Prioritization of sub-tropical fruit plants for the frost prone low hill region of Himachal Pradesh

Shashi K Sharma* and S D Badiyala
Dr. Y S Parmar University of Horticulture and Forestry
Regional Horticultural and Forestry Research Station, Neri
P. O. Khagal, Distt. Hamirpur- 177 001, Himachal Pradesh, India
*Correspondent author, E-mail: shashi_uhf@yahoo.com

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Abstract

Frost is a major limiting factor in the development of horticulture in the low hill and valley region of Himachal Pradesh. The average minimum temperature of the region remains below 10ºC for about four months. Sub-zero temperature is also common during winters. Heavy intensities of the frost were observed in the closed basin areas, frost intensity decreased with the increase in elevation along the slope of the hills. There were defined six types of Agro Ecological Situations (AES) and for each situation separate order of priority for different sub-tropical fruit species have been discussed in this paper keeping in view the frost and economic considerations. The observations of this study may prove to be useful for Horticulture departments and Extension agencies in hilly regions of other states also.

Keywords: Sub-tropical fruits, Frost, Mango, Litchi, Papaya, Citrus, Aonla, Loquat, Guava, Himachal Pradesh.

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Introduction

Frost is generally defined as the solid deposition of water vapours from saturated air, it normally happens when solid surfaces in contact with air are chilled below the deposition point (frost point). Specific heat, thermal emissivity of the surfaces alongwith the amount of water vapours available, defines the intensity of the frost. It is also affected by the differences in absorptivity and specific heat of the ground which in absence of wind greatly influences the temperature attained by the super incumbent air. Because cold air is denser than warm air, it forms close to the ground, in calm weather cold air pools at the ground level. This is known as 'surface temperature inversion' and explains why frost is more common and extensive in low lying areas. Frost can form in these areas even when the reported temperature is above the freezing point of water[1].

Low hill and valley region of Himachal Pradesh comprise of number of ranges which run roughly parallel to each other for long distances and converge at places, meet and diverge again giving rise to small and longitudinal hills/hillocks (Fig. 1, Map). These ranges arise gradually from plains of adjoining states and goes on attaining height of 300 to 1100 m. Owing to these topographical conditions, surface temperature inversion is a phenomenon of common occurrence during winters. The region is highly frost sensitive and sub-optimal for growing of sub-tropical fruits; despite the fact that climate of the region is generally characterized as of sub-tropical nature[1]. The average minimum temperature of the region remains below 10ºC for about four months during winters (Fig. 2). Sub-zero temperatures are also not uncommon in the region. Frost is experienced mostly during the month of January; sometimes in December and February also. Both early and late frosts are dangerous for sub-tropical plants and inflict heavy damages

