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Influence of Planting Density, Canopy Architecture and Drip Fertigation on Plant Growth and Productivity of Apple (*Malus* × *Domestica* Borkh.)

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Abstract: The experiment laid out in a randomized block design (factorial) had treatment combinations of three planting density, two training systems and fertigation doses of 100 and 75 per cent of AD (NPK). The results revealed that trees planted at a density of 2666 trees ha^{-1} registered highest annual shoot growth, increase in tree height, spread, scion girth, and volume. The lowest tree growth was recorded in high density planting of 5333 trees ha^{-1}. The results showed a positive relationship between productivity and planting density. The productivity increased with increasing density, while yield per trees decreased. Among the training systems, vertical axis trained trees reported the highest annual shoot growth, increase in tree height, spread, scion girth, and volume and the lowest tree growth was observed in vertical axis system. However, the maximum productivity was registered by the trees trained with Tall spindle system and the minimum was noted in vertical axis system. In case of fertigation, significantly highest tree growth parameters and productivity was registered by the trees subjected 100 % AD (NPK). Among three factors interaction, the highest tree growth parameters were recorded in trees planted at density of 2666 trees ha^{-1}, trained with vertical axis and subjected 100 % AD (NPK).

Keywords: Planting density, Tall spindle, Vertical axis, Fertigation, Plant growth, Productivity

Apple industry in the country is confronted with many problems contributing to low productivity, wide annual fluctuations in production and poor quality of produce. Several factors are associated with these problems but low density plantations with their improper canopy management are major. Most of the existing apple orchards in the state are on seedling rootstocks and planted under low density at a spacing of 7.5 x 7.5m (standard varieties) with a planting density of 178 trees ha^{-1} and at a spacing of 5.0 x 5.0m (spur type varieties) with a planting density of 400 plants ha^{-1}. High density planting (HDP) is one of the important methods to achieve high productivity per unit area.

High-density planting in fruit growing was first established in the apple in Europe in the early sixties (Robinson 2003). The continued decline in the availability of cultivable land, rising energy, and land costs together with the mounting demand for produce, has given a thrust to the adoption of HDP in fruit crops. High-density planting is more efficient since it is precocious, easily manageable, has higher yield potential with better quality fruits and higher returns/unit area. Training system and pruning are two important horticultural practices of canopy architecture that plays significant role in quality fruit production (Jackson and Palmer 1977). The aim of training system is to shape canopy architecture to improve light interception and distribution for optimizing fruit quality and yield. Thus, the choice of the training system plays a critical role in orchard profitability. Over the past two or three decades a large number of new intensive training systems for high-density apple orchards have been developed and recommended in Europe, America and New Zealand (Tall Spindle, Central Leader, Fruiting Wall, Palmette, Slender Pyramid, Slender Axis, Slender Spindle, Solaxe, Super Spindle, Vertical Axis, V-shaped and Y-trellis) (Robinson 2003).

Apart from managing crop loads (Meland 2011), balancing optimum plant nutrient contents and regulating water supply are important tools for influencing annual growth, productivity and fruit quality. Fertigation permits close synchronization of nutrient application with plant demand as the nutrients are delivered directly to the root system, therefore, the uptake of minerals is more efficient and nutrient leaching and run off are limited (Raina et al 2011). The rate of uptake and usage of different nutrients vary throughout the season in apple trees (Neilsen et al 2009).

MATERIAL AND METHODS

The present investigation was carried out in the experimental farm of Department of fruit science, University of Horticulture & Forestry, Nauni, Solan to ascertain the effect of different planting densities, training systems and fertigation levels on tree growth and productivity of apple under high density planting. The experimental site is situated at an elevation of 1256 m above mean sea level with 30° 51´ North latitude and 77° 88´ East longitude. Field trial was conducted during the years 2019 & 2020 on 4-years-old apple cultivar Jeromine grafted on M9 rootstock having uniform vigour and size. The apple plantation was done with three planting densities viz. 4000 trees ha^{-1} (2.5 × 1.0 m), 3200 trees ha^{-1} (2.5 × 1.25 m) and 2666 trees ha^{-1} (2.5 × 1.5m), trained to two training systems i.e., tall spindle and vertical axis. The experiment was laid out in a randomized block design (factorial) with treatment combinations of three planting density, two training systems and fertigation doses (50 and 37 per cent of RDF) and each replicated three times having two trees per replication.

