

Impact of Weather on Yield of Sugarcane at Different Growth Stages

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ABSTRACT

A study has been conducted using yield data of sugarcane and mean meteorological parameters at Lucknow and for 14 districts of Uttar Pradesh where sugarcane is grown as a major crop. The optimum climatic requirements at different growth stages juxtaposed with the weather experienced by the crop was analysed critically. Correlation and multiple regression techniques were used to work out the optimum ranges of weather parameters at different growth stages. The study revealed that maximum temperature, morning humidity and sunshine hours have played the most important role during germination stage. Maximum temperature of about 26.8°C was found ideal at germination stage. Higher maximum temperature was found detrimental causing reduction in yield. At tillering stage the crop favoured higher minimum temperature (about 26.2°C), high relative humidity and high rainfall. Lower maximum and higher minimum temperature and light wind were found favourable for the growth of sugarcane at active and elongation stages.

The increasing trend of sugarcane yield ranging from 30 t/ha in east U.P. to 50 t/ha in west U.P. was observed associated with favourable weather condition in west and northern parts of east U.P. The higher maximum temperature in the range of 36 to 40°C which is much higher than the optimum temperature requirement < 36°C during germination to active growth stages is one of the reason for reduction in yield in east U.P. On the other hand in west U.P. Maximum temperature ranged from 30 to 36°C during the same period resulting in better yield. The large departure of maximum temperature in east U.P. from optimum requirement has profound detrimental effect on germination and subsequent growth and yield of sugarcane. West U.P. received well distributed and higher rainfall of about 800 mm compared to that of east U.P. which received maximum rainfall of about 700 mm during different growth stages. Higher amount of rainfall in west U.P. contributed positively in increasing the yield of sugarcane in west and north east districts of U.P.

Introduction

Sugarcane is a highly versatile plant and can be grown successfully under a wide range of soil and climatic conditions. Being a tropical plant it thrives best in hot, humid and sunny areas. Sugarcane grows all year round and thus passes through fluctuations in climatic factors such as very high temperatures in summer and very low minimum temperatures in winter, the ultimate yield of the crop are profoundly influenced by the weather elements. Thus by taking in to a account of the weather experienced by the crop at different growth stages till the time of harvest, it is possible to work out pre-harvest yield forecasting models by developing regression equations between the yield and the weather parameters during each of the growth stages viz., germination, tillering, early growth etc. up to harvest. The weather variables

also create conditions favourable or unfavourable for the development of pests and diseases. The complex interactions among weather parameters experienced by sugarcane crop at its different growth stages and pest and diseases incidences make a challenging problem to adopt suitable management practices for better performance of the crop. Thus an attempt has been made in this paper.

- i) to find out the spatial variation of sugarcane yield in relation to mean meteorological parameters at different growth stages of the crop in U.P.
- ii) to work out the climatic requirements of the crop at different growth stages and identify those weather abnormalities which have hindered the growth and yield of sugarcane in U.P.

- iii) to assess the climatic constraints that have caused reduction in yield in different regions of U.P. and strategic management practices to overcome such constraints.

Methodology

The study has been divided into two parts. In part I, mean sugarcane yield based on 20 years data (1972-91) for major sugarcane growing districts of U.P. were correlated with the mean meteorological parameters of the respective districts for each of the growth stages. Based on correlation study the spatial variation of yield in relation to climatic constraints was established for different agroclimatic regions of U.P. In the second part of this study meteorological elements such as maximum and minimum temperature, relative humidity (hr 1 and hr 11), duration of bright sunshine, wind speed and actual evapotranspiration (ET) as well as yield data of sugarcane (variety CO-1148) for Lucknow were used to develop multiple regression equation to assess the impact

of meteorological parameters on growth and yield of sugarcane at different stages viz, germination, tillering, early growth, active growth and elongation. Multiple regression equation has been developed for each of the growth stages using meteorological parameters which were found significantly correlated with sugarcane yield. The correlation coefficients (ccs) between meteorological parameters and sugarcane yield for the districts of U.P. and Lucknow for each of the growth stages were computed and presented in Table 1 (a) and (b). Optimum weather requirements for each of the growth stages are presented in Table 2.

The estimated yield with the highest and lowest values for each meteorological parameters which the crop experienced at different growth stages at Lucknow have been presented in Figs. 1 to 5. In estimating the yield it is assumed that only one parameter is influencing the yield and the other meteorological parameters remain constant.

