Journal of Asia-Pacific Biodiversity 9 (2016) 17–21

Contents lists available at ScienceDirect

Journal of Asia-Pacific Biodiversity

journal homepage: http://www.elsevier.com/locate/japb

Original article

Variations in pollinator density and impacts on large cardamom (*Amomum subulatum* Roxb.) crop yield in Sikkim Himalaya, India

Kailash S. Gaira [a,*], Ranbeer S. Rawal [b], K.K. Singh [a]

[a] *G. B. Pant Institute of Himalayan Environment and Development, Sikkim Unit, Campus Pangthang, Gangtok, East Sikkim, India*
[b] *Biodiversity Conservation and Management Theme, G. B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora, Uttarakhand, India*

ARTICLE INFO

Article history:
Received 22 September 2015
Received in revised form
29 December 2015
Accepted 31 December 2015
Available online 8 January 2016

Keywords:
Bombus sp.
large cardamom
pollination
pollinator
Sikkim Himalaya

ABSTRACT

Large cardamom (*Amomum subulatum* Roxb.), a perennial cash crop, cultivated under an agroforestry system in the eastern Himalaya of India, is well recognized as a pollination-dependent crop. Observations on pollinator abundance in Mamlay watershed of Sikkim Himalaya were collected during the blooming season to evaluate the pollinator abundance across sites and time frames, and impact of pollinator abundance on crop yield from 2010 to 2012. The results revealed that the bumblebees and honeybees are most frequent visitors of large cardamom flowers. The abundance of honeybees, however, varied between sites for the years 2010–2012, while that of bumblebees varied for the years 2011 and 2012. The abundance of honeybees resulted in a variation within time frames for 2010 and 2011, while that of bumblebees varied for 2010 and 2012 ($p < 0.01$). The density of pollinators correlated positively with the number of flowers of the target crop. The impact of pollinator abundance revealed that the increasing bumblebee visitation resulted in a higher yield of the crop (i.e. 17–41 g/plant) and the increasing abundance of all bees (21–41 g/plant) was significant ($p < 0.03$). Therefore, the study concluded that the large cardamom yield is sensitive to pollinator abundance and there is a need for adopting the best pollinator conservation and management practices toward sustaining the yield of large cardamom.

Introduction

The large cardamom (*Amomum subulatum* Roxb.), family Zingiberaceae, is one of the major perennial cash crops in the eastern Himalaya of India, Nepal, and Bhutan. In particular, Sikkim, a Himalayan state of India, contributes nearly 57% of world's total production (Sharma et al 2000). The species is cultivated between an elevation of 600 m and 2000 m above sea level (asl) under different agroforestry systems (Sharma et al 2009). In addition, cultivation of large cardamom is considered cost effective compared with other crops as it is a less labor-intensive and non-nutrient exhaustive crop (Singh et al 2005; Singh 2008). The capsule and seeds are used as condiments for culinary and other preparations due to their pleasant aromatic odor; the seeds contain 3% essential oil with a high cineole content having medicinal properties (Sharma et al 2000; Sinu and Shivanna 2007; Singh 2008; Kishore et al 2012). The species has subterranean rhizomes that give rise to leafy shoots with spikes. The flowers emerge during the months of April–June, and the numbers of inflorescences produced on each bunch range from 20 to 45 depending on the age of the clump (Sinu and Shivanna 2007). Each inflorescence produces ~30–50 yellowish flowers (4.5–8 cm in length). The most prominent part of the flower (i.e. yellowish labellum/lip) provides a platform for the visiting insects (Sinu and Shivanna 2007).

A. subulatum is a pollinator-dependent crop (Sharma et al 2000), and its quality and quantum of yield is determined by effective pollination services. In spite of its proven value, pollination studies on this species have been neglected until recently, when Sinu and Shivanna (2007) explored pollination biology of this species in Sikkim part of the Indian Himalaya. Subsequently, other workers have contributed to the knowledge base on pollinators and pollination biology of *A. subulatum* (Deka et al 2011; Sinu et al 2011; Kishore et al 2012). Although Kishore et al (2011) have studied the pollination efficiency and nectar production in large cardamom, several issues, which pertain to pollinator

* Corresponding author. Tel.: +91 9593261157.
E-mail address: kailash_gaira@rediffmail.com (K.S. Gaira).
Peer review under responsibility of National Science Museum of Korea (NSMK) and Korea National Arboretum (KNA).

http://dx.doi.org/10.1016/j.japb.2015.12.010
pISSN2287-884X eISSN2287-9544/

diversity, frequency, habitat dependence, and more importantly impact of pollinator activity on the yield of the crop, have not yet been resolved. Realizing this and considering its importance, the present study targets *A. subulatum* in Sikkim Himalaya for exploring the following: (1) variations in pollinator abundance during the blooming period across diverse site conditions (different levels of naturalness as described under the "Materials and methods" section); (2) interaction of pollinators with flowering frequency; and (3) impact of pollinator abundance on crop yield.

Materials and methods

Study areas and observational sites

The Mamlay watershed (from 27°12′3″ to 27°16′4″N latitude, and from 88°19′2″ to 88°23′30″E longitude), situated in the southern part of Sikkim in India, forms the study area and covers an area of 31.89 km^2 (Figure 1). Watershed experiences diverse land-use patterns (i.e. agricultural land 11.22 km^2, open mixed forest and scrub land 10.41 km^2, reserved forest 8.63 km^2, and settlement 2.61 km^2) along an extensive altitudinal range (300–2650 m asl) that represents a wide range of traditional agricultural practices including agroforestry.

Observational sites were identified in the large cardamom-growing areas traditionally cultivated by farmers. The sites were selected to represent three distinct landscape features: Site 1—within village boundary (human inhabited area where interventions in natural conditions are frequent in diverse form); Site 2—under forest canopy (villagers frequently harvest forest products—leaves for fodder, wood for fuel, etc.); and Site 3—close to reserved forest, i.e. 200 m (villagers seldom use forest products). The minimum distance between any two sites was 1.5 km. Four subplots of 20 × 20 m^2 were established at each site for this study.

Data collection

Data were recorded in the observational plots from the onset of the main blooming period of the target crop (3rd week of May onward). Pollinator abundance was measured by scan sampling (Levin et al 1968) in four different time intervals (1st, May 23–31; 2nd, June 2–10; 3rd, June12–20; and 4th, June 22–30). These time intervals were chosen to capture the overall changes in flowering abundance across the flowering season. The recording hours [i.e. morning hours (0800–1200 hours)] were same for each site. During the recording time, weather conditions, i.e. sunny or overcast, were also observed. A day was considered sunny when the cloud cover varied between 0% and 50% and overcast when the cloud cover varied between 50% and 100%. Scan sampling process was a slow walk along a set path or row, and recording of the insect visitors/pollinators seen on individual floral parts (i.e. simultaneously count the 100 open flowers and visit of insects/pollinators to open flowers). The pollinator abundance was recorded per 100 open flowers with a similar process in each plot of the three observational sites. Moreover, the recording time in each plot was logged (count the insects/pollinators within 15 minutes). Considering the covariance effect on pollinator diversity, flowering observation was recorded for five randomly selected plants in individual plots (i.e. 20 plants in each site). The number of full-bloomed flowers from each plot was counted for a given period of time. For estimating the deficit of pollination in the target crop, yield data (fruit weight per plant) of the crops of the selected plots were measured during harvesting (i.e. mid-October). The mean of randomly selected five plants per plot was considered for measurement of the yield per plant.

Data analysis

The mean ± standard error of pollinator abundance was calculated. Based on the observational data structure, generalized linear

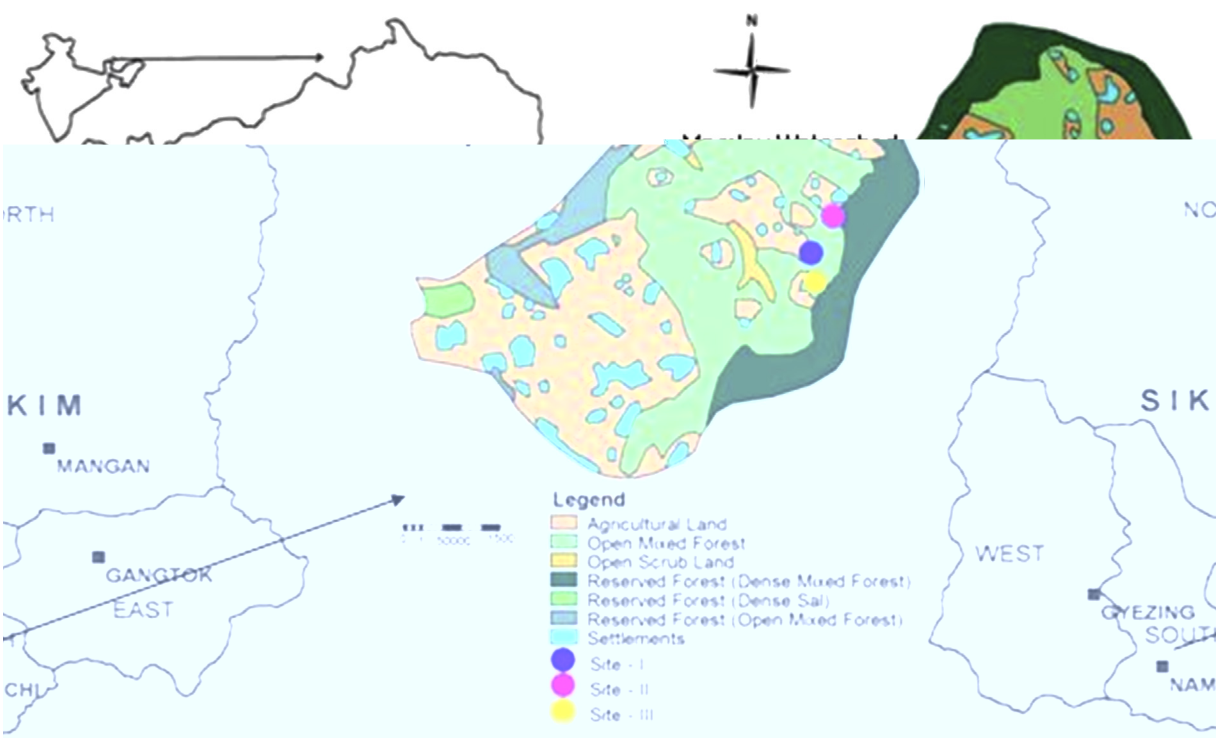

Figure 1. Land use pattern of study area (Mamlay watershed).