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Performance of *Apis mellifera* L. in cabbage hybrid seed production in net houses

Cabbage, *Brassica oleracea* var. *capitata* is a highly cross-pollinated species. For the seed production of open pollinated varieties as well as hybrids, an isolation distance of about 1.6 km is recommended[1]. Generally, such isolated distances are difficult to achieve in the field due to the cross compatibility of the crop with other members of cole group, namely cauliflower, knol khol, broccoli, etc. An alternative is to use insect-proof enclosures for seed production.

The pollen of cabbage is heavy and sticky, and hence not easily wind-borne; therefore, it is dependent upon various pollinators for pollination. A number of insect pollinators are associated with this crop. Amongst them, honey bees are the most predominant. Pollination of crops by honey bees is one of the most practical and promising methods of increasing crop production[2]. Honey bees exhibit flower constancy and can forage for longer duration. Bees collect pollen and nectar to supply to the next generation, whereas other insects collect them for their individual needs only. Hence, bees make more flower visits. Their long tongues, coats of long collecting hair, and the ability to warm themselves and to work in cool weather make them generally more efficient pollinators than most other insects. Amongst honey bees, *Apis mellifera* L. is a commercial bee species which can be managed in sufficient numbers where and when required.

Orientation is a key behaviour shown by the bees. Whenever bees are kept in a new place (beyond flight range) or in confinement say in a net house, bees first orient and then start foraging. Past observations have shown that honey bees do not forage and work in net houses of smaller size. Hence, the present study was undertaken with the objective to primarily standardize the minimum dimensions (length × breadth × height) of the net house where bees can forage. Since information on the utilization of honey bees in cabbage seed production in net house conditions is not available, a preliminary attempt has been made to study the performance of *Apis mellifera* L. as pollinator in seed production of this crop.

Seed production of cabbage hybrid H-702 under net house conditions was studied during 2011–12 and 2012–13 at the Research farm of Department of Vegetable Crops and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (altitude 1290 m amsl, between 32.11°N and 76.23°E). During 2011–12, cabbage was raised in a small ($l \times b \times h = 3 \times 2 \times 2.25$ m) and a large ($l \times b \times h = 15 \times 7 \times 4.5$ m) net house. During 2012–13, dimensions of the net house were $15 \times 7 \times 4.5$ m. For raising the seed, self-incompatible (SI) lines, i.e. I-4-6 and pollen parent, i.e. Golden Acre (Palampur strain) were used for producing seed. Table 1 provides details of materials used and methods employed.

During both the years of study, at the initiation of flowering in the crop, a queen right colony of *A. mellifera* of 1.5 bee frame strength was placed in one corner of each net house. The net house was maintained insect-proof from the very beginning of planting of the crop so that insects from the outside could not enter inside and bees were forced to remain confined in the net house. Data on foraging of bees were recorded in both the net houses (small and large) during 2011–12 and in a large net house during 2012–13. Besides, bee activity, including number of pollen and nectar gatherers, outgoing bees at the hive entrance (per 5 min) and the density of bees in 1 m^2 of the cropped area at the peak of flowering were also recorded at different time intervals (between 10.00 and 10.30 am (T_1), 12.00 and 12.30 pm (T_2), 2.00 and 2.30 pm (T_3) and 4.00 and 4.30 pm (T_4)) for six days. After the crop was ready, yield data were recorded during both the years of study.

During 2011–12, bees did not forage in the small net house and remained resting on the net house walls. No bee was observed to forage in this net house even up to five days, and some of the bees were observed to die in the net house. However, in the large net house bees were observed to rest on the net house walls for one day, but on the second day of placing of the bee colony, bees started their foraging activity normally. Foraging behaviour of bees was similar in both the years of study.

During 2011–12, the number of pollen-gathering bees was counted to be 34.67 ± 8.62 at T_1, which increased to 37.67 ±

Table 1. Details of materials used and methods employed during different years of study in net houses

Materials/methods	Years of study		
	2011–12		2012–13
	Net house I	Net house II	
Net house dimensions (m)	3 × 2 × 2.25	15 × 7 × 4.5	15 × 7 × 4.5
Date of nursery sowing	7 September 2011	7 September 2011	19 September 2012
Date of transplanting	24 October 2011	24 October 2011	25 October 2012
Crop spacing (cm)	50 × 45	50 × 45	50 × 45
Planting geometry	Two rows of self-incompatible lines and one row of pollen parent Golden Acre (Palampur strain)	Two rows of self-incompatible lines and one row of pollen parent Golden Acre (Palampur strain)	Two rows of self-incompatible lines and one row of pollen parent Golden Acre (Palampur strain)
Plant population			
(i) Self-incompatible line (I-4-6)	Out of 20 plants, 16 were retained	Out of 60 plants, 40 were retained	Out of 90 plants, 70 were retained
(ii) Golden acre (Palampur strain)	Out of 10 plants, 8 were retained	Out of 36 plants, 30 were retained	Out of 54 plants, 42 were retained
Date of placement of honey bee colony	6 April 2012	6 April 2012	8 April 2013
Date of lifting bee colony	13 April 2012	27 April 2012	28 April 2013
Plants taken for recording yield data	0 (no formation of siliqua)	40	70

Table 2. Yield of cabbage seed in net house conditions pollinated by *Apis mellifera*

Parameters	Year	
	2011–12	2012–13
Number of plants taken for recording yield data	40	70
Yield (g)	550	900
Yield (g) per plant (mean ± SD)	13.75 ± 1.46	12.86 ± 1.39
Weight (g) of 1000 seeds plant (mean ± SD)	3.71 ± 0.52	4.34 ± 0.36

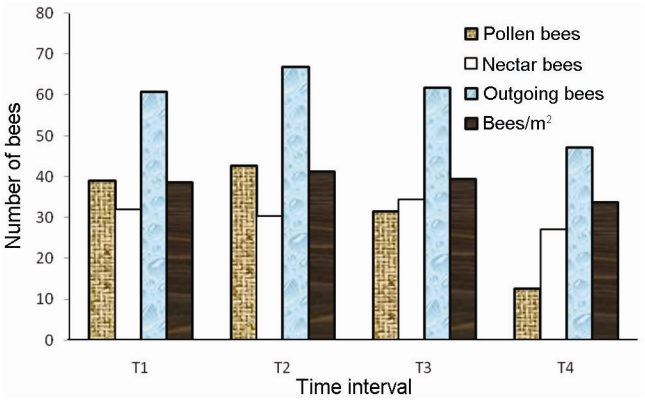

Figure 1. Foraging behaviour of *Apis mellifera* in cabbage in net house.

2.88 at T_2. Thereafter, the number declined steadily at the subsequent data recording intervals and was recorded as 27.50 ± 4.09 at T_3 and 10.67 ± 1.63 at T_4. The nectar-gathering bees at T_1 were counted to be 29.50 ± 7.01, which increased with the advancement of the day; the maximum number was observed at T_3 (29.33 ± 5.57). Minimum number of nectar gatherers was recorded at T_4 (23.83 ± 5.42).

During 2012–13, maximum number of pollen and nectar bees was recorded at the same intervals as that during 2011–12. The number of pollen gatherers varied from 14.67 ± 2.50 (T_4) to 47.83 ± 4.79 (T_2), and those of nectar gatherers varied from 30.50 ± 4.64 (T_4) to 39.33 ± 6.06 (T_3).

The number of outgoing bees during 2011–12 and 2012–13 was recorded as 54.67 ± 9.89 and 67.00 ± 10.18, 55.50 ± 4.32 and 78.50 ± 6.47, 49.00 ± 2.61 and 74.83 ± 4.92, as well as 47.67 ± 9.24 and 46.67 ± 5.68 at T_1, T_2, T_3 and T_4, respectively. The density of bees in 1 m^2 area was recorded to be maximum at T_2 during both the years.

Figure 1 shows the mean foraging activity of two years (2011–12 and 2012–13). The maximum number of pollen bees (42.75 ± 3.79), outgoing bees (67.00 ± 5.81) and bees per sq metre (41.34 ± 6.05) were recorded at T_2 (12.00–12.30 pm), whereas maximum number of nectar bees was found at T_3 (34.33 ± 5.34). Higher number of nectar bees at T_3 may be because of more nectar secretion at this time interval in the crop.

From the above results on activity of *A. mellifera* in net house of the dimensions 15 × 7 × 4.5 m, it is inferred that the bee species show normal activity in the net house on the crop. Verma and Partap[3], while studying the impact on vegetable seed productivity in the hills with the honey bee (*Apis cerana* Fab.) in different crops, recorded 28%, 35% and

40% increase in pod setting, seed setting and seed weight respectively, in cabbage.

Since there was no formation of siliqua in the plants raised in the net house of dimensions of 3 × 2 × 2.25 m, no yield could be recorded. Table 2 presents the data recorded on yield in the net house of dimensions of 15 × 7 × 4.5 m during two years. It can be seen from the table that during 2011–12, 550 g (from 40 plants) and during 2012–13, 900 g (from 70 plants) of seed was produced. The mean yield (per plant) and weight of 1000 seeds for two years were calculated to be 13.31 g and 4.03 g respectively.

There are variable reports on the cabbage seed yield under open field conditions which depend on various factors. Seed yields of 568 kg/ha from India and 500–600 kg/ha from Bangladesh have been documented[4,5]. In USA, seed yield to the extent of 22.5 g per cabbage plant has been reported and 1000 seeds were found to weigh 3.2 g (ref. 6).

From this study, it can be concluded that *A. mellifera* requires a minimum spacing for successful foraging in the net house and thus a net house of at least 15 × 7 × 4.5 m dimensions may be used for seed production in cabbage.

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Propagation techniques of *Zanthoxylum alatum* Roxb. (a Himalayan toothache shrub)

Uttarakhand Himalaya has a rich diversity of medicinal plants. *Zanthoxylum alatum* is a large evergreen shrub distributed mainly between 900 and 2100 m elevation. It is locally known as Timur or Timru[1]. It has high medicinal value and whole plant parts are used as medicine. Locally, it is used as a condiment and for water purification. Its dried fruits on steam distillation yield 2.3% essential oil. The chief content of oil is linalool and root bark contains spilanthol. The oil has anti-fungal activity; essential oil possesses antiseptic, disinfectant, deodorant properties; extract of fruits is useful in expelling roundworms[2]. Similarly, the seed and bark are used as a tonic in fever, dyspepsia and cholera, and twigs of branches are used for toothache[3].

Z. alatum is a well-known medicinal plant in the hills of Uttarakhand Himalaya; local harvesters have been collecting it from forest areas for many years for either local or commercial purpose. At present, this plant species has become scarce in the forest due to climate change, insufficient regeneration, unscientific and excessive harvesting, and human interference in its habitat. Rapidly increasing demand in the market and human pressure are having an adverse effect on its population. In future, it can become endangered or rare in the absence of sufficient natural regeneration and conservation measures. Currently, there is a need for mass propagation for future plantation along with creating awareness among the indigenous people, villagers and various forest divisions to conserve and protect this valuable species by means of plantation.

The present study was conducted in the forest nursery of Silviculturist (Silva Hill), Nainital, Uttarakhand during 2010–2013. The area is located at 29°22.751′N lat. and 79°25.955′E long. at an altitude of 1775 m. The climate of the area is temperate. Temperature ranges from 1°C to 30°C, with 1800 mm annual rainfall. The major portion of rainfall is received during July and August (monsoon period). Frost occurs from December to February.

Z. alatum leading shoots cuttings were collected from healthy and vigorous

Table 1. Effect of different indole 3-butyric acid (IBA) concentrations on sprouting (%) and rooting (%) parameters in *Zanthoxylum alatum*

Treatment	Sprouting (%)	Standard error of mean	Rooting (%)	Standard error of mean
MT1P	47.78	4.84	37.78	1.11
MT2P	53.33	1.92	50.00	1.92
MT3P	46.66	1.11	38.89	3.33
MCP	32.22	2.94	18.88	5.87

M, Sand; T1, IBA 4000 ppm; T2, IBA 5000 ppm; T3, IBA 6000 ppm; C, Control and P, Mist chamber.