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Effect of planting densities and varieties on yield and yield associated characters of apple (*Malus* × *dometica*) on semi-dwarfing rootstock

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ABSTRACT

Four apple (*Malus* × *domestica* Borkh) varieties (Starkrimson, Cooper IV, Red Chief, and Mollies Delicious) were planted at 3 planting densities (1600, 1142 and 952 plants / ha) on semi-dwarf rootstock during 2002-03 and data on yield and growth were recorded after 7 years. Results indicated that maximum mean trunk cross sectional area was registered in Mollies Delicious at all the densities (103.79, 92.61 and 77.06 cm^2) and lowest (67.01, 75.65 and 80.33 cm^2) in Cooper IV. Largest sized fruit (177.80 g/ fruit) recorded in the S3 (952 tree/ha) and minimum (160.73 g/ fruit) in S1 density (1600 tree/ha). Maximum mean yield and yield efficiency were recorded in Starkrimson and Red Chief and minimum yield and yield efficiency in Cooper IV. Density has a detrimental effect on yield efficiency, it was maximum (0.48 kg/cm^2) in S3 and minimum (0.21 cm^2) in S1 density. The fruit weight increases with decrease in plant density, fruit size has negative correlation with number of fruit tree. Positive correlation was obtained between yield and yield efficiency (0.999) and planting densities with yield efficiency (0.691).

Key words: Apple, High density planting, MM 106, Yield efficiency, Trunk cross sectional area

Apple (*Malus* × *domestica* Borkh) is a very important fruit crop of temperate zone, occupies more than 70% area and 60% production of total temperate fruits in India. Apple productivity is the production function of rootstock, planting density, variety, plant architectural and pest and disease, irrigation, pollination, fruit number/tree and in addition and floor management. Apple culture using dwarfing trees can be traced back to three centuries before Christ in Persia and Asia Minor. With the advancement in knowledge on orchard engineering and rootstock science, the modern days orcharding initiated on higher densities with a range from 1000 to 10000 trees/ha (Robinson 2003). From the last few decades hdp has changed the scenario of orchards in Europe, New Zealand, Australia and USA, which had resulted increased productivity many folds. Dwarfing rootstocks have become widely acceptable by the fruit industry as a tool to increase orchard efficiency, as they are determinants of the tree size, yield and plant density per unit area (Barritt *et al*. 1995), besides influencing canopy size, precocity, fruit quality, yield efficiency, mineral uptake and to withstand adverse environmental conditions (Fallahi *et al*. 2002). Semi-dwarfing rootstock (MM-106) causes high yield efficiency with high yield of good quality fruits and fits our soil and climatic conditions. The tree size is generally expressed in trunk cross sectional area (TCSA), it is most common and reliable factor to determine tree size and tree potential to produce fruits (Jimenez and Diaz 2004, Wright *et al*. 2006). Research findings have indicated that hdp allows early cropping, better light interception into the canopy, uniform and high quality fruits (Sansavini and Corelli 1991). Hence, in order to efficient harnessing the available natural resources for increasing productivity, an experiment was conducted to study the effect of planting density and variety on yield efficiency in apple under Srinagar conditions.

MATERIALS AND METHODS

The present experiment was carried out during 2011 to 2013 at ICAR-Central Institute of Temperate Horticulture, Srinagar, J&K located at 34^0, 45' N latitude and of 74^0, 50'E longitude and 1640 m asl, receives average maximum and minimum temperature 19.63^0 C and 6.52^0 C, respectively with an average rainfall of 60.72cm annually. The experiment comprised 4 apple varieties, viz. Starkrimson (V1), Cooper IV (V2), Red Chief (V3) and Mollies Delicious (V4) grafted on MM 106 rootstock and planted at three densities 1600 plants/ha (S1), 1142 plants/ ha (S2) and 952 plants/ha (S3). The plot size were 450 m^2 (2.5 × 2.5 m), 630 m^2 (2.5 × 3.5 m) and 756 m^2 (3 × 3.5 m) respectively. The trees were trained on a modified central leader training system. The experiment was laid out in factorial randomized block design replicated thrice. Uniform cultural operations were applied in all the trees under study. Each year, the trunk diameters