Table 1(a). Correlation coefficient between sugarcane yield and predominant meteorological parameters at various growth stages of sugarcane in the districts of U.P.

Growth stages	Maximum temperature	Minimum temperature	Relative humidity-I	Relative Humidity-II	Sun shine hours	Rain-fall
Germination	-0.57*	-0.49*	+0.46*	+0.10	-0.45*	+0.54*
Tillering	-0.71**	-0.75**	+0.21	-0.10	-0.36	+0.20
Early growth	-0.54*	-0.79**	+0.25	+0.05	-0.35	+0.21
Active growth	-0.61**	-0.72**	+0.54*	+0.43	-0.37	+0.67**
Elongation	-0.72**	-0.48*	+0.61**	+0.51	-0.12	+0.76**

*significant at 5% level

**significant at 1% level

Table 1(b). Correlation coefficient between sugarcane yield and predominant meteorological parameters at various growth stages of sugarcane at Lucknow

Growth stages	Maximum temperature	Minimum temperature	Relative humidity-I	Relative humidity-II	Sun shine hours	Rain-fall	Wind speed	Total evaporation
Germination	0.61*	0.48	0.61*	-0.33	0.74**	0.32	-0.17	0.03
Tillering	0.44	0.57*	0.23	0.57*	0.39	0.57*	-0.48	0.40
Early growth	-0.35	0.36	0.37	0.54	-0.26	0.72**	-0.80**	0.74**
Active growth	-0.56*	-0.30	0.53	0.54	-0.32	0.55	-0.83**	0.91**
Elongation	-0.45	-0.34	-0.26	0.13	0.20	0.19	-0.39	0.39

*significant at 5% level

**significant at 1% level

Table 2. Optimum weather requirements for each of the growth stage for sugarcane at Lucknow

Growth stages	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity-I (%)	Relative humidity-II (%)	Sun shine hours	Rain-fall (mm)	Wind speed (kg/hr)	Total evaporation (mm)
Germination	26.8	-	-	-	9.2	-	-	-
Tillering	-	26.2	-	48	-	100	-	-
Early growth	-	-	-	45	-	800	-	39
Active growth	31.0	28.0	-	-	-	-	0.5	-
Elongation	30.0	18.0	-	-	-	-	0.6	-

Results and Discussions

Germination

The influence of each of the weather elements on yield was studied by working out the correlation coefficients at this stage. The study revealed that maximum temperature, sunshine hours and morning humidity have played the most important role at Lucknow. The germination period in U.P. is for about 9 weeks. The crop experienced an average maximum temperature of 31.70°C, R.H. 1-70% and daily mean hours of bright sunshine 8.97 during this stage. Fig. 1(a) shows that optimum yield was reached when maximum temperature at this stage was around 26.8°C. The yield showed a decreasing trend with increase in maximum temperature. Biswas (1988) reported that for optimum germination, the temperature should be between 20 and 32.0°C. Rupa Kumar (1984) while analyzing the yield response of sugarcane to weather variations in northeast Andhra Pradesh noted that maximum temperature, minimum temperature and relative humidity during the first three months of the crop (germination to tillering phases) are found to have a profound influence on the yield.

Fig. 1(b) shows that optimum yield was reached when R.H. I ranged between 35-45 %. The yield showed a decreasing trend with increase in morning humidity. The lowest yield was observed when the morning humidity was above 80%. On the other hand sharp increase in yield was observed with increase in sunshine hours (Fig. 2(c)). 9.2 hours of bright sunshine experienced at this stage was found ideal for optimum yield.

When spatial variation of sugarcane yield along with variation in meteorological parameters were

