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Cultivation of Black Cardamom and Climate Economic Management Challenges in Mountainous Regions of Bhutan

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Authors' contributions

This work was carried out in collaboration among all authors. Authors BSK, LC and DSK designed the study, collected the various statistics, literatures and wrote the manuscript. Authors BS, RC and KS analyzed data and supervised overall research. Thus, all the authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Black Cardamom are commonly grown crop in eastern Himalayan countries and in Bhutan, the cultivation of Black Cardamom are specially done in south western districts whereby the people immensely depend on the crop for their livelihood income. Further, the crop significantly contributes in gross domestic product growth as it falls under the top ten highly exported commodity of the country. The high value obtained from Black Cardamom has encouraged farmers to expand the

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cultivation in different land use types. When the farmers are gaining income, the challenges in management of cultivated Black Cardamom are also increasing. In the recent times, vital change in climate activity have been recorded. The erratic temperature and rainfall are declining the yield of Black Cardamom. The increasing number of pest and diseases outbreak in cultivated land are creating concern and challenge on the farmers depending on Black Cardamom for living. The farmers are in dismay with no proper management skills and techniques taught to them. Relying on traditional methods for improving the productivity has failed to be a good strategy with changing time and climate being erratic. The climate resilient management activity need to be initiated and enormous studies are in need to prevent the future catastrophe on Black Cardamom and the cultivator's livelihood.

Keywords: Agroforestry; climate resilient; management; pollution.

1. INTRODUCTION

Black Cardamoms are one of the oldest spice that have been used in Ayurvedic since 6th century BC. It was in 4th century BC, Theophrastus recorded it as *Amomum* [1]. However, William Roxburgh gave the confine name as *Amomum subulatum* [2,3]. *Amomum subulatum*, commonly known as a Large Cardamom or Black Cardamom have been used as traditional spice. The spice being non-perishable crop, it has been widely grown in eastern Himalaya ranging from Northeast India, Eastern Nepal and South-West Bhutan as an agro-forestry crop. But, due to its high market value, the cultivation has been extended to agriculture land [4]. Lepchas from Sikkim were believed to be the first indigenous people to cultivate Cardamom as an agroforestry crop and this system has helped in livelihood and biodiversity conservation [1].

The farmers of Bhutan started growing Cardamom in early 1970s after the border-states such as Sikkim, Assam and West Bengal showed a way of growing and earning income from the Black Cardamom [4]. Through seeing the farmers interested in Black Cardamom cultivation, the Bhutanese government also provided a support to the farmers [5]. The government provided a government reserved forest and land to farmers in lease for the cultivation of Black Cardamom. During the year 1973 – 1974, the department of agriculture provided planting material to the farmers and the cultivation of Black Cardamom was rapidly spreading in South-western districts [4].

In 1990s the production of Black Cardamom was 1100-1400 metric tons but the bountiful harvest was hardly hit by an epidemic. Which caused a viral and fungus infection in Cardamom and the farmers started growing vegetables. Again, after one and half decades the cultivation of Black Cardamom was initiated by farmers. So far, annually, the three nation (India, Nepal and Bhutan) produces around 10,000 – 15,000 metric tons of Black Cardamom that are exported in global market to enhance the livelihood of traders and cultivators [4].

Recently, the farmers are worried due to the decline in Black Cardamom yield. They have few knowledge in managing Black Cardamom for high yield. In the current period where the weather patterns are abnormal and climate change are hampering the crop [6,7], the continuous use of traditional way can lead to poor management and quality of Black Cardamom will decrease [4]. Therefore, this review was carried out to help extension workers, researcher and policy makers know the challenges face by the farmers in Cardamom cultivation due to changing climate pattern and come up with proper Black Cardamom management strategies in future.

2. METHODOLOGY

Various journal articles and reports were referred for a critical review. The charts and graphs were made based on the data obtained from reports, agriculture sector and other relevant organization. The statistics from Department of Agriculture (DoA) [8]. National Statistics Bureau (NSB) [9], Department of Trade (DoT) [10] and World Bank [11] were used for the analysis.