The experimental trees were subjected under drip irrigation and fertigation system, consisting of two online emitters per plant, placed at a distance of 15 cm away from the tree trunk at an angle of 180°C to each other with a discharge rate of 4.2 l h^{-1}. The experimental trees were pruned every year during January to remove dead, diseased and unwanted branches and kept under uniform cultural practices with permanent support system during the course of investigation. Fertigation was done through venturi starting from third week of March of each experimental year and continued till July in fifteen equal split applications at weekly intervals. The water soluble fertilizer (WSF-19:19:19) was used for fertigation, fulfilling its phosphorus requirement and rest of the nitrogen and potassium requirement were supplemented with urea and muriate of potash (MOP).

Considering the solubility and compatibility of WSF, urea and MOP (Waterman, 2001), a 25 litres of stock solution having all the three fertilizers was prepared fresh for each fertigation. The quantity of WSF, urea and MOP was computed to be 24.56, 10.13 and 9.33 g $tree^{-1}$ $split^{-1}$, respectively with the application of 100 % of AD (NPK) and 18.13, 7.46 and 6.86 g $tree^{-1}$ $split^{-1}$, respectively with 75 % of AD (NPK) on 4-years-old plantation in the year 2019, whereas for 5-years-old plants (2020) the quantity came out to be 30.66, 12.68 and 11.68 g $tree^{-1}$ $split^{-1}$, respectively with 100 % of AD (NPK) and 22.69, 9.38 and 8.64 g $tree^{-1}$ $split^{-1}$, respectively with 75 % of AD (NPK). The observations were recorded on tree growth parameters and productivity and presented separately for two years of study.

Statistical analysis: The data obtained from this investigation were appropriately computed, tabulated and analysed using Randomized Block Design (Factorial). The statistical analysis was carried out for each observed character using MS-Excel and OPSTAT as per the design of experiment. The critical difference was calculated at a significance level of 5 per cent.

RESULTS AND DISCUSSION

Tree height: The perusal of data given in Table 1 indicates that planting densities, training systems and fertigation levels individually had a significant effect on tree height during both the years, however, their interactions were found non-significant. Considering the effect of planting densities, the highest increase in tree height (27.21 and 29.56 cm) was recorded in planting density of 2666 trees ha^{-1} and was found significantly superior to planting density of 4000 trees ha^{-1}) and 3200 trees ha^{-1}. However, the lowest increase in tree height (21.09 and 21.80 cm) was found in 4000 trees ha^{-1} planting density. Among the training systems, the maximum increase in tree height was observed in vertical axis training system, which was significantly higher than all spindle training system during both the years. Similarly, data of fertigation levels also showed significant effect on tree height and the highest increase in tree height (26.60 and 28.10 cm) was attained by trees subjected under F_1 fertigation level, which was significantly higher than F_2 level of fertigation (21.65 and 23.01 cm). The data also reveals that interactions between T×D×F were found non-significant. However, among three factors interaction, the highest increase in tree height (32.67 and 35.29 cm) was recorded in trees planted at D_3 density, trained with vertical axis and subjected under F_1 level of fertigation and the lowest (15.53 and 16.01 cm) was noticed in trees planted at D_1 density, trained with Tall spindle and subjected under F_2 level of fertigation.

Tree spread: The perusal of the data given in Table 2 revealed that different planting densities, training systems, fertigation levels exhibited significant effect on tree spread during both the years. Among the planting densities, the highest increase in tree spread (19.23 and 21.60 cm) was observed in 2666 trees ha^{-1} planting density, which was significantly superior to D_2 and D_1 planting densities. Whereas, the lowest increase in tree spread of 13.96 and 14.69 cm was found in 4000 trees ha^{-1} density. In case of training systems, the maximum increase in tree spread (18.72 and 20.02 cm) was attained by trees trained with vertical axis training system, which was significantly higher than tall spindle training system during both the years. Similarly, the trees subjected to F_1 fertigation level showed significantly more increase in tree spread (18.14 and 19.65 cm) than F_2 level of fertigation (15.21 and 16.59 cm). It is apparent from the data that interactions between T×D×F were found non-significant, however, among three factors interaction, the highest increase in tree spread (22.82 and

25.07 cm) was recorded in trees planted at D_3 density, trained with vertical axis and subjected under F_1 level of fertigation.

