OsZIP10) and seven (*OsNAC*, *OsYSL2*, *OsYSL9*, *OsZIP4*, *OsVIT1*, *OsNAAT1* and *OsNRAMP7*) genes in correlation with high Fe and Zn contents respectively.

Elucidating the genotype-dependent response of the genes involved in metal homeostasis mechanism, particularly grain loading of micronutrients will be helpful in planning effective breeding strategies. The efforts made in the present study towards this concept reveal concordance of expression of related genes with the Fe/Zn content in tissues as well as mature grains for genotypes selected on the ground of their Zn content. Thus we have characterized the expression of metal-related genes in selected set of rice genotypes providing insight into the tightly regulated mechanism of metal homeostasis with respect to different tissue types, which is useful in understanding source–sink relationship of mineral acquisition and remobilization in the rice genome.

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Occurrence of the hispa *Asamangulia cuspidata* and its parasitoids in South India

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The occurrence of the leaf miner *Asamangulia cuspidata* Maulik (Coleoptera: Chrysomelidae: Cassidinae: Hispini) on sugarcane in Coimbatore, Tamil Nadu, India, is reported here with notes on pest biology and parasitoid activity. A minor pest in a few states of subtropical India, the miner was first noticed in May 2014 during routine surveys. Systematic observations in selected experimental and growers' plots revealed low levels of incidence and intensity, the highest mean attack rates being 4.18% on plant basis and 12.41% on leaf basis. Mean mined leaf area showed a high of 4.24 sq. cm and it constituted 1.28% of the total leaf area. Cross-sections of young and mature mines indicated feeding on softer tissues by the solitary grub in the early stages, but extensive mining by the grown-up grub leading to complete drying of the mined area. One apparently new *Bracon* sp. (Hymenoptera: Braconidae), two *Pediobius* spp. (Hymenoptera: Eulophidae) and one *Eurytoma* sp. (Hymenoptera: Eurytomidae) were recovered from the miner. While *Bracon* sp. contributed 70% to the overall parasitism rate of 39.3%, the remaining parasitoids accounted for 30% with likely hyperparasitism among them. The possible origin of the miner and the role of parasitoids in its natural control at the present study site are also discussed.

Keywords: Leaf miner, parasitoids, parasitism, pest biology, sugarcane.

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ORIGINALLY described from Pusa, Bihar, India[1], *Asamangulia cuspidata* Maulik (Coleoptera: Chrysomelidae: Cassidinae: Hispini) is distributed in Afghanistan, India, Indonesia, Japan, Nepal, Saudi Arabia (?), Taiwan and Thailand on hosts such as *Oryza sativa* L., *Miscanthus*, *Phragmites*, *Saccharum officinarum* L., *Saccharum* sp. and *Sorghum* (Poaceae)[2,3]. In India, it was reported as a minor pest of sugarcane with wide distribution but more frequent occurrence in Bihar, Uttar Pradesh (UP) and Punjab than in south India[4]. Other reports also documented its occurrence in subtropical locations such as Bihar[5,6], Delhi[7] and West Bengal[8]. The only reference to its occurrence on sugarcane in South India appears to be that of Nair[6]. Biological notes describe that the adult feeds by scraping the leaf surface, whereas the grub feeds voraciously on the mesophyll and other soft tissues between the two epidermal layers of the leaf lamina and pupates within[4,9]. The tunnels made by the grubs measure 2–8″ (5–20 cm) long and 1–2″ (2.5–5.0 cm) wide[7]. Life cycle takes about 3½–4 weeks and adult lives for 2–3 months[6]. *Elasmus* sp., *Microbracon* sp. and unidentified pupal and grub parasitoids were bred in the laboratory; a threatened outbreak of the miner in north Bihar was controlled by parasitoids in August 1939 (ref. 10). Several parasitoids including *Bracon* sp. (*Microbracon* sp.), *Elasmus* sp., *Closterocerus* sp. and a pupal parasitoid occurred in succession during the activity period of the miner[11]. These three parasitoids find a place in a compendium of sugarcane insects[12] and Universal Chalcidoidea Database of the Natural History Museum[13]. Quicke and Polaszek[14] described *Aneuradesha harleyi* Quicke from *A. cuspidata* collected in Muzaffarnagar, UP, and mentioned that the ectoparasitoid *Microbracon* sp. recorded as causing 38% parasitism of the grubs by Anwar[11] could be a misidentification of *A. harleyi*. In the present communication, the occurrence and status of the leaf miner *A. cuspidata* in Coimbatore, Tamil Nadu, India, as well as Agali and Kannur, Kerala, India, and preliminary observations on its natural enemies in Coimbatore are reported.

