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Agroclimatic requirement of large cardamom (*Amomum subulatum* Roxb.) for the state of Sikkim

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सार – इस शोध पत्र में सिक्किम राज्य में बड़ी इलायची की मुख्य फसल के नष्ट होने के कारणों का पता लगाने हेतु अध्ययन किया गया है । इस उद्देश्य के लिए ऊष्मा की मात्रा (जी.डी. डी.) और कृषि जलवायु वर्षा सूचकांक (ए. आर. आई.) के आकलन के लिए गंगटोक और तडोंग नामक दो केन्द्रों से लिए गए तीन वर्षों के मौसम विज्ञान आंकड़ों और पश्चिम बंगाल के उप हिमालय क्षेत्र में स्थित दो निकटवर्ती केन्द्रों से लिए गए संभाव्य वाष्पन–वाष्पोत्सर्जन के आंकड़ों का उपयोग किया गया है ।

इस अध्ययन से यह पता चला है कि फसल की बढ़ोतरी की अवस्था में उच्चतम मान और फसल तैयार होने की अंतिम अवस्था में न्यूनतम मान के साथ वर्षा की उपलब्धता और संभाव्य वाष्पन–वाष्पोत्सर्जन में एक जैसी प्रवृति पाई गई है । इस समय फसल के लिए आवश्यक कुल ऊष्मा की मात्रा बहुत अधिक थी'; इसके मान नर्सरी में छोटे–छोटे पौध तैयार करने की अवस्था से लेकर इनको प्रतिरोपित करने की अवस्थाओं तक बढ़े हैं; तत्पश्चात पौधे के तैयार होने की अंतिम अवस्था के दौरान इसमें तेजी से गिरावट आई; इसके बाद पौधे की बढ़ोतरी की अवस्था में यह अधिकतम था जिसमें पौधे के बढ़ोतरी बाद की अवस्था में तेजी से कमी आई । दोनों केन्द्रों पर पौधे के प्रतिरोपण और फूल आने की अवस्थाओं ए. आर. आई. के बहुत उच्च मान अभिलेखित किए गए। फसल नष्ट होने के बाद किए गए अध्ययन से यह पता चला है कि फसल के लिए उच्च सापेक्षिक आर्द्रता और शीतल तापमान समेत सुवितरित, पर्याप्त मात्रा में वर्षा की आवश्यकता होती है जो वर्ष 1998–99 के दौरान उपलब्ध नहीं थी जिससे फूल आने के बाद की अवस्था में फसल काफी प्रभावित हुई ।

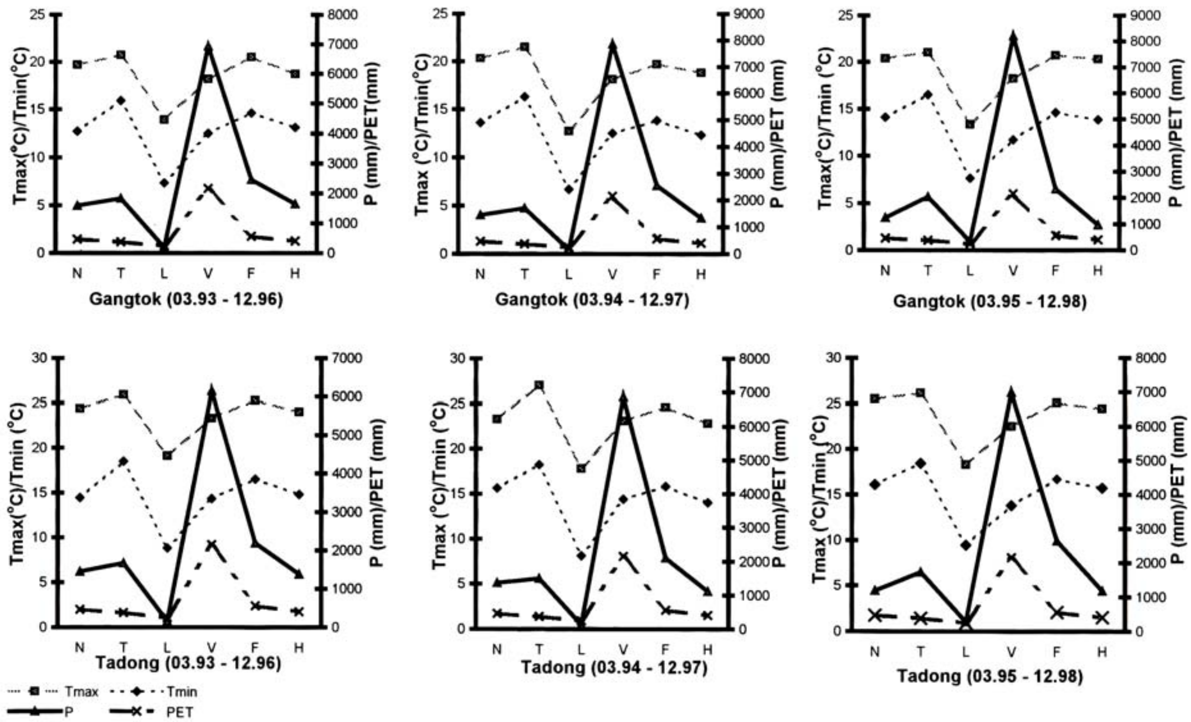
ABSTRACT . The present study was carried out to identify the cause of major yield losses of large cardamom in the state of Sikkim. For this purpose three years meteorological data from two stations *viz*. Gangtok and Tadong and the potential evapotranspiration data from two adjacent stations located in the sub-Himalayan West Bengal were used for computation of heat unit (GDD) and agroclimatic rainfall index (ARI).

