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Incidence of hailstorms damage and strategies to minimize its effects on large cardamom (*Amomum subulatum* Roxburgh) plantations in Sikkim, North East India

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सार — **सिक्किम में मौसम की चरम घटनाओं में और हाल ही में हुई ओलावृष्टि से बड़ी इलायची की फसल को काफी नुकसान हुआ है। सिक्किम के ऊंचाई वाले क्षेत्र में आमतौर पर मार्च और अप्रैल में ओलावृष्टि होती है और इससे बड़ी इलायची के बागानों को भारी नुकसान होता है। इस शोध पत्र में, ओलावृष्टि से हुए नुकसान की घटनाओं और बड़ी इलायची के बागानों पर इसके प्रभाव को कम करने की कार्यनीतियों का विस्तृत विवरण दिया गया है। ओलावृष्टि की आवृत्ति वितरण से पता चला है कि पिछले आठ वर्षों के दौरान सिक्किम के पंगथांग क्षेत्र में ओलावृष्टि** 1427 **बजे से** 1532 **बजे के बीच हुई और औसतन लगभग** 37 **मिनट तक जारी रही। हालाँकि, उत्तरी सिक्किम के काबी क्षेत्र में, ओलावृष्टि आम तौर पर** 1621 **से** 1628 **बजे तक होती है और** 21.25 **मिनट तक जारी रहती है। ओले की आकृति का व्यास** 0.5 **से** 1.0 **सेमी तक का होता है। ओला वृष्टि से पौधे के ऊतकों को होने वाली क्षति मुख्य रूप से उसके आकार, तूफान की अवधि और चोट लगने पर पौधे के ऊतकों की स्थिति पर निर्भर करती है। ओलावृष्टि से बड़ी इलायची में शिराओं के समानांतर पत्तियों की फलकें टूट गई। ओलावृष्टि के कारण बड़ी इलायची के पौधों के पुष्प भागों में कायिक क्षतिफूल आने के चरण में हुई और इस क्षति की मात्रा के आधार पर ऋतु की अगली फसल की उपज भी प्रभावित हुई। यहाँ बार-बार होने वाली ओलावृष्टि की घटनाओं की पहचान की गई है और बड़ी इलायची के बागानों को होने वाले नुकसान को कम करने के उपायों पर चर्चा की गई है। इस अध्ययन में गंगटोक और आईसीएआर अनुसंधान परिसर में स्थित कृषि मौसम क्षेत्र इकाइयों (एएमएफयू) के सहयोग से भारत मौसम विज्ञान विभाग/पृथ्वी विज्ञान मंत्रालय द्वारा एनईएच क्षेत्र, सिक्किम केंद्र, ताडोंग कृषि विज्ञान केंद्र-पूर्वी सिक्किम, रानीपूल के लिए शुरू की गई प्रचालनात्मक कृषि मौसम सेवाओं के माध्यम से प्राप्त जानकारी बड़ी इलायची की फसल के नुकसान को कम करने में बहुत उपयोगी पाई गई है।**

ABSTRACT. Among the extreme weather events, hailstorms in the recent past caused significant damage to large cardamom crops in Sikkim. In the high-altitude area of Sikkim, hailstorms generally occur in March and April and caused severe damage to large cardamom plantations. In this paper, a detailed account of the incidence of hailstorm damage and strategies to minimize its effects on large cardamom plantations are discussed. The frequency distribution of hailstorms showed that during the last eight years' hailstorms in the Pangthang area of Sikkim occurred between 1427 to 1532 hrs and continued for around 37 minutes on average. However, in the Kabi area of North Sikkim, hailstorm generally occurs from 1621 to 1628 hrs and continues for around 21.25 minutes. Hailstorms varied in size from 0.5 to 1.0 cm in diameter. Damage caused by hailstorms on plant tissue depends mainly on its size, the duration of the storm event, and the condition of the plant tissue when the injury occurs. Hail storms ruptured the lamina of leaves parallel to veins in large cardamom. Physical damage to floral parts of large cardamom plants due to hailstorms occurred at the flowering stage and depending on the extent of damage the yield of the plant was also affected in the subsequent crop season. Frequent hail episodes are identified and measures to minimize the damage to large cardamom plantations are discussed. The information generated in this study was found to be very useful in minimizing large cardamom crop loss through

operational Agromet services launched by the India Meteorological Department/Ministry of Earth Sciences in collaboration with the Agromet Field Units (AMFUs) located at Gangtok and ICAR Research Complex for NEH Region, Sikkim Centre, Tadong through Krishi Vigyan Kendra-East Sikkim, Rani pool.