Following the detection of leaf mines at Coimbatore in routine surveys in May 2014, the status of the miner and its natural enemies was assessed during May–December 2014 in representative experimental plots of ICAR-Sugarcane Breeding Institute (ICAR-SBI, Coimbatore) and growers' farms adopting a combination of random and systematic sampling methods. Besides, species clones at ICAR-SBI Research Centre, Agali, and germplasm collection at ICAR-SBI Research Center, Kannur, were also surveyed. In the experimental plots at ICAR-SBI, where planting in 6 m rows is routinely practised, a row was first selected randomly in the second block from the border and subsequently every tenth row was selected. Whenever the end of the block was reached, an inward turn to the right or left was taken to continue sampling in the next block; the procedure was repeated until 10 random rows were completed. The growers' plots where the rows were of variable length, were arbitrarily divided into 6 m wide blocks perpendicular to the rows, the demarcation often facilitated by bunds or irrigation channels opened up by the cultivator, to give rows of 6 m length serving as the sample units. Sample rows were located according to the procedure followed for experimental plots. A similar procedure was followed for the survey in species clones at Agali and germplasm collection at Kannur.

Cane and leaf infestation rates were assessed broadly following our earlier procedure standardized for another leaf miner of sugarcane, *Aphanisticus aeneus* Kerremans (Coleoptera: Buprestidae)[15]. First, the number of plants showing at least one mined leaf and the total number of plants in each sample row were recorded and percentage of infested canes was computed. Secondly, in the infested canes, beginning from the topmost leaf with visible dewlap and moving down, the number of leaves showing one or more mines and all green leaves were counted, and the percentage of damaged leaves was computed. Infested leaves were excised and brought to the laboratory to estimate the mined leaf area and total leaf area in a leaf area meter (LICOR, USA). The total area of the infested leaf was assessed first and the mined area was estimated next by excising the mined portion with a pair of scissors. Three trials were run for each whole leaf or mined leaf portion and the highest value was recorded. The sum of the area of individual mines constituted the total mined leaf area in the rare cases of multiple mines per leaf.

Leaf tissue damage was examined by compound and scanning electron microscopy (SEM). For light microscopy study, a simple procedure used by us earlier to examine the damage caused by *A. aeneus* was followed[15]. Leaf bits from healthy and mined leaves were mounted in papaya petiole block and transverse sections were prepared using a razor blade. The thin sections were stained with saffranin, mounted on glass slides with 1% glycerol and observed under a ZEISS Primostar microscope, and images captured. For SEM study, fresh leaf sections were prepared and examined under SEM Quanta 250-NST.

Random samples of mined leaves were collected from surveyed plots, brought to the laboratory, examined for field parasitism symptoms and maintained in glass tubes. Parasitoids that emerged from the mines in the laboratory were identified and parasitism rates computed. Field-collected or laboratory-maintained mines showing parasitoid emergence holes were teased open and examined for observations on parasitoid biology.

Data on percentage of infested plants or canes, percentage of damaged leaves, total leaf area, mined leaf area and percentage of mined leaf area from different locations were subjected to analysis of variance after suitable data transformation and means compared by Student–Newman–Keuls test. The independence of mined leaf area from total leaf area for the observations

Table 1. Status of leaf miner *Asamangulia cuspidata* in sugarcane experimental and growers' plots during May–December 2014

