Relationship between spatial variation of weather parameters and sugarcane yield in Maharashtra and Uttar Pradesh (and Uttaranchal)

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सार – महाराष्ट्र और उत्तर प्रदेश (तथा उत्तरांचल) राज्यों में गन्ने के उत्पादन को नियंत्रित करने वाली जलवायविक स्थितियों को समझने के लिए मौसम की परिवर्तनशीलता के संबंध में स्थानिक विविधता की जांच की गई है। चूँकि इस फसल की अधिकतम बढ़ोतरी में सहायक अनुकूलतम मौसम स्थितियों के बारे में पहले ही से पता है, अतः यह भी महत्वपूर्ण है कि खेत में घासपात और सिंचाई के उपयोग द्वारा सूक्ष्म जलवायविक परिचालन हेतु अनुकूलतम मानों से बढ़ोतरी की प्रत्येक अवस्था में मौसम की स्थितियों में होने वाले परिवर्तनों का मूल्यांकन किया जाए। इस अध्ययन से यह पता चला है कि महाराष्ट्र और उत्तर प्रदेश (और उत्तरांचल) में किस प्रकार औसत मौसम प्राचलों में स्थानिक विविधता के कारण गन्ने के औसत उत्पादन की स्थानिक विविधता प्रभावित हुई। यह देखा गया कि गन्ने के उत्पादन में कमी का मुख्य कारण अधिकतम और न्यूनतम तापमान के औसत में स्थानिक विविधता रही। यह भी देखा गया कि गन्ने की फसल के उत्पादन के लिए किल्लियां फूटने और बढ़ोतरी की आरंभिक अवस्थाओं में सुबह ओर शाम की सापेक्ष आर्द्रता के औसत में स्थानिक विविधता लाभदायक रही। इसके अलावा यह भी पता चला है कि गन्ने के उत्पादन की स्थानिक विविधता में वर्षा की स्थानिक विविधता का महत्वपूर्ण योगदान रहा। उत्तर प्रदेश (और उत्तरांचल) के जिलों में अधिक वर्षा फसल की बढ़ोतरी की विभिन्न अवस्थाओं में लाभदायक रही जबकि अनुमानतः मृदा के प्रकार में विविधता और सिंचाई के संसाधनों के कारण महाराष्ट्र में बढ़ोतरी की कुछ अवस्थाओं में इसका नकारात्मक प्रभाव रहा।

ABSTRACT. Spatial variation in sugarcane production is examined in relation to weather variables to understand the role of climatic conditions controlling the yield of sugarcane in the states of Maharashtra and Uttar Pradesh (and Uttaranchal). Since a set of optimum weather conditions that are conducive for maximum rate of growth of this crop are already documented, it is also important to assess the variation of weather conditions at each of the growth phases from the optimum values for making microclimatic manipulation by using mulch and irrigations in the field. The present study has brought out how the spatial variation of mean sugarcane yield was affected due to the spatial variation of mean meteorological parameters in the state of Maharashtra and Uttar Pradesh (and Uttaranchal). It was observed that the spatial variation of mean maximum and minimum temperature played a crucial role in reducing the yield of sugarcane. It was also seen that the spatial variation of average morning and evening relative humidity at tillering and early growth stages were beneficial for sugarcane yield. Further it was found that the spatial variation of rainfall played an important role with the spatial variation of sugarcane yield. Higher rainfall in the districts of Uttar Pradesh (and Uttaranchal) had beneficial effects at all growth stages whereas it showed negative effects at some growth stages in Maharashtra presumably due to variation of soil types and irrigation resources.

Key words – Spatial variation, Sugarcane yield, Weather requirement.

1. Introduction

The first and foremost question that arises in studying the yield variation of sugarcane is why there is so much variation in yield within the state and also from state to state. Reasons could be many for such variations. The most important amongst them are: variety, soil, management practices, the climate and its variations. Keeping management practices more or less same with the high yielding varieties, the variation in yield could be explained with the climatic variation (Raheja, 1951). During the life cycle, the crop experiences extreme weather *viz.*, very high and very low temperatures at some growth stages, prolonged dry spell in non-rainy months and even during south-west monsoon season in some occasion. It also experiences long wet spell associated with very humid and hot weather at some other stages causing pest and disease infestation. Duration of bright

sunshine hours also varies from place to place due to variation of latitude and variation in cloud amount. Strong wind causes lodging and advected heat causes more desiccation. Though extreme weather conditions at some stages of growth are the major cause of reduction in yield, yet a critical evaluation of spatial variation of such weather condition for each of the growth stages would help in explaining the variation of yield within the state and from state to state.

Sugarcane being a tropical plant, its growth and yield are more sensitive to weather conditions (Kushwaha and Pal, 2000). The maximum and minimum temperature limits for its growth are generally known to be around 40° C and 10° C respectively with 30° C as optimum value (Rupkumar and Subbaramayya, 1980). It is also reported that there is a specific weather requirement for each of the growth stages of the crop (Biswas, 1988). Thus it is not only the optimum values of weather parameters but also the spatial variation of weather parameters at each of the growth stages that are equally important for the growth and development of the crop in the states of Maharashtra and Uttar Pradesh (and Uttaranchal). The objective of the present study is to understand how the spatial variation of meteorological parameters at different growth stages of the crop in different agroclimatic regions within a state and in different states in the tropical and sub-tropical belts affect the sugarcane yield.

2.   Climate of Maharashtra and Uttar Pradesh (and Uttaranchal)

The climate of Maharashtra (IMD, 1989) can be classified under three categories *viz.*, monsoon, dry and tropical rainy. The region under monsoon climate is confined to the coastal belt and the adjoining ghats (annual rainfall $\geq$ 100 cm, mean daily temperature (TT) $\geq$ 22° C except the coldest month when $TT \leq$ 22° C but above 18° C, mean daily relative humidity (RH $\geq$ 50 % for most of the months); dry climate covers the semi-arid regions of Jalgaon, Nasik, Aurangabad, Pune, Beed, Satara, Osmanabad, Kolhapur, almost whole of Dhulia, Ahmednagar, Solapur and Sangli districts (annual rainfall between 60 cm and 80 cm, mean daily $TT \geq$ 18° C and RH $\leq$ 50 %) and tropical rainy climatic region covers the part of Nasik, Jalgaon, eastern portion of Aurangabad, Beed and Osmanabad as well as remaining districts of Maharashtra and Vidarbha (annual rainfall $\leq$ 70 cms , $TT \geq$18° C and RH $\geq$ 50 % except during summer months when it is $\leq$ 30 %).