3. RESULTS AND DISCUSSION

3.1 Black Cardamom Varieties and Shift in Land Use Types for Cultivation

There are varieties of Cardamom grown by farmers in eastern Himalayan region and in total there are 16 varieties of Black Cardamom grown

in the world [12,13]. In 1970s, Bhutan government introduced three varieties of large Cardamom know as Ramsey, Golsey and Sikkimey. But in 1990s, when the Cardamom was hit by disease, it was all uprooted. In recent years the farmers have started the cultivation of Black Cardamom with new variety known as Bharlange [4].

In Bhutan, only 6% of Black Cardamom are cultivated under agro-forestry practices. The increasing number of people are choosing dry land (49%) and shift agriculture (44%) for planting Black Cardamom [5]. The farmers are taking up Black Cardamom cultivation without any prior knowledge on land use types and altitude wise cultivation of Black Cardamom varieties in the country [4]. The Black Cardamom needs to be planted base on suitability and adaptability of the crop in various altitudes [5]. If they continue to plant without concept on land use types and altitudinal wise cultivation, there are higher potential this crop will be susceptible to pest and diseases due to the erratic climatic factors [14,5].

The major shifts in habitat of Black Cardamom are mainly due to socio economic factors such as illiterate farmers, high labour charge, traditional methods of cultivation and few trainings on the use of modern farming in villages [15,16]. The modernization has left only elderly in the home. Their children prefer to live a life in town, making it difficult for elderly to work in agroforestry habitat [16]. Therefore, the farmers prefer agriculture fallow land for cultivating Black Cardamom. As it is easy to work on the plants and observe the plants directly. Currently, the Black Cardamom is grown in every inch of land and there are farmers from 14 districts (Fig. 1) engaged in Black Cardamom plantation [8].

3.2 Economic Benefits and Livelihood Sustenance

The Black Cardamom being high value cash crop, every individual in the family are involved in the cultivation (Table 1). Not only it improves the life of farmers, the export of Black Cardamom to outside world generates high revenue to the government [6]. In Bhutan, the Black Cardamom falls under top ten highly exported commodities generating yearly income in millions (Table 1) [10] and it has been exported all the way to India, Pakistan, Afghanistan, Bangladesh, UK, Malaysia, Japan and Middle East [4].

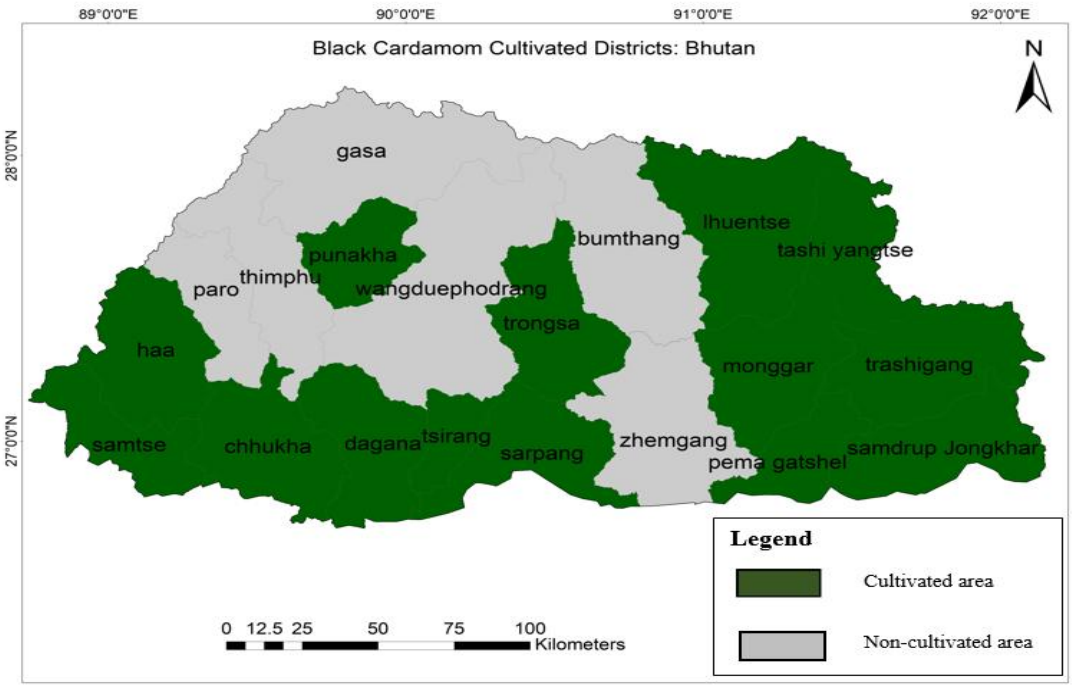

Fig. 1. Black Cardamom cultivated Districts

Table 1. Area cultivated and production trends (NSB, 2021)