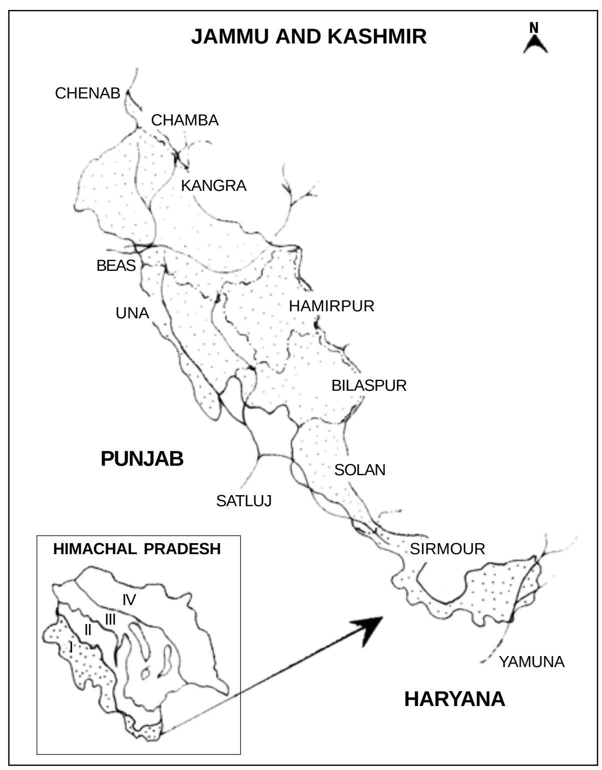

Fig. 1: Low hill and valley area of Himachal Pradesh

in killing of foliage, twigs, branches, flowers, etc.[2, 3]. Evergreen sub-tropical fruit species like papaya, mango, litchi, aonla, guava, etc. are highly susceptible to cold injury and every year farming community suffers a huge economic loss under the low hill conditions of Himachal Pradesh. As fruit growing is a capital intensive and long term enterprise, planting of an orchard at an improper site reduces the returns greatly. Further, this region is densely populated (it support 38% of the total population of the state while occupying only 18% of the total geographical area) and there is high pressure on the landholdings for drawing maximum output. In the recent past around 172% increase in the area under sub-tropical fruits has been observed[3]. But, the corresponding increase[4] in production and productivity of these crops is still questionable. In a strategic research, extension and planning conducted under National Agricultural Technology Project (NATP), it has been speculated that frost is the major limiting factor in the development of these fruit plant species in the region. The present studies were thus, undertaken to delineate the frost prone sites and to work out the relative priority of commercially important sub-tropical fruit species for frost prone sites in the region.

Methodology

The studies were conducted during the years 2002 to 2007 in the low hill and valley region (400 to 1100 m) of Himachal Pradesh. Low hill and valley region of Himachal Pradesh was taken as the area of study, in which the representative sites were selected as per standard sampling procedures described by Gupta and Kapoor[5]. Initially there were marked fifteen agro-ecological situations depending upon the topographical variations. These sites have been depicted pictorially in Fig. 3. These situations were evaluated for frost proneness for four years. Seedling mango trees are widely distributed across the low hill region of Himachal Pradesh and these trees are considered as the best indicator of intensity of frost at a particular site. The intensity of frost observed at different sites is given in Table 1.

Observations

The intensity of frost was quantified as low when the damage to the foliage of the seedling mango trees growing in the region was less than thirty percent. It was classified as medium when the foliage damage was 30-60% with the complete damage to the twigs of thickness less than 1.5cm. When the foliage damage was 60-90% with the complete damage of the twigs or branches of thickness up to 3cm, it was quantified as heavy frost damage. Under the very heavy frost damage category foliage damage to the seedling mango trees was up to 90% or more with complete damage of the branches of more than 3cm in thickness.

The data on the frost intensity at different sites were collected and pooled for interpretation for every 200m

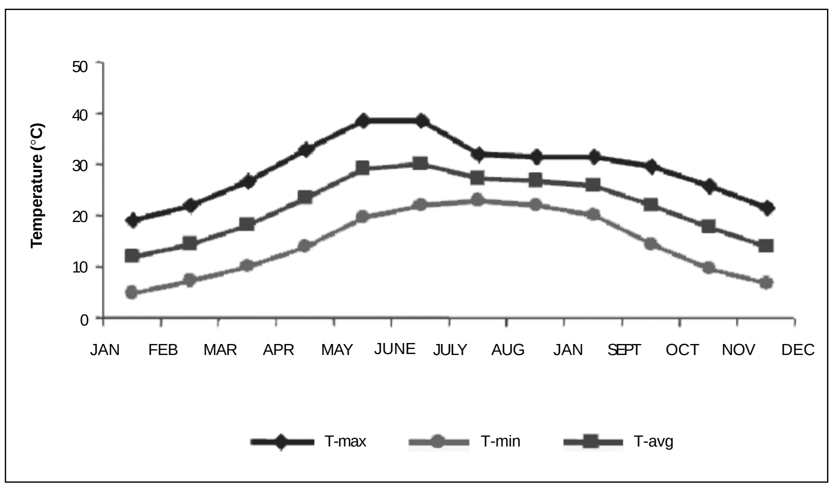

Fig. 2: Maximum, minimum and average temperature details of low hill region of Himachal Pradesh

