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Generative developments and pomological traits of apple (*Malus x domestica* Borkh.) scion cultivars canopy on dwarf clonal rootstocks in dry temperate ecosystem of north-west Himalayas

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ABSTRACT

The investigations were undertaken to study the generative developments of thirteen scion cultivars grafted onto four dwarfing rootstock clones viz., EMLA.111, EMLA.7, MM.111 and BUD.9 for pomological traits in dry temperate ecosystem of north-west Himalaya of India. Comparing scion cultivars after 7 years of planting, the survival was recorded maximum for 'Gale Gala' grafted onto EMLA.111 and the poorest for 'Oregon Spur-II' grafted onto BUD.9 rootstock clone. EMLA.111 and EMLA.7 performed very well with "Gale Gala" and 'Golden Spur' with regard to agro-morphometric traits and elevated yield efficiency. The growth vigor of trees grafted onto EMLA.111 and EMLA.7 was larger than those on BUD.9. After seventh harvest season, the rootstock and scion cultivar significantly affected TCSA, TCV, CA, root suckering, yield efficiency and fruit size. Maximum TCSA, TCA and CA were recorded in scion cultivar grafted onto EMLA.111. The greatest root suckering was developed from EMLA.111 (Gibson Golden) and EMLA.7 (Red Gravenstein, Sparton), and the least in EMLA.111 (Gale Gala). Correlation analysis of different attributes representing the pomological traits also resulted in a significant association at alpha = 0.05 attribute pairs. PCA of pomological and fruit quality traits was also worked out to evaluate the differences among scion cultivars tested on different dwarfing rootstock clones. PC4 accounted for 93.9% (pomological traits) and 80.6% (fruit quality) of the cumulative variance of scion cultivars studied. PCA-F1 had the highest positive loadings from plant height, tree girth, TCSA, and TCV followed by PCA-F2 (fruit yield and cumulative fruit yield). Further, no significant differences were obtained when the calculated factor scores of PCA-F1, PCA-F2 and PCA-F3 for fruit quality attributes were analyzed. The study inferred that the ability of the rootstock clones to perform better than current commercial standards, while, promoting orchard health and productivity with enhanced insect-pest and disease resistance.

1. Introduction

Most critical decision to establish an apple orchard is the right selection of rootstock, which affects tree size, yield, and fruit quality. Rootstock influenced the profitability of orchards which offers flexible and the cheapest method of tree vigor control (Webster, 1993). Improper understanding of how a rootstock affects these characteristics can result in an inefficient or even unsuccessful block. Therefore, it is important for fruit growers to have an adequate knowledge of rootstock performance when grown with varieties and the climatic conditions experienced in the region. Nowadays, dwarfing rootstocks have become widely accepted by fruit industry as a tool for increasing orcharding enterprise. Dwarfing rootstock clones influenced tree size, planting density per unit area and fruit yield (Barritt et al., 1995). During modern era, the planting systems are based on high tree densities (1000–6000 trees ha^{-1}) and may be as high as 10,000 trees ha^{-1} (Robinson, 2003). The increasing planting density alone, however, didn't increased yield (Hampson et al., 2002). Dwarf rootstock clone controls scion growth in apple by reduction of canopy spread, branches compression and other vegetative growth traits. Moreover, the reduction of canopy parameters has inductive effect of vegetative dwarfing rootstock when compared with semi-dwarf or seedling rootstocks (Blanco et al., 2008). It is well documented that

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the orchard and pomological performance also varied considerably within fruit trees (Wu et al., 2005), associated to light interception (Génard and Baret, 1994), crop load (Marini and Sowers, 1994), pruning intensity (Kumar et al., 2010), training systems (Hampson et al., 2002) and the methods of irrigation supplemented (Lopez et al., 2010). Hrotkó (2008) and Franken-Bembenek (2010) have intensely investigated several new rootstocks with a wide range of tree vigor to study the effect on tree vigor, tree size control and precocity in high density orcharding system. The dry temperate zone of India especially Himachal Pradesh (Kinnaur) has its own importance due to steep mountainous terrains, ensured irrigation and dry temperate agro-climatic conditions. The valley area included the trans-Himalayan belt on the northern side of the western Himalayas, which is cold, arid and windswept (Köppen's climate classification).

Apple is the most important cash crop of the hill State and constitutes about 49 per cent of the total area and about 85 per cent of the total fruit production, thereby generating economy of around 523 million US dollars. The Kinnaur district stretching up to the Tibetan border in south-east is a tribal district represents typically a dry temperate ecosystem. The prime horticultural produce in this area is apple and around 78 per cent of the local people have their own apple orchards. The growing importance of apple industry has brought about a revolutionary change in recognizing the potential of horticulture in promoting livelihood, employment opportunity and prosperity in the State. The normal apple production in Kinnaur is between 2 and 2.2 million apple boxes (20 kg capacity each), which is 6–7 per cent of the total yield in the State. Whereas, the productivity ranges from 6 to 11.5 tons ha^{-1} against 35–40 tons in more advanced countries. The average number of plants ha^{-1} ranged between 200 and 1250 in different planting densities i.e. <250, 250–500 and 500–1250 trees ha^{-1} based upon the steepness of the mountains (Bera, 2015). Low tree density per unit area therefore, has been one of the major constraints in enhancing the productivity in this tough terrain ecosystem. Traditionally, almost all the plantations are of 'Delicious group' as standard variety raised on seedling rootstocks. Besides, the apple industry in the region is also facing stiff challenge from better quality imports that are often competitively priced. However, the strength of the district that around 78 per cent of the area is under irrigation needs to be exploited for high density orchard planning. The investigation thus, targets the evaluation of the exotic scion cultivars grafted onto dwarf rootstock clones to have their effect on canopy development under high density orcharding conditions. The second objective of the study reported here to compare performance of the newest rootstock clones with and within a variety of increasing importance to retail orchardists to provide the information for choosing appropriate rootstock, and to give an impetus to ameliorate the production and productivity of apple in the dry temperate region of Indian Himalaya.

