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Low Temperature and Cold Drought Risks in Crop Production in Temperate Kashmir

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Temperature plays a vital role in life processes and crop production. Physical and chemical processes within plants are temperature dependent; these processes in turn control biological reactions in crop plants. Temperature also plays a significant role in some aspects of crop physiological cycles: the diffusion rate of gases and liquids changes with temperature; the solubility of substances is temperature dependent; rapid progress occurs as a result of temperature increases; and the equilibrium and stability of various systems and compounds (including enzymes) is a function of temperature.

Air temperature at the screen level is one of the most important variables affecting crop production in temperate Kashmir. Most crop plants are injured or killed by low night temperatures, especially those plants that are growing rapidly or flowering. Low temperature in combination with wet soil may result in the accumulation of harmful products in plant cells while low temperature coupled with water shortage results in cold drought.

A drought-like situation existed in the latter half of 1998 in temperate Kashmir. Because of decreased rainfall from September onward, when minimum temperature was rapidly decreasing, a cold drought-like situation prevailed, resulting in crop damage. Our earlier analysis had indicated higher reliability in forecasting changes in minimum temperatures (Hasan and Kanth, 1997) and also a significant variability in weekly/monthly precipitation (Hasan, 1997). However, a very unusual situation arose in 1998 when both precipitation and minimum temperature were surprisingly low. We therefore made an objective analysis of the historical weather information available to us.

In the present study, weekly and monthly mean minimum temperature and total precipitation for 1983–97 (15 years) at Shalimar (1,587 m) have been used. The 15-year means have been compared with the data for 1998 (Figures 1 and 2). The “low temperature frequency” analysis has been carried out for 1983–98. The frequency distribution has been done for the number of times that weekly mean minimum temperature was reduced by more than 1°C, compared to the previous week. Finally, the summarized forecast verification analysis (1995–98) for temperature changes is also given to characterize the weather of this region.

The minimum temperature profile is given in Table 1. It indicates extremes of daily minimum temperature (-13.6°C for January 20, 1991, and 24°C for August 1, 1983). The lowest weekly mean minimum temperature is known to occur between the 48th and 5th standard meteorological weeks (SMW)—i.e., during the months of December and January. Favorable and higher minimum temperatures have been recorded between SMW 29 and SMW 33 (i.e.,

1. Lowest weekly mean ever	-7.8°C (SMW 2)
2. Highest weekly mean ever	21.4°C (SMW 31)
3. Lowest weekly means	-2.43 to 0.08°C between SMW 48 and SMW 6
4. Highest weekly means	18.1 to 18.63°C between SMW 29 and SMW 33
5. Lowest average weekly mean, 1983-97	-2.43°C (SMW 4)
6. Highest average weekly mean,1983-97	18.63°C (SMW 31)
7. Lowest daily ever	-13.6°C (Jan. 20, 1991)
8. Highest daily ever	24.0°C (Aug. 1, 1983)

Table 1. Minimum temperature profile at Shalimar (1,587 m) during 1983–97.