Annual shoot growth: The data pertaining to the effect of different planting densities, training systems, fertigation levels and their interactions on annual shoot growth depicted in Table 3 reveals that planting densities, training systems and fertigation levels exhibited significant effect on annual shoot growth, during both the years, however their interactions were found non-significant. Among the planting densities, the highest annual shoot growth (34.81 and 38.14 cm) was recorded in 2666 trees ha^{-1} planting density, which was significantly higher than D_2 and D_1 planting densities. However, the lowest annual shoot growth of 25.73 and 28.19 cm was found in 4000 trees ha^{-1} planting density. The maximum annual shoot growth (31.95 and 35.21 cm) was observed in vertical axis training system and it was found statistically significant than Tall spindle system. Similarly, the trees subjected to F_1 fertigation level registered significantly more annual shoot growth (31.53 and 35.03 cm) than F_2 fertigation level. The data also reveals that interactions between T×D×F were found non-significant. However, among three factors interaction, the highest annual shoot growth (37.34 and 41.71 cm) was recorded in trees planted at D_3 density, trained with vertical axis and subjected under F_1 level of fertigation, whereas, the lowest annual shoot growth (22.87 and 24.80 cm) was noted in trees planted at D_1 density, trained with Tall spindle and subjected under F_2 level of fertigation.

Scion girth: The data presented in Table 4 reveals that planting densities, training systems and fertigation levels had marked influence on scion girth, during both the years, however their interactions were found non-significant. Among the planting densities, the highest increase in scion girth (6.93 and 5.20 mm) was registered in 2666 trees ha^{-1} planting density, which was significantly higher than D_2 and D_1 planting densities. On the contrary, the lowest increase in scion girth of 5.72 and 4.29 mm was found in 4000 trees ha^{-1} planting density. The maximum increase in scion girth (6.30

Table 1. Effect of different planting densities, training systems and fertigation levels on tree height and spread of apple cv. Jeromine during 2019 and 2020

T/D/F	Tree height 1st year (2nd year)						Tree spread 1st year (2nd year)					
	T_1			T_2			T_1			T_2		
	F_1	F_2	Mean (T×D)	F_1	F_2	Mean (T×D)	F_1	F_2	Mean (T×D)	F_1	F_2	Mean (T×D)
D_1	20.82 (21.45)	15.53 (16.01)	18.18 (18.73)	26.28 (27.21)	21.73 (22.51)	24.01 (24.86)	13.38 (14.31)	10.71 (11.56)	12.05 (12.94)	17.45 (18.13)	14.28 (14.76)	15.87 (16.45)
D_2	23.63 (24.76)	18.38 (19.33)	21.01 (22.05)	29.72 (31.18)	24.58 (25.97)	27.15 (28.58)	16.16 (17.62)	13.28(14.67)	14.72 (16.15)	20.42 (21.55)	17.53 (18.48)	18.98 (20.02)
D_3	26.48 (28.73)	21.86 (24.03)	24.17 (26.38)	32.67 (35.29)	27.83 (30.19)	30.25 (32.74)	18.63 (21.23)	15.52 (17.94)	17.08 (19.59)	22.82 (25.07)	19.96 (22.15)	21.39 (23.61)
Mean (T×F)	23.64 (24.98)	18.59 (19.79)		29.56 (31.23)	24.71 (26.22)		16.06 (17.72)	13.17(14. 72)		20.23 (21.58)	17.26 (18.46)	
Mean (T)		21.12 (22.39)			27.14 (28.73)			14.61 (16.22)			18.74 (20.02)	