Field description	No. of plants/ row	Percentage of infested canes	No. of leaves/ row	Percentage of damaged leaves	No. of leaves examined	Total leaf area (cm^2)	Mined leaf area (cm^2)	Percentage of mined leaf area	$r^{\#}$
Experimental plots of ICAR-Sugarcane Breeding Institute, Coimbatore									
Agronomy	43–67	4.18[i] a[ii] (0.00–8.47)[iii]	0–37	12.41[i] ab (0.00–15.15)	18	300.94 ab (130–525)	1.59 a (0.15–4.50)	0.55[i] a (0.08–1.48)	0.329^{ns}
National hybridization garden	42–104	3.37 a (0.00–5.08)	0–29	11.35 ab (0.00–14.29)	10	349.40 a (135–635)	3.18 ab (1.20–7.30)	1.25 a (0.35–3.85)	–0.353^{ns}
Breeding farm	35–64	3.84 a (0.00–7.32)	0–29	11.20 ab (0.00–15.38)	10	296.10 ab (126–471)	3.03 ab (0.85–7.20)	1.17 a (0.23–2.82)	–0.301^{ns}
Entomology	19–52	3.04 a (0.00–8.02)	0–20	10.14 abc (0.00–20.00)	14	368.57 a (185–486)	4.24 b (1.90–7.60)	1.28 a (0.41–2.61)	–0.319^{ns}
Erianthus spp. collection	42–90	1.44 a (0.00–3.85)	0–29	5.25 abc (0.00–11.11)	23	417.13 a (211–518)	3.66 ab (1.01–6.90)	0.92 a (0.20–1.71)	–0.093^{ns}
Vedapatty farm	21–46	2.00 a (0.00–4.55)	0–16	4.75 bc (0.00–12.50)	–	–	–	–	–
Growers' farms, Coimbatore									
Growers' farm I	38–86	2.85 a (0.00–5.77)	0–26	10.15 ab (0.00–15.38)	7	402.86 a (308–406)	3.53 ab (1.58–6.10)	0.89 a (0.35–1.41)	0.078^{ns}
Growers' farm II	72–122	2.97 a (0.00–7.14)	0–38	11.79 ab (0.00–16.67)	5	219.20 b (126–291)	2.49 ab (1.01–5.93)	1.10 a (0.56–2.20)	0.562^{ns}
Growers' farm III	29–91	3.54 a (1.32–6.90)	9–25	12.16 a (10.53–14.29)	25	371.08 a (188–577)	2.82 ab (0.53–5.72)	0.81 a (0.13–1.77)	0.054^{ns}
ICAR–Sugarcane Breeding Institute Research Centre, Agali, Kerala									
Species clones	16–90	3.60 a (0.00–16.67)	0–53	3.02 c (0.00–8.33)	–	–	–	–	–
ICAR–Sugarcane Breeding Institute Research Centre, Kannur, Kerala									
Germplasm[@]	–	0	0	0	0	0	0	0	–

[i] $(x + 0.5)^{0.5}$ transformed values analyzed.
[ii] Means followed by the same letter in a column are not significantly different ($P > 0.05$) by analysis of variance and Student–Newman–Keuls test.
[iii] Figures in parenthesis are ranges.
[#] Correlation coefficient between total leaf area and leaf area mined; $^{ns}P > 0.05$.
[@] Excluded from analysis due to lack of infestation.

recorded at Coimbatore was determined using Pearson's product moment correlation coefficient.

Attack rates of *A. cuspidata* on plant basis were generally low in the observation plots at Coimbatore and Agali (Table 1). While the mean attack rate on plant basis was the highest (4.18%) in one of the experimental plots at Coimbatore, the highest percentage of infested plants in a single sampled row (16.67) was recorded at Agali; the attack rates did not differ significantly among different plots. Mean attack rates on leaf basis showed significant and overlapping differences among the observation plots. While the highest mean attack rate (12.41%) and percentage of damaged leaves in a single sample row (20.00) were recorded at Coimbatore, the lowest values were observed at Agali. Total leaf area and mined leaf area showed significant and overlapping differences among different observation plots. The overall mined leaf area among all the sampled leaves ranged from 0.15 to 7.60 sq. cm, the highest mean value being 4.24 sq. cm in an experimental plot. Percentage of mined leaf area, with a range 0.08–3.85 in individual leaves, did not differ among the different plots. The correlation coefficients between total leaf area and mined leaf area were not significant for all observation plots. The miner was not observed in the germplasm collection at Kannur.

The overall low level of *A. cuspidata* attack apparently did not manifest in significant differences in plant attack rates, i.e. between-host distribution, among the observation plots, despite the presence of diverse germplasm in some plots. Varietal uniformity in experimental and growers' plots, and homogeneity of the hybrids maintained in the National Hybridization Garden at ICAR-SBI possibly explain the more or less uniform leaf colonization rates, which represent the within-host plant distribution or intensity of attack in these plots. On the other hand, unsuitability of *Erianthus* spp. and isolated location of Vedapatty farm adjacent to research paddy plots could be the reason for the significantly lower leaf colonization rates in these plots. The variable leaf area reflected differences in crop age and health among the plots, with the largest leaf area of *Erianthus* spp. being a generic character. The uniform mined leaf area in all plots, with a couple of exceptions, indicated the lack of differential suitability of the variety or hybrids or genotypes. Despite the greater propensity to collect larger mature mines than smaller young ones in field sampling, the leaf mines observed in the present survey were smaller than those described earlier[7]. The non-significant correlations between total leaf area and mined leaf area, and the uniform percentage of mined leaf area among all plots established that the miner did not exhibit enhanced levels of damage with increasing leaf size.