Years	Area grown (Acres)	Production (MT)	Value (M)
2010	4771	476.2	222.2
2011	4144	427	384.3
2012	5083	643	ND
2013	6904	1162	ND
2014	8683	1781	ND
2015	10,610	845.74	940.75
2016	11086	1289.01	1342.38
2017	13880	2031.31	1330.22
2018	14362	1698.03	929.41
2019	15614.77	2451.08	1227.62

MT: Metric tons, M: Million, ND: no data

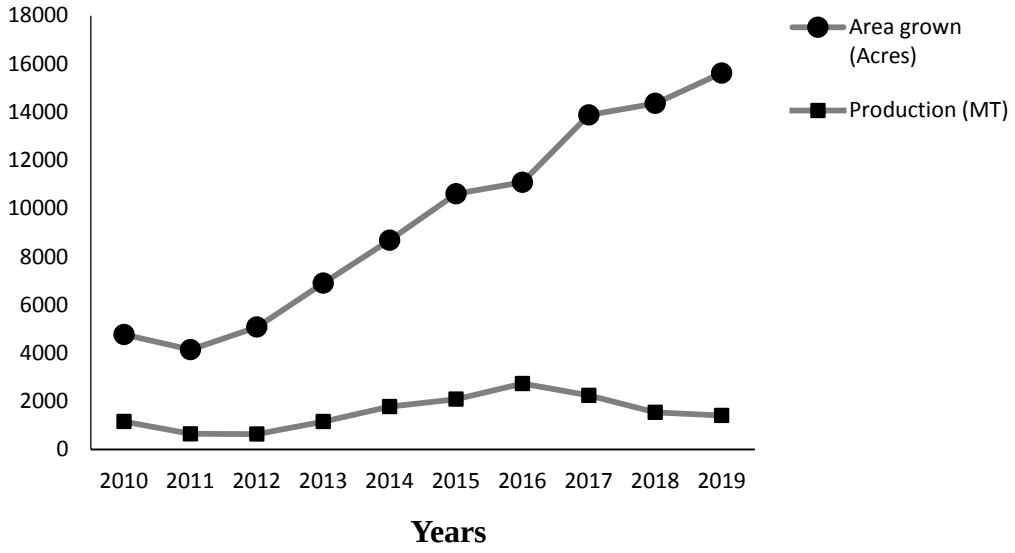

Fig. 2. Area grown and production trend (last 10 years)

The reasons for having diversity of buyers of Black Cardamom are due to the medicinal properties and essential oil (2-3%) it contains. The decoctions of Cardamom seed are used in preventing teeth and gum infections. Even the seeds are referred as antidote for snake and scorpion venom [17]. There are other numerous health benefits of the seed such as curing throat troubles, inflammation of eyelid, digestion, pulmonary tuberculosis and congestion of lungs. It is widely used as raw spice in making kheer, biryani, sweets and curry [18].

Being the top ten exported commodity of the country, it has contributed to increase the gross domestic product of the country. In 2019, the primary sector (Agriculture, Livestock, Forestry) has contributed 15.82% in the growth of GDP. Out of 15.82%, the export of Black Cardamom alone contributed around 4.3% making it a highly valuable agriculture crop that has contributed to the GDP of the country (NSB, 2020). The cost of Cardamom at the current period ranges from 350 to 400 per kilogram [19,20].

This spice being less labor intensive crop, every year there are increase in area cultivated (Table 1) with Black Cardamom [8]. However, mono-croppings are not a wise strategy for earning and increasing the economy of the country. Himalayan regions are cautioned highly susceptible to climate change [21]. In this context, any climate catastrophe can decline the economy gain from the Black Cardamom [22]. The climate resilient Black Cardamom variety and productivity have to be explored for further strengthening the economy of the country [6].