F/D	F × D			CD (0.05)						
	F_1	F_2	Mean (D)	T	2.02 (2.09)	F_1	F_2	Mean (D)	T	2.10 (2.13)
D_1	23.55 (24.33)	18.63 (19.26)	21.09 (21.80)	F	2.02 (2.09)	15.42 (16.22)	12.50 (13.16)	13.96 (14.69)	F	2.10 (2.13)
D_2	26.68 (27.97)	21.48 (22.65)	24.08 (25.31)	D	2.47 (2.56)	18.29 (19.59)	15.41 (16.58)	16.85 (18.08)	D	2.57 (2.61)
D_3	29.58 (32.01)	24.85 (27.11)	27.21 (29.56)	T×F	NS(NS)	20.73 (23.15)	17.74 (20.05)	19.23 (21.60)	T×F	NS (NS)
Mean (F)	26.60 (28.10)	21.65 (23.01)		T×D	NS(NS)	18.14 (19.65)	15.21 (16.59)		T×D	NS (NS)
				F×D	NS(NS)				F×D	NS (NS)
				T×F×D	NS(NS)				T×F×D	NS (NS)

Training system (T):- T_1: Tall spindle
T_2: Vertical axis
Fertigation level (F):- F_1: 100 % of AD (NPK)
F_2: 75 % of AD (NPK)

Planting density (D):- D_1: 4000 trees ha^{-1} (2.5 × 1 m)
D_2: 3200 trees ha^{-1} (2.5 × 1.25 m)
D_3: 2666 trees ha^{-1} (2.5 × 1.5 m)

Table 2. Effect of different planting densities, training systems and fertigation levels on annual shoot growth of apple cv. Jeromine during 2019 and 2020

T/D/F	Annual shoot growth (cm)- 2019						Annual shoot growth (cm)- 2020					
	T_1			T_2			T_1			T_2		
	F_1	F_2	Mean (T×D)	F_1	F_2	Mean (T×D)	F_1	F_2	Mean (T×D)	F_1	F_2	Mean (T×D)
D_1	25.63	22.87	24.25	28.74	25.67	27.21	28.21	24.80	26.51	32.25	27.49	29.87
D_2	29.82	27.43	28.63	33.37	31.26	32.32	33.09	29.91	31.50	37.45	33.85	35.65
D_3	34.28	32.29	33.29	37.34	35.34	36.34	37.47	34.86	36.17	41.71	38.52	40.12
Mean (T×F)	29.91	27.53		33.15	30.76		32.92	29.86		37.14	33.29	
Mean (T)		28.72			31.95			31.39			35.21	

F/D	F × D			CD (0.05)						
	F_1	F_2	Mean (D)	T	2.14	F_1	F_2	Mean (D)	T	2.22
D_1	27.19	24.27	25.73	F	2.14	30.23	26.15	28.19	F	2.22
D_2	31.60	29.35	30.47	D	2.61	35.27	31.88	33.58	D	2.72
D_3	35.81	33.82	34.81	T×F	NS	39.59	36.69	38.14	T×F	NS
Mean (F)	31.53	29.14		T×D	NS	35.03	31.57		T×D	NS
				F×D	NS				F×D	NS
				T×F×D	NS				T×F×D	NS

Training system (T):- T_1: Tall spindle
T_2: Vertical axis
Fertigation level (F):- F_1: 100 % of AD (NPK)
F_2: 75 % of AD (NPK)

Planting density (D):- D_1: 4000 trees ha^{-1} (2.5 × 1 m)
D_2: 3200 trees ha^{-1} (2.5 × 1.25 m)
D_3: 2666 trees ha^{-1} (2.5 × 1.5 m)

Table 3. Effect of different planting densities, training systems and fertigation levels on tree volume of apple cv. Jeromine during 2019 and 2020

T/D/F	Increase in tree volume (cm) - 2019						Increase in tree volume (m^3)- 2020					
	T_1			T_2			T_1			T_2		
	F_1	F_2	Mean (T×D)	F_1	F_2	Mean (T×D)	F_1	F_2	Mean (T×D)	F_1	F_2	Mean (T×D)
D_1	0.95	0.77	0.86	1.65	1.49	1.57	1.13	0.99	1.06	2.00	1.92	1.96
D_2	1.11	1.08	1.10	1.42	1.40	1.41	1.47	1.36	1.42	1.93	1.86	1.90
D_3	1.77	1.28	1.53	1.96	1.56	1.76	2.41	1.75	2.08	2.80	2.18	2.49
Mean (T×F)	1.28	1.04		1.68	1.48		1.67	1.37		2.24	1.99	
Mean (T)		1.16			1.58			1.52			2.12	