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of each variety were measured 15 cm above the graft union. The trunk cross sectional area was calculated by using standard formula (TCSA=Girth^2/4π). For fruit weight, 15 fruits were randomly harvested at maturity, weighted using digital electronic balance and fruit yield was calculated as total weight of fruit per tree and yield efficiency calculated by yield per tree/ TCSA and expressed in kg/cm^2 at the time of harvest. The data were analyzed statistically as per procedure given by Sheoran *et al*. (1998), and are being presented in the table for interpretation of the results.

RESULTS AND DISCUSSION

During 3 years of evaluation, differences in TCSA among the varieties were present. Throughout the test period, Mollies Delicious (V4) exhibited maximum trunk cross sectional area (TCSA), 89.5 cm^2 (2011) to 93.21 cm^2 (2013) and minimum (64.46, 67.40 and 70.51 cm^2 in Cooper IV during 2011, 2012 and 2013, respectively (Table 1). TCSA was significantly influenced by the planting density, maximum mean TCSA (82.23 cm^2) was recorded in S3 and minimum (77.89 cm^2) in S1. Combined effect of variety and density have significant effect on TCSA, maximum mean TCSA (78.05, 85.91 and 103.20 cm^2) was found in V4 × S1, V4 × S2 and V4 × S3, during 2011, 2012 and 2013, respectively (Fig 1). The general trend was, lower the planting density, higher the trunk cross sectional area. Higher the TCSA in low density might be due to higher uptake and translocation of nutrient from the soil, resulting higher production of photosynthates in return more growth of TCSA. Mollies Delicious exhibits high TCSA, may be due to larger leaf size, which may intercept more sun energy in turn more photosynthates production. Loerti *et al*. (1978) also observed the reduction in growth parameters in apple trees planted at higher densities. These results are in conformity with Mir *et al.* (2016) and Kumar *et al.* (2012) in apple and almond respectively.

Fruit weight was significantly influenced by varieties, as maximum mean weight (226.88 g/fruit) was recorded in Cooper IV, and minimum (139.74 g/fruit) in Starkrimson. During 3 years of study, maximum fruit weight was recorded (230.60, 212.44, 226.22 g/ fruit) in Cooper IV while as, minimum in Starkrimson and Mollies Delicious over the years. The fruit weight was also significantly influenced by density, a thumb rule is that decrease in density, increase in fruit weight, maximum fruit weight was recorded in S3 and minimum in S1 over the years. The mean of three years showed that maximum fruit weight (177.80 g/ fruit) was recorded in S1, minimum (160.73 g/fruit) in S1 (Table 1). Combined effect of variety and density showed significant variation in fruit weight. Maximum fruit weight (218.67, 229.44 and 232.55 g/fruit) were recorded in V2 × S1, V2 × S2 and V2 × S3 and minimum (123.50 and 125.67 g/ fruit) in V4 × S1 and V4 × S2, respectively (Fig 2). Since the variety which has tendency to bear less fruit number, resulted high fruit weight irrespective of plant density. Guglielmo Costa *et al.* (1997) reported similar fruit weight in apple in high density orcharding. Similar trend in nut weight was reported by Kumar *et al.* (2012) in almond under hdp. Variation in fruit weight among different varieties may be due to the difference genetic constituents of individual variety, as it is evident from the data that a low crop load resulted in a larger fruit weight than a high crop load due

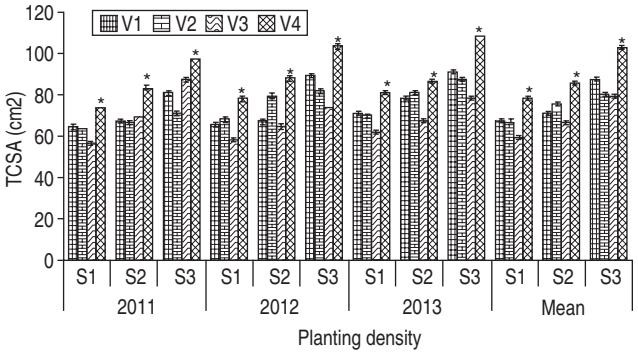

Fig 1 Combined effect of densities and varieties on TCSA (cm^2)