3.3 Climate Change and Productivity in the Last One Decades

The increase in yield of Black Cardamom and high price in past years have encouraged farmers to extend the cultivation in broader areas. In recent times, the yield has been decreasing (Fig. 2), though the area of cultivation has been increasing [8]. The low productivity of Black Cardamom is due to infestation of pest and diseases caused by unseasonal rainfall, poor management activity and climate change attributing to decline in yield [23]. Some farmers from southern Bhutan are removing Black Cardamom for other cash crop plantation and some are in dilemma without ideas on management of Black Cardamom against climate change leading to income lose and resource wastage [24].

However, studies are still carried in India and Nepal to produce climate resilient Black Cardamom plants. Advocacy program for farmers on management of Black Cardamom are organized [6]. In Bhutan, such measures are not initiated by extension officers due to scanty studies on productivity and management of Black Cardamom against climate change issues [5]. It has been critical to look into climate change and performance of Black Cardamom for future livelihood sustenance [25,26].

Black Cardamom depends on solar radiation, temperature and precipitation for optimum growth. On the other hand, the erratic weather can hamper crop growth through increasing pest and diseases, and deteriorating soil nutrients [27,28,29]. The warmer temperature and dry land will trigger more evapotranspiration from the crop leading to poor yield and disease infestation [30,31].

The temperature and rainfall are the two largest climatic factors, where their effects are four times higher than variation in light incident on crops [32]. The temperature and rainfall have become erratic from past several years in Bhutan (Fig. 3) hampering the productivity of Black Cardamom. The seasonal variation in rainfall influences the crop yield especially perennial spices such as Cardamom and Black pepper [33-35,11,12].

The Black Cardamom requires rainfall of around 3,000 to 4,000 mm per year for around 250 days [5]. The change in climate has alter the precipitation whereby Black Cardamom has been receiving low amount of rainfall and erratic temperature (Fig. 3). The low rainfall and high temperature trigger the microbial activity of pest and diseases leading to higher rate of infestation to Black Cardamom [20]. The Black Cardamom is prone to frostbite but it can survive up to 1ºC temperature [24]. The growth rates are slow in

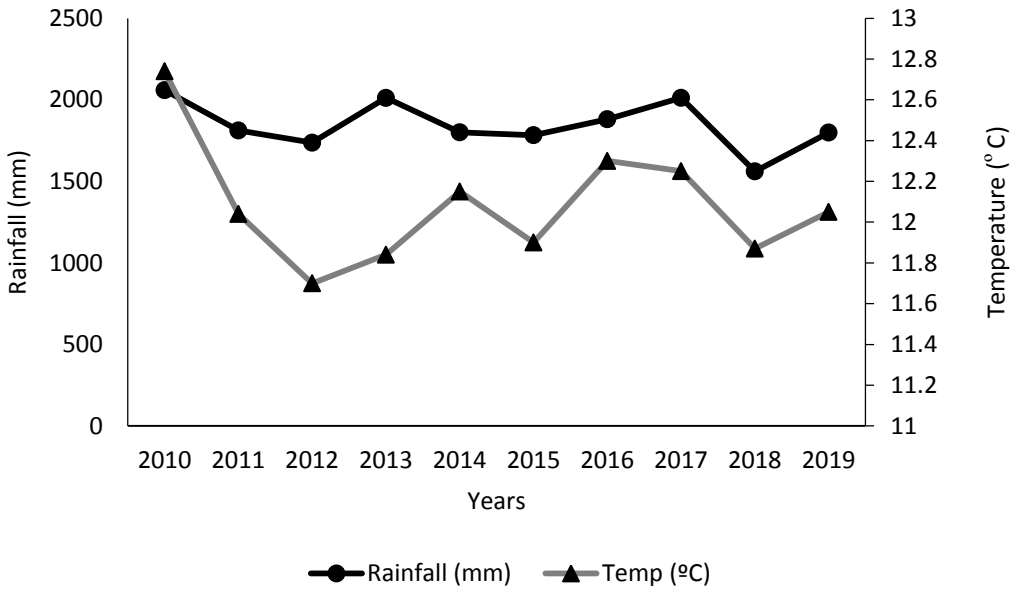

Fig. 3. Change in annual average rainfall and temperature in the past 10 years

dry season and prolonged sunlight dries out the leaves. Irrigating two times in a week for 3-4 hours results a good harvest [5].