The regions of U.P. (and Uttaranchal) experience the extreme cold in winter and extreme hot in summer (IMD, 1989). May is the hottest month with the mean maximum
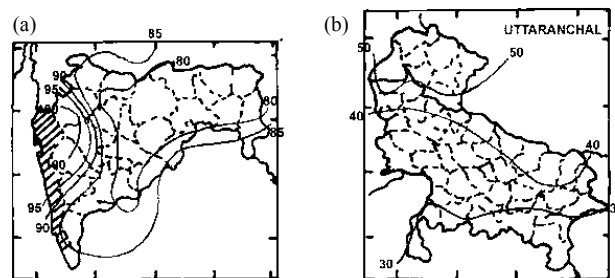
Figs. 1(a&b). Spatial variation of average yield (t/ha) in (a) Maharashtra and (b) Uttar Pradesh (and Uttaranchal) (1972-92)

temperature of 41° C in the plains, Plateau regions and elevated places recording 2 to 5° C lower temperature as compared to plains. January is the coldest month when mean minimum temperature for the plains of U.P. (and Uttaranchal) as a whole is 8.5° C varying from about 6.5° C in the west to about 10° C in the east. The relative humidity ranges between 50 to 80 % in monsoon. It is least in summer when it becomes about 20-30 % making the summer dry and hot. The total annual rainfall over the plain varies from 60 cm over the areas adjacent to east Rajasthan to 140 cm over the areas near the foothills of the Himalayas.

3.   Data used and methods

Mean meteorological and average yield data of sugarcane for 1972-1992 (21 years) for 14 districts of U.P. (and Uttaranchal) and 10 districts of Maharashtra (Statistical abstracts, 1992-93), distributed all over the respective states were considered for this study. Maximum and minimum temperature, morning humidity (RH-I), and afternoon humidity (RH-II), total sunshine hours and total rainfall during each of the crop growth stages were collected from National Data Center, IMD, Pune to study the spatial variation and impact of meteorological parameters on sugarcane yield. The weekly normals of the meteorological elements for the selected districts of the state of Maharashtra and U.P. (and Uttaranchal) were computed for the selected districts. The districts were chosen so as to represent the different agroclimatic regions of the states. The average duration of germination, tillering, early growth, active growth, elongation, maturity and harvesting is 9, 6, 4, 4, 20, 4 and 4 weeks respectively. Normally the planting is done in the 7th (12 – 18 February) standard week. Stage wise mean meteorological data for each of the crop growth stages were computed district wise and same were taken into consideration in this study. Sunshine hours and rainfall were taken as totals for each of the growth stages.
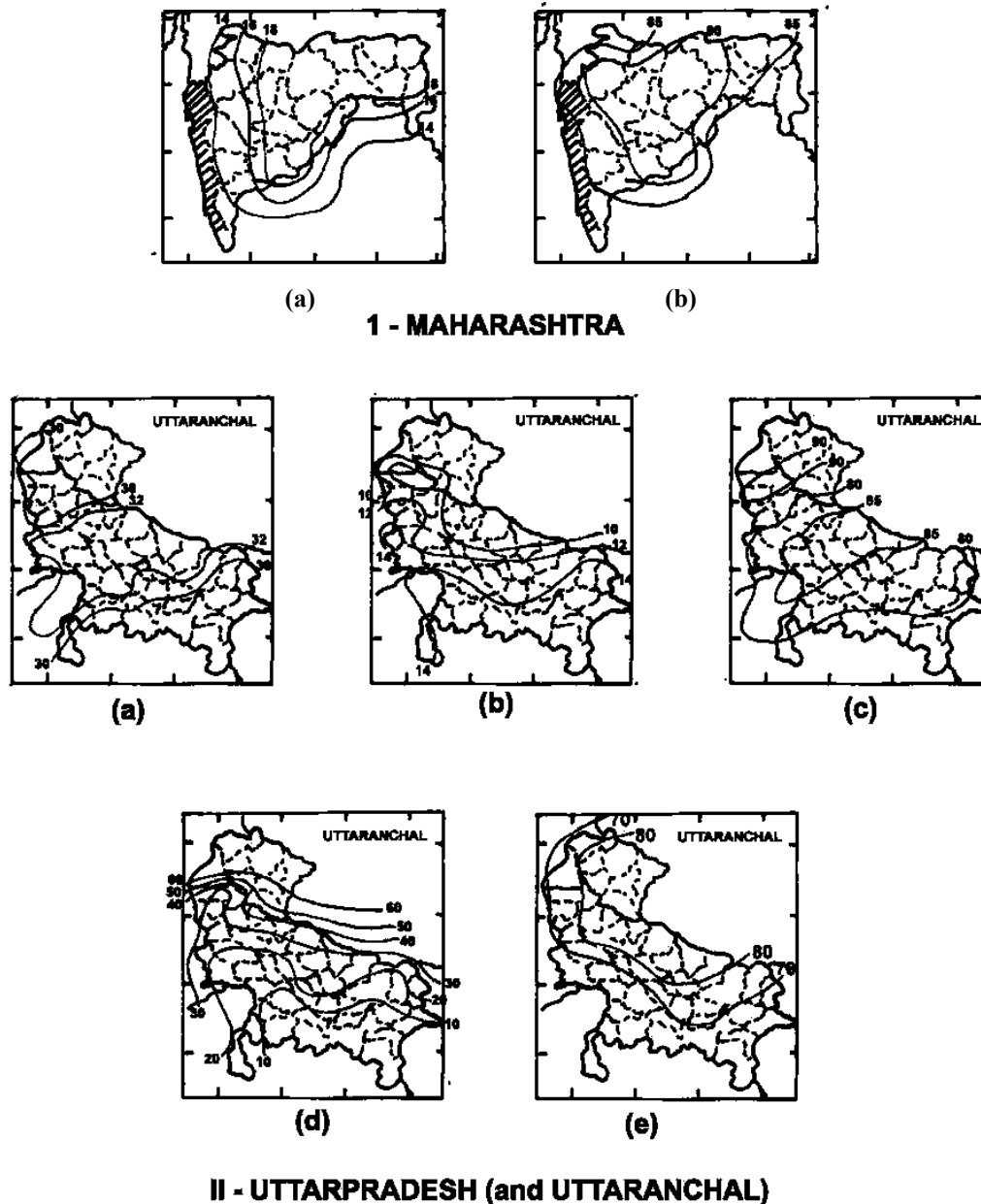
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Fig. 2. Spatial variation of meteorological parameters at germination stage

Stage wise meteorological data and sugarcane yield data were subjected to correlation analysis.