Despite earlier observations of 2–3 month longevity[6] and presence in numbers when the cane is young and especially during the rains[5], adults were less frequently encountered than mines in the present field surveys. Although freshly laid eggs alone were difficult to locate in the field, empty shells of the usually singly laid eggs could be noticed in the young or more prominent mature mines (Figure 1). The characteristic adult feeding damage in linear streaks could be replicated (Figure 1), and mating (Figure 2) and oviposition induced by enclosing field-collected or laboratory-emerged adults on potted plants in the glasshouse. In captivity too, eggs were invariably laid singly on leaf margins along the linear axis partly embedded in the epidermis (Figure 2) as was also indicated earlier[5]. However, these observations are in contrast with the earlier report that up to 11 eggs were found in a single cluster, of which only one apparently survived to mine the leaf[9]. It is unlikely that adults lay eggs in clusters under intense local competition for oviposition space, especially in the backdrop of the huge foliage biomass the crop offers. While small freshly formed, yellowish, blotch-like mines (Figure 1) harboured young grubs (Figure 2), long tunnel-like mature mines contained grown-up grubs or pupae (Figure 2). The inside of the lower epidermis in all sample mines was filled with fresh or dry faecal matter depending on the age of the mine (Figure 1). Although all mines, young or mature, contained only one immature stage, it was not unusual to encounter a leaf with multiple mines on both margins (Figure 1) or mines in the upper half of the leaf and towards the leaf tip.

The grub is known to feed voraciously on the mesophyll and other soft tissues between the two epidermal layers of the leaf lamina[4], avoiding the larger vascular bundles, as indicated by transverse sections of mined leaves[9]. Cross-sections of young and mature mines in the present study too indicated similar feeding pattern on softer tissues with the difference that larger mature grubs created far greater mine volume by stretching the lower epidermis to accommodate their larger body size (Figure 3). Although such restricted feeding on softer

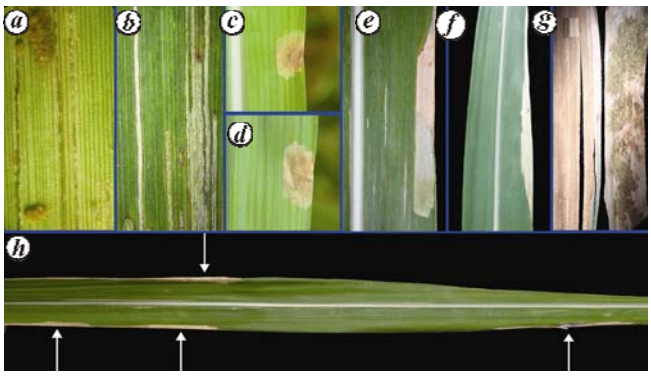

Figure 1. Damage symptoms of the leaf miner *Asamangulia cuspidata* in sugarcane: (***a***) fresh and (***b***) old linear feeding streaks made by the adult; view of young mine on the upper (***c***) and lower (***d***) leaf surfaces; ***e***, active mine with grown-up grub towards the lower end; ***f***, dried mature mine; ***g***, opened mine showing faecal matter on the inside of lower epidermis; ***h***, multiple mines on a single leaf.

tissues and green appearance of the mined portion seem to suggest minimal damage in the early stages, extensive feeding by the grown-up grub, partial damage to the vascular bundles and filling up of the mine with faecal matter (Figure 1) in the later stages result in complete drying of the mined area[5]. Besides, the portion of leaf lamina above the mines on the leaf margin too dries up due to the general disturbance to the vascular system leading to probable loss of productive area greater than the mined area. Similar loss of productive leaf area occurs due to the serpentine mines made by the leaf miner *A. aeneus* despite the smaller adult size, narrower leaf mine and location of mines in the middle of the lamina[15], unlike *A. cuspidata* which oviposits and locates its mines invariably close to the margins.

Several mines located in field surveys, particularly mature ones, showed emergence holes (Figures 4 and 5) either on the upper or lower or both sides, which indicated parasitoid activity. Field-collected samples (n = 168) of mature mines maintained in the laboratory showed an overall parasitism rate of 39.3% on the basis of emergence holes, including a few samples that showed parasitoid emergence holes at the time of collection, and/or parasitoid emergence; adults of *A. cuspidata* emerged in 21.4% samples. The parasitoids recovered include one apparently new *Bracon* sp. (Hymenoptera: Braconidae) (Figure 6 *a*), two species of *Pediobius* (Hymenoptera: Eulophidae) (Figure 6 *b* and *c*) and a possible hyperparasitoid *Eurytoma* sp. (Hymenoptera: Eurytomidae) (Figure 6 *d*). Two different types of grub/pupal remains were observed when mines that showed parasitoid emergence were split open. In type-I, parasitized grub was reduced to a shrivelled carcass and 1–7 cocoons, often in groups of up to 7 (Figure 4), were found distributed inside sampled mines (n = 30). One to seven adults of *Bracon* sp. emerged from sampled mines (n = 43) with cocoons. In type-II, mines revealed mummified grub/pupal remnants with fewer emergence holes (Figure 5) than the number of parasitoids emerged, which indicated that these parasitoids attack late stage grubs and more than one parasