

Low Temperature and High Vapour Pressure Deficit Risks to Cool Season Crops in the Sub-tropics

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Abstract : Low temperature and high vapour pressure deficit risks has been made by using cumulative percentage frequency distribution method for judicious crop planning in cool season, on the basis of 24 year (1971-72 to 1993-94) meteorological data for Hisar, India. During the period, January 1 to 28, the risk of $<2^{\circ}\text{C}$ temperature at the screen level is 45 to 65%. This may reduce crop growth. The risk of vapour pressure deficit (>35 mb), at the ear emergence/anthesis stage, emerging from 19th March to 2nd April is 50 to 92%. As such, for the Hisar area, cultivars that reach double ridge/floral bud initiation after 28th January and maturity/harvesting before 19th March, may be selected. The date of sowing is suggested as an indicator for defining crop ideotypes that may be better adapted to altered conditions.

Key words : Temperature, vapour pressure, crops, cool season, sub-tropics, risks.

Economic risks due to weather variability are common in crop production. The decision making capacity of farmers and resource planners would be greatly enhanced, if some means of linking weather risk to strategy options are established. The risk analysis component could evaluate options and provide an interpretive summary. The empirical study was undertaken to evaluate the effect of low temperature and high vapour pressure deficit on the growth, development and production of cool season crops.

Three objectives were considered : first, to screen strategies for avoiding crop production losses under low temperature (T) and high vapour pressure deficit (VPD); second, to identify the main features of crops/cultivars that are suited to lower T during double ridge/floral bud initiation stage and higher VPD during ear emergence/anthesis; and third, to evaluate the response to date of sowing.

Materials and Methods

The data on minimum daily temperatures for a 12 week period, week 49 (Dec. 3) to 8 (Feb. 19), have been analysed to evaluate the risk of

low temperature. The minimum and maximum temperatures for seven weeks, week 9 (Feb. 26) to 15 (Apr. 9), were also analysed to assess response of VPD. The 1971-72 to 1993-94 datum period was used. Data were obtained for the agrometeorological observatory, the CCS Haryana Agricultural University, Hisar, India (Lat $29^{\circ}10'N$ and Long $75^{\circ}46'E$). The cumulative percentage frequency distribution (Porter and Miglietta, 1991) of low temperature and high VPD for selected weeks was calculated to illustrate the effect of these meteorological parameters on the growth, development and productivity of cool season crops. VPD was determined according to the following relationship (Smith, 1991):

$$(i) \text{VPD} = e_a - e_d = ((e_a(T_{\text{max}}) + e_a(T_{\text{min}}))/2) - e_d$$

where,

VPD = vapour pressure deficit (kPa)

$e_a(T_{\text{max}})$ = saturation vapour pressure at T_{max} (kPa)

$e_a(T_{\text{min}})$ = saturation vapour pressure at T_{min} (kPa)

e_d = actual vapour pressure (kPa)

(ii) Saturation vapour pressure (ea)

$$ea = 0.611 \cdot \exp [(17.27 \cdot T) / (T + 237.3)]$$

where,

ea = saturation vapour pressure (kPa)

T = maximum temperature (°C)

(iii) Actual vapour pressure (ed)

$$ed = 0.611 \cdot \exp [(17.27 \cdot T_{min}) / (T_{min} + 237.3)]$$

where,

ed = actual vapour pressure (kPa)

T = temperature (°C)

For this analysis, T base of 0°C, T optimum of 26°C and T max of 37°C were used, following Weir *et al.* (1984) for winter crops. 3 to 4 kPa (30-40 mb) was considered as the maximum values of VPD (Monteith, 1986).

Results and Discussion

Major uncertainties with respect to crop response to temperature and VPD changes in

weather exists. To screen ideotypes suited to varying weather, it is necessary to examine long term weather data to estimate VPD. For north-western India, having sub-tropical hot dry climate with monsoonal regime of rainfall, an example for Hisar, based on a 24-year weather record (1971-72 to 1993-94) is presented.

Minimum temperature

During the record period, the cumulative percentage frequency distribution of min T for the selected period of 12 weeks, commencing with the week 49 is presented in Figs. 1a and 1b, which show that in 45 to 65% of the years, the min T < 2°C occurred in weeks 1 to 4 (1-28 Jan.). The temperature <= 2°C in the screen is critical for crop growth because the canopy temperature used to be lower upto 3°C than that of the screen (Singh *et al.*, 1985, 1987, 1993). The crop growth is considerably reduced at this temperature (Weir *et al.*, 1984). A min T of 2°C in January reduces yield of winter crops

