Delineation of Frost Prone Agro-ecological Situations and Fruit Crops Prioritization for the Subtropical Himalayan Region of Himachal Pradesh

Shashi K. Sharma, K. S. Verma, Preet Pratima, Ajay Banyal

Dr Y. S. Parmar University of Horticulture and Forestry
College of Horticulture and Forestry Hamirpur at Neri
P.O. Khagal, Distt. Hamirpur (HP) – 177001, India

Abstract- Despite **of being subtropical the lower Himalayan region (28° 57' to 33°12' N latitude and 75°47' to 80° 08'E longitude) is suboptimal for subtropical fruit growing due to prevalence of intense winter and frost. Studies conducted (during the years 2006 to 2013) have revealed that there occurred high inter-annual variation in frost induced damage to the fruit crop species in the region. Intensity of low temperature rather than persistence of low temperature were found to be associated more to the damage caused. The entire subtropical Himalayan region has been delineated into four agro-ecological situations depending upon the observance of frost intensity and productivity status. Relative order of priority of the fruit crops for different agro-ecological situations have been worked out depending upon the economic score and frost damage score. High order of priority has been observed for pomegranate under frosty conditions whereas for mango under non-frosty or mild frosty conditions.**

Key words: frost damage score, prioritization, fruit Crop, shiwalik Himalayas, soil productivity.

I.INTRODUCTION

Commercial importance of many of the tropical species like mango, papaya, banana, litchi, aonla etc. has extended the cultivation of these fruit crops just into the Himalayan region. In the region, these fruits mature at the time when they are over from the lower plains. In natural habitat plants are rarely injured by climatic stresses as they have evolved adaptive physiological mechanisms that permit them to escape the abiotic stresses. But, under non-habitat conditions these plants suffer heavy damages due to exposure to abiotic conditions beyond the cardinal limits. Lower Himalayan region though has been classified as subtropical [1], but has been found to be suboptimal for subtropical fruit growing due to intense winter cold. Despite of this fact there has been observed considerable increase in area under subtropical fruits in this region due to the fact that these fruits mature in the region at the time when it is over from the lower plains, the growers therefore get handsome price for their produce.

The North-West Himalayan ranges (28° 57' to 33°12' N latitude and 75°47' to 80° 08'E longitude) are diverse as these 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 which gradually arise from plains of NW India and goes on attaining height of 300m to around 1100m above mean sea level with an average altitude of about 700m. Owing to these topographical conditions, surface temperature inversion and frost are the phenomena of common occurrence during winters. Therefore, subtropical fruit growing always remain under serious threat of frost induced freezing during the winters. Unlike the temperate species, the evergreen broad leaved subtropical or tropical species lack the intrinsic mechanism to fight the sever winters and frost [2]. During a frost event, damage to the crops occurs typically through cellular dehydration and/or rupturing of cell membranes due to inelastic expansion caused by the ice crystals. Therefore, more economic losses are being caused by frost in the region than any other meteorological factor.

Avoidance of the potential threat is one of the best mechanisms to combat the problem of frost induced freezing. Therefore, efforts have been made to delineate the areas with potential threat and to prioritize the suitable fruit crops for the different agro-ecological situations of the zone.

II .MATERIAL AND METHODS

The systematic studies were started during the year 2006 in the subtropical Himalayan region of Himachal Pradesh having geographical coordinates of 28° 57' to 33° 12' N latitude and 75° 47' to 80° 08'E longitudes. Initially, there were selected two locations (one below and one above 700m, the mean altitude of the region) for meteorological observations and *in- vivo* frost damage assessment. The meteorological observations were recorded with the help of MADGE-TECH, RHTemp101 data loggers and Medgetech 2.0.05 software. Papaya, mango and pomegranate, the highly frost sensitive, medium frost sensitive and low frost sensitive indicator fruit crops [3] were selected for frost damage assessment. Overall frost sensitivity observed during the different years of study was quantified in the form of frost damage score which was calculated with partial modification to the method described by Sharma and Badiyala [3] as:

Frost Damage Score (FDS) = [{(M+D)/2}/10]

Where, M = %mortality observed in young plantations due to frost
D = % damage observed to the bearing orchards due to frost

FDS for individual site was calculated by averaging the score of indicator fruit species i.e. Papaya, Mango and Pomegranate.

For delineation of different agro-ecological situations for frost sensitivity and fruit crop production potential initially (during the year 2009) there selected ten experimental sites (5 below altitude of 700m and eight above 700m) with broad topographical variations viz: Low lying basin area, lower and upper portion the hill slope, top of the hill or hillock and northern aspect of the slope. There were selected three replications for the each site having almost similar type of topography and productivity.