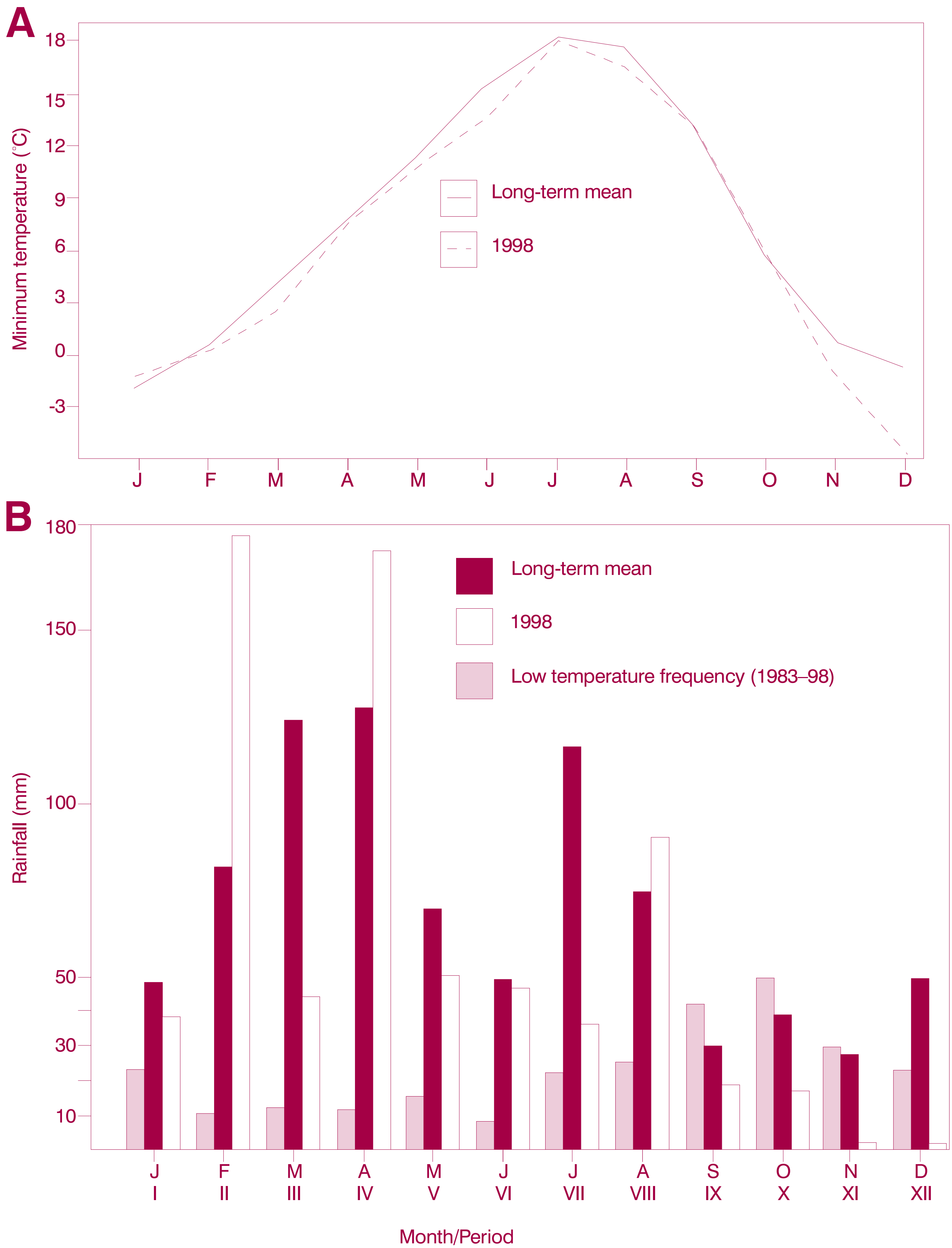

Figure 1. Minimum temperature and rainfall in relation to the long-term mean at Shalimar (1,587 m), Kashmir, India.

mid-July to mid-August). Low temperature frequency analysis for 1983–98 showed minimum frequencies for reduction in minimum temperatures by more than 1°C during June and maximum frequencies during October. Periods V and VII (Figure 1b), corresponding to the months of May and July, do have higher frequencies. During May, the rice crop is in the nursery stage, while in July it completes tillering to enter into the panicle initiation/flowering stages. With such a historical profile for minimum temperature, let us consider further the weekly/monthly behavior of minimum temperature and precipitation during 1998 in relation to the long-term means (Figures 1 and 2). It is clearly evident that 1998 witnessed lower mean monthly minimum temperatures and precipitation, compared to the long-term mean (Figure 1). Likewise, all months except February, April, and August had deficient precipitation, and November and December did not receive any precipitation. A cold drought thus prevailed from SMW 44 on (Figure 2), which proved quite damaging to rabi (winter) crops like rapeseed-mustard. Moreover, the low inherent soil moisture led to poor crop growth, thereby increasing the crops' susceptibility to low temperature damage. Table 2 gives the comparative resistance of crops to sub-zero temperature regimes. It is quite evident from the table that crops are very susceptible to low temperatures during flowering. A study in

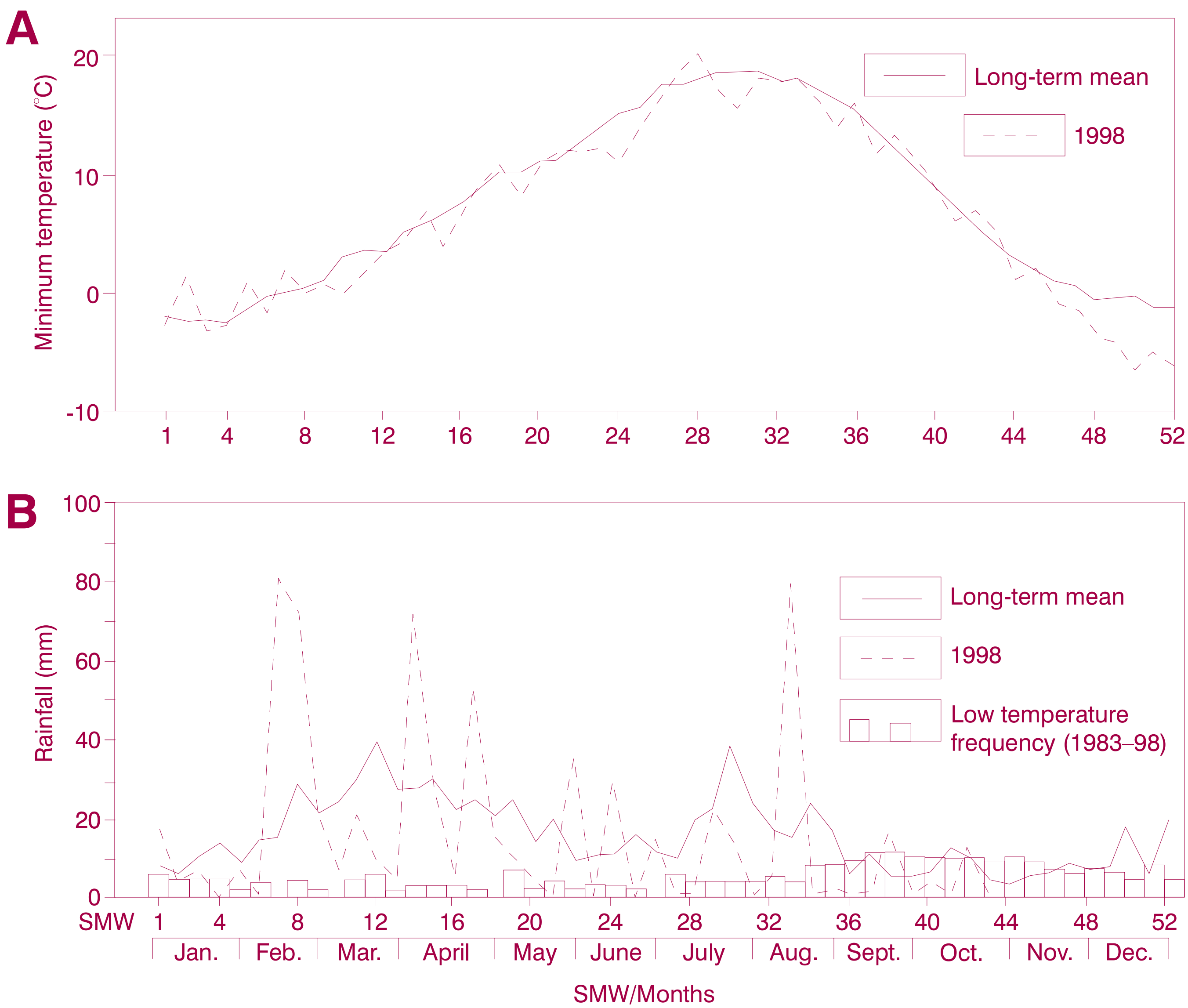

Figure 2. Minimum temperature and precipitation during 1998, in relation to the long-term mean at Shalimar (1,587 m), Kashmir, India (on a weekly basis).