4. Results and discussion

4.1. Spatial distribution of yield

In Maharashtra higher yield (>90 t/ha) was observed in the southern, western and south-eastern districts (Avg. 64.0 to 74.0 t/ha) [Fig. 1(a)]. Yield decreased slowly towards the northeastern districts of the state. The maximum yield was observed in the districts of Niphad (99 t/ha), Pune (97.4 t/ha), Sakkarnagar (92.5 t/ha), Solapur (92.5 t/ha) and lowest yield was observed in northeastern districts of Nagpur (74.4 t/ha), Sindewahi (73.0 t/ha) and Parbhani (64.3 t/ha). Sugarcane yield ranged between 70-90 t/ha in the central part of the state.

TABLE 1

Correlation coefficients and level of significance with the predominant meteorological parameters at various growth stages of the sugarcane in Maharashtra and Uttar-Pradesh (Uttaranchal)

Stages	Max.Temp. (°C)	Min.Temp. (°C)	SSH (hrs)	Rainfall (mm)	RH-I (%)	RH-II (%)
Maharashtra						
Germination	-0.46	-0.61*	+0.34	-0.52	+0.19	-0.51
Tillering	-0.66*	-0.69*	+0.11	+0.46	+0.72**	+0.25
Early growth	-0.69*	-0.62*	+0.10	-0.54	+0.68*	+0.63*
Active growth	-0.56*	-0.59*	+0.03	-0.42	+0.12	+0.18
Elongation	-0.38	-0.62*	-0.20	-0.57*	+0.14	-0.10
Maturity	+0.16	+0.09	+0.20	-0.69*	+0.04	-0.17
Uttar-Pradesh (Uttaranchal)						
Germination	-0.57*	-0.49*	-0.45	+0.54*	+0.46*	+0.10
Tillering	-0.71**	-0.75**	-0.36	+0.20	+0.21	-0.10
Early growth	-0.54*	-0.79**	-0.35	+0.21	+0.25	+0.05
Active growth	-0.61*	-0.72**	-0.37	+0.67*	+0.54*	+0.43
Elongation	-0.72**	-0.48*	-0.12	+0.76**	+0.61*	+0.51*
Maturity	-0.54*	-0.20	-0.14	+0.67*	+0.51*	+0.42

* : Significant at 5 % level, ** : Significant at 1 % level

On the contrary higher yield was observed in the northern districts of U.P. and adjoining Uttaranchal and decreasing trend was observed in the southern districts of the U.P. [Fig. 1(b)]. The maximum yield was observed in Muzaffarnagar (51.0 t/ha), Dehradun (50.5 t/ha), Rishikesh (50.5 t/ha), Nagina (47.4 t/ha). The minimum yield was observed in the southern, South-western and south-eastern districts of U.P. *viz.*, Jhansi (34.9 t/ha), Aligarh (31.3 t/ha), Lucknow (35.8 t/ha.) and Agra (36.3 t/ha.). The spatial distribution of sugarcane yield ranged between 35 to 45 t/ha in the central part of the state. It is interesting to note that sugarcane yield was considerably lower by 30 – 50 t/ha in the state of U.P. (and Uttaranchal) as compared to that of Maharashtra situated in the tropical belt where the cane is grown mostly under assured irrigation.

4.2. *Spatial Relationship with meteorological parameters*

4.2.1. *Germination Stage*

It was observed that during germination stage the spatial distribution of T_{max} varied in a narrow range between 30 to 32° C showing increasing trend from southeastern to central regions of U.P. (and Uttaranchal) [Fig. 2 II(a)]. The correlation coefficient (CC) between the

sugarcane yield and T_{max} was found to be negatively correlated (r = - 0.57* -Table 1). The optimum T_{max} requirement during this stage was reported around 26.3° C. But average T_{max} during this stage was found to be $\geq$ 30° C. Thus the crop had experienced adverse thermal regime during germination stage. The negative CC values (Table 1) suggest that lower ranges of T_{max} in the districts of Maharashtra and U.P. (and Uttaranchal) would be beneficial to grow sugarcane.

The spatial distribution of T_{min} varied between 14 to 18° C showing the increasing trend from south-western to north-eastern regions of Maharashtra and 10 to 14° C showing the increasing trend from north-western to southern regions in U.P. (and Uttaranchal) during germination stage [Figs. 2I(a), II(b)]. The CCs between T_{min} and sugarcane yield were negatively correlated [r = -0.61* and - 0.49* for Maharashtra and U.P. (and Uttaranchal) respectively]. The sugarcane crop at its germination stage in U.P. (and Uttaranchal) experienced lower temperature ranges as compared to Maharashtra. A higher temperature range of 4 to 5° C in Maharashtra compared to that in U.P. (and Uttaranchal) enhanced quick germination and better growth in Maharashtra. Kushwaha and Pal (2000) working with sugarcane weather relationships at Pantnagar in U.P. (and Uttaranchal) also reported that the T_{min} remained below
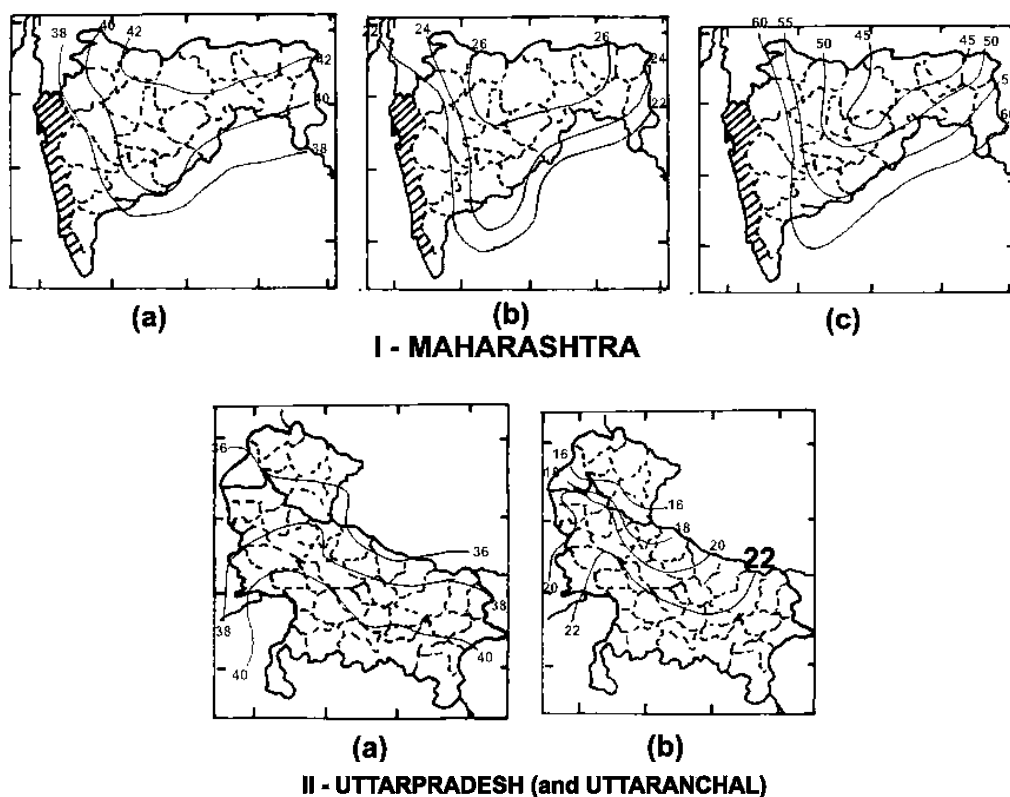
Fig. 3. Spatial variation of meteorological parameters at tillering stage