If climate change continues to occur in the mountain ecosystem, it will promote more pest and pathogens in crops leading to pesticide application. A quantitative study is necessary to prevent higher rate of pesticide application and consumption in future [36]. Furthermore, more data on agro-ecological impact of climate change [24] on climate change trends are needed and its impact has to be studied through past records [37-39].

3.4 Climate Resilient Management Challenges in Gaining Sustainable Economy through Cultivation

3.4.1 Pest and diseases in black cardamom

For the first time in 1997 some diseases of Black Cardamom such as *Macluravirus* sp. (Chirkey) and *Nanovirus* sp. (Furkey) was detected and still there are no proper methods and technology to cure them [4]. In Bhutan, two major diseases known as *Colletotrichum* sp. (blight) and *Fusarium oxysporum* are damaging the growth of Black Cardamom. In addition, the viral disease Chikery and Foorkey are also contributing to yield decline. So far with no measure control on this viral disease, the only option left for the Bhutanese farmers was to uproot and burn the whole plant [40,4].

The aphids were found to be the main cause for the spread of viral disease known as Chirkey and Foorkey. On top of that the erratic climate and change in ecosystem such as insufficient rainfall during dry season and poor climate resilient management practices are spreading diseases. Further the disease can be spread from planting infected suckers and using same knife while harvesting Black Cardamom [18].

In recent times, several other diseases and pest has been reported on Black Cardamom in Bhutan [4] such as stem hardening disease, leaf burning and infection, blight and stem borer, leaf eating caterpillar and rodents. The farmers are in dilemma as they lack knowledge on management activities against pest and disease and the agriculture sectors has scanty climate resilient management research studies on the spice [15].

The farmers need to be advocated on use of bio-pesticide such as cattle urine and dung that can remove some pest and diseases in Black Cardamom. Rodents can be controlled through barn owl strategy as it was found that the barn owl having strong night vision, they can eat more than 5000 rodents in a year [5]. The leaf eating caterpillar *Artona chorista* can be controlled by culturing its predator. If the insecticides are applied the predator will extinct leading to outbreak of the pest [18].

3.4.2 Agroforestry and choice of tree species

Agroforestry has a great potential in mitigating climate change as it has higher carbon sequestration rate [41]. Uttis (*Alnus nepalensis*) trees provide excellent shade, supply a good amount of litter from twigs and leaves, and nitrogen from the root nodules to understory Black Cardamom when they are young [15].

There are diverse benefits growing Black Cardamom as an agroforestry crop such as slope management, soil and water management, high carbon sequestration and increase soil fertility. The crop helps in sustainable utilization of forest resources [42]. It fulfills both economic and conservation demand of people and policy makers. The agroforestry system also provides wide range of benefits such as medicinal plants, mushrooms, tubers, firewood, fodder and wild edible source [1].

The large Cardamom grown under the *Alnus* tree have proved to have better productivity, soil nutrient dynamics and stand energy efficiencies comparing to mixed forest trees [1]. Therefore, about 70% of Black Cardamom are grown under *Alnus nepalensis* and 30% under mixed tree [1]. Many rural people prefer growing Black Cardamom under the shade/canopy cover of *Alnus nepalesis* [18,43,1]. The Black Cardamom grown under agroforestry systems has highly improved the life of mountain regions [31].

As the production increases, the threats to the Black Cardamom are also high. The farmers need to be educated on the cultivation of Black Cardamom with proper shade tree species. The percent shade required by the crop need to be taught to the farmers [44]. If the shades are overcrowded, it provides a suitable habitat for pest and diseases to hide during heavy rainfall and hot weather conditions. If the large Cardamom is planted with few shades. The crop can be easily damage by windstorm and direct

sunlight [45,44]. The proper management practices and best habitat suitability study are required for the growth of Black Cardamom by the farmers [4].

3.4.3 Soil nutrient management

Productivity of Black Cardamom depends on many factors such as irrigation, fertilizers applied, farm management, insect and pest control, and government training on growth management to farmers [31]. In Sikkim, the best growth of Black Cardamom was found where there was high amount of soil moisture, nitrogen, medium phosphorus and potassium, and pH range between 4.5 to 6.0. Proper amount of organic and inorganic matters should be applied for better yield of Black Cardamom during the month of April or May. However, if the crop residues are recycled, it is not necessary to apply fertilizers [18].