Key words – Hailstorm, Large cardamom, Damage, Himalayas, Weather.

1. Introduction

Large cardamom (*Amomum subulatum* Roxburgh), a high-value cash crop often referred to as currency crop and is also the main source of income for the farmers in the eastern Himalayan region (Sikkim, West Bengal (Darjeeling District), Arunachal Pradesh and Nagaland) including the Eastern part of Nepal, some part of Myanmar and Southern Bhutan (Sharma *et al.*, 2000). In Sikkim, it is cultivated since time immemorial and is believed to be the native of the region (Gudade *et al*., 2015). It grows well at an altitude ranging from 1000 to 2200 m amsl with well-distributed rainfall spread around 200 nos. of rainy days with a total of about 3000-3500 mm/year (Gudade *et al.*, 2014). Sikkim has more than 18000 ha under large cardamom, but the production is not obtained from the entire area and hence, the production area (the actual area that provides an agronomic yield yearly) is relatively less. The average productivity of large cardamom in Sikkim is very low (240 to 260 kg/ha) (Gupta *et al.*, 2012) as against its potential yield (1200 kg/ha) obtained at the Research Farm of Indian Cardamom Research Institute (ICRI). There are several reasons for the low productivity of large cardamom, *viz*., improper nutrition, insect pest, and disease infestation, open field cultivation, climate variability, and moisture stress, especially during winter months. Dry weather at the beginning of the cardamom flowering, erratic rainfall at full blooming, and capsule formation stage resulting in poor fruiting are the major causes for declining large cardamom productivity in Sikkim (Sharma *et al.*, 2016). Climate change is a happening marvel in the Indian Himalayas region which leads to various extremes like unpredictable and erratic rainfall, warmer weather during summer, reduction in winter days in hilly areas, poor snowfall coupled with the rapid melting of glaciers in the mountains, droughts, hailstorm and the drying up of water sources, *etc.* (Chattopadhyay *et al*., 2017; Sharma and Rai, 2012), which severely hampered the cardamom-based farming systems. Amongst weather hazards, hailstorms cause great damage to standing crops.

In past decades, hailstorms are mostly observed during the pre-monsoon season from March to April, especially in the North Eastern Himalayas of India. However, hail storms occasionally occur during late February and mid-May also. The hailstorms damaged crops in lakhs of acres of farmland in North Eastern states of India, which resulted in massive monetary loss to the poor farmers. Hailstorm causes substantial damage to standing crops within a very short time. However, the damage with hails is determined by the hailstorm sizes, hailstones intensity, wind speed, and crop growth stage. The average frequency of 10 hailstorms per year (slight, moderate, and heavy) was reported in the eastern and northeastern parts of India (Philip and Daniel, 1976). Hail is often associated with thunderstorm activity and weather fronts. This is formed in huge cumulonimbus clouds, commonly known as thunderheads. Das *et al.* (2010) identified sea level trough East Uttar Pradesh/Bihar to North-East India and low-level cyclonic circulation over Bihar and neighborhoods as the significant synoptic situation associated with the occurrence of hailstorms over Guwahati during pre-monsoon season.

Recently, unusual widespread and untimely hailstorms occur in North East India, particularly in Sikkim causing huge damage to standing crops. Hailstorm events have triggered an imperative need for developing comprehensive strategies to combat hailstorm losses in large cardamom. Hail being a very short-term and localized phenomenon, its prediction well in advance and informing all stakeholders of adequate preventive measures is a major challenge. Poor availability of accurate hailstorm data in remote areas again creates a great hurdle in hailstorm forecasting at the local level. Hence, an attempt has been made to synthesize the available data of hailstorms at ICRI, Spices Board, Tadong, which provides a prediction of hailstorms happening in the region and also assesses the extent of damage in large cardamom due to hails during the last few years besides suggesting the strategies to minimize its effects on large cardamom plantations in Sikkim. In beginning an attempt was made to know the prone zones, time of occurrences of hailstorms, their damage, and the frequency of occurrence at two research farms of ICRI, Pangthang, East Sikkim, and Kabi, North Sikkim from 2010 to 2017 was documented.