the optimum requirement for germination of sugarcane. According to Humbert (1968) temperature below 10° C suppresses the germination. This clearly indicates that proper thermal management, especially soil temperature by using suitable black colour polyethylene mulch or other mulch *viz.*, unused dry sugarcane leaves or straw, would prevent the negative soil heat flux from the soil to provide better thermal regimes.

Both in Maharashtra and U.P. (and Uttaranchal) [Figs. 2I(b), II(c)] the spatial distribution of sun shine hour (SSH) were found to vary between 85 to 90 hours and 80-90 hours showing the higher SSH in the central districts and lower values in the surrounding districts. The CC between SSH and yield of sugarcane was low but positive ($r = + 0.34$) in Maharashtra where as the CC was negative ($r = -0.45*$) in U.P. (and Uttaranchal). The CCs between SSH and yield of sugarcane at tillering, early growth, active growth, elongation and maturity stages of the crop growth in the districts of Maharashtra were 0.11, 0.10, 0.03, -0.20, and 0.20 respectively, but same for U.P. (and Uttaranchal) were -0.36, -0.35, -0.37, -0.12 and -0.14 respectively. In general, total bright SSH was more by about 5 to 10 hours at all growth stages except at active growth and elongation stages in the districts of Maharashtra in comparison to that of U.P. (and Uttaranchal). It is interesting to note that SSH was negatively and significantly correlated with the sugarcane yield only at germination stage in U.P. (and Uttaranchal). None of the other CCs between SSH and sugarcane yield were significant. In Maharashtra CCs were low but positively correlated at all growth stages except at elongation stage when CC was found negatively correlated. This shows that though SSH played the positive role towards increasing yield of sugarcane in Maharashtra yet contribution of SSH was not significant. Contrary to this non-significant and negative CCs at all the growth stages in U.P. (and Uttaranchal) clearly indicate that higher SSH in the districts of U.P. (and Uttaranchal) might have hindered the growth and ultimately lowered the yield of sugarcane, probably in combination with other constraints *viz.*, low irrigation resources, thermal stress imposed by very high or low air and soil temperature.

In U.P. (and Uttaranchal) [Fig. 2II (d)] the spatial distribution of rainfall varied between 10-60 mm from southern to northern districts. During this stage rainfall was meagre but found positive and significantly correlated ($r = + 0.54*$). Though variations in rainfall were small in
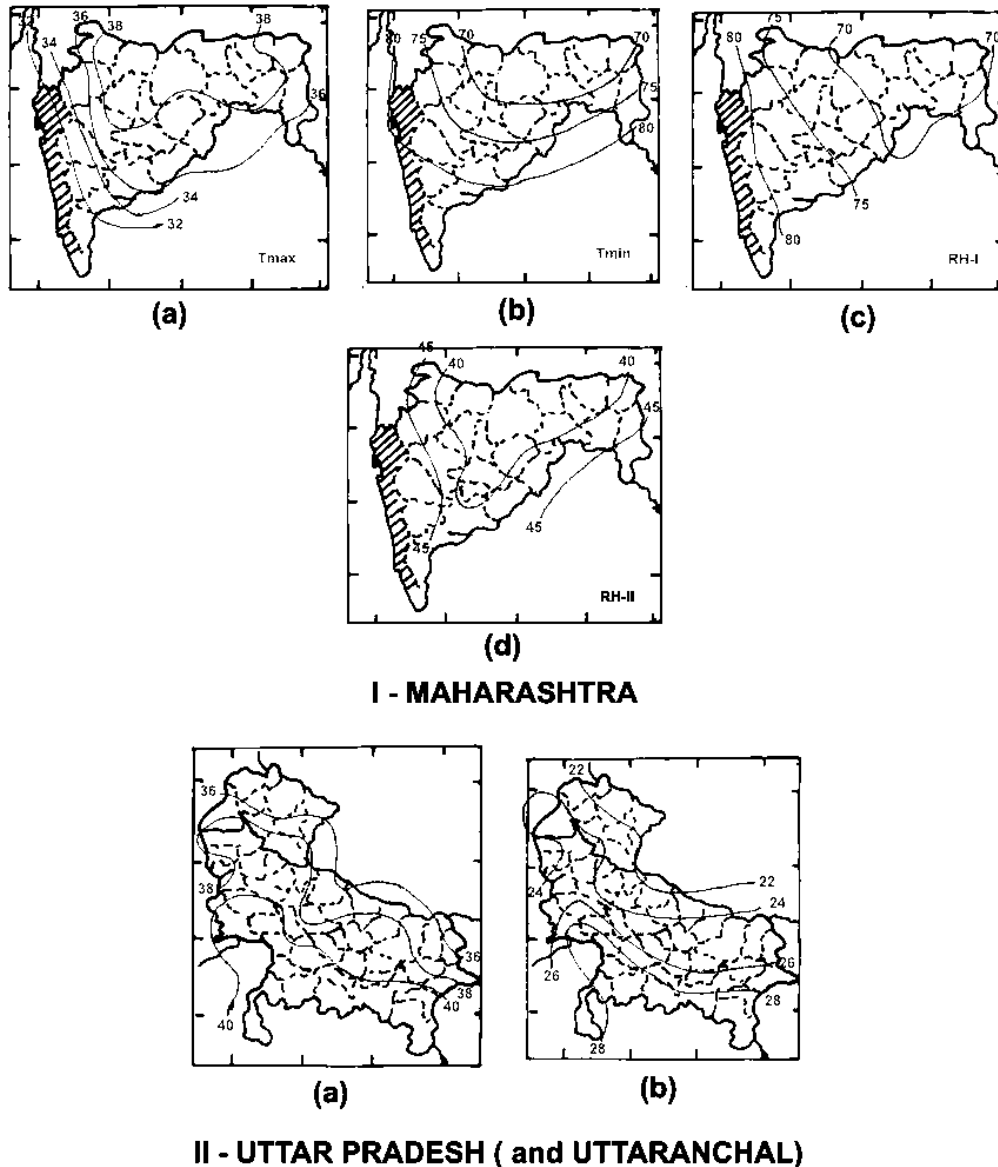
(a)   **(b)**   **(c)**