F/D	F × D			CD (0.05)						
	F_1	F_2	Mean (D)	T	0.013	F_1	F_2	Mean (D)	T	0.014
D_1	1.30	1.13	1.22	F	0.013	1.57	1.46	1.51	F	0.014
D_2	1.25	1.25	1.25	D	0.015	1.70	1.61	1.66	D	0.017
D_3	1.86	1.42	1.64	T×F	0.018	2.60	1.96	2.28	T×F	0.019
Mean (F)	1.47	1.27		T×D	0.022	1.96	1.68		T×D	0.024
				F×D	0.022				F×D	0.024
				T×F×D	0.031				T×F×D	0.033

Training system (T):- T_1: Tall spindle
T_2: Vertical axis
Fertigation level (F):- F_1: 100 % of AD (NPK)
F_2: 75 % of AD (NPK)

Planting density (D):- D_1: 4000 trees ha^{-1} (2.5 × 1 m)
D_2: 3200 trees ha^{-1} (2.5 × 1.25 m)
D_3: 2666 trees ha^{-1} (2.5 × 1.5 m)

Table 4. Effect of different planting densities, training systems and fertigation levels on scion girth of apple cv. Jeromine during 2019 and 2020

T/D/F	Increase in scion girth (mm) -2019 1st year (2nd year)						Increase in scion girth (mm) -2020 1st year (2nd year)					
	T_1			T_2			T_1			T_2		
	F_1	F_2	Mean (T×D)	F_1	F_2	Mean (T×D)	F_1	F_2	Mean (T×D)	F_1	F_2	Mean (T×D)
D_1	5.66	5.73	5.70	5.72	5.78	5.75	4.36	4.15	4.26	4.42	4.24	4.33
D_2	6.24	6.03	6.14	6.29	6.11	6.20	4.83	4.71	4.77	4.92	4.87	4.90
D_3	6.94	6.86	6.90	6.98	6.92	6.95	5.21	5.07	5.14	5.33	5.18	5.26
Mean (T×F)	6.28	6.21		6.33	6.27		4.80	4.64		4.89	4.76	
Mean (T)		6.24			6.30			4.72			4.83	

F/D	F × D			CD (0.05)						
	F_1	F_2	Mean (D)	T	0.05	F_1	F_2	Mean (D)	T	0.09
D_1	5.69	5.76	5.72	F	0.05	4.39	4.20	4.29	F	0.09
D_2	6.27	6.07	6.17	D	0.06	4.88	4.79	4.83	D	0.11
D_3	6.96	6.89	6.93	T×F	NS	5.27	5.13	5.20	T×F	NS
Mean (F)	6.31	6.24		T×D	NS	4.85	4.70		T×D	NS
				F×D	NS				F×D	NS
				T×F×D	NS				T×F×D	NS

Training system (T):- T_1: Tall spindle
T_2: Vertical axis
Fertigation level (F):- F_1: 100 % of AD (NPK)
F_2: 75 % of AD (NPK)

Planting density (D):- D_1: 4000 trees ha^{-1} (2.5 × 1 m)
D_2: 3200 trees ha^{-1} (2.5 × 1.25 m)
D_3: 2666 trees ha^{-1} (2.5 × 1.5 m)

and 4.83 mm) was observed in Vertical axis training system and it was found statistically significant than Tall spindle system. Similarly, the trees subjected to F_1 fertigation level registered significantly more increase in scion girth (6.33 and 4.85 mm) than F_2 fertigation level. The data also shows that interactions between T×D×F were found non-significant. However, among three factors interaction, the maximum increase in scion girth (6.98 and 5.33 mm) was recorded in trees planted at D_3 density, trained with Vertical axis and subjected under F_1 level of fertigation.