2. Data and methodology

Data regarding the occurrence of hailstorms for eight years from 2010 to 2017 at Pangthang East Sikkim (1952 m amsl; latitude 27° 22′ 26.11″ N; longitude 88 °34′ 26.34″ E) and Kabi North Sikkim (1610 m amsl; latitude 27° 24′ 18.42″ N; longitude 88°37′ 09.26″ E) research farms of Indian Cardamom Research Institute (ICRI), Regional Research Station, Sikkim have been collected from the weather register of the respective farms and presented in Table 1 and Table 2. The effect of a hailstorm

TABLE 1

Hail storm frequency and duration at Pangthang, East Sikkim from 2010 to 2017

Year	Observed Frequency	Duration in minutes
2010	1	10
2011	4	300
2012	2	40
2013	1	55
2014	3	165
2015	1	5
2016	4	58
2017	4	105
Total	20	738

TABLE 2

Hail storm frequency at Kabi, North Sikkim from 2015 to 2017

Year	Observed N	Duration in minutes
2015	1	10
2016	3	75
2017	4	85
Total	8	170

on the plant tissues of different cultivars of the large cardamom has been recorded from each farm to assess the damage. Descriptive statistics like central tendency frequency distribution, standard deviation, and pie chart were employed in spread Excel sheet Windows 10 Microsoft to depict the hailstorm happening pattern of the study period.

3. Results and discussion

3.1. *Occurrence of hailstorm at Pangthang, East Sikkim*

The frequency of hailstorms happening days in Pangthang during the last eight years is shown in Table 1. As per the study data, generally, hailstorms occurred in the afternoon (1427 hrs to 1532 hrs) and continued for around 37 minutes on average. The photographs of hailstorms collected during April 2016 are shown in Figs. 2(a&b). The duration was the longest (2 hrs) on 6thApril, 2011 while the lowest (0.5 minutes) was in the year 2015. The year 2011 registered the highest hailstorm occurrence as it took place 300 minutes in the year followed by the year 2014 (165 minutes) as shown in Table 1 and Fig. 4. By observation of Table 1 and Fig. 3, it is difficult to detect a particular trend of starting time and ending times of hailstorms. However, from Table 3, it is seen that starting time varies less (1.88) as compared to the ending time (2.01) during the period. In totality exactly 12 and a half hours (738 minutes) of hailstorms took place during

Fig. 1. Large cardamom under *Bamboo Machan*

TABLE 3

Descriptive statistics of starting time, ending time, and total duration of hailstorm incidence in Pangthang and Kabi

	Mean	Std. Deviation	Minimum	Maximum
		Pangthang		
Starting time in Hrs.	15.32	1.88	11.45	19.00
Ending time in Hrs.	15.87	2.01	12.30	20.00
Duration in minutes	36.90	32.70	5.00	120.00
		Kabi		
Starting time in Hrs.	15.81	2.44	13.55	21.45
Ending time in Hrs.	16.28	2.27	14.05	21.55
Duration in minutes	21.25	9.54	10.00	30.00

the last eight years. The percentage share of hailstorm occurrence duration is given in (Fig. 4). More occurrences of hail storms might be due to weather variability over the period. Furthermore, the higher elevation (1952 amsl) of Pangthang might favor the hail storm occurrence although multiple mechanisms are responsible for a hailstorm. Although the dominant mode for hailstorm form varies with the region (Zhou *et al*., 2021).