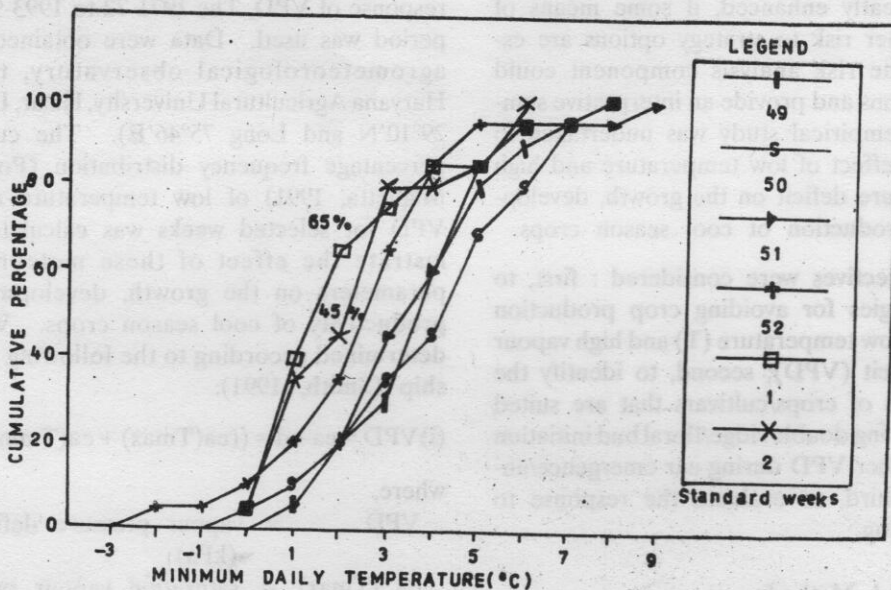


Fig. 1a. The cumulative percentage frequency distribution of the minimum daily temperatures of 49th to 2nd standard week meteorological record (1971-72 to 1993-94) of HAU, Hisar

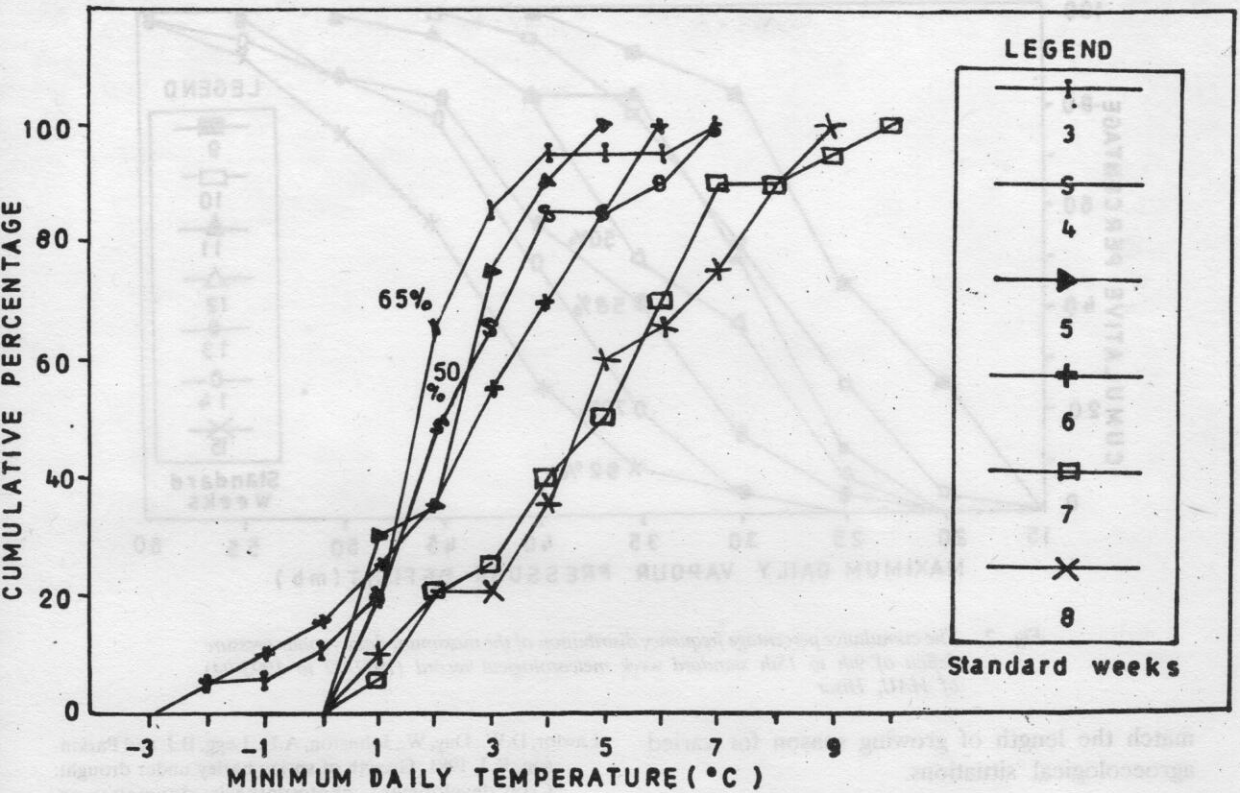


Fig. 1b. The cumulative percentage frequency distribution of the minimum daily temperatures of 3rd to 8th standard week meteorological record (1971-72 to 1993-94) of HAU, Hisar