The study revealed that rainfall availability and potential evapotranspiration followed the same trend with the highest value at vegetative stage and the lowest value at lag phase of the crop. The total heat unit requirement of the crop was very high; its value increased from nursery seedling to transplanting stages and then reduced sharply during lag phase; afterwards the peak was attained at vegetative growth stage, which sharply reduced at later growth stages. Very high ARI values were recorded at transplanting and flowering stages for both the stations. The postmortem study suggests that the crop requires well distributed, plentiful rainfall with high relative humidity and cool temperature, which were not available during 1998-99, affecting the crop severely at secondary flowering stage.

Key words – Large cardamom, Heat unit, Agroclimatic rainfall index, Anomaly, Lag phase, Minimum threshold temperature.

1. Introduction

The large cardamom (*Amomum subulatum* Roxb.) is the most important cash crop in the State of Sikkim, which is grown since time immemorial. The pride cash crop of the State contributes 70% of the total production of the country. The crop, which belongs to Zingiberaceae family, is a perennial herb with around 2.0 to 2.5 meters plant height. It gives rise to several leafy shoots and panicles. The crop usually takes 3 to 4 years from nursery seedling to first harvesting and then the ratoon crop from rhizome is harvested every year. The crop is adapted at medium to high altitude and requires moist but well drained loose soil. Plentiful well distributed rainfall with high relative humidity and cool temperature favour good production of the crop. As the crop grows throughout the year, its temperature requirement varies from 6° C in winter to 30° C in summer. The research data revealed



LEGENDS : N - Nursery seedling, T - Transplanting, L - Lag phase, V - Vegetative, F - Flowering, H - Harvesting

Fig. 1. Observed meteorological parameters [*viz*. rainfall (P), potential evapotranspiration (PET), maximum temperature (T_{max}) and minimum temperature (T_{min})] at Gangtok and Tadong during various growth stages of large cardamom

that a minimum threshold temperature of 2.5° C for the crop below which there will not be any growth (Subba 1984). The potential crop grows well as pure crop under plenty of shades in sloppy hills with good drainage. However, most of its plantations suffer due to absence of optimum shade, depleted soil condition, low level of effective population and degenerated rhizomes. Moreover, due to defective planting system, lack of soil, water conservation, orchard hygiene and pests and diseases problem, yield is low in the State. The crop is grown in an area (in thousand hectares) of 7.1700, 6.2384, 4.0340 and 4.5959 in north, east, west and south districts, respectively with a total production of around 4000 tonnes of cured cardamom annually for State (Bhutia 1992).

The potential evapotranspiration data were collected from two adjacent stations. The crop requirement of heat unit and agroclimatic rainfall index were computed. During the summer season of 1998-99, large cardamom at secondary flowering stage suffered a major setback in the State. At least 60 to 70% of the crop was dried up damaging the rhizomes also and most of its flowers were withered causing major crop failure. This resulted in severe effect on the State economy. This study was undertaken to identify the meteorological reasons, responsible for the huge loss.