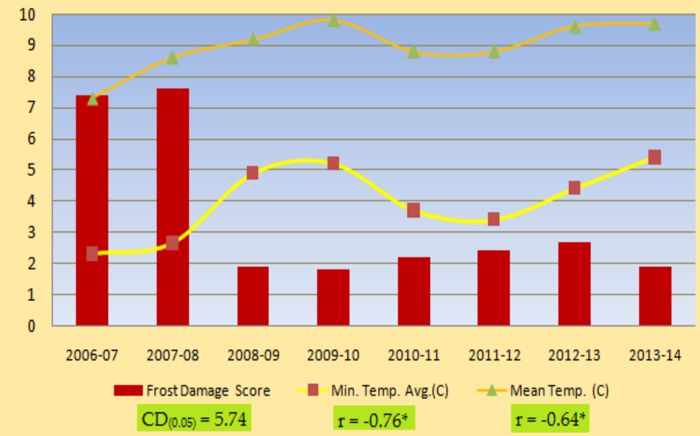
Productivity status of the sites was accessed as per soil organic carbon status, which has been established to be integrally associated to many soil quality indicators and is arguably the most significant single indicator of soil quality and productivity [4, 5, 6,7]. Random sampling of the soil at each site was done and the organic carbon status was accessed as per the procedure described by Walkley and Black [8] and Negi and Gupta [9]. Productivity score (PS) was assigned as 1/10th of the soil organic carbon status of the soil. Further, Site Score (SS) was arrived at by the sum total of FDS and PS. On the basis of critical difference in the site score values at five percent level of significance, different Agro-ecological situations (AES) were defined. The sites with non significant critical difference in site score value were grouped together into a single AES.

In order to work out the order of priority of different fruit species under different AES, the survey and sampling work was done in accordance to the procedures laid by Gupta and Kapoor [10] and all the pooling and statistical analysis of data were done as per standard procedure described by Gupta and Gupta [11] and Chandel [12]. On the basis of FDS and Economic Score (EC) calculated for different fruit species under different AESs' the priority score of different species was worked out as described by Rao [13]. The EC was calculated as per method described by Sharma and Badiyala [3].

III. RESULT AND DISCUSSION

The intensity of low temperature and subsequent frost damage was observed to be variable for the different years of observation (Fig. I). The highest frost damage score (FDS) was observed for the years 2006-07 and 2007-08 where as for the rest of the period of observations the frost damage was almost of same intensity. Daily mean temperature and the minimum temperature were also observed lowest for the years 2006-07 and 2007-08. The FDS was found to be more positively correlated with the minimum temperature observed than the mean daily mean temperature. It can therefore be inferred that

Figure 1. Yearly variation in frost damage score average and temprature parameters observed under subtropical Himalayan region



frost damage was found to be a function more of the minimum temperature lesser of the daily mean temperature. It implies that duration of low temperature is not as important as the minimum observed temperature is for causing frost damage to the fruit plant species. These findings are in close proximity with those of Soleimani et al. [14] who through the electrolyte leakage studies reported that damage caused due to frost induced freezing is highly influenced by the daily minimum temperature, air humidity, light exposure and other meteorological factors. Sharma [15] also reported minimum temperature as a critical factor for frost induced freezing and used this parameter for developing 'S-frost protection guide chart'.

The data on descriptive features of different sites under study has been presented in Table 1. It is evident from the data that at all the sites highest FDS was recorded for papaya followed by mango and pomegranate as per the earlier findings of Sharma [16]. The average FDS was observed highest for site 1 followed by site 2 and 4 at the lower elevations. At the higher elevation (>700m) it was highest for low lying basin areas followed by lower end of hilly slope followed by Northern aspect. The intensity of frost was comparatively lower at higher elevation sites than the low lying areas. Altitudinal variation in occurrence of frost has also been reported by Altitudinal variation in frost intensity has also been mentioned by Sharma and Badiyala [3] who narrated that in the valley areas the highest intensity of frost was observed upto 40 to 80m above the lowest exit point of a watershed. There was observed medium to low degree of frost in areas which were high in altitude (the basin level >700m). The hill slopes comparatively remain 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 [17].