if it occurs when crops are at double ridge/floral bud initiation stage of the apical meristem (Kirby, 1988; Morison and Butterfield, 1990). An adapted crop or its cultivar would be one that reaches double ridge/floral, but initiation during a period when min T is > 2°C. Thus, a suitable target date for double ridge/floral bud initiation to occur with a minimum risk at Hisar would be 28 January.

Maximum VPD

To analyse risk of maximum VPD for seven weeks (week 9 to week 15) on crop yields indicated that chances of > 35 mb VPD during 12 to 15 weeks (19 March to 15 April) are 50 to 92% (Fig. 2). The VPD value of 35 mb has been shown to result in drastic crop yield reduction preceding to monsoon season in India (Monteith, 1986). It has been shown by Schulze and Hall

(1982) and Ekanayke *et al.* (1994) that even an increase in VPD from 10 to 20 mb results in a 50% decrease in stomatal conductance. In Hisar conditions, the values above 35 mb, from 19 March onward can cause reduction in grain yield under water limited conditions (Lawlor *et al.*, 1981). Both the number of fertile grains and the rate of grain filling are reduced. Thus, either a farmer should have assured irrigation from the time VPD exceeds 35 mb, or cultivars be developed that are tolerant to high VPD, or the crop should reach maturity prior to the time high VPD is reached, or the sowing date may be adjusted so that maturity reaches prior to high VPD's period.

This study shows that appropriate analysis of the weather data could enable breeders, physiologists and farmers to select cultivars that

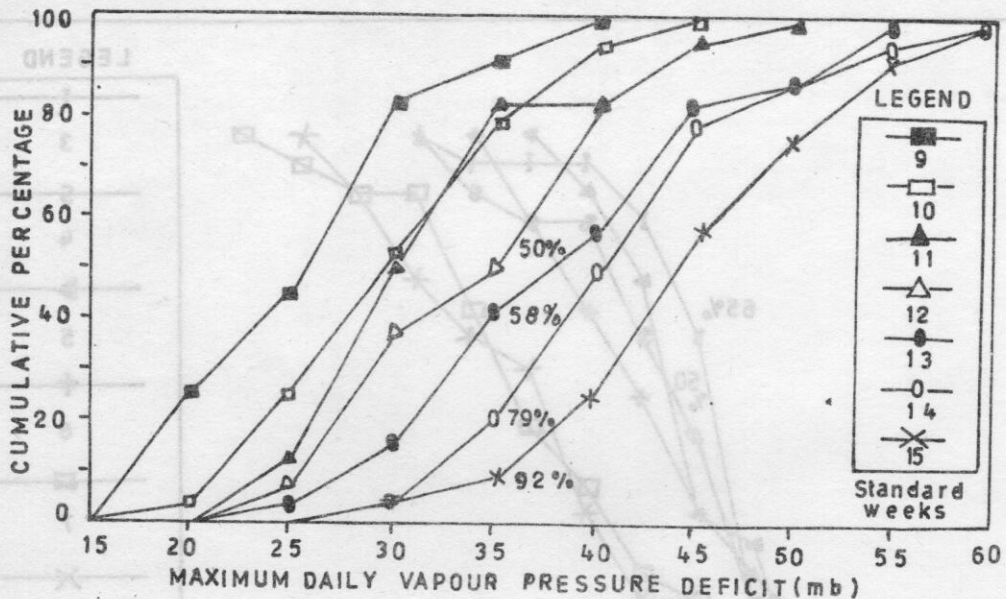


Fig. 2. The cumulative percentage frequency distribution of the maximum daily vapour pressure deficit of 9th to 15th standard week meteorological record (1971-72 to 1993-94) of HAU, Hisar

match the length of growing season for varied agroecological situations.

Conclusion

To avoid the risk of minimum temperature and maximum vapour pressure deficit, it is suggested that such a crop variety or date of sowing should be chosen so that the crop reaches double ridge/floral bud initiation stage after January 28 and maturity/harvesting before March 19 at Hisar. Significant new research initiatives are required with the objective of exploring ideotypes which suit low temperature and high vapour pressure deficit.

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