2. Methodology

Based on the literature/research data available at the State level with the State Department of Agriculture, I.C.A.R. and Spices Board, six (6) main crop growth stages of large cardamom were identified during the crop span (March to December) of around four (4) years (on an average), which were nursery seedling (N), transplanting (T), lag phase (L), vegetative growth (V), flowering (F) and harvesting (H); the average duration of each of the growth stages were 4 months, 4 months, 4 months, 24 months, 5 months and 5 months respectively. The meteorological data were collected from two meteorological offices (M.O.) *viz*., Gangtok and Tadong located in the State for the latest available consecutive 3 seasons (*viz*., 1993 to 1996, 1994 to 1997 and 1995 to 1998). The daily maximum, minimum temperatures and rainfall were used for both the stations and growth stage-wise values were computed and are presented in Fig. 1. The potential evapotranspiration data (PET) were collected from two other adjacent stations (*viz*., Nagri in Darjeeling district and Nagarkatta in Jalpaiguri district) located in the sub-Himalayan West Bengal as reported by Khambete and Biswas (1992). From the weekly values, growth stage-wise PET values were obtained.

In computation of heat unit (*i.e*., GDD or growing degree days) the basic assumption is that there is a linear and direct relationship between temperature and growth of plants and the concept is valid for thermosensitive crops. The heat unit was determined by the formula :

$$\text{GDD} = \sum_{i=1}^{n}\left(\frac{T_{\max}+T_{\min}}{2.0} - T_t\right)$$

where, $T_{\max}$ and $T_{\min}$ are the daily maximum and minimum temperatures, respectively; T_t is the minimum threshold temperature, which is 2.5°C for large cardamom (as experimented by the scientists of the Spices Board, ICAR; Subba 1984). Nieuwolt (1981) proposed agroclimatic rainfall index (ARI), which is given by the formula :

$$\text{ARI} = 100 \times \frac{\text{P}}{\text{PET}}$$

where, P and PET are growth stage-wise rainfall and potential evapotranspiration respectively.

To identify the crop setback at secondary flowering stage during the summer season of 1998-99 various meteorological parameters (*viz*., rainfall, mean relative humidity, the maximum and minimum temperatures) as recorded at M. O. Gangtok and M. O. Tadong were studied. The daily data for the recent 3 years (*viz*., 1998 to 1999, 1997 to 1998 and 1996 to 1997) during October to March were considered and the monthly values were computed. These values were compared with the meteorological normals for the State (data during 1979 to 1998 were used for computation of normals) and the mean monthly anomalies were obtained.

3. Results and discussion

3.1. *Observed temperature during growth stages of large cardamom*

The analysis of data as presented in Fig. 1 revealed that the availability of both the maximum and minimum temperatures after initial high values at nursery seedling stage increased slightly during transplanting stage. The higher temperature at transplanting stage helped in better root establishment of the crop. Both the maximum and minimum temperatures at lag phase were the lowest with around 6 to 9° C mean diurnal fluctuation resulted in almost suspended growth during November to February. Afterwards, during vegetative stage, the crop experienced wide range of temperature variations for its two years of span, which was high enough during flowering stage and reduced slightly during harvesting stage. It was noticed that the mean maximum temperature and the mean minimum temperature at various growth stages of the crop were higher by 5° C and 2° C respectively, at Tadong as compared to Gangtok. This spatial temperature variation has significant effect on crop requirement of heat unit.

3.2. *Observed rainfall and potential evapotranspiration*

Availability of rainfall and potential evapotranspiration data revealed that the cumulative rainfall at both the stations were high during nursery seedling stage, which increased partially at transplanting stage (Fig. 1). At lag phase the amount of rainfall received was very low (during November to February), while at vegetative growth period of the crop the rainfall amount was the highest followed by flowering stage, which decreased further at harvesting stage. The crop developed the maximum during the two years of its vegetative growth, with receipt of good cumulative rain. Low rainfall during lag phase resulted in suspended crop growth. In absence of the potential evapotranspiration data from Sikkim, the values obtained from two adjacent stations (*viz*., Nagri and Nagarkatta) located in the sub-Himalayan West Bengal as recorded by Khambete and Biswas (1992) were used. The data revealed that PET values were much lower (in comparison with the cumulative rainfall) during various growth stages of the crop. The value recorded was the lowest at lag phase and the highest at vegetative growth stage of the crop, which reduced at flowering and harvesting stages.