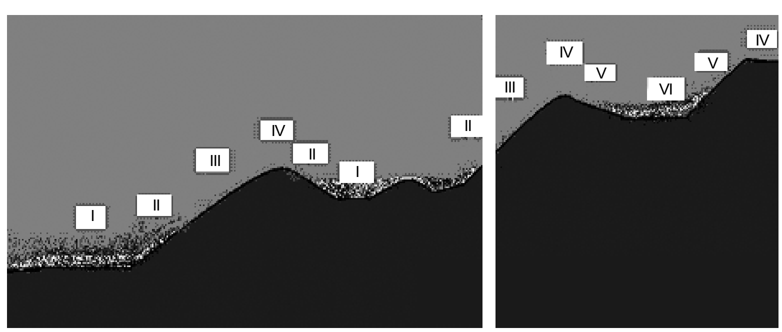

Fig. 3: Pictorial representation of different Agro-ecological situations and frost prone sites

Table1 : Altitudinal variation in frost intensity

Altitude at site basin (m)	Height of a site above the basin (m)	Intensity of frost observed
Up to 500	0 -40 40- 80 80-120 120-160	Very Heavy to Heavy Heavy to Medium Medium to Low Low to No Frost
500-700	0 -40 40- 80 80-120 120-160	Very Heavy to Heavy Heavy to Medium Medium to Low No Frost
700- 900	0 -40 40- 80 80-120 120-160	Heavy Medium to Low No Frost No Frost
>900	0 -40 40 - 80 80-120 120-160	Medium to Low No Frost No Frost No Frost

altitudinal variation at the basin level. On the hill slopes it was observed that the frost intensity decreased with the increase in the altitude along the slope. Under the severest frost conditions the effect of surface temperature inversion i.e. pooling of cool layers near the ground in the basin area was observed up to 40 m, hence along the slope the data on frost intensity was collected at the altitudinal increase of 40m. The data on different altitudinal sites are presented in Table 1.

During the studies it was also observed that the low lying areas which were surrounded by small or medium hills/hillocks were highly frost prone up to 700m altitude. Beyond this altitude the intensity of frost was lower. The sites which were just above the basin area (up to about 40-80m above basin area i.e. lower portion of the hills) experienced heavy to medium frost. Upper portion of the slopes experienced no frost, however in some of such areas low degree of frost was observed where there was some topographical obstruction in the down flow of cool air. The very upper portions of the slope or the top of the hills/hillocks were found to be frost free. In some areas influence of cold winds were observed at these sites. There was observed medium to low degree of frost in areas which were high in altitude (at the basin level >700m above mean sea level). The hill slopes were comparatively frost free in such areas. Low degree of frost on some slopes was observed where there was topographical obstruction in the down flow of cool air. Normally, temperature remains lower at the higher elevations, but due to temperature inversion cool air move down filling the local valley and closed basins displacing the warmer air upward and this may be the reason that why the upper portion of hills is generally frost free[6].

It is the advantage for the low lying areas that the run off water from the slopes drain most of the productive soil and nutrient to the lower areas and this is the main reason that the basin areas are more productive than the sloppy areas. During these studies, it was also observed that the low lying areas/basin areas were more productive than the sloppy areas (Table 2). Depending upon the frost condition of the various sites, their topographical conditions and the corresponding productivity status, these sites were regrouped in following Agro-ecological situations (AES):

I. Low lying, productive –Very heavy to Heavy frost sites

II. Lower portion of the hills/ hillocks, medium productive – Heavy to medium frost sites

III. Upper portion of the hills/ hillocks, low productive – Medium to low frost sites

IV. Top of the hills/ hillocks, medium productive – Low to no frost sites

V. Hill / hillock slopes at higher altitudes (>700m at basin level), low productive – Low frost sites

VI. Basin area surrounded by hills/ hillocks in the upland region (>700m altitude), productive – Medium to low frost area.

The data pertaining to the frost damage score, economic score and relative priority score are presented in Tables 2, 3 and 4. Different fruit species studied have been enlisted in Table 5 for their descending order of the preference for different agro-ecological situations.

Similar work on categorization of area into such AES was done for Hamirpur district of Himachal Pradesh[4].