Tree volume: An inquisition of the data given in Table 5 clearly indicates that different planting densities, training systems, fertigation levels and their interactions produced a significant effect on tree volume during both the years. Considering the effect of planting densities, the highest increase in tree volume (1.64 and 2.28 m^3) was recorded in D_3 (2666 trees ha^{-1}) planting density the lowest increase in tree volume of 1.22 and 1.51 m^3 was found in D_1 (4000 trees ha^{-1}) planting density. Among the training systems, the maximum increase in tree volume of 1.58 and 2.12 m^3 was observed in Vertical axis system, which was significantly higher than Tall spindle system during both the years. Under fertigation, the highest increase in tree volume (1.47 and 1.96 m^3) was attained by trees subjected under F_1 fertigation level, which was significantly higher than F_2 level of fertigation (1.27 and 1.68 m^3). In case of interactions between planting densities and training systems, significantly highest increase in tree volume of 1.76 and 2.49 m^3 was recorded in trees planted at density D_3 and trained with vertical axis and the lowest increase in tree volume was observed in trees planted at density D_1 and trained with tall spindle (0.86 and 1.06 m^3). Among training systems and fertigation levels interactions, the maximum increase in tree volume of 1.68 and 2.24 m^3 was registered in trees trained with Vertical axis and subjected to F_1 fertigation level, whereas, the lowest in tall spindle trained trees subjected to F_2 fertigation level. Among planting densities and fertigation levels interactions, the highest increase in tree volume of 1.86 and 2.60 m^3 was observed in trees planted at D_3 density and subjected under F_1 level of fertigation, while the lowest was noticed in trees planted at D_1 density and subjected under F_2 level of fertigation. In case of three factors interaction, significantly highest increase in tree volume (1.96 and 2.80 m^3) was attained by the trees planted at D_3 density, trained with Vertical axis and subjected under F_1 level of fertigation.

Productivity: A critical appraisal of data presented in Figure 1, 2 and 3 indicates that different planting densities, training systems and fertigation levels and their interactions had significant effect on fruit yield per hectare (productivity). Considering the effect of planting densities (Fig. 1), the highest yield (35.81 and 39.39 t ha^{-1}) was recorded in 4000 trees ha^{-1} planting density, which was significantly higher than planting density of 3200 trees ha^{-1} and 4000 trees ha^{-1}. However, the lowest yield of 30.49 and 34.09 t ha^{-1} was found in 2666 trees ha^{-1} planting density. Among the training systems (Fig. 2), the highest yield of 35.58 and 38.61 t ha^{-1} was observed in tall spindle training system, which was significantly higher than vertical axis training system. Considering the effect of fertigation levels (Fig. 3), the maximum yield (35.07 and 38.38 t ha^{-1}) was attained by trees subjected under F_1 fertigation level, which was significantly higher than F_2 level of fertigation. The highest yield of 38.58 and 41.52 t ha^{-1} was recorded in trees planted at density of 4000 trees ha^{-1} and trained with Tall spindle, which was significantly superior to other interactions. However, the lowest yield was observed in trees planted at density of 2666 trees ha^{-1} and trained with Vertical axis. Among training systems and fertigation levels interactions, the maximum yield of 37.43 and 40.69 t ha^{-1} was recorded under trees trained with Tall spindle and subjected to F_1 fertigation level, however lowest under Vertical axis trained trees subjected to F_2 fertigation level. The significantly highest yield of 38.10 and 40.91 t ha^{-1} was obtained in subjected to F_1 level of fertigation, while lowest (28.80 and 32.38 t ha^{-1}) was noticed in trees planted at density of 2666 trees ha^{-1} and subjected under F_2 level of fertigation. Among three interaction, significantly highest yield (40.92 and 43.34 t ha^{-1}) was found in trees planted at D_1 density, trained with Tall spindle and subjected under F_1 level of fertigation, which was found superior to all the interactions. However, the lowest yield (26.74 and 31.08 t ha^{-1}) was recorded in trees planted at D_3 density, trained with Vertical axis and fertigated with F_2 level.

The results of present investigation revealed that vegetative growth traits such as tree height and spread, annual shoot growth, scion girth and tree volume was significantly influenced by planting density, training system and fertigation level. The study shows that the planting density had a strong negative effect on tree growth parameters. Tree height, spread and volume, annual shoot growth, scion and stock girth, tree volume, leaf area and pruning wood weight was found more in planting densities of 2666 trees ha^{-1} compared to the other planting densities. The larger tree size in lower densities might be due to the more availability of space for vegetative growth of the trees and lack of competition for the nutrients, water and light, while smaller tree size in higher densities may be due to the more competition for nutrients and water (Dhiman et al 2018). These results are in confirmatory with the studies of Robinson (2007), Lordan et al (2018) and Reig et al (2019), who reported maximum TCSA and crown volume per tree at wider spacing and minimum under close spacing in apple. Similarly, Dhiman et al (2018) recorded that the tree growth parameters like tree height spread, annual shoot growth, scion and stock girth, and tree volume was highest in low planting density of 2666 trees ha^{-1}.