3.3. *Growing degree days (GDD or heat unit) for various growth stages*

The computed GDD values as recorded at various growth stages of the crop in both the stations (Table 1) revealed same trend at both Gangtok and Tadong. The total requirement of GDD for large cardamom was very high *viz*., around 18000 and 23000 at Gangtok and Tadong respectively. The values increased marginally from nursery seedling to transplanting stages and then reduced to almost half at lag phase. The requirement was the lowest at lag phase (only around 5 – 6 % of the total requirement). Afterwards, at vegetative stage the values

TABLE 1

Heat unit (GDD) and agroclimatic rainfall index (ARI) at various growth stages of large cardamom at Gangtok and Tadong

Crop growth stages (duration)	Growing seasons					
	1993-96		1994-97		1995-98	
	GDD (% of total)	ARI	GDD (% of total)	ARI	GDD (% of total)	ARI
(a) Gangtok						
Nursery seedling (4 months *i.e.* Mar- Jun)	1671 (9.1)	345	1769 (9.7)	316	1793 (9.7)	269
Transplanting (4 months *i.e.* Jul - Oct)	1943 (10.6)	493	2017 (11.1)	459	2005 (10.9)	548
Lag phase (4 months *i.e.* Nov - Feb)	972 (5.3)	78	864 (4.8)	69	956 (5.2)	138
Vegetative growth (24 months *i.e.* Mar - Feb)	9430 (51.3)	323	9357 (51.4)	366	9125 (49.6)	382
Flowering (5 months *i.e.* Mar - Jul)	2310 (12.6)	443	2188 (12.0)	461	2310 (12.5)	423
Harvesting (5 months *i.e.* Aug - Dec)	2050 (11.1)	410	2004 (11.0)	335	2218 (12.1)	242
(b) Tadong						
Nursery seedling (4 months *i.e.* Mar- Jun)	2062 (8.9)	314	2062 (9.0)	297	2233 (9.7)	257
Transplanting (4 months *i.e.* Jul - Oct)	2423 (10.5)	448	2472 (10.8)	400	2423 (10.5)	463
Lag phase (4 months *i.e.* Nov - Feb)	1380 (6.0)	64	1260 (5.5)	51	1367 (5.9)	112
Vegetative growth (24 months *i.e.* Mar - Feb)	11915 (51.4)	287	11915 (52.1)	320	11461 (49.9)	325
Flowering (5 months *i.e.* Mar - Jul)	2815 (12.1)	396	2708 (11.9)	380	2815 (12.3)	478
Harvesting (5 months *i.e.* Aug - Dec)	2588 (11.1)	345	2433 (10.7)	278	2678 (11.7)	293

were the maximum (around 50 % of the total demand), which decreased during flowering and very marginally during harvesting at both the stations. The uni-modal distribution of data with the peak at vegetative stage suggested that the crop duration at that stage was the longest (2 years). The mean requirement of GDD values showed spatial variation along with temporal variation. The mean values revealed that requirement was sufficiently high at Tadong as compared to that recorded at Gangtok at various growth stages of the crop.

3.4. *Agroclimatic rainfall index(ARI)*

The computed ARI values showed that throughout the life span of the crop at most of the growth stages, rainfall was high enough to meet the crop PET demand and thus the values were more than 100 %. However, only during the lag phase the values were less than 100% during 1993-96 and 1994-97 seasons at both Gangtok and Tadong. Higher ARI values were recorded at transplanting as well as at flowering stages for both the stations. Again, ARI values at each of the growth stages of the crop were higher at Gangtok as compared to that recorded at Tadong.

3.5. *Anomaly of observed meteorological parameters during growth stages*

It was observed that during the summer season of 1998-99 the crop was severely affected and at least 60 to 70 % of the crop was damaged. In order to identify some meteorological parameters involved in the major

TABLE 2

Mean monthly anomaly and normals of meteorological parameters during October – March at Gangtok and Tadong