(d)

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(a)   **(b)**

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Fig. 4. Spatial variation of meteorological parameters at early growth stage

both the states yet CC values at this stage clearly indicate that even this meagre amount of rainfall was beneficial in U.P. (and Uttaranchal) whereas negative correlation in Maharashtra showed that higher rainfall did not contribute to the higher yield as the crop was under irrigation.

The spatial distribution of morning relative humidity in the state of U.P. (and Uttaranchal) varied between 70 to 80 % and showed the increasing trend from south-west to north-east regions of the states [Fig. 2II(e)]. The CC was positively correlated ($r = + 0.46^*$). The average RH-I during this stage in U.P. (and Uttaranchal) was 75 %,

about 30% higher as compared to that in the regions of Maharashtra.

4.2.2. *Tillering stage*

During tillering stage of the crop T_{max} varied between 38 to 42° C and 36 to 40° C showing the similar increasing trend in Maharashtra and U.P. (and Uttaranchal) [Figs. 3I(a), II(a)] respectively. The CC between sugarcane yield and T_{max} was negatively correlated ($r = - 0.66^*$), in Maharashtra but it was not significantly correlated in U.P. (and Uttaranchal). The
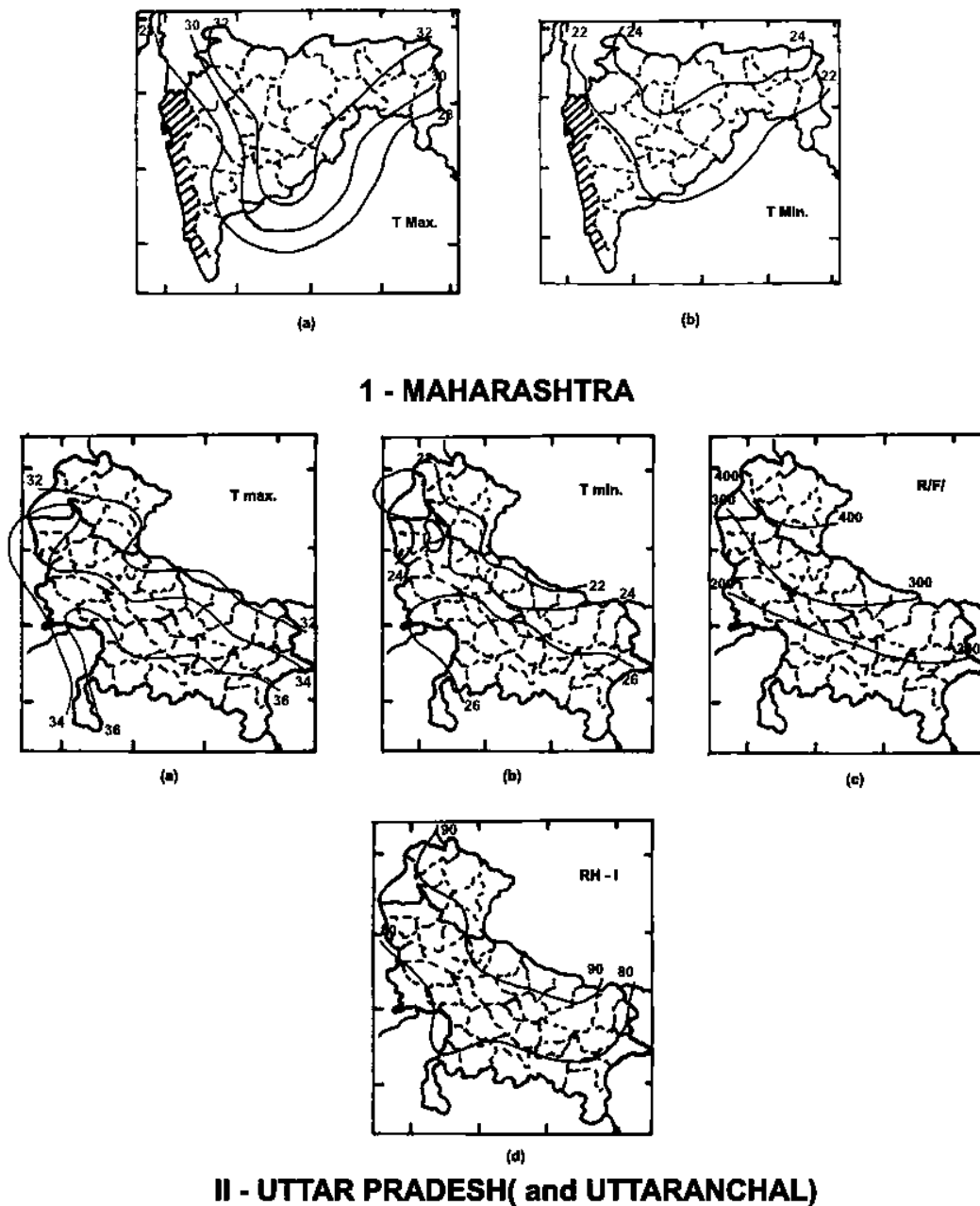
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Fig. 5. Spatial variation of meteorological parameters at active growth stage

average T_{max} during this stage was 40.3° C. The optimum requirement of T_{max} during tillering stage was about 35.0° C. Thus there was large difference between optimum requirement and average T_{max} that sugarcane had experienced. Singh and Singh (1966) also reported that number of tillers were greater when the day temperature was around 26° C.