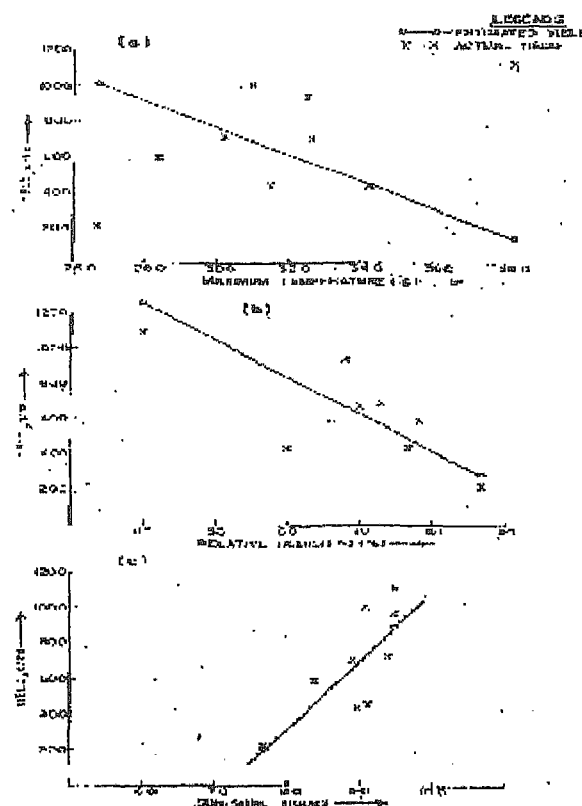


Fig. 1. Relationship between sugarcane yield and (a) maximum temperature (b) relative humidity-I and (c) sunshine hours at germination stage

considered for the state of U.P. during germination stage, it was observed that maximum temperature varied in a narrow range between 30 to 32°C showing increasing trend from south eastern to central regions of the state. Maximum temperature was less by 2°C in the southeastern region from that in the central region. The cc worked out between the sugarcane yield and maximum temperature experienced by the crop at this stage in different districts of U.P. was found negatively correlated ($r = -0.57$, significant at 5% level (Table

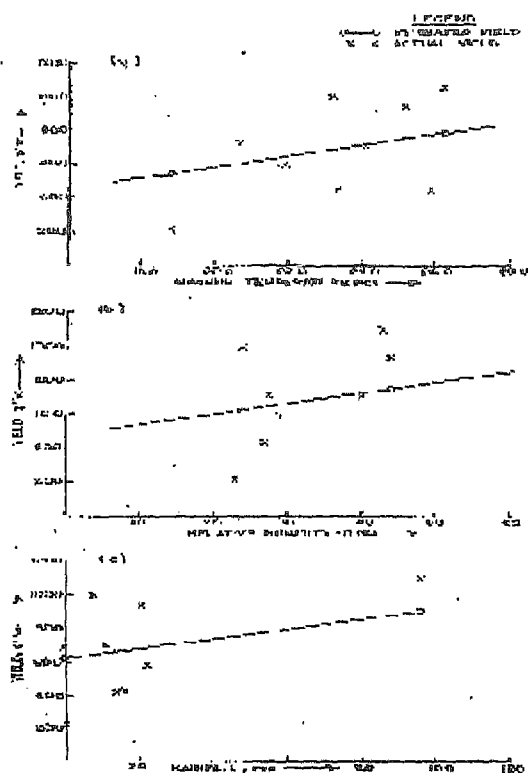


Fig. 2. Relationship between sugarcane yield and (a) minimum temperature (b) relative humidity-II and (c) rainfall at tillering stage

1(a)). At this stage the crop experienced average maximum temperature of about 30.3°C . The optimum temperature requirement during this stage is about 26.8°C (Raheja, 1959). Thus there is a considerable difference between optimum requirement and the temperature that the crop experienced at this stage, thereby affecting germination and inturn overall yield of sugarcane in the districts of U.P. where maximum temperature was higher.

Tillering stage

At this growth stage minimum temperature, afternoon humidity and rainfall have played the most important role towards yield. The tillering of sugarcane starts at and around 1st week of June. The crop experienced an average minimum temperature of 23°C , afternoon humidity 32% and total rainfall of 21.2 mm. Fig.2(a) shows that at this stage minimum temperature of about 26.2°C was ideal for profuse tillering which contributed towards optimum yield. Yield increased gradually