In the present study, Vertical axis training system resulted in higher growth as compared to Tall spindle. The lesser vegetative growth in trees trained with tall spindle is due to bending of branches below horizontal and no heading back of branches and leader during dormant pruning, which reduced branch growth due to more accumulation of carbohydrates resulting in to small canopy (Robinson 2007). The present findings are similar to that observed by Robinson et al (2013)

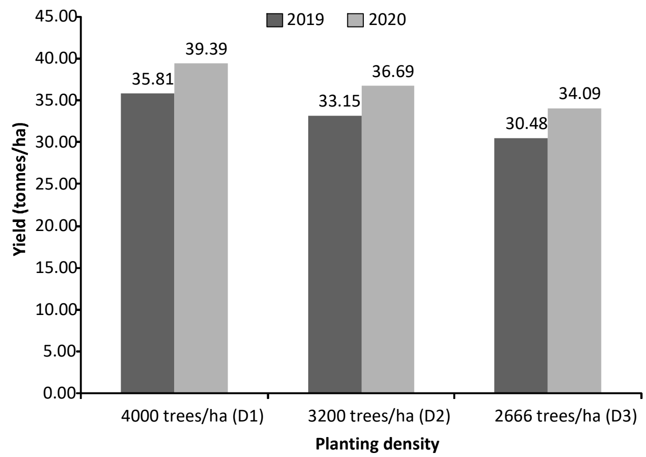

Fig. 1. Effect of different planting densities on yield of apple cv. Jeromine during 2019 and 2020

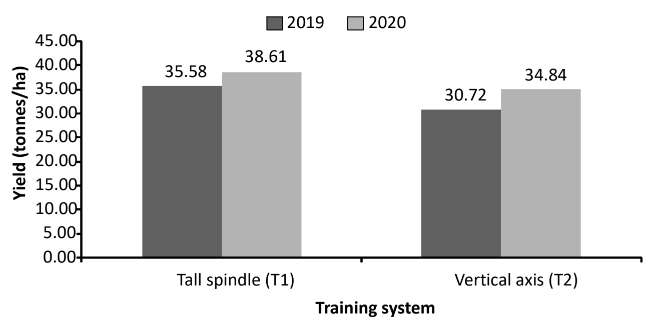

Fig. 2. Effect of different training system on yield of apple cv. Jeromine during 2019 and 2020

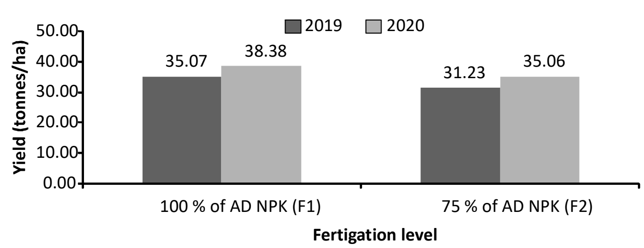

Fig. 3. Effect of different fertigation level on yield of apple cv. Jeromine during 2019 and 2020

and Reig et al (2019), who reported that the tall spindle trained trees were least vigorous and TCSA was 25 per cent lower than vertical axis.

Higher growth was reported under higher levels of fertigation, which declines with decreasing fertigation doses. The higher growth characteristics at higher fertigation levels may partially be assigned to the higher leaf nutrient content (NPK) in the tree foliage, which had a positive correlation with the level of fertilizer used (Treder 2006). The present findings are in confirmatory with the studies of Raina et al (2013), Kumar et al (2016) and Thakur et al (2020)**,** who observed maximum tree height and spread, annual shoot growth, trunk girth and tree volume with the application of 100 per cent AD (NPK) fertigation dose.

CONCLUSION

It was concluded that planting of trees at 4000 trees per ha density and trained with tall spindle training system and subjected to 100 per cent AD (NPK), resulted in highest productivity.

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