T_{min} varied between 22 to 26° C from southern to northern regions of Maharashtra and 16 to 22° C from northwestern to southern regions of U.P. (and Uttaranchal) [Figs. 3I(b), II(b)]. For both Maharashtra and U.P. (and Uttaranchal) the CCs between T_{min} and sugarcane yield were found to be negatively correlated (r = -0.69*, and -0.75** respectively). The optimum T_{min} requirement

during this stage was 23° C. Higher T_{min} affected tillering of the sugarcane crop in the northern region of Maharashtra causing reduction in yield. Whereas T_{min} was in the favourable range and helped tillering by providing the optimum thermal regimes in the southern and southwestern regions of the state. The average T_{min} which the crop had experienced fell short by 7° C in the north-western region and 3° C in the central region and about 1 to 2° C in the southern region of U.P.(and Uttaranchal) adversely affecting the sugarcane production.

The spatial distribution of RH-I varied between 45 to 60 % showing increasing trends from northern to southern regions of Maharashtra [Fig. 3I(c)]. The CC was found positively correlated (r = +0.72**). The average morning relative humidity during this stage was 54%.

4.2.3. *Early growth stage*

The spatial distribution of T_{max} over Maharashtra was found to vary between 34 to 38° C showing increasing trend from southern to northern regions of state. However in U.P. (and Uttaranchal) same was found to be 36-40° C in southern and south-western region of the states and showed decreasing trend in the northern region [Figs. 4I(a), II(a)]. Both in Maharashtra and U.P. (and Uttaranchal) T_{max} was negatively correlated with the sugarcane yield (r = -0.69* and -0.54* respectively). The negative and significant CCs clearly indicate that higher T_{max} at early stage of the growth is detrimental for growth and ultimately for the yield of sugarcane both in Maharashtra and U.P. (and Uttaranchal).

The spatial distribution of T_{min} in Maharashtra and U.P.(and Uttaranchal) ranged between 22 to 26° C and 22 to 28° C showing decreasing trend from south-western to north-eastern regions of Maharashtra [Fig. 4I (b)] and increasing trend from north-eastern to south-western regions [Fig. 4II (b)] of U.P. (and Uttaranchal). T_{min} in Maharashtra was slightly lower than the average T_{min} in the districts of U.P. (and Uttaranchal). The CCs were found negatively correlated [r = - 0.79**, - 0.62* respectively in U.P. (and Uttaranchal) and Maharashtra].

The spatial distribution of RH-I and RH-II varied from 70 to 80 % and 40 to 45 % showing the increasing trend from north-eastern to southern regions of Maharashtra [Fig. 4I(c&d)]. The CCs were positively correlated (r = + 0.68* and +0.63* for RH-I and RH-II respectively).

4.2.4. *Active growth stage*

It was found that T_{max} varied between 26 to 32° C showing the increasing trend from western to north-

eastern regions of Maharashtra and 32 to 36° C showing the increasing trend from north-western region to south-eastern region of U.P.(and Uttaranchal) [Figs. 5I(a), II(a)]. The CCs between sugarcane yield and T_{max} were negatively correlated (r = - 0.56*, and – 0.61* for Maharashtra and U.P. (and Uttaranchal) respectively). The average T_{max} experienced during this stage was 31.5° C.

The spatial distribution of T_{min} varied in a narrow range between 22 to 24° C showing the increasing trend from southern to northern regions of Maharashtra whereas 22 - 26° C showing increasing trend from north-eastern to south-western regions of U.P. (and Uttaranchal) [Figs. 5I(b), II(b)]. The CCs were found negatively correlated [r = - 0.59* and - 0.72** respectively for both Maharashtra and U.P. (and Uttaranchal)].

In U.P. (and Uttaranchal) the spatial distribution of rainfall varied between 200-400 mm. Rainfall during this stage was 200 mm in the southern districts, 300 mm in the central and 400 mm in the northern region of the U.P. (and Uttaranchal) [Fig. 5II(c)]. The CC was found positive and significant (r = + 0.67*). This indicated that rainfall at this stage of crop growth had played very important role for growth and higher yield of sugarcane in U.P. (and Uttaranchal). At the same time negative (not significant) CC value during this stage of sugarcane growth for Maharashtra showed negligible contribution under fully irrigated conditions when water was made available as and when required.

RH-I varied between 80% to 90% and showed the increasing trend from south - western to northeastern regions in U.P. (and Uttaranchal) [Fig. 5II(d)]. The CCs were positively correlated [r = + 0.54* and 0.21 in U.P. (and Uttaranchal) and Maharashtra respectively].
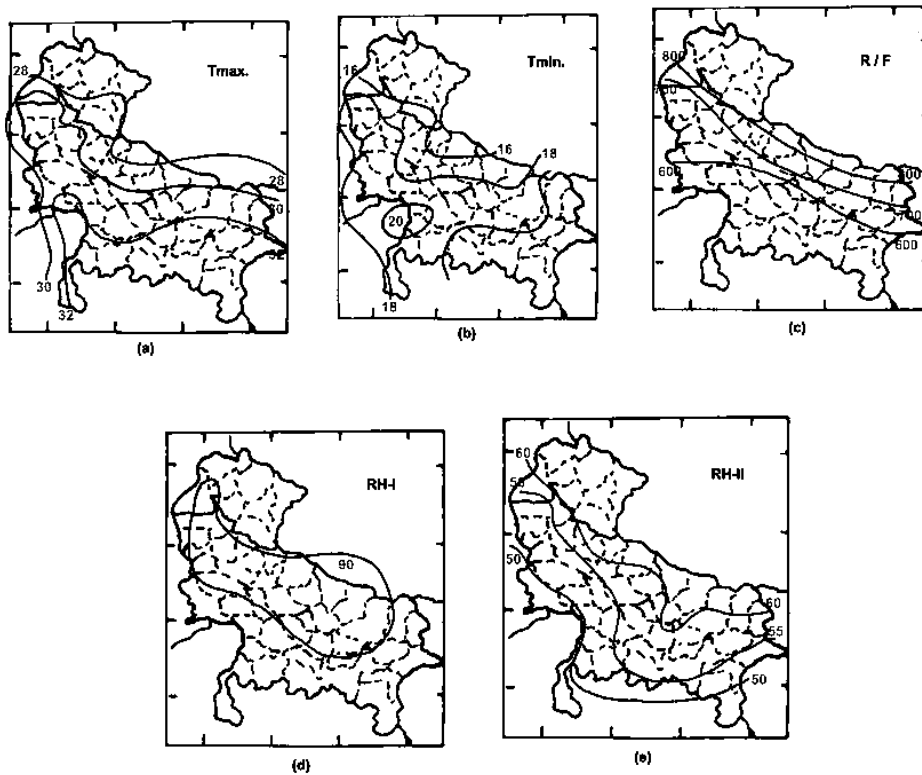
4.2.5. *Elongation stage*