Table 1 Main effect of densities and varieties on TCSA and fruit weight of apple

Factors	Trunk cross sectional area (TCSA cm^2)				Fruit weight (g)			
	2011	2012	2013	Mean	2011	2012	2013	Mean
Varieties								
Starkrimson (V1)	68.61	74.16	78.31	73.69	130.9	132.11	142.66	139.74
Cooper IV (V2)	64.46	67.40	70.51	67.46	230.60	212.44	226.22	226.88
Red Chief (V3)	70.86	71.00	80.76	74.20	177.60	183.00	173.44	176.03
Mollies Delicious (V4)	89.50	91.67	93.21	91.12	144.89	146.80	140.00	143.85
LSD (P=0.05) for variety	4.77	3.70	4.76	3.26	5.58	33.35	4.59	2.48
Densities								
2.5 × 2.5 m (1600 plants/ ha) (S1)	71.00	78.17	84.51	77.89	165.00	157.70	168.50	060.73
2.5 × 3.5 m (1142 plants/ ha) (S2)	74.13	81.70	85.58	80.40	171.00	169.83	165.00	168.61
3.0 × 3.5 m (952 plants/ ha) (S3)	75.80	83.60	87.30	82.23	175.75	178.25	175.25	177.80
LSD (P=0.05) for density	4.13	3.20	4.12	2.82	4.83	NS	3.98	2.14

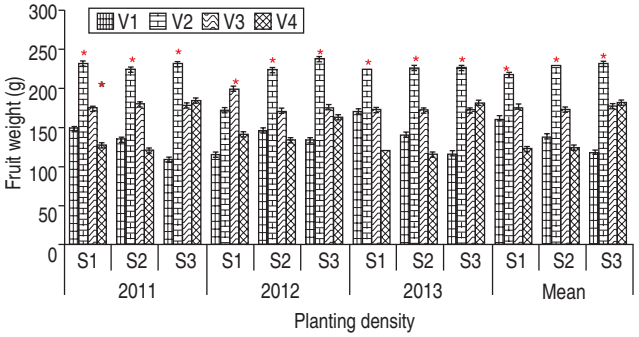

Fig 2 Combined effect of planting densities and varieties on fruit weight (g)

to less competition for available photosynthates and natural resources. In low density, there were abundant availability of natural resources (space, light, CO_2 and moisture) which results, high production of photo-assimilates and more 'C' partitioning to the sink (fruits). In case the demand for photo-assimilates exceeded the amount available, due to high crop load it led to decreased in fruit weight (Corelli Grappadelli 1993). Most of the findings revealed that fruit size has negative relation with number of fruits/ tree/ha, as fruit size is mainly determined by number of cells/fruit and their subsequent enlargement (Harada *et al.* (2005). Good yield was recorded in all the varieties except (V2) Cooper IV, during all the years. However, the highest mean yield (30.38 kg/tree) was recorded in V1 closely followed by V3 (30.28 kg/tree), whereas it was minimum (19.22 kg/tree) in V2. Constantly high yield recorded year after year in Starkrimson and Red Chief. In general higher the planting density, higher the yield per unit area. Maximum mean yield (35.66 kg/tree) was recorded in S3, whereas the minimum (14.42 kg/tree) in S1 (Table 2). The yield trends showed that during 2011 yield/tree was high and it decreased progressively in 2012 and 2013 in S3 and S2, respectively. Though, during 2011 in S1, yield of individual tree was low this showed increasing trend in subsequent years. Combined effect of variety and density influenced the yield significantly, maximum mean yield (51.20 kg/tree) recorded in V4 × S3 and minimum (7.59 kg/tree) in V3 × S1 which was statically at par to V2 × S1 (8.90 kg/tree) (Fig.3). Individual tree showed high yield potential under low density, but overall productivity was high in close spacing, because in low density, less competition among trees for natural resources. Mir *et al.* (2016) reported similar findings in apple var. Starkrimson, Mollies Delicious, Red Delicious in 4.0 × 4.0 m. Further, Kumar *et al.* (2012), observed similar trend in yield with decreasing in plant density in almond, it was minimum yield in V2 in all the densities over the years (Fig 3). Maximum yield efficiency 0.54, 0.40 kg/cm^2 were recorded during 2011 and 2013 respectively in Red Chief and minimum in Cooper IV over the years. The densities have detrimental effect on yield efficiency, it was observed maximum 0.53, 0.40 and 0.37 kg/cm^2 in S1 during 2011, 2012 and 2013 respectively, while as, it was minimum in S1. Combined effect of variety and density on yield efficiency was found