2. Materials and methods

2.1. Geographical location and the experimental set up

The experiment was conducted in the Research Farm of Regional Horticultural Research & Training Station and Farm Science Centre (KVK) of Dr YS Parmar University of Horticulture and Forestry, Sharbo (Reckong Peo), Kinnaur, Himachal Pradesh, India (2250 m amsl; 31°32′20″N latitude and 78°16′03″E longitude) for five consecutive years between 2010 and 2014 growth periods. The exotic apple orchard was established in April, 2008 as eighteen rows north-south to optimize effective light interception with low air humidity. The climate of the experimental area was typically a dry temperate and humid (north-west Himalaya). The annual rainfall (about 250 mm) and the temperature remain very low throughout the year. Heaviest snowfall occurs between the months of December to February and sometimes even up to mid March. Meteorological data were moderate to low rainfall in the monsoon season. The southwest monsoon in the region usually sets in June and withdraws in the end of September, contributing to about 75% of the annual rainfall. The remaining 25% rainfall is received during the non-monsoon period in the wake of western disturbances.

The feathered (branched) trees procured from 'Van Well' fruit nursery, USA, were graded before transplanting and the excellent trees were selected. These trees were transplanted in north-south row orientation, in light loamy soil at 2.5 m within the row and 2.5 m between rows with the graft union above 15 cm of the soil line. This planting spacing resulted into a tree density of 1600 trees ha^{-1}. The trees were trained with the slender spindle training system. The orchard performance of the exotic apples for pomological traits of thirteen cultivars grafted onto four dwarf virus-free rootstock clones viz., Akane onto EMLA.7, Braeburn onto EMLA.111, Coe Red Fuji onto EMLA.7, Compact Winter Banana onto EMLA.111, Early Red One onto EMLA.111, Gale Gala onto EMLA.111, Gale Gala onto EMLA.7, Gibson Golden onto EMLA.111, Gibson Golden onto EMLA.7, Golden Spur onto EMLA.111, Oregon Spur-II onto BUD.9, Oregon Spur-II onto EMLA.111, Oregon Spur-II onto EMLA.7, Red Gravenstein onto EMLA.7, Royal Gala onto MM.111, Sparton onto EMLA.7, Super Chief onto BUD.9 and Super Chief onto EMLA.111 was studied. The experiment was arranged as randomized complete block design with three replicates and three trees per scion cultivar per rootstock clone were chosen for each harvest season. All sampled trees were uniform sized, without any visible symptoms of disease or pest infestation at the time of the commencing of the trial. The trees bear fruit samples in 2009. The experimental orchards were even grown on steep slopes. There is considerable loss of top soil due to erosion followed long snowy winter months.

2.2. Horticultural practices

During the initial cropping years (first and second growth periods), the trees were hand-thinned 30 days after full bloom. Subsequently, for the balanced vegetative and reproductive loads, the thinning of fruitlets in each tree per limb was also carried out. Limbs of similar crop load were chosen and manually de-fruited during the period of pit hardening to achieve sufficient load to bear fruit after third year of harvest season. The accuracy of fruit thinning percentage was measured by counting the number of fruits per limb cross sectional area i.e. the crop load. Trees were pruned and standard cultural practices were applied to achieve a manageable uniform size, a balance between growth and regular yields and to allow proper penetration of light and spray to the tree centre. Further, the trees also received usual horticultural cares in accordance with the scientific principles, the framework of fertilizing operations, weeds control and other optimal-cultivation operations. Apple scion cultivars received routine horticultural care in accordance with the scientific principles for commercial fruit production including the framework of fertilization, weeds control, the optimal operations for irrigation and plant protection (Table 1). The field was irrigated each harvest year from mid April to October. Drip irrigation system was also installed with a 0.5 m emitter spacing to supply a uniformly wet surface within the orchard. Flood irrigation was generally supplemented between July-August (hot and dry weather). Fertilization of the trees with 10 kg of farm yard manure (FYM), 70 g of N (280 g of calcium ammonium nitrate, 25%), 35 g of P (220 g of single super phosphate, 16% P_2O_5), and 70 g of K_2O (115 g of muriate of potash, 60% K_2O) in accordance to one year old tree age basis during the middle of winters was supplemented. The half of the dose of N, the full dose of P and K fertilizers along with full