(pitched) back and forth violently. This observation and the measured data did not provide any clue with regard to achieving stability of the vehicle in pitch. This led to a thought process about how a person balances a stick in his palm. There is no calculation done in the brain to balance the stick. Even a kid, after observation, learns to balance the stick in his palm. How is it done.

After a lot of contemplation, it led to a realization that we balance the stick in our palm by feeling. So how does one measure the feeling and use it in feedback control for stability? It became clear that human beings cannot feel position or velocity, but can feel acceleration which is the second-order time derivative of position. We cannot feel zeroth order or first-order derivative (velocity) of position. The *least* order of derivative we can feel is the second-order derivative of position. Maybe that is the reason, Newton's law relates force to acceleration (second-order time derivative of position, which is a feeling). (Then naturally a more fundamental question arises immediately: Could there be a more general relation having higher-order derivatives? May be possible!)

Figure 3. Attitude control of a mini helicopter under tethered hover flight.

On realizing the influence of feeling, the acceleration quantity (in the present case angular acceleration or pitch acceleration, evaluated by simple finite difference scheme using angular rate data at two time instances) was included in the feedback loop, and it was possible to stabilize the vehicle without any problem. It was experimentally observed that we could stabilize the vehicle even with zero rate feedback, despite the fact that the rate quantity represents damping. Figure 2 *a* and *b* shows the stabilized time response of the pitch motion and the corresponding control input respectively. The pitch angle was maintained at zero value, which refers to the vertical position of the helicopter. It is clear that the highly unstable pitch motion is made stable using acceleration (i.e. the quantity of feeling) feedback.

Incorporating acceleration feedback in the control loop, the attitude (pitch–roll–yaw degrees of freedom) control of the model helicopter under tethered hover flight was tested. The helicopter showed excellent attitude control. Figure 3 shows a snapshot of the helicopter in tethered hover flight. The effectiveness of acceleration feedback has also been reported recently[1,2].

This simple experiment and observation has raised an interesting point whether the events in nature (related motion) happen based on feeling, which can be a combination of several higher-order time derivatives of position. We plan to test this concept while we conduct future experiments on autonomous flights of the helicopter model.

1. Sebastijanovic, N., Yang, H. T. and Ma, T.-W., *J. Eng. Mech., ASCE*, September 2010, vol. 136, pp. 1187–1191.
2. He, Y. Q. and Han, J. D., *J. Guidance, Control, Dyn.*, 2010, **33**(4), 1236–1250.

ACKNOWLEDGEMENTS. I thank the Department of Science and Technology, New Delhi for funds; all the project employees for their contributions to this project and the reviewer for providing the recent references on acceleration feedback.

Received 18 November 2010; revised accepted 11 March 2011

C. VENKATESAN

Department of Aerospace Engineering,
Indian Institute of Technology,
Kanpur 208 016, India
e-mail: cven@iitk.ac.in

Melissopalynological studies on mangrove honeys from Sunderbans (Bangladesh) and Little Andaman (India)

A diverse spectrum of 27 pollen types belonging to 19 families was recovered from 12 honey samples, collected from the Sunderbans (Bangladesh) and Little Andaman (India). Melissopalynology, the study of honey with respect to its pollen composition, is an effective tool for studying the interaction between honey bees and vegetation, and is important in establishing apiculture-based honey industries. Pollen analysis of honey is used to determine its type, quality and origin, and indicate the floral nectar sources utilized by bees to produce honey[1–6]. In the growth and development of honey bees, nectar is the source of carbohydrates, whereas proteins are provided by the pollen[7]. The honey bees frequently make use of the resources available close to the site of the hives and analysing the proportional representation of different pollen types allows the characterization of honey from different regions, in terms of flora and vegetation.

Pollen analytical studies of Indian honeys are mostly fragmentary, although the honey and pollen load samples from different parts of India have been palynologically studied by several workers[8–11]. The importance of mangroves in honey industry has also been stressed[12–14]. However, melissopalynological studies from the Sunderbans (Bangladesh) are limited[15], whereas no such work has been undertaken from Little Andaman (India). Thus, the present study is aimed to understand the composition of vegetation around the bee hives and identify the major, medium and minor pollen plants through analysis of pollen content of regional honeys of the respective areas, and also to establish a basis for differentiation between honey samples procured from Katka, the Sunderbans, Bangladesh and from Dugong Creek and Jackson Creek, Little Andaman, India (Figure 1 and Table 1).

The Sunderbans is the largest single block of tidal halophytic mangrove forests in the world that lies at the mouth of the rivers Brahmaputra and the Ganga,

Table 1. Qualitative comparison between the Sunderbans and Little Andaman mangrove honeys (represented in percentages)

Locality	Sunderbans									Little Andaman		
Sample no.	K1	K2	K3	K4	K5	K6	K7	D1	D2	D3	J1	J2
Acanthus ilicifolius		18.41		17	6.87	2.32						
Cocos nucifera			1.42									1.51
Nypa fruticans		1.46					1.97	1.85				3.79
Phoenix paludosa							7.73			1.29		
Avicennia marina		9.55			17.44				4.32			
Salmalia malabaricum										22.74	17.96	20.25
Chenopodiaceae						+						+
Laguncularia racemosa		2.49		3.28								
Lumnitzera racemosa	2.85	7.34	8.57	1.75	8.08			4.28	1.57	2.23		
Terminalia sp.								2.35	1.74	4.19	1.37	4
Excoecaria agallocha	20.95			5.10	12.58		26.83	18.21				
Acacia sp.									6.12	1.65	1.14	8.25
Albizzia lebbeck											3.43	8.26
Pongamia pinnata								2.71	6.63	1.36		1.26
Barringtonia racemosa								21.42	24.35	53.01	17.16	20.34
Lagerstroemia sp.										4.61	3.66	19.79
Thespesia populnea										5.47		
Xylocarpus granatum	7.42		2.85		2.93	17.95					17.73	
Aegiceras corniculatum		2.42	10.50	1.45			7.89					
Osbornia sp.	2.66					1.91						
Syzygium sp.									5.51	3.45	5.49	
Poaceae			+						+			
Bruguiera sp.	11.61			16.93			2.52					
Rhizophora mucronata		30.71	20	54.06	24.10	5.28			19.99			
Scyphiphora hydrophyllaceae			1.28		1.41							
Sonneratia apetala	53.09	26.01	55.03		26.59	70.17	51.68	49.18	28.99		27.72	38.67
Clerodendron inerme		1.61					1.42				1.14	2.35

Sample sites: K1–K7, Katka; D1–D3, Dugong Creek; J1–J2, Jackson Creek. Values below 1% are indicated with +.

spreading across areas of Bangladesh and West Bengal, India. The deltaic region consists of numerous islands, mostly covered with mangrove forests, some of which are inhabited. The forests are dominated mostly by four major tree species, viz. *Heritiera fomes*, *Excoecaria agallocha*, *Sonneratia apetala* and *Ceriops decandra.* The species of Rhizophoraceae exist in more saline areas in the south and west, but they are also found in the north and east, although relatively infrequently. *H. fomes*, *E. agallocha* and *C. decandra* jointly cover 95% of the forest area. The common undergrowth species of the study area are *Acrostichum aureum*, *Acanthus ilicifolius*, *Phoenix paludosa*, *Pandanus foetidus*, *Porteresia coarctata*, *Dalbergia spinosa*, *Derris trifoliata* and *Hibiscus tiliaceus.* Among grasses and palms, *Porteresia coarctata*, *Myriostachya wightiana*, *Phragmites karka* and *Nypa fruticans* are well distributed[16].

The Little Andaman Island is one of the prominent islands, the Andaman and Nicobar archipelago and encompasses tidal flats, mangrove swamps, beaches, coastal plains and two major creeks, i.e. Dugong Creek in the northeast and Jackson Creek in the northwest. The natural vegetation consists of at least 2315 species of vascular plants ranging from hardwood trees, palms, lianas and many other creepers, tocanes, bamboos and orchids. The mangrove forests are mainly composed of *Rhizophora mucronata*, *R. apiculata*, *Bruguiera gymnorrhiza*, *B. parviflora*, *Heritiera littoralis*, *Nypa fruticans*, *Sonneratia apetala* and *Xylocarpus granatum*. The other significant associate members are *Casuarina equisetifolia*, *Terminalia catapa*, *Derris scandens*, *Pongamia pinnata*, *Syzygium claviflorum*, *Thespesia populnea*, *H. tiliaceus*, *Barringtonia asiatica* and *B. racemosa*[17].

Of the total samples, seven were collected from different places in the Katka region of the Sunderbans, and five from Dugong Creek and Jackson Creek of Little Andaman. For the extraction of pollen, 5 ml of honey from each sample was dissolved in 20 ml warm distilled water and centrifuged twice (2500 rpm) for 10 min. Thereafter, standard technique of acetolysis was employed[18], using acetolysing mixture (9 : 1 acetic anhydride and concentrated sulphuric acid), followed by several rinsings with glacial acetic acid and distilled water. Qualitative analysis of the samples was carried out by the standard method described[19]. Four hundred pollen grains per sample were identified and counted, and were placed into one of the following pollen frequency classes – predominant pollen type (> 45%), secondary pollen type (16–45%), important minor pollen type (3–16%) and minor pollen type (< 3%). Honey samples containing more than 45% of a single type of pollen were considered as 'unifloral' honey.

Among the seven honey samples from the Katka region, five were found to be unifloral and two were multifloral. According to frequency classes, two pollen types, e.g. *S. apetala* and *R. mucronata* were identified as predominant (> 45%) type. Pollen grains of *S. apetala* are dominantly represented in honeys from the Katka region, as this type is found to be predominant in four samples (K6, K3, K1 and K7), and as secondary pollen type in two samples (K5 and K2). *R. mucronata* pollen grains were identified as predominant type in one sample (K4), secondary pollen type in three samples (K2, K5 and K3), and as important minor pollen type in one sample (K6). Secondary pollen types are represented by *E. agallocha*, *B. gymnorrhiza*, *A. ilicifolius*, *X. granatum* and *Avicennia marina*. Important minor pollen types are *Aegiceras corniculatum*, *Lumnitzera racemosa*, *Laguncularia racemosa* and *Phoenix paludosa* along with *Osbornia* sp., *Cocos nucifera*, *Scyphiphora hydrophyllaceae*, *Clerodendron inerme* and *N. fruticans*. The frequency of pollen grains of Poaceae and Chenopodiaceae was sporadic in the honey samples.

Pollen analysis of five honey samples from Little Andaman (three from Dugong Creek and two from Jackson Creek) indicates that two samples were unifloral and the remaining three were multifloral. *S. apetala*, is the most important plant taxa, and its pollen emerged as the predominant pollen type in one sample (D1) and as secondary pollen in three samples (J2, D2 and J1). The next important bee plant appears to be *B. racemosa*, as its pollen grains were found as the predominant contributor in one sample (D3) and as secondary pollen type in four samples (D2, D1, J2 and J1). Secondary pollen types are represented by *E. agallocha*, *Salmalia malabaricum*, *R. mucronata* and *X. granatum*. Important minor pollen types are *L. racemosa*, *Acacia* sp., *Syzygium* sp., *Lagerstroemia* sp., *Albizzia lebbeck*, *Terminalia* sp., *P. pinnata*, *T. populnea* and *A. marina*. Some of the locally naturalized taxa, viz. *N. fruticans*, *P. paludosa*, *C. inerme* and *C. nucifera* were also recorded as minor pollen types. Pollen grains of Poaceae show very low contribution in the pollen spectra of honey samples of Little Andaman.

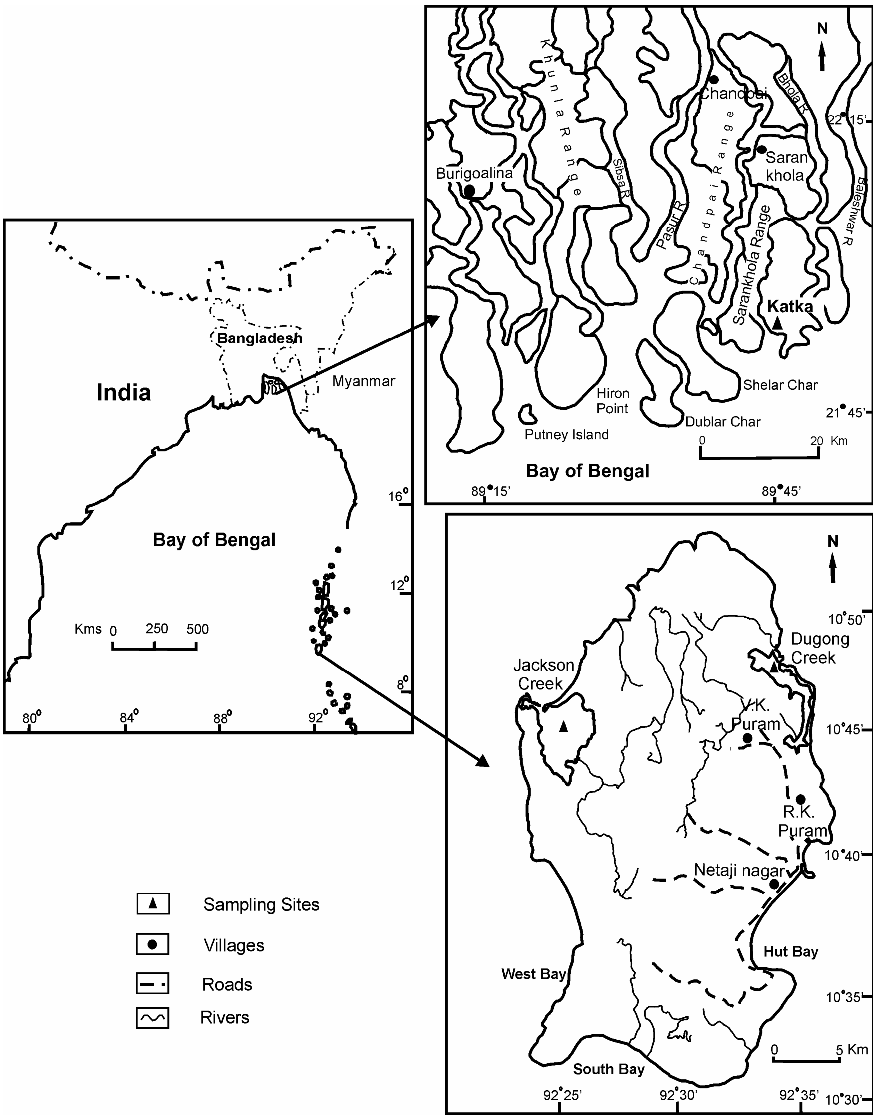

Figure 1. Map showing the location of sampling sites in the Sunderbans (Bangladesh) and Little Andaman (India).

The results of this study show a high level of utilization of native flora by honey bees in the respective study areas. The observations also reveal that with regard to native and wild plants, considerable dominance of mangrove flora is apparent. *S. apetala* was the most important bee plant in both the regions, as it has been identified as the predominant pollen in four samples of the Sunderbans and one sample of Little Andaman. It has also been found as the secondary pollen type in five samples (Katka – 2, Jackson Creek – 2 and Dugong Creek – 1). *Sonneratia* flowers are pollinated mainly by nocturnal species of nectarivorous bats, which forage the *Sonneratia*-dominated mangrove forests for their sustenance (Dawn Bat, Long-tailed Bat and Lesser Short-nosed Fruit Bat); and also by hawk moths (Sphingidae). Besides bats and moths, *Sonneratia* flowers also provide the major source of nectar to honey bees. In the honey samples of the Sunderbans (West Bengal), pollen grains of Rhizophoraceae were found to be dominant; *Bruguiera* sp. and *Phoenix* sp. being the dominant genera as far as percentage was concerned[12]. *R. mucronata* was the predominant pollen type in one sample, as secondary pollen type in three samples, and can also be considered as a good nectar source in the honey samples of the Sunderbans (Bangladesh). In Little Andaman, *S. apetala* and *B. racemosa* were

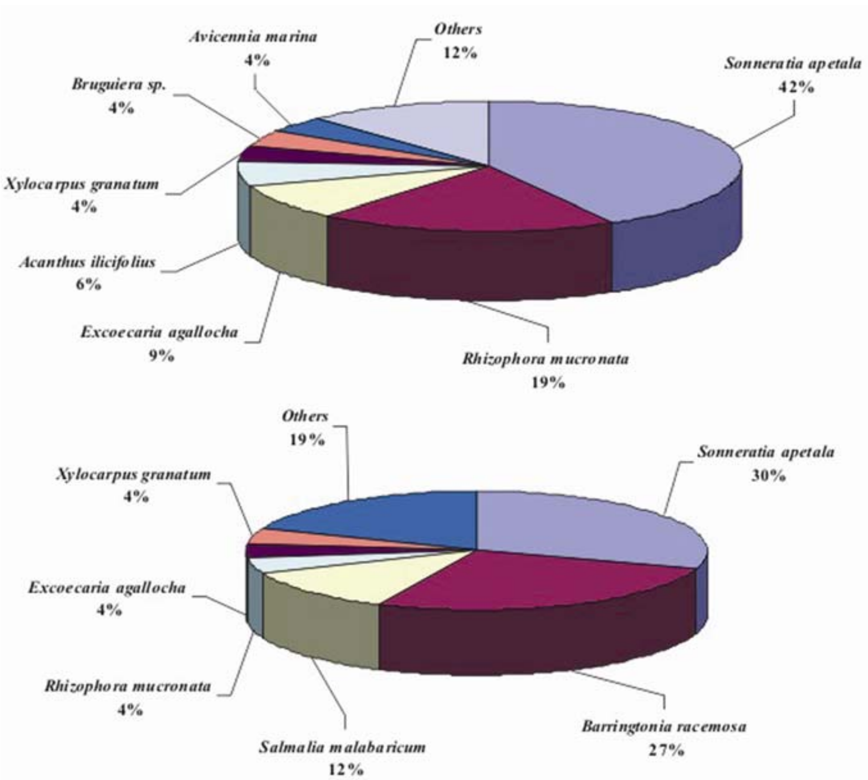

Figure 2. ***a***, Composite pollen spectrum of mangrove honeys from (***a***) Katka, the Sunderbans (Bangladesh) and (***b***) Dugong Creek and Jackson Creek, Little Andaman (India).

found to be important nectar sources. In the multifloral composition of Little Andaman honeys, the pollen grains of *S. malabaricum*, *S. apetala*, *R. mucronata*, *X. granatum* and *B. racemosa* are represented as secondary pollen type, but in different combinations.

The Sunderbans and Little Andaman are floristically rich forests and well known for their mangrove vegetation. This fact is reflected in the pollen content of the honeys, where the hives were in proximity. It can be concluded that the main sources of unifloral honey in the Sunderbans are: *S. apetala* and *R. mucronata*, and in Little Andaman, *S. apetala* and *B. racemosa*. *S. apetala* is the best exploited pollen type in both the mangrove forests; honey from the Katka region, the Sunderbans, is remarkably richer in mangrove pollen content than that from Dugong Creek and Jackson Creek, Little Andaman (Figure 2). Both the Sunderbans and Little Andaman mangrove forests, therefore, have considerable potential for medium to large-scale bee keeping ventures for the production of good quality honey.

1. Sen, J. and Banerjee, D., *Bee World*, 1956, **37**, 52–54.
2. Mittre, V., *J. Sci. Ind. Res*., 1958, **17**, 123–124.
3. Nair, P. K. K., *J. Indian Bot. Soc*., 1964, **43**, 179–191.
4. Sharma, M., *Grana*, 1970, **10**, 35–42.
5. Seethalakshmi, T. S., In Proceedings of the Second International Conference on Apiculture in Tropical Climates, New Delhi, 1980, pp. 609–622.
6. Barth, O. M., *J. Apicult. Res*., 1990, **29**, 89–94.
7. Lin, S. H., Chang, S. Y. and Chen, S. H., *Taiwania*, 1993, **38**, 117–133.
8. Sharma, M. and Nair, P. K. K., *Indian J. Hortic*., 1965, **22**, 46–51.
9. Suryanarayana, M. C. and Thakar, C. V., *Indian Bee J*., 1966, **28**, 17–20.
10. Kalpana, T. P. and Ramanujam, C. G. K., *J. Swamy Bot. Club*, 1989, **6**, 57–64.
11. Lakshmi, K. and Suryanarayana, M. C., *J. Palynol*., 1997, **33**, 263–272.
12. Mandal, M. and Mitra, K., *Geophytology*, 1980, **10**, 137–139.
13. Chakrabarti, K., *J. Bombay Nat. Hist. Soc*., 1987, **84**, 133–137.
14. Jana, D. and Bera, S., *Phytomorphology*, 2004, **54**, 51–57.
15. Pasha, M. K., Ghosh, D. R. and Roy, S. K., *J. Bot*., 1991, **20**, 105–107.
16. Muhibbullah, M., Chowdhary, M. A. T. and Sarwar, I., *J. Biol. Sci*., 2007, **7**, 384–388.
17. Dagar, J. C., Mongia, A. D. and Bandyopadhyay, A. K., In *Mangroves of Andaman and Nicobar Island*, Oxford and IBH, New Delhi, 1991, pp. 68–84.
18. Erdtman, G., *Sven. Bot. Tidskr*., 1960, **54**, 561–564.
19. Louveaux, J., Maurizio, A. and Vorwohl, G., *Bee World*, 1978, **59**, 139–157.

ACKNOWLEDGEMENTS. We thank Dr N. C. Mehrotra, Director, Birbal Sahni Institute of Palaeobotany, Lucknow for encouragement and providing infrastructural facilities. We also thank Dr Asha Khandelwal and Dr M. S. Chauhan for useful suggestions.

Received 21 January 2011; revised accepted 9 February 2011

SHILPA SINGH*
RATAN KAR

Birbal Sahni Institute of Palaeobotany,
53 University Road,
Lucknow 226 007, India
**For correspondence*
e-mail: spsp2226@yahoo.co.in