The nitrogen fixing trees (*Alnus* sp.) increases the amount of nitrogen and phosphorus in the soil with faster rate of litter decomposition. The annual litter production was higher in *Alnus* Cardamom with better uptake of phosphorus comparing to mandarin and other forest trees. Immobilization of Nitrogen and Phosphorus are higher in *Alnus* sp. to mandarin-based Cardamom cultivation [46]. The better nutrient cycling and less nutrient uptake by *Alnus* sp. makes it a better agroforestry tree to be grown with Black Cardamom [43]. In Nepal and India, crop productivity has been found to decrease with low soil moisture and soil nutrients [41]. Better techniques need to be taught to the farmers on climate soil management for high yield.

3.4.4 Curing capsule and environment pollution

The harvesting of Black cardamom is done based on the crop grown in different altitudes. In low and mid altitude, the harvesting begins from August to September. In high altitude, harvesting is done from November to December as the pods mature late due to cold climatic condition [23]. Further the spice is harvested along with spikes when the top of capsule starts turning brown. The spikes are heaped and capsules are dried. The calyx is removed from the capsule through rubbing and the capsules are cured [18].

In most parts of eastern Himalaya, the curing is done using traditional way (Bhatti) [47]. The Black Cardamom is cured in the lumps of smoke that requires enormous amount of firewood. The farmers have to stay in the smoke to prevent the burning of capsules. They have to inhale and shed the tears of smoke to earn cash for their living. The smoke can have implications on their respiratory health in future [33]. Further, the smoke can create pollution and impact the nearby environment.

The increasing number of people taking up Black Cardamom as the source of earning and living can lead to use of more timbers for curing. The increase in amount of smoke produce in the process can increase the pollution rate affecting living beings [48-50]. Proper methods and technology have to be implemented where the curing can be done without pollution. Also, the traditional way leads to darker Cardamom with smoky smell where farmers fetch low price [18].

The modern technology has been made by Indian Cardamom Research Institute (ICRI). It involves indirect heating of Black Cardamom at 45 to 50 ºC. The Energy and Resources Institute (TERI) have made gasifier to improve the quality Cardamom while drying. But, the farmers prefer traditional way of curing due to high cost involved in modern method [47,18]. Affordable technology have to be made to encourage farmers in preventing pollution. The cured capsules are packed in polythene bags and kept on wooden materials to prevent absorption of moisture and growth of fungus. The dried Cardamom retains 10-12% moisture. The farmers keep their harvest for one or two years and sell it when the market price is high [51,18].

4. CONCLUSION

The Black Cardamom have been grown from five to six decades in Bhutan and it has improved the livelihood of farmers residing in various districts. In terms of economy, the Black Cardamom are listed in top ten highly exported commodity of the country. The high income generated from the Black Cardamom have immensely encouraged farmers to grow Cardamom in various habitats.

The advancement in the cultivation of Black Cardamom with lack of knowledge can create challenges in future productivity. In the country, there are lack of knowledge on Black Cardamom varieties that should be planted in different altitudes. The farmers, extension workers and policy makers have scanty knowledge on Black Cardamom and climate resilient management.

In neighboring countries, various scientific methods have been used to increase the productivity of Black Cardamom and to ease the farmer's life. The modelling has been done to find the habitat suitability of Black Cardamom. Comparative study on the growth of Black Cardamom in agroforestry and mandarin have been done. Soil analysis have been done for the best growth. Associated tree canopy cover have been investigated. Pest and diseases on Black Cardamom have been studied. People's perception on Black Cardamom have been considered. Even for the future yield of Black Cardamom, climate resilient management was sought out.

In Bhutan, farmers still relay on traditional way of cultivating and nurturing the Black Cardamom despite the climate change effects. The intensive use of wood for curing the capsules results in air pollution and effect on self-health. There is lack of Black Cardamom management education provided to the farmers and officials. There are needs of proper investigation on diseases, soil, canopy cover, crop yield in different habitats and climate resilient strategies to prevent current decline in Black Cardamom yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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