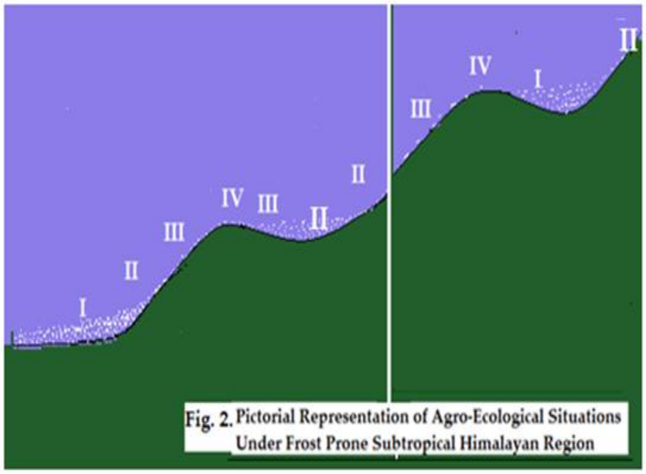


Fig. 2. Pictorial Representation of Agro-Ecological Situations Under Frost Prone Subtropical Himalayan Region

Strong temperature inversion in the low hill and valley regions has also been reported by Synder [18] and GRDC [19].

During the studies it has been observed that low lying areas were comparatively more productive than the upper and lower portion of the slopes (Table 1). It might be due to the fact that slopes of the hills they get washed off with the runoff water reducing the productivity status of the soils. The productivity status of the soils was also found to be better on the northern slopes may be due to slower decomposition of organic matter. At higher altitude also the productivity level was found to be better than that on the slopes of lower altitude areas. In both the cases it might be due to persistence of lower temperature for longer time on the northern slopes and higher elevations which might have resulted in slower decomposition of organic matter.

On the basis of site score there have been found four distinct agro-ecological situations in the entire low hill and valley region of Himachal Pradesh. These newly defined agroecological situation have been depicted pictorially in Fig. 2. From the data presented in table 2 it can be observed that highest mortality in young and commercial bearing orchards was observed in papaya thereby the it was having the highest frost damage score. Among the subtropical fruit species loquat was least affected whereas all the low chill requiring temperate fruit species like peach, pear and pomegranate were rarely affected by frost at different AES. At AES –I the lowest frost damage score was recorded for pear, loquat, peach and pomegranate (in case of peach and pomegranate sporadic damage to some extent was observed at highly frost sensitive locations). Similar type of trend was observed at AES-II. At AES –III and IV most of the low chilling fruit species were not at all affected by frost. Some was highest for mango, papaya, aonla and guava where as at AES – IV highest EV was calculated for mango, papaya, citrus and guava. The priority score derived on the basis of the FDS and EV has been presented in Table 3.

Table 3. Relative order of priority of different fruit crops worked out for different agro-ecological situations

AES	Descending order of priority of different subtropical fruit species
I	Pomegranate, Citrus(Kinnow, Sweet Orange), Peach, Litchi, Pear, Loquat
II	Pomegranate, Peach, Pear, Guava, Citrus (Kinnow, Sweet Orange), Litchi
III	Mango, Guava , Papaya, Aonla, Pear, Peach, Citrus(Lime, Lemon), Loquat
IV	Mango, Papaya, Guava, Aonla, Pear, Pomegranate, Citrus(Lime, Lemon)

level of damage was observed for different subtropical fruit species. As far as the economic value of the fruit species were concerned, at AES – I highest EV was estimated for Litchi followed by Citrus and Mango; at AES – II it was highest for pomegranate, litchi and mango; at AES – III it Order of priority presented above depicts that for the frost prone locations emphasis should be given to pomegranate. In the low lying basin areas the second priority should be given for citrus whereas on the slopes peach should be preferred over citrus. Mango may be considered as the priority crop for the middle and upper portion of the slopes which experience low levels of frost. After mango it is the guava which should be given priority in the low frost regions but at the top of the hills or hillocks which are comparatively frost free papaya can be given due priority. The finding presented over here are in close conformity with those of Sharma and Badiyala [20] who narrated mango and guava as the important subtropical crops for the rainfed frost free areas of Himachal Pradesh.

CONCLUSION

From the results discussed above it can be concluded that frost is a highly variable meteorological event and besides being influenced by topographical features the damage caused by it is highly dependent on the daily minimum temperature observed. Highest damage due to frost induced freezing has been observed in the low lying basin areas whereas the higher reaches of the slopes were comparatively frost free; the general productivity of the sites was found to be opposite to it. The entire subtropical zone was categorized into four agro-ecological situations and relative order of priority of fruit species for each AES was found to be Pomegranate, Citrus (Kinnow, Sweet Orange), Peach; Pomegranate, Peach, Pear; Mango, Guava , Papaya and Mango, Papaya, Guava respectively.