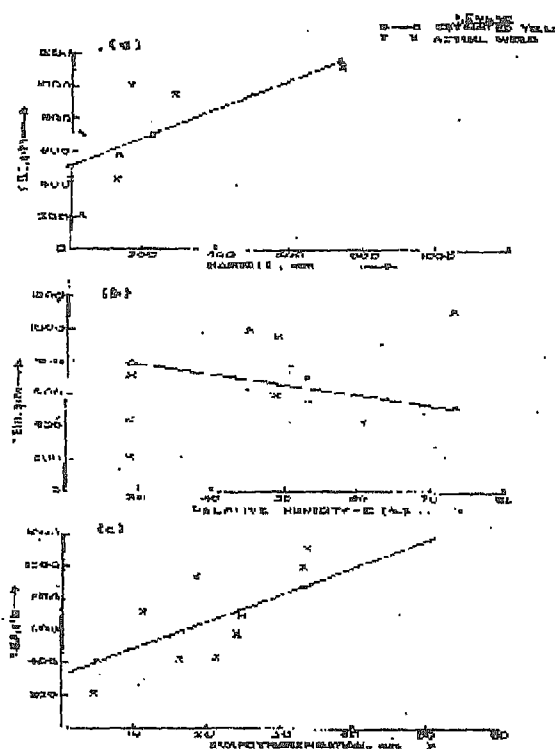


Fig. 3. Relationship between sugarcane yield and (a) rainfall (b) afternoon relative humidity and (c) evapotranspiration at the early growth stage

as the minimum temperature increased. Raheja (1959) and Singh and Singh (1966) have also reported that number of tillers is greater in long duration crops when the day temperature alternates between high and low around the mean temperature of 26°C .

Fig.2(b) shows that yield increased steadily with an increase in afternoon humidity. The crop requires a fairly high humidity for proper growth. However, spells of high afternoon humidity together with congenial temperatures in sunny weather might have triggered more tillering. It may be seen from fig.2(c) that a rainfall of about 96 mm was ideal for optimum yield at this stage. Yield increased gradually with an increase in rainfall. Sarkar (1965), in his study reported that the weather experienced by the crop at tillering phase appears to be more important in determining yield than the weather that the crop experienced at other growth stages. Maximum temperature varied between 36 to 40°C during tillering stage. The

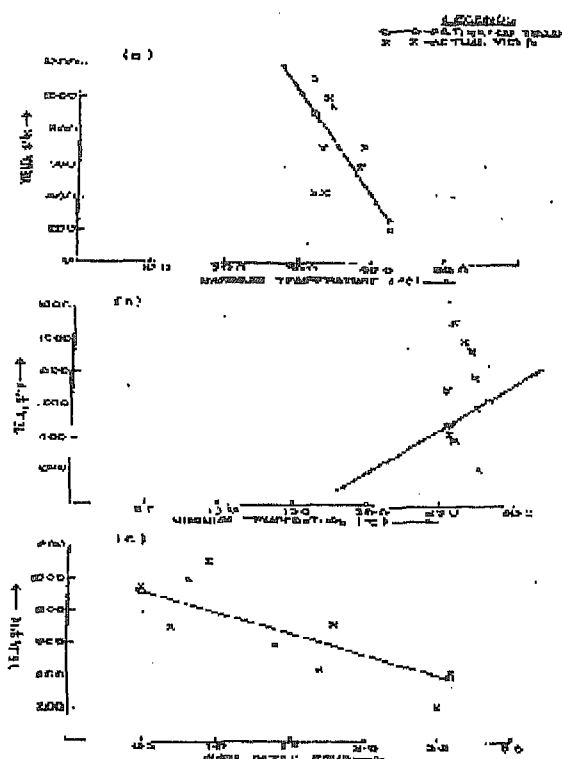


Fig. 4. Relationship between sugarcane yield and (a) maximum temperature (b) minimum temperature and (c) wind speed at active growth stage

crop experienced average maximum temperature of 38.7°C , minimum temperature of about 21°C and rainfall of about 19.6 mm. Increasing trend of maximum temperature was observed from northern to southern region of U.P. Yield in the districts of U.P. was found negatively correlated with the corresponding maximum temperature ($r=-0.54$, significant at 5% level). An adequate supply of soil moisture is also essential for proper cane growth. Sugarcane often experience moisture stress during the formative phase, which generally coincides with the summer months and hence reduction in growth, associated with yield decline is a constant constraint in sugarcane cultivation in U.P. particularly in the districts where irrigation resources are limited.

