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Growth restoration studies in frost-affected mango (*Mangifera indica* L.) orchards in sub-Himalayan region

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ABSTRACT

Frost is a major constraint in mango production in the sub- Himalayan region. To restore growth and productivity in frost-affected Dashehari mango orchards, effect of different growth-restoring treatments was studied at highly frost-sensitive, medium frost-sensitive, low frost-sensitive and frost-free locations. Foliar application of urea, benzyladenine, gibberellic acid (individually or in combination) was made during the post-spring season. As the cut ends of branches or damaged open area serve as entry points for the propagation of ice crystals through the vascular system in plants, the experiments were also carried out with and without prior winter covering of cut ends of branches with wax or polythene cover. At low and high frost-sensitive locations, 7 and 5.5 number of news shoots emerged, on average, per scaffold when frost-affected trees were sprayed with benzyladenine (BA 20ppm), followed by 2% urea spray after fifteen days. Better restoration of reproductive growth was observed with this treatment. Pre-winter waxing or polythene covering of the cut ends of branches was very effective in preventing lethal frost-damage (stem injury below 20cm) to the trees. Effect of benzyladenine and urea treatments was found to be additive in trees whose cut surfaces were waxed or covered with polythene sheets.

Key words: Frost, benzyladenine, gibberellic acid, urea, corrective pruning, mango

INTRODUCTION

India is the largest producer of mango in the world, with a share of 39.5% of total production (Anon., 2010). Though a majority of mango producing areas in our country are the tropical and subtropical plains, considerable improvement in acreage under this fruit crop has been noticed in the low-hill and valley region of NW Himalayas. Mango from this region comes to the market when the crop season is over elsewhere in the country. In Himachal Pradesh, area under mango has increased from a mere 2,600 hectare in 1971 to 37,840 hectare at present (Anon., 2009). 'Dashehari' is the main cultivar of the region, followed by 'Langra' and 'Chausa', besides the rich heritage of local varieties. In Himachal Pradesh, mango is grown primarily in the subtropical region of Kangra, Hamirpur, Bilaspur, Una, Solan, Sirmour, Chamba and Mandi districts.

Owing to high levels of radiative cooling and a varied topographical feature, frost of variable intensity is quite common in the low-hill and valley region of Himachal Pradesh. This is one of the major factors governing productivity of mango in the region. The present level of productivity is quite low (0.9t/ha) compared to national and international productivity averages. A majority of the loss occurs due to radiation and frost (Sharma and Badiyala, 2008) affecting not only the current season's growth and productivity, but also the subsequent 2-3 years (the crop can get affected by even a single instance of frost damage). In view of the severity of this problem, Agriculture Technology Management Agency, Hamirpur (Himachal Pradesh) treated it as a researchable issue and assigned the responsibility of developing an effective technology for restoration of growth in such orchards to Regional Horticultural and Forestry Research Station, Bhota/ Neri, Hamirpur, Himachal Pradesh.

MATERIAL AND METHODS

Studies were conducted during the years 2006-07 to 2008-09 at four types of location described as: L_1- highly frost-sensitive low-lying area (0-80m from the lowest point of a micro watershed), L_2- medium frost-sensitive, lower portion of the sloppy area (80-120m from the lowest point of a micro watershed), L_3- low-frost sensitive middle portion of the sloppy area (120-160m from the lowest point of a micro watershed), and, L_4- least frost-sensitive, upper portion of the sloppy area (above 160m from the lowest point of a micro watershed). Three replicates of each location were selected in Hamirpur, Bilaspur and Una districts. Selection of locations for frost sensitivity was in accordance with Sharma and Badiyala (2008). At every location selected, there were four mango orchards of cv. Dashehari in the age group of 15 to 20 years, growing on loam to silt loam soils with almost neutral soil reaction, and uniform level of orchard management as per standard package of practices. In each orchard, five trees were selected randomly for recording various observations.

The experimental trees were subjected to corrective pruning in mid-February for removal of frost-affected dead parts. Immediately after corrective pruning, the trees were sprayed with copper oxychloride (0.3%) as per standard recommendation (Anon., 2008). Thereafter, the experimental trees were subjected to following set of growth restoring treatments: T_1- 0.5% urea spray (Low urea dose on tender growth), T_2 - 20 ppm gibberellic acid (GA_3) spray, T_3 - 20 ppm Benzyladenine (BA) spray [all these treatments (T_1 to T_3) were given 15 days after corrective pruning], T_4 - T_1 + 2% urea spray, 15 days after T_1, T_5 - T_2 + 2% urea spray (higher dose of urea for accelerating vegetative growth), 15 days after T_2, T_6 - T_3 + 2% urea spray, 15 days after T_3, T_7 - Control (water spray at the time of T_1 and T_4). Observations were recorded on shoot regeneration by counting the number of new shoots that emerged per scaffold at the canopy-top until April-mid. Further growth of shoots was measured at the end of September, and was termed 'shoot extension growth'. For this purpose, ten shoots were tagged per scaffold. Treatment effect was also measured for reproductive growth of the tree in terms of proportion of the canopy producing flowers, fruit retention by April-end (pea stage) and June-end (pit hardening stage). Data was pooled for the years 2007 and 2008.

It was a pre-experimentation observation that trees were subjected to heavy corrective-pruning (pruning that involved cutting of branches >2" diameter) suffered more if the frost occurred during the subsequent year as well. For preventing of this type of damage, prior to winter onset, the following set of treatments were imposed: C_1-Pre-winter waxing of cut-ends (>2" diameter), C_2- Pre-winter polyethylene covering of cut-ends (>2" diameter), and C_3- Control (no covering of cut-ends). These trees received growth restoring set of treatments as detailed described above; observations recorded were also similar. Data were pooled for all the locations and the years of study i.e., 2007-08 and 2008-09.

Randomization, experimental layout and statistical analyses were done as per 'Repeated Measurement Design (factorial)' wherein the same experimental units received two sets of treatment at different times, and observations were recorded after applying of the respective set of treatments (Freeman, 1959; Hoblyn *et al,* 1954).

RESULTS AND DISCUSSIONS

BA + urea treatment (T_6) significantly enhanced number of shoots regenerated on the top scaffolds (Table 1). Influence of location on shoot regeneration was found to be non-significant, though, interaction effect of the treatments and location was significant. Effect of the above-stated treatment was highest at a location of low frost-sensitivity (L3) and was statistically at par with the least frost-affected sites (L4) (Table 1). Similar pattern was observed for shoot extension growth: BA + urea outscored the other treatments, though statistically it was at par with GA_3 + urea (T_5) treatment. Location and location-treatment interactions were observed to be non-significant in influencing shoot extension growth. Such an effect of benzyladenine (BA) on shoot regeneration and shoot extension growth may be attributed to its known, characteristic effect on protein and RNA content in leaves and meristematic regions. This stimulates the anaboloid mechanism in the plant, leading to enhanced shoot regeneration and growth (Nailo *et al*, 2007). Further, Garner *et al* (1997) also reported BA as inducing lateral buds by activating epicormic buds on the main branches and the stem in woody species. Application of urea yielded effects additive to that of BA owing to urea's active contribution in protein synthesis (Daoudi *et al,* 1998). Effect of location on shoot regeneration can be understood in the light of findings of Wisniewski *et al* (2001) who studied damage to heartwood and lateral meristematic regions of the plant at variable levels of low-temperature exposure. At low frost-sensitive sites (L_3), lateral meristematic tissues of the scaffolds may have been rarely damaged; therefore, these plants gained active growth immediately after winters ceased.

Proportion of the canopy restored to flowering was not influenced significantly by various treatments, although this figure was significantly higher at locations that were less frost-affected (Table 2). Under highly frosty conditions (L_1), proportion of the flowering canopy was lowest

(12.11%), as, a majority of the canopy was damaged by frost. Count of fruitlets at the end of April, representative of initial fruit-set, was found to be highest with T_6 (BA+urea treatment) non-significantly, followed by T_4 (urea+urea treatment). Positive effects of BA and urea treatments on reproductive behavior of treated plants may be attributed to a lower flower and fruit abscission under these treatments. Similar observations were recorded by Daoudi *et al* (1998) and Talaie *et al* (2006) in pistachio nut. Location-wise variation in fruit-set was found to be significant only in the case of L_4 (least frost affected site) where the variation was lowest. This may be attributed to lower water and fertility regime at the site (Sharma and Badiyala, 2008). Fruit retention by the end of June was considerably higher at L_1 (Low-lying areas) owing to better water and fertility regimes. Effect of the treatments was also significant under this location, although interaction effects were non-significant. Variation in fruit yield was not significant with respect to the location under study, primarily due to the opposite order of variation in flowering and fruit retention. For yield, both treatment and treatment x location interactions were found to be significant. BA+urea produced significantly higher fruit yield than other treatments. Highest fruit yield was recorded in this treatment at L_1. Anti-senescence properties of both benzyladenine and nitrogen may have resulted in retention of higher number of fruits and better fertility regime at the location (Sharma and Badiyala, 2008) thereby, contributing significantly to fruit yield.

It is quite clear from the results (Fig. 1a) that covering the cut-ends of the scaffolds with wax or polyethylene sheet significantly reduced frost/ freeze induced damage to shoots and stems (damage of upto 6.23cm, 16.9cm and 77.3cm was observed for wax, polyethylene and uncovered treatments, respectively). The effect of spring season's growth promoting treatments and their interaction effect with cut-end covering treatments was found to be non-significant with reference to freeze damage of stem or shoots. These findings was supported by inferences of Wisniewski *et al* (2001) who demonstrated that during a frost event, once the ice nucleation occurs, the ice spreads very fast across the vascular system of the plant, upon its entry into the vascular strands. Thus, when the cut-ends were not covered, these acted as entry points for ice propagation through the tree's vascular system, and resulted in grave damage to the plant system.

Though regeneration of new shoots significantly improved by cut-end treatment as well as growth promotion treatment (Fig. 1b), interaction between the two was found to improve shoot regeneration significantly. Highest number of shoots regenerated (8.2) on scaffolds whose cut-ends covered with polyethylene were given a spray of BA+ urea. Shoot extension growth recorded highest with wax cover treatments (Fig. 1c), and was found at par with polyethylene cover treatment coupled with BA+urea. This may be attributed to a possibility that wax or polyethylene protected

Table 1. Effect of various treatments on growth restorations in frost affected mango orchards at different locations (pooled data for the years 2007 and 2008)

Location	Shoots emerged/scaffold (Number)					Shoot extension growth (cm)				
	L_1	L_2	L_3	L_4	Mean	L_1	L_2	L_3	L_4	Mean
Treatment										
T1	1.2	2.6	4.2	4.0	3.00	12.2	11.6	12.4	11.2	11.85
T2	0.6	1.8	3.1	3.2	2.18	11.4	11.2	10.4	9.7	10.68
T3	3.2	3.4	3.2	3.7	3.37	14.2	13.4	13.7	12.9	13.55
T4	2.7	3.2	3.8	3.9	3.40	12.2	9.4	12.3	11.2	11.27
T5	3.4	3.7	3.8	3.6	3.63	18.4	16.7	12.6	16.4	16.02
T6	5.5	6.5	7.0	6.1	6.28	20.7	19.3	11.2	19.1	17.58
T7	2.1	2.9	2.7	2.7	2.60	10.1	10.2	8.1	10.2	9.65
Mean	2.67	3.44	3.97	3.88		14.2	13.1	11.5	12.1	
CD *(P=0.05)*	L - NS					L - NS				
	T - 2.57					T - 3.76				
	L x T-1.48					L x T - NS				

T_1 - 0.5% urea spray
T_2 - 20ppm gibberellic acid (GA_3) spray
T_3 - 20ppm benzyladenine (BA) spray
T_4 - T1 + 2% urea spray 15 days after T1
T_5 - T2 + 2% urea spray, 15 days after T2
T_6 - T3 + 2% urea spray, 15 days after T2
T_7 - Control (water spray at the time of T1 and T4)

L_1 - Highly frost sensitive area (0-80m from the lowest point of a micro watershed)
L_2 - Medium frost sensitive area (80-120m from the lowest point of a micro watershed)
L_3 - Low frost sensitive area (120-160m from the lowest point of a micro watershed)
L_4 - Least frost sensitive area (above 160m from the lowest point of a micro watershed)

Table 2. Effect of various treatments on reproductive growth and fruit yield under different locations (pooled data for the years 2007 and 2008)

Location	Canopy proportion (%) restored to flowering					No. of fruits/panicle at the end of April (Pea stage)					No. of fruits/panicle at the end of June (Pit hardening stage)					Av. fruit yield / tree (kg)				
	L_1	L_2	L_3	L_4	Mean	L_1	L_2	L_3	L_4	Mean	L_1	L_2	L_3	L_4	Mean	L_1	L_2	L_3	L_4	Mean
Treatment																				
T_1	8.4	27.4	41.8	41.6	29.80	7.2	4.8	5.9	4.2	5.53	0.61	0.23	0.30	0.28	0.355	24.5	26.2	16.1	31.2	24.50
T_2	9.2	30.2	54.2	54.2	36.95	7.4	5.9	6.9	4.0	6.05	0.42	0.35	0.28	0.19	0.310	19.1	26.4	31.3	39.6	29.10
T_3	14.2	28.6	50.4	51.2	36.10	7.2	6.4	6.1	6.1	6.95	0.64	0.39	0.30	0.39	0.430	39.7	36.3	28.5	26.4	32.72
T_4	13.2	25.4	44.4	42.4	13.35	7.6	8.1	7.4	6.4	8.13	0.70	0.38	0.30	0.30	0.420	39.1	31.4	29.6	38.3	34.6
T_5	10.4	27.2	38.4	51.6	39.90	8.7	8.9	7.8	6.1	7.88	0.71	0.42	0.29	0.37	0.448	30.8	34.2	36.2	30.4	32.90
T_6	19.6	32.9	49.9	56.4	39.70	10.1	9.7	9.3	8.4	9.88	1.03	0.56	0.59	0.67	0.713	62.8	45.4	47.4	44.8	50.1
T_7	9.8	26.2	44.4	54.6	33.75	7.1	3.1	3.8	4.1	5.42	0.21	0.29	0.18	0.26	0.235	25.8	22.7	12.4	11.5	15.6
Mean	12.11	28.27	46.21	50.28		7.90	6.70	6.74	5.61		0.617	0.374	0.320	0.351		34.5	31.8	27.8	31.7	
CD (P=0.05)	L - 19.75					L - 2.71					L - 0.212					L - NS				
	T - NS					T - 1.87					T - 0.281					T - 9.82				
	LxT - NS					LxT - NS					LxT - NS					LxT - 21.76				

T_1 - 0.5% urea spray
T_2 - 20ppm gibberellic Acid (GA_3) spray
T_3 - 20ppm benzyladenine (BA) spray
T_4 - T_1 + 2% urea spray, 15 days after T_1
T_5 - T_2 + 2% urea spray, 15 days after T_2
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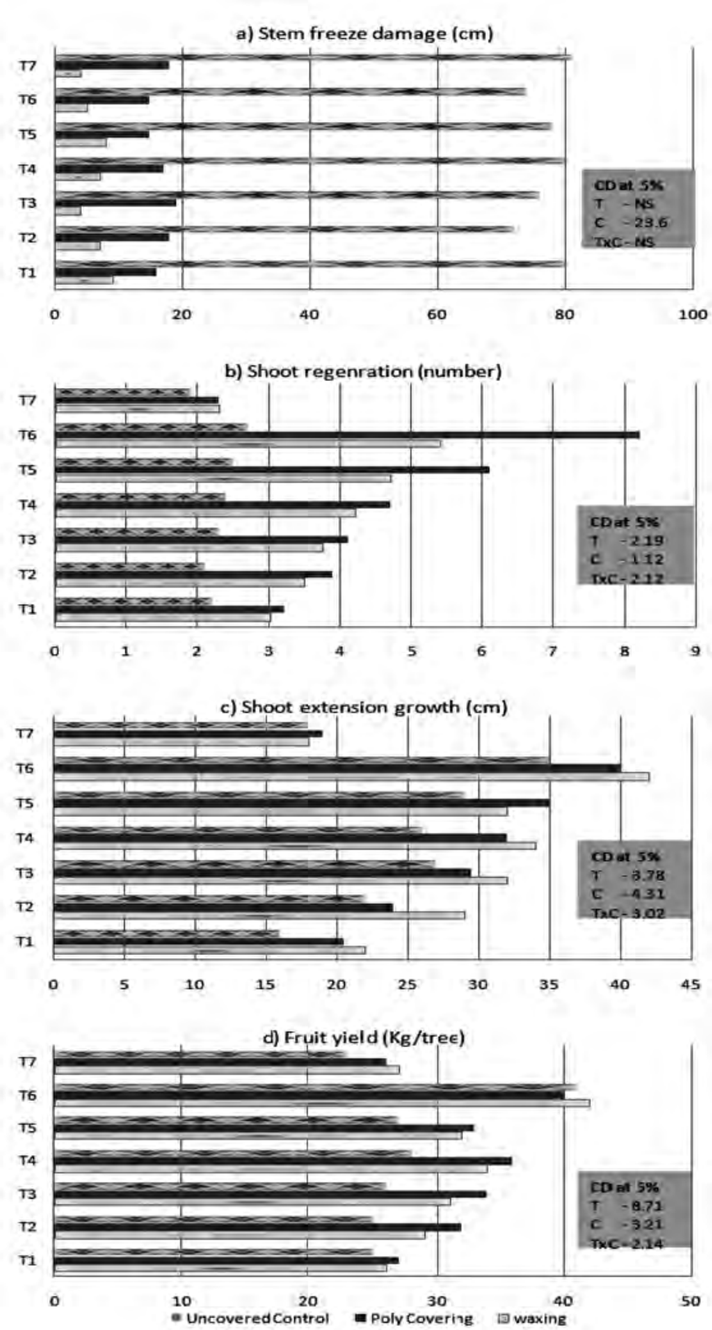

Fig 1. Effect of scafolds' cut end covering and growth restoring treatments on frost damaeg, vegetative growth and fruit yield in 'Dashehari' mango

(Pooled data for location and years 2008 and 2009)

cut-ends prevented damage to the meristematic regions of shoots, and these regions supported the plants in early restoration of growth.

Fruit yield per tree was also influenced significantly by these set of treatments and their interactions. Highest fruit yield (42kg/tree) was recorded in trees where the cut-end of a scaffold was covered with wax and which had received BA+urea treatment for growth restoration (Fig. 1d). Wax and polyethylene treatments were statistically at par, which may be attributed to the fact that covering of the cut-ends of scaffolds prevented severe injury to these branches, thereby restoring reproductive growth better than in an uncovered branch. In uncovered branches, photosynthates may have been used up first for recouping vegetative losses rather than restoring yield in the plant system. Altered biomass partitioning towards vegetative growth has also been demonstrated earlier by Hancock *et al* (2007) under induced stress.

On the basis of results above, it may be concluded that application of benzyladenine, followed by urea (2%) spray after fifteen days enhanced regeneration of vegetative and reproductive growth of frost-affected mango orchards, along with increase in yield over the Control. Covering tree wounds or cut-end surfaces of branches with wax or polythene sheet protected the trees from severe damage while retaining the vegetative and reproductive growth capacity of shoots.

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