Table 2 : Relative Frost score of different fruit species under different agro-ecological situations

Agro-ecological situation	Mango			Litchi			Citrus			Guava			Loquat			Papaya			Aonla		
	M	D	F	M	D	F	M	D	F	M	D	F	M	D	F	M	D	F	M	D	F
I	84	82	1.7	46	44	5.5	18	14	6.8	16	10	8.7	2	0	9.9	90	84	1.3	56	42	5.1
II	72	46	2.05	32	22	4.6	10	4	8.6	4	6	9.0	0	0	10.0	86	72	2.1	42	24	6.7
III	26	22	7.6	11	8	8.1	4	0	9.6	2	0	9.8	0	0	10.0	24	16	8.0	12	6	9.1
IV	12	30	7.9	10	14	7.6	4	0	9.6	1	0	9.9	0	0	10.0	14	6	9.0	10	8	9.1
V	65	71	3.2	39	26	3.5	12	10	7.8	12	0	8.8	0	0	10.0	78	76	2.3	37	16	7.35
VI	86	89	1.25	45	58	5.15	16	22	6.2	14	14	7.2	4	4	9.7	94	86	1.0	52	44	5.2

M- % mortality observed in young plantations due to frost; D- % damage to the bearing orchards due to frost; F- Frost damage score

Table 3 : Relative Economic score of different fruit species under different agro-ecological situations

Agro-ecological situation	Mango (R=10)				Litchi (R=20)				Citrus (R=15)				Guava (R=8)				Loquat (R=10)				Papaya (R=8)				Aonla (R=5)			
	Y	EV	EW	E	Y	EV	EW	E	Y	EV	EW	E	Y	EV	EW	E	Y	EV	EW	E	Y	EV	EW	E	Y	EV	EW	E
I	36	4.8	10	7.4	36	9.6	8	8.8	34	6.8	8	7.4	30	3.2	6	4.6	20	2.67	6	4.33	30	3.2	7	5.1	42	2.95	7	4.98
II	36	4.8	8	6.4	26	6.93	7	6.97	22	4.4	6	5.2	22	2.35	6	4.18	12	1.6	5	3.3	32	3.41	7	5.21	48	3.40	7	5.20
III	30	4.0	8	6.0	15	4.00	5	4.5	10	2.0	4	3.0	20	2.13	5	3.57	10	1.3	4	2.65	26	2.77	7	4.89	46	3.06	7	5.03
IV	32	4.26	8	6.13	16	4.27	6	5.14	12	2.4	4	3.2	20	2.13	5	4.07	11	1.47	4	2.74	28	2.99	7	5.0	41	2.73	7	4.87
V	36	4.8	8	6.4	28	7.47	5	6.24	27	5.4	5	5.2	22	2.35	6	4.18	11	1.47	4	2.74	22	2.35	7	4.68	44	3.24	7	5.12
VI	37	4.93	9	6.97	32	8.53	7	7.77	30	6.0	8	7.0	26	2.77	6	4.39	12	1.6	4	2.8	26	2.77	7	4.89	40	2.70	7	4.85

R- Average whole sale rate in local market (Rs./kg); Y- Average observed yield (kg/tree); EV- Economic value; EW- Average; EV assigned by experts; E- Economic Score

Table 4 : Relative Priority score (P) of different fruit species under different agro-ecological situations

Agro-ecological situation	Mango			Litchi			Citrus			Guava			Loquat			Papaya			Aonla		
	F	E	P	F	E	P	F	E	P	F	E	P	F	E	P	F	E	P	F	E	P
I	1.7	7.4	4.55	5.5	8.8	7.15	6.8	7.4	7.1	8.7	4.6	6.65	9.9	4.33	7.1	1.3	5.1	3.2	5.1	4.98	5.04
II	2.05	6.4	4.25	4.6	6.97	5.79	8.6	5.2	6.9	9.0	4.18	6.59	10.0	3.3	6.65	2.1	5.21	3.66	6.7	5.20	5.95
III	7.6	6.0	6.8	8.1	4.5	6.3	9.6	3.0	6.3	9.8	3.57	6.68	10.0	2.65	6.33	8.0	4.89	6.45	9.1	5.03	7.06
IV	7.9	6.13	7.01	7.6	5.14	6.37	9.6	3.2	6.4	9.9	4.07	6.99	10.0	2.74	6.37	9.0	5.0	7.0	9.1	4.87	6.99
V	3.2	6.4	4.8	3.5	6.24	4.87	7.8	5.2	6.5	8.8	4.18	6.48	10.0	2.74	6.37	2.3	4.68	3.49	7.35	5.12	6.23
VI	1.25	6.97	4.11	5.15	7.77	6.46	6.2	7.0	6.6	7.2	4.39	5.80	9.7	2.8	6.4	1.0	4.89	2.95	5.2	4.85	5.03