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Table 1. Descriptive features of selected frost prone sites

Site	Altitude (m)	Topography	Frost Damage score				Organic carbon status (t/ha)	Productivity Score (PS)	Site Score (FDS+PS)	AES No. Assigned
			Papaya	Mango	Pomegranate	Mean (FDS)				
1	<700	Basin area	9.9	8.9	4.1	7.6	46	4.6	12.2	I
2		Lower end of slope	9.1	7.1	2.1	6.1	35	3.5	9.6	II
3		Upper portion of slope	6.3	4.2	0.0	3.5	31	3.1	6.6	III
4		Northern aspect of slope	8.4	5.2	1.2	4.9	39	3.9	8.8	II
5		Top of the hill/ hillock	5.1	2.3	0.0	2.5	33	3.3	5.8	IV
6	>700	Basin area	9.9	7.1	1.9	6.3	34	3.4	9.7	II
7		Lower end of slope	7.4	6.4	2.2	5.3	36	3.6	8.9	II
8		Upper portion of slope	5.4	3.1	1.2	3.2	30	3.0	6.2	III
9		Northern aspect of slope	7.3	5.0	2.1	4.8	40	4.0	8.8	II
10		Top of the hill/ hillock	4.5	2.2	0.6	2.4	37	3.7	6.1	IV
	$CD_{(0.05)}$	-	1.7	2.0	2.6	1.23	3.6	1.01	1.24	

Table 2. Priority Score of different fruit species growing under different AES

		Frost Damage Score			Economic Score				Priority Score
AES	Fruit Crop	M	D	F	Y	EV	EW	E	P
I	Mango	64	42	5.3	36	4.8	8.2	6.5	4.3
	Litchi	46	44	4.5	36	9.6	8	8.8	7.2
	Citrus	18	14	1.6	34	6.8	8.4	7.6	8.0
	Guava	16	10	1.3	30	3.2	6	4.6	6.7
	Loquat	2	0	0.1	20	2.7	5.5	4.1	7.0
	Papaya	92	84	8.8	30	3.2	7	5.1	3.2
	Pomegranate	32	18	2.5	22	12	8.5	10	8.8
	Peach	0	1.2	0.1	30	4	7.6	5.8	7.9
	Pear	0	0	0	40	5.3	3.1	4.2	7.1
	Aonla	56	42	4.9	42	3	3.2	3.1	4.1
II	Mango	57	26	4.2	36	4.8	8	6.4	6.1
	Litchi	32	22	2.7	26	6.9	5.4	6.2	6.8
	Citrus	10	4	0.7	22	4.4	4.8	4.6	7.0
	Guava	4	6	0.5	22	2.4	6.8	4.6	7.1
	Loquat	0	0	0	12	1.6	5	3.3	6.7
	Papaya	86	72	7.9	32	3.4	7	5.2	3.7
	Pomegranate	10	6	0.8	18	9.6	5.2	7.4	8.2
	Peach	0	0	0	25	3.3	7.9	5.6	7.8
	Pear	0	0	0	32	4.3	4.9	4.6	7.3
	Aonla	42	24	3.3	48	3.4	3	3.2	5.0
III	Mango	18	9	1.4	30	4	8	6	7.3
	Litchi	11	8	1	15	4	2.4	3.2	6.1
	Citrus	4	0	0.2	10	2	4	3	6.4
	Guava	2	0	0.1	20	2.1	5.1	3.6	6.8
	Loquat	0	0	0	10	1.3	4	2.7	6.4
	Papaya	43	32	3.8	30	3.2	8.8	6	6.6
	Pomegranate	0	0	0	12	5.4	1.6	3.5	6.3
	Peach	0	0	0	21	2.8	2.8	2.8	6.4
	Pear	0	0	0	25	3.3	2.7	3	6.5
	Aonla	12	6	0.9	46	3.1	4.6	3.9	6.5
IV	Mango	9	4	0.7	32	4.3	8	6.1	7.7
	Litchi	10	14	1.2	16	4.3	2	3	5.9
	Citrus	4	0	0.2	12	2.4	4.8	3.6	6.4
	Guava	1	0	0.1	20	2.1	5.1	3.6	6.8
	Loquat	0	0	0	11	1.5	1.5	1.5	5.8
	Papaya	34	26	3	30	3.2	8.8	6	6.9
	Pomegranate	0	0	0	10	4.3	1.1	2.7	6.4
	Peach	0	0	0	24	3.2	1.8	2.5	6.2
	Pear	0	0	0	25	3.3	2.7	3	6.5
	Aonla	10	8	0.9	41	2.7	5.3	4	6.6

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