3.2. *Occurrence of hailstorm at Kabi, North Sikkim*

The frequency of hailstorms happening days in Kabi during the last eight years is shown in (Table 2). As per the study dataset generally hailstorm occurs in the afternoon (1621 hrs to 1628 hrs) and continues for around 2125 minutes on average. Starting time varies more (2.44) as compared to that ending time (2.27) during the period as shown in (Table 3). In totality, exactly 0323 hours (170minutes) of hailstorms took place during the last 3 years. The low occurrence of hailstorms at Kabi farm might be due to the lower elevation as compared to Pangthangfarm. Thunderstorms are usually associated with a hailstorm. Long-duration in thunderstorms occurrence is very rare, especially during pre-monsoon season as reported byKumar and Mohapatra, (2006).

Figs. 2(a-f). Hailstorm damage in large cardamom plantations at Sikkim, North East India (a&b. Hailstorm collected during April 2016; c. Torn leaves due to hailstorm; d. Symptoms of torn leaves after thirty days of hailstorm; e. Protected large cardamom plants under local shade trees; f. Protected large cardamom plants under 50 percent agro shade net)

3.3. *Crop damage due to hail storms to large cardamom*

Unseasonal rains with thunderstorms and hailstorms across the North Eastern parts of the country during the late part of February have wreaked havoc on farmlands and agricultural output (Chattopadhyay *et al*., 2017). The standing large cardamom plants were hit the hardest. A lot of farmers have been driven to despair by the unseasonal rains and hailstorms which extensively damaged large cardamom crops. Hailstorms can vary in intensity and duration, and when they occur during the growing season, hailstorms severely damage large cardamom plants. Hailstorms varied in size from 0.5 to 1.0 cm in diameter. Damage caused by the hailstorms on plant tissue depended mainly on the size of the hailstorms, the duration of the storm event and the condition of the plant tissue when the injury occurs. Hail one's damage to foliage and pseudo stem appeared as bruising, physical mangling. Large cardamom being a

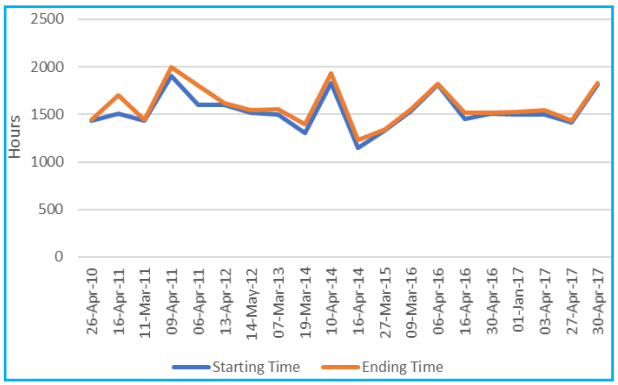

Fig. 3. Starting and ending time of hailstorm occurrence in Pangthang

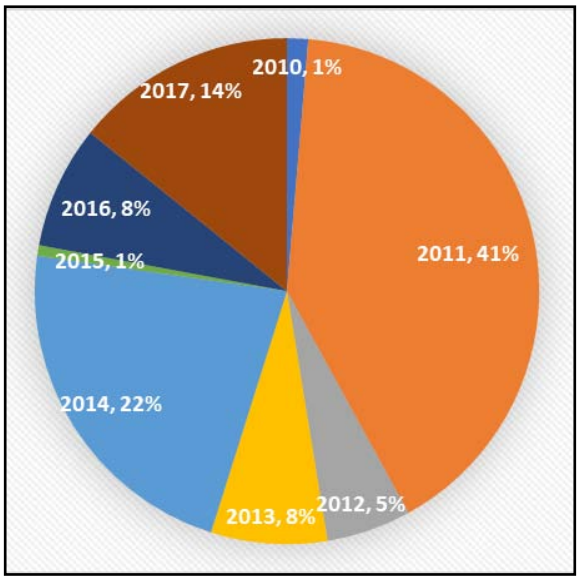

Fig. 4. Year-wise percentage share of hailstorm happening time in minutes at Pangthang during the study period

