe, 2019). The trees with bigger canopy and older productive age may have more ability to gain and store nutrients and carbohydrates (Carbone *et al*, 2013) and tended to produce more fruits. A positive and significant correlation was found between trunk cross sectional area and fruit yield in 'Kinnow' mandarin (Dalal and Brar, 2012). Similar results of higher fruit yield in older trees were also reported in 'Newhall' navel orange (El-Sayed, 2018).

Conclusions

The increment in plant growth parameters of Kinnow trees was greater in early growth phase, at 5 years of age and successively decreased with increase in age. The leaf nutrient status was having variable response and with high level of macronutrients in older trees while high micronutrient in the leaves of younger trees. The yield of plant was significantly increased with increase in age and highest was recorded in trees with 25-years-age.

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