	Temperature (°C) harmful to plant during:					
	Germination		Flowering		Fruiting	
Highest resistance to frost						
Spring wheat	-9	-10	-1	-2	-2	-4
Oats	-8	-9	-1	-2	-2	-4
Peas	-7	-8	-2	-3	-2	-4
Lentils	-7	-8	-2	-3	-2	-4
Resistance to frost						
Beans	-5	-6	-2	-3	-3	-4
White mustard	-4	-6	-2	-3	-3	-4
Turnip	-6	-7	–	–	–	–
Medium resistance to frost						
Soyabeans	-3	-4	-2	-3	-2	-3
Low resistance to frost						
Corn	-2	-3	-1	-2	-2	-3
Potatoes	-2	-3	-1	-2	-1	-2
No resistance to frost						
Rice	-0.5	-1	-0.5	-1	-1	–
Tomatoes	0	-1	0	-1	0	-1

Source: Ventskevich, 1961

Table 2. Resistance of crops to frost in different phases.

France by Lardon and Triboi-Blondel (1995) revealed that freeze and cold treatments in winter rapeseed at the beginning of the flowering period (day/night: 7°/0°C) induced major modifications in plant yield architecture by overcompensating certain yield components. Ram and Singh (1995) studied low temperature risks to cool season crops under Hisar (India) conditions by analyzing 24 years of meteorological data and suggested adjustments in sowing dates so that the crop reaches the double ridge/floral bud initiation stage after January 28 (since the risk of temperatures of less than 2°C at screen level is 45–65% between January 1 and January 28) and maturity/harvesting before March 19.

The forecast verification analysis (Table 3) showed more reliable forecasting for changes in minimum temperature compared to maximum temperature. Furthermore, the seasonal analysis indicated a better forecast reliability for changes in minimum temperatures for summer months than for winter months (during 1995–96 and 1996–97). Thus, when minimum temperatures were drastically reduced during winter months, changes in minimum temperature could not be reliably forecasted for 2 of the 3 years, indicating a probable risk to crop production in temperate Kashmir.

To find a solution to the problem of low temperature risks to crops and for a better understanding of temperature trends expected, we have undertaken a daily low temperature probability analysis by fitting normal distribution to the daily data of the last 18 years. The months of October to May (winter or rabi season) have been considered, and the probability of minimum temperatures below a certain level is being worked out (Table 4). Thus we shall be able to identify critical crop growth stages with associated maximum probabilities.

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I. Overall picture of usable forecasts (%)

T_{max} parameter	1995–96 (120 reports)			1996–97 (99 reports)			1997–98 (84 reports)		
	Total usable	Summer	Winter	Total usable	Summer	Winter	Total usable	Summer	Winter
T_{max}	55	59	67	57	53	60	52	47	62
T_{min}	71	78	74	70	59	81	66	69	62

II. Correlation between forecasted and actual temperatures

Parameter	1996–97			1997–98		
	Entire year	Summer	Winter	Entire year	Summer	Winter
T_{max}	—	*0.815	*0.869	**0.916	**0.86	**0.87
T_{min}	—	*0.644	*0.828	**0.930	**0.89	**0.87

*** significant at 5%; ** significant at 1%**

III. Daywise analysis (RMSE)

Parameter	1996–97						1997–98					
	Summer			Winter			Summer			Winter		
	d-1	d-2	d-3	d-1	d-2	d-3	d-1	d-2	d-3	d-1	d-2	d-3
T_{max} 2.98	3.51	2.97	2.65	3.31	4.96	4.3	4.5	2.5	3.72	3.46	3.10	
T_{min} 1.61	2.69	2.95	2.58	2.07	2.74	2.0	2.5	2.5	2.60	2.60	2.17	

RMSE = root mean square error

Table 3. Forecast verification analysis of temperature changes at Shalimar, Kashmir (India).

Months	T_{min}, °C	Probability of T_{min} (°C) regime below										
		-4	-3	-2	-1	0	1	2	4	6	8	10
January	all sub-zero	*	*	*	*	*	*					
February	-1 to 1.3	*	*	*	*	*	*					
March	0 to 10					*		*	*	*	*	
April	1-11							*	*	*	*	*
May	5 to 15							*	*	*	*	*
October	sub-zero to 12							*	*	*	*	*
November	sub-zero to 6		*	*	*	*	*					
December	sub-zero to 5		*	*	*	*	*					

*** indicates the probability determination of that particular temperature regime during the month**

Table 4. Low temperature probability analysis—minimum temperature ranges and regimes for various months