It was observed that the spatial distribution of T_{max} varied between 28 to 32° C showing the increasing trend from northeastern to southern regions of the U.P. (and Uttaranchal) [Fig. 6II(a)]. During this stage the CC between T_{max} and sugarcane yield was found significantly and negatively correlated (r = - 0.72**) for U.P. (and Uttaranchal) but same was not significant for Maharashtra.

In Maharashtra T_{min} dropped considerably and varied between 18 & 20° C and in U.P. (and Uttaranchal) it was found to be in the range 16 - 20° C. It showed increasing trend from south and southwestern to northern districts of Maharashtra and from northern to south-eastern regions
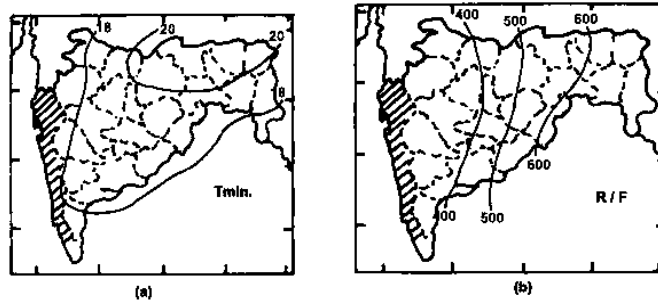
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Fig. 6. Spatial variation of meteorological parameters at Elongation stage

of U.P. (and Uttaranchal) [Figs. 6I(b), II(b)]. The CCs between T_{min} and sugarcane yield were found negatively correlated [r = - 0.62* and - 0.48* in Maharashtra and U.P. (and Uttaranchal) respectively]. The optimum T_{min} requirement for the crop during elongation stage was around 17 to 20° C. The negative CCs at significant level clearly brought out that spatial variation of yield of sugarcane and T_{min} acts in opposite direction. Higher T_{min} caused reduction in yield in both the states. This also indicates that further study would be required to get clear insight about the influence of each of the weather elements at different growth stages especially for optimization and manipulation of thermal regimes and microclimate in the sugarcane field.
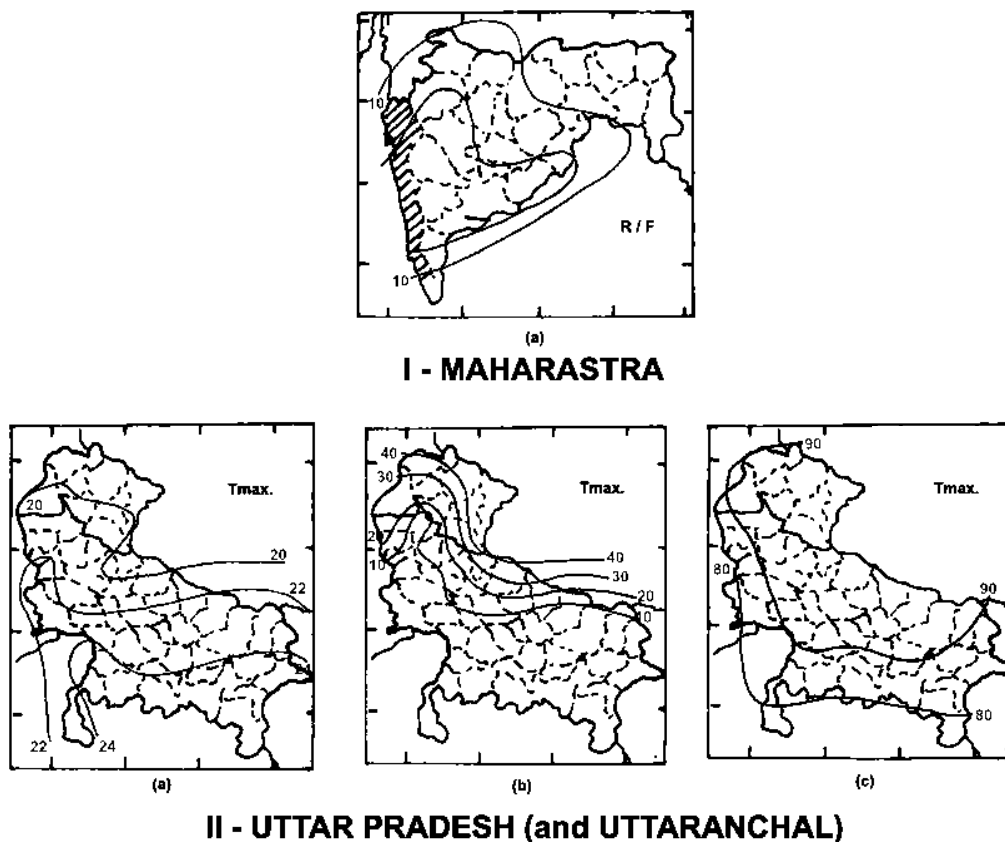
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II - UTTAR PRADESH (and UTTARANCHAL)

Fig. 7. Spatial variation of meteorological parameters at maturity stage

Rainfall during elongation stage varied between 400-600 mm and showed the increasing trend from western (excluding Konkan region) to eastern regions in Maharashtra and 600-800 mm in U.P.(and Uttaranchal) showed increasing trend from south-western to north-eastern regions of the state [Figs. 6I(b), II(c)]. The CCs were found significantly and negatively (r = -0.57*) for Maharashtra and positively correlated (r = + 0.76**) for U.P. (and Uttaranchal) respectively.