During this stage the spatial variation of afternoon humidity ranged between 25 to 30% in U.P. The average values of R.H.11 during this phase were much lower than the optimum requirement. During the tillering stage the crop received much

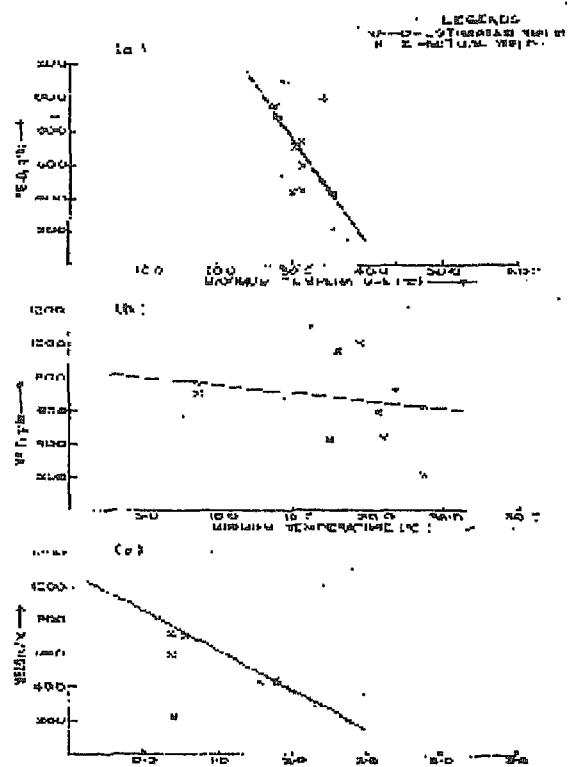


Fig. 5. Relationship between sugarcane yield and (a) maximum temperature (b) minimum temperature and (c) wind speed at elongation stage

less rainfall in the range of 10 to 20 mm compared to its requirement. Rainfall showed increasing trend from southern to northern region of the state. It showed positive correlation between sugarcane yield and rainfall ($cc=+0.20$ not significant at 5% level). The crop received an average rainfall of about 27.4 mm. The positive correlation at this stage indicates that even a small amount of rainfall in U.P. had contributed towards growth and higher yield of sugarcane.

Early growth stage

At this stage evapotranspiration (ET), rainfall and afternoon humidity played the most significant role in contributing higher yield. The mean period of this growth stage coincides with 2nd week of July. The crop experienced a mean total rainfall of 190.9 mm, afternoon humidity of 46% and average total ET loss of about 21.1 mm during this phase. Fig.3 (a) shows that higher rainfall >400 mm was ideal for optimum yield at this stage. Sugarcane

being a long duration crop requires more water either from rainfall or irrigation for its growth. Fig. 3(b) shows decreasing trend in yield with increase in afternoon humidity. Fig. 3(c) shows that at this stage optimum yield was observed when mean weekly total ET was around 33 mm. Sharp rise in yield was observed with increase in weekly total ET. During this growth stage, good rainfall combined with higher evapotranspiration loss in association with higher insolation favoured cane growth.

The spatial variation of maximum temperature ranged between 36 to 40°C at this stage. The average temperature during this stage was 38.9°C. Minimum temperature varied between 22 and 24°C. Both maximum and minimum temperature showed significant negative correlation ($r=-0.54$ and -0.79 respectively) with the sugarcane yield. The rainfall received during this stage was relatively higher and varied between 50 to 100 mm showing increasing trends from south western to northeastern region of the state. The cc was positive but found to be not significant ($r=+0.21$). The western region of U.P. receives on an average about 76.2 mm rainfall and has good irrigation facilities.

The average rainfall received in east U.P. is about 127.0 mm and the crop is mostly grown as a rainfall crop in this region with life saving irrigation. It suffers moisture stress even during the monsoon months due to prolonged dry spell caused by long break in rainfall.

Active growth

Active growth stage of the crop is characterized by increase in stalk length and girth. At this growth stage maximum and minimum temperature and wind speed were favourable for the growth of sugarcane at Lucknow. The mean period of this stage coincides with the 2nd week of August. During this stage the sugarcane experienced average maximum temperature of 35.5°C, minimum temperature 26.5°C and wind speed 2.4 km/h. Fig. 4(a) shows that maximum temperature of about 32.0°C was ideal for optimum yield. Yield reduced sharply as maximum temperature increased. On the other hand, yield increased with the increase in minimum temperature and optimum yield was observed at and around 28°C (Fig.4(b)).

Higher temperature and lower humidity were found to be favourable during this phase of the crop (Rupa Kumar, 1984; Biswas 1988).