Met. parameters	Months	Seasons 1996-97	1997-98	1998-99	Normal
(a) Gangtok					
Rainfall (mm)	Oct	325.7	-60.5	71.3	162.3
	Nov	-38.2	-34.9	-31.4	38.4
	Dec	-21.9	53.6	-22.1	22.2
	Jan	4.7	-6.4	-0.8	29.8
	Feb	58.1	-8.8	-66.2	67.4
	Mar	-20.2	118.3	-80.6	121.9
Mean RH (%)	Oct	3	0	8	81
	Nov	2	6	2	75
	Dec	-8	6	-11	77
	Jan	5	4	-12	79
	Feb	10	2	-10	79
	Mar	19	14	-7	71
T_{max} (° C)	Oct	-0.4	0.2	1.6	20.0
	Nov	-0.3	0.3	2.8	17.0
	Dec	0.8	-0.1	3.3	13.5
	Jan	-1.2	0.3	3.2	11.9
	Feb	-4.1	2.0	5.8	13.4
	Mar	-0.2	-1.1	3.4	17.1
T_{min} (° C)	Oct	1.9	-0.1	3.1	11.9
	Nov	2.2	1.2	3.0	8.5
	Dec	1.7	0.8	2.5	5.5
	Jan	0.6	1.2	1.8	4.1
	Feb	-0.8	2.0	4.8	5.2
	Mar	1.8	0.3	2.7	8.2
(b) Tadong					
Rainfall (mm)	Oct	164.3	-55.8	78.5	142.0
	Nov	-32.6	-32.5	-30.1	33.3
	Dec	-17.4	31.1	-17.5	17.5
	Jan	3.7	-8.9	5.4	22.2
	Feb	48.2	4.8	-58.2	59.0
	Mar	-42.6	110.1	-71.1	111.0
Mean RH (%)	Oct	-6	5	4	79
	Nov	3	4	4	75
	Dec	1	1	-4	76
	Jan	3	3	-9	74
	Feb	5	0	-9	74
	Mar	2	5	-8	69
T_{max} (° C)	Oct	0.2	-0.8	1.0	24.8
	Nov	-0.8	-0.9	1.3	21.9
	Dec	1.2	-1.5	1.9	18.3
	Jan	-1.0	-0.3	2.1	16.6
	Feb	-4.2	1.4	5.0	18.1
	Mar	0.0	1.7	3.0	21.8
T_{min} (°C)	Oct	1.5	-1.3	3.1	14.1
	Nov	1.5	0.9	2.4	10.4
	Dec	0.6	0.0	1.5	7.5
	Jan	-0.1	0.8	2.2	6.6
	Feb	-1.4	1.3	3.7	7.9
	Mar	1.0	0.1	2.1	10.6

agricultural setback in the State economy, the study revealed that the rainfall (cm) during November, December, February and March were less than normal in the 1998-99 season as compared to the other two seasons at both Gangtok and Tadong (Table 2). Rainfall anomaly was very high (negative) during February, March of 1998-99 season at both the stations. The mean monthly relative humidity (RH) anomaly (%) revealed that in 1998-99 season the values during December to March were 4 to 9 % at the negative side of normal at Tadong and 7 to 12 % at the negative side of normal at Gangtok, while at the other seasons during October to March the mean RH anomaly were mostly at the positive side of normal. The maximum temperature anomaly (° C) in 1998-99 season were at the positive side of normal for the entire study period (*i.e.*, from October to March) at both the stations. The positive anomaly during December to March 1998-99 season were 3 to 6° C and 2 to 5° C at Gangtok and Tadong, respectively; while in the other seasons the anomaly was much closer to normal during the study months at both the stations. Similarly, the minimum temperature anomaly (° C) in 1998-99 season revealed that the values were at the positive side of normal for the study period. The positive anomaly during 1998-99 season varied from 2 to 5° C and 1.5 to 4° C at Gangtok and Tadong respectively; while in the other two seasons the anomaly values were not high, though they were mostly at the positive side of normal. The combined effect of these parameters during 1998-99 intensified the problem throughout the entire State of Sikkim and the State economy suffered due to setback in large cardamom at secondary flowering stage.

4. Conclusions

The study of large cardamom for the State of Sikkim revealed the following conclusions.

(*i*) Both the maximum and minimum temperatures were high during transplanting and flowering stages and were low during lag phase of the crop. The mean maximum and mean minimum temperatures were higher around 5° C and 2° C respectively, during various growth stages of the crop at Tadong as compared to Gangtok.

(*ii*) The rainfall showed peak at vegetative stage and the lowest value at lag phase of the crop; while the PET demand was much lower in comparison with cumulative rainfall, though the peak and the lowest values were recorded at vegetative and lag phases respectively.

(*iii*) The total GDD requirement for the crop was very high (around 18000 and 23000 at Gangtok and Tadong, respectively). The GDD increased initially from nursery seedling to transplanting stages, which reduced sharply during lag phase and then reached the peak during vegetative growth period (contributed around 50 % of the total GDD demand), which decreased afterwards at the end growth stages. The GDD demand at each of the growth stages was higher at Tadong as compared to Gangtok.

(*iv*) The ARI values indicated that at most of the growth stages (excluding lag phase) the values were more than 100 %.

(*v*) Negative rainfall and relative humidity anomaly and positive maximum and minimum temperatures anomaly have influence on the production of large cardamom in Sikkim.

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