broad-leaved plant, the lamina tears parallel to the veins [Fig. 2(c)] and symptoms of large cardamom leaves after thirty days of hailstorms [Fig. 2(d)]. The pseudo stem showed open, ragged-edged wounds that are produced on the vertically or obliquely oriented pseudo stems depending on the wind direction during the hailstorm. Subsequent sunny days resulted in partial or complete drying of the damaged foliage. This can increase the chance of disease, rotting, and insect infestation. The duration of the hailstorm event at Kabi was too short as compared to Pangthang due to differences in altitude, location, and aspects Saju *et al*., (2011). Moreover, the size of the hail stones at Kabi measured 20 mm (maximum) and hence, the damage was not to that extent as observed at Pangthang. Extensive damage could be seen on leaves in the exposed areas without shade trees. No hailstorm damage under shade trees having spread out canopies and in protected areas with 50 percent agro-shade net [Figs. 2(e&f)]. Similar results were also reported in large cardamom by Saju *et al*., (2011). In large cardamom, complete damage occurred in exposed areas, and plants under the shade trees were partially affected. Physical damage to floral parts due to hail occurred at the flowering stage and depending on the extent of damage the yield of the plant was also affected in the subsequent crop season. However, accurate estimates of crop reduction are not available. Dev, (1992) recorded the pattern of thunderstorms, hailstorms, and snow fall in Sikkim; however, their effect on large cardamom has not been studied. Hailstorm damage to large cardamom plantations is a regular phenomenon, especially at high altitudes in Sikkim.

3.4. *Strategies to minimize hail storms effects on large cardamom plantations at Sikkim, North East India*

Even a short episode of hail can cause severe injury to large cardamom plants, resulting in poor economic yield. Hence, there is a need to reduce hailstorm impacts by establishing adaptation and mitigation strategies, taking into consideration local and indigenous knowledge. Some of the hailstorm management strategies are given hereunder to minimize the ill effect of hailstorms.

3.4.1. *Before the occurrence of hailstorms*

(*i*) Use hail net/Agro shade net (50%) for large cardamom plantations to protect from hail damage in established plantations of large cardamom. Hail netting can be 70-80% effective.

(*ii*) New plantation of large cardamom should be done under 50% shade of local trees with proper spacing to protect the crop from hail damage.

(*iii*) Arrange for adequate drainage to avoid water stagnation in standing large cardamom plantations if any.

(*iv*) An eco-friendly vertical farming concept should be adopted while planting the large cardamom in open conditions. Therefore, a "*Bamboo Machan*" should be constructed after the planting of large cardamom/or in an established large cardamom field (Fig. 1). After that cucurbitaceous crops, like bottle gourd, ridge gourd and squash should be planted at 3 meters apart. Cucurbit will trill above the *machan*, spread very fast and provides shade to the large cardamom plants, which can minimize the impact of hail storms besides reducing the runoff of water from land during intense rainfall and additional income to the farmers. Furthermore, in vertical farming, multiple numbers of crops are growing, so if any one crop fails the other can generate some income.

3.4.2. *After the occurrence of hailstorms*

(*i*) To clean up the debris and leaves of plants to avoid the further spread of pests and diseases.

(*ii*) If the hail event is associated with heavy rainfall farmers are advised to drain out excess water from standing large cardamom fields either through land modifications.

(*iii*) If a large cardamom crop has not been organically fertilized, the application of organic fertilizer to the impacted plants can help them to resurrect and develop new tillers. Similarly, an organic-based fungicide should also apply to prevent rot from entering before the wounds can heal, because open wounds on the growing shoots and scaffolds present entry points for bacterial and fungal pathogens and also insects.

(*iv*) Plants damaged in the spring season benefit from a layer of organic mulch around the base of the plant to help it survive in summer.

(*v*) Some plants are too heavily affected and fixing hail damage is not possible. These plants should be removed and replaced with new plants.

4. Conclusions

Thus, it can be concluded that hailstorms cause severe damage to large cardamom plants. Hence, there is a need to systematically document the data on the temporal and spatial distribution of hailstorms with the consequent damage in the hilly region of northeast India. Establishment of a Doppler Weather Radar (DWR) network in the region to monitor mesoscale phenomena, and assimilate RADAR data in numerical weather prediction models to forecast the occurrence of hailstorms over larger areas. Hence, there is a necessity to formulate a pilot project involving IMD, ICAR, SAUs and progressive large cardamom farmers to undertake studies on the suppression of hailstorms and to explore economically viable protection strategies to minimize the losses due to hailstorms in large cardamom plantations.

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