Light wind favoured growth of cane at this stage and a wind speed of about 0.5 km/hr favoured optimum yield. Gradual fall in yield was observed with an increase in wind speed indicating that high wind is detrimental for the growth of cane. Humbert (1968) in his study reported that cane plants exposed to high wind often show a stunted growth and an increase in root development to overcome uprooting on lodging.

During the active growth stage the spatial variation of mean maximum temperature ranged between 32 to 36°C showing increasing trend from northwestern region to southeastern region of U.P. state. The cc worked out between sugarcane yield and mean maximum temperature was found negatively correlated ($r=-0.61$, significant at 1% level) with yield. Higher ranges of temperature and frequent spells of very high temperature >36°C in the south eastern region of U.P. had detrimental effect on sugarcane yield.

Elongation stage

At this growth stage maximum and minimum temperature and wind speed played the most important role. The elongation period was from 3rd week of August to 3rd week of December. During this phase, the crop experienced mean maximum temperature of 30.4°C, minimum temperature of 18.7°C and wind speed of about 0.87 km/h.

Fig.5(a) shows that maximum temperature of about 28°C at this stage was ideal for optimum yield. Sharp fall in yield was observed as the maximum temperature increased. In general, cane shows signs of wilting irrespective of water supply, when temperature rises about 36°C (Biswas, 1988). Yield reduced with the increase in minimum temperature (Fig.5(b)). At this stage light wind was favourable for optimum yield. Optimum yield was found for wind speed of about 0.7 km/hr (Fig.5(c)). Strong winds caused mechanical damage to crops, especially when the crop is tall and the canopy is fully developed. The cane is broken and even uprooted due to high wind at this stage.

During elongation stage of the crop, the spatial variation of maximum temperature ranged between 28 to 32°C showing increasing trends from northeastern to southern region in U.P. Maximum temperature during this stage was found negatively correlated ($r=-0.72$, significant at 1% level) with the yield. The crop experienced an average maximum temperature of 30.8°C during this stage. During this stage the morning relative humidity was 90% in the central parts of the state. The cc worked out between morning relative humidity and sugarcane yield was positively correlated ($r=+0.61$, significant at 1% level).

During this stage rainfall varied between 600 to 800 mm showing increasing trend from southwestern region to northeastern regions of the state. This stage coincides with the later half of monsoon and post monsoon seasons. Higher amount of rainfall during this stage contributed positively towards the yield, ($r=+0.76$, significant at 1% level). Rupa Kumar (1984) also observed that rainfall, minimum temperature and morning relative humidity at elongation stage had a significant influence on the yield variations.

The favourable meteorological parameters have resulted in higher yield in northern districts, on the other hand decreasing trend in yield was observed in the southern districts due to unfavourable weather conditions. Maximum yield was observed in Muzaffarnagar (51.0 t/ha) and Dehradun (50.5 t/ha) districts. The spatial distribution of sugarcane yield ranged between 35 to 45 t/ha in the central part of the state. Sugarcane yield in the southern region was considerably low and ranged between 25 to 30 t/ha.

Managing climatic constraints

By applying scientific methods of crop selection and management practices suiting to different climatic onstraints viz., moisture stress conditions, abnormal high or low thermal stress associated with very high maximum temperature >36°C or low minimum temperature <10°C, very high wind speed and very high and long duration of mean relative humidity (>75%) it will be possible to reduce climatic impact for operational farm management. The knowledge of climatic variability and its interaction with crop

environment would also help the farmers to plan better within the constraints of climatic and weather fluctuaitons. This constraints can also be overcome to a certain extent by insulating the crop from adverse climate conditions through irrigation, mulching, spraying anti transpirants etc. and also by controlled environment farming.

Genetic improvements in crops offer resistance to the temperatures and precipitation extremes so as to equip them to survive under hot and cold wave as well as under flooding and soil moisture stress conditions. The impact of meteorological variables as well as extreme weather events on crop growth and on specific processes such as photosynthesis, transpiration, respiration etc. are required to be studied further by using controlled chambers and simulation models. The extreme limits can be decided and suitable modifications can be attempted by using available resources and crop rotation can also be practiced. As crop growth, development and yield of sugarcane are affected by weather it exprienced through out the year at different growth stages, thus with adequate weather information and advisories under particular extreme weather events, farmers will be better able to tailor management decisions to existing and expected weather, thereby reducing production risks.

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