The elongation stage coincided with later half of monsoon and post monsoon seasons. As the sugarcane crop was grown mostly under irrigated condition with supplemental or life saving irrigation at critical growth stages in the districts where irrigation resources were limited, the higher amount of rainfall during the elongation phase has contributed positively and significantly (r = + 0.76**) towards higher yield in U.P. (and Uttaranchal). It is interesting to note that higher amount of rainfall over the sugarcane growing regions of Maharashtra and U.P. (and Uttaranchal) played different role. Rainfall contributed significantly towards better

growth and higher yield in U.P. (and Uttaranchal) whereas it did not contribute or caused reduction in growth and ultimately yield perhaps by providing congenial weather condition for pests and diseases attack under fully irrigated but humid and cloudy condition in Maharashtra. Heavy black cotton clay soil also caused damage to root system under heavy rainfall condition in Maharashtra.

The spatial distribution of RH-I varied between 80% to 90% in U.P. (and Uttaranchal) [Fig. 6II(d)]. The CC was positively correlated (r = + 0.61*). The average RH-I during this stage was slightly higher in U.P. (and Uttaranchal) as compared to that in the regions of Maharashtra.

The spatial distribution of RH-II during this stage varied between 50% to 60% from southwestern to northeastern regions of U. P. (and Uttaranchal) [Fig. 6II(e)]. The CC was positively correlated (r = + 0.51*) for U.P. (and Uttaranchal). The average value of RH-II during the stage was 57%, which was about 6% higher compared to that observed in the regions

of Maharashtra. Thus higher percentage of RH-II in the regions of U.P. (and Uttaranchal) was favourable for elongation of sugarcane.

4.2.6. *Maturity stage*

In U.P. (and Uttaranchal) the spatial distribution of T_{max} varied between 20 to 24° C showing increasing trend from northeastern to southern region of the state [Fig. 7II (a)]. The CC was negatively correlated (r = -0.54*). The average T_{max} during this stage was 22.1° C. The spatial distribution of rainfall during maturity stage was meagre and varied between 5 & 10 mm in Maharashtra [Fig. 7I (a)]. The CC was found negatively correlated (r = - 0.69*). The spatial distribution of rainfall varied between 10 to 20 mm [Fig. 7II (b)]. The CCs between rainfall and sugarcane yield showed positive correlation [r = + 0.67* for U.P. (and Uttaranchal) and negative correlation r = - 0.69* for Maharashtra]. This meagre amount of rainfall contributed towards higher yield by saving the crop from the wilting condition under limited irrigated condition in U.P. (and Uttaranchal). The turning point of CCs at different stages show the importance of spatial variation of rainfall and its impact on growth and yield at different growth stages in the states of Maharashtra and U.P. (and Uttaranchal) (Table 1).

The spatial distribution of RH-I varied between 80% to 90% showing the similar trend as observed during the active growth stage *i.e.*, increasing trend from south-western to north-eastern regions of U.P.(and Uttaranchal) [Fig. 7II(c)]. The CC was positively correlated (r = +0.51*). The average RH-I during this stage was considerably higher in U.P. (and Uttaranchal) compared to that in the regions of Maharashtra.

5. Summary

(*i*) The correlation coefficients between sugarcane yield and maximum temperature at all growth stages were significant and negative except at maturity stage both in Maharashtra and Uttar Pradesh (and Uttaranchal). Sugarcane yields were significantly reduced in the regions of U.P. (and Uttaranchal) and Maharashtra where higher maximum temperatures prevailed.

(*ii*) Minimum temperature was lower than optimum requirement at germination and maturity stages. On the other hand minimum temperature was in the higher side of the optimum requirement at other growth stages. Minimum temperature experienced by the crop at its different growth stages in Maharashtra and Uttar Pradesh (and Uttaranchal) showed negative and significant correlation except at maturity stage (CCs not significant).

The lower yields in the regions of Maharashtra and Uttar Pradesh (and Uttaranchal) were in association with either lower minimum temperature at germination stage or higher minimum temperature at other growth stages. Considerable drop in yield of sugarcane was observed in the southern districts of Uttar Pradesh (and Uttaranchal) due to higher minimum temperature.

(*iii*) The correlation coefficients between bright sunshine hours and sugarcane yield at different growth stages were low but positive in Maharashtra but negative in Uttar Pradesh (and Uttaranchal) except at germination stage when it was negatively and significantly correlated at 5 % level. The study revealed that higher bright sunshine hour in the regions of Maharashtra was beneficial. But higher values of bright sunshine hours in the regions of Uttar Pradesh (and Uttaranchal) were not favourable. This may be due to other environmental and management constraints.

(*iv*) The correlation coefficients between rainfall and sugarcane yield were negative and significant at elongation and maturity stages in Maharashtra whereas it was positive and significant at germination, active growth, elongation and maturity stages in U.P. (and Uttaranchal). The rainfall at different growth stages over the sugarcane growing regions of Maharashtra and U.P. (and Uttaranchal) played contrasting role. Rainfall contributed significantly towards better growth and higher yield in U.P. (and Uttaranchal) whereas it hampered growth and ultimately yield in Maharashtra.

(*v*) The average morning relative humidity during germination, tillering, early growth, active growth, elongation and maturity stages, in general, were slightly higher in the districts of U.P. & Uttaranchal compared to that in the districts of Maharashtra. The positive and significant correlation coefficients between morning relative humidity and sugarcane yield at tillering and early growth stages in Maharashtra and at active growth, elongation and maturity stages in U.P. (and Uttaranchal) indicated that higher humidity in the morning hours had profound effect on sugarcane yield. Similarly positive and significant correlation coefficient at all growth stages except tillering stage in U.P.(and Uttaranchal) clearly indicated, that higher afternoon relative humidity had played important role in increasing the sugarcane yield in both the states.

6. Concluding remarks

It is worth mentioning that sugarcane yield is an outcome of combined influence of different meteorological parameters at different stages of its growth and also the constraints associated with management

practices. Further microclimatic studies are to be undertaken to get a better insight into the influence of meteorological condition on the growth and yield of sugarcane in the two potentially large sugarcane growing states of the country.

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