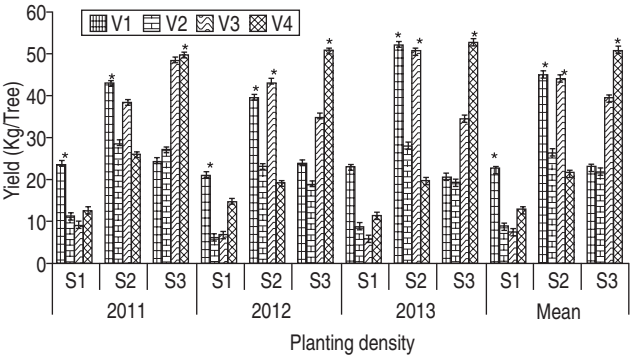

Fig 3 Combined effect of planting density and variety on yield (kg/tree)

Table 2 Main effect of densities and varieties on yield and yield efficiency

Factors	Yield (kg/tree)				Yield efficiency (kg/ cm^2)			
	2011	2012	2013	Mean	2011	2012	2013	Mean
Varieties								
V1	30.72	28.41	32.0	30.38	0.46	0.40	0.38	0.41
V2	22.46	16.21	19.0	19.22	0.34	0.25	0.27	0.29
V3	32.30	26.62	30.55	29.82	0.54	0.37	0.40	0.44
V4	29.64	28.31	28.12	28.69	0.44	0.34	0.32	0.37
r with yield efficiency*				0.999				
LSD (P=0.05) for variety	2.85	4.04	2.08	1.50	NS	0.057	0.04	0.053
Densities								
S1	18.50	16.35	12.43	15.33	0.19	0.15	0.22	0.21
S2	34.23	31.36	32.88	32.82	0.50	0.40	0.45	0.44
S3	37.66	36.99	32.35	35.67	0.53	0.40	0.37	0.48
r with yield efficiency*				0.691				
LSD (P=0.05) for density	2.47	3.50	1.80	1.31	0.13	0.05	0.035	0.046

*r, Co-efficient of correlation (0.05)

significant, maximum (0.78 kg/cm^2), (0.65 kg/cm^2) and (0.76 kg/cm^2) in V3 × S1 and V1 × S2 and V4 × S3 respectively. Significantly positive correlation was obtained between yield and yield efficiency (0.999) and planting densities with yield efficiency (0.691). The yield efficiency is a composite factor which is influenced by variety, spacing, tree vigour, training and pruning, environmental interactions and more over inherent, characters of the genotypes. Similar trend in yield efficiency was observed by Mir *et. al.* (2016) in Starkrimson, Mollies Delicious and other Spur bearing varieties under hdp.

In conclusion the results showed that the choice of varieties and plant density should take into consideration the vigour and productivity per unit area. The trunk cross sectional area is a vigour indicative; the TCSA was recorded maximum in 952 tree/ ha (S3) and minimum in 1600 tree/ ha (S1). TCSA increases with decrease in tree density. The maximum and minimum TCSA were recorded in Mollies Delicious and Cooper IV respectively over the years. As the tree density decreases the fruit weight increases, fruit size has negative correlation with number of fruit/tree. Yield and yield efficiency were recorded maximum in Red Chief and Starkrimson whereas, lowest in Cooper IV. The lower plant density though exhibits high yield per tree but cumulative yield per ha was more in hdp.

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