F- Frost damage score; E- Economic score; P- Priority score

Table 5 : Different fruit species in the descending order of the priority for different agro-ecological situations

Agro-ecological situation	Descending order of priority of different sub-tropical fruit species
I	Litchi, Citrus, Loquat, Guava, Aonla, Mango, Papaya
II	Citrus, Loquat, Guava, Litchi, Aonla, Mango, Papaya
III	Aonla, Mango, Guava , Papaya, Loquat, Citrus, Litchi
IV	Mango, Papaya, Aonla, Guava, Citrus, Litchi, Loquat
V	Citrus, Guava, Loquat, Litchi, Aonla, Mango, Papaya
VI	Citrus, Litchi, Loquat, Guava, Aonla, Mango, Papaya

Further studies were concentrated on these AES. At each AES there were selected ten fruiting orchards of sub-tropical fruit species (mango, litchi, citrus, guava, loquat, papaya and aonla). In each orchard, randomly, there were selected ten plants and the average value of these plants comprised a unit of observation. The sampling procedures adopted during the studies were as described by Gupta and Kapoor[5]. The prioritization techniques adopted were based on the methods described by Rao[7]. In order to prioritize the different fruit species for a specific site, the data were collected on frost damage to the young and mature plants. Each species was assigned frost damage score for each AES. The frost damage score was calculated as follows:

Frost Damage Score (F) = [100-(M+D)/2]/10

M = % mortality observed in young plantations due to frost

D = % Damage observed to the bearing orchards due to frost

Economic Score (E) = (EV+EW)/2

EV (Economic Value) = (Y×R)/75

Y = Average observed yield (kg/plant) of the species at a particular AES

R = Average whole sale rate (Rs/kg) of the fruits

EW = Average EV assigned to different species by 5 experts

Priority Score (P) = (F+E)/2 i.e. average of Frost damage score and Economic score.

In the above defined equations different constant values have been used to fit each score to the scale of 0 to 10. More emphasis on the average values were given in order to minimize the systematic error, if any, present in the observations.

It is evident from the frost score table (Table 2) that loquat, citrus and guava were the crops which were least affected by frost whereas papaya and mango were the crops which were badly affected. AES-I, II, V & VI were frost prone whereas AES-III & IV were least affected by the frost. As far as the economic score of different fruit species was concerned it was observed that litchi, mango and citrus were having greater economic importance in comparison to papaya, loquat, guava and aonla. Perhaps, it might be the reason that people use to plant mango and litchi again and again ignoring the damages incurred due to frost. On the basis of frost damage score of the species and the economic value of these species the priority scores (P) for different species under agro-ecological conditions has been presented in Table 4.

Conclusion

From the above discussed observations it can be concluded that: at situations which are low lying and highly frost sensitive — Litchi, Citrus, Loquat and Guava should be considered at priority; lower ends of the hill/hillock slopes which experience medium to high frost should be preferred for Citrus, Loquat, Guava and Litchi; the upper portion of the slopes (both low and higher altitude areas) which experience low or no frost should get priority for Aonla, Mango, Guava and Papaya; top area of the hills or hillocks which are relatively frost free should be preferred for Mango, Papaya, Aonla and Guava. The basin areas at higher altitudes (nearest basin altitude >600m) should be preferred for Citrus, Litchi, Loquat and Guava whereas at the lower portion of slopes at the higher altitudes (nearest basin altitude >600m) should be given priority for Citrus, Guava, Loquat and Litchi. The above said findings can play a critical role in micro planning of the low hill region of Himachal Pradesh, which is highly frost sensitive and suffer huge economic loss due to frost every year. These findings can be further strengthen by taking in to consideration the low chilling temperate fruits under these sub-tropical conditions, the prioritization work for these crops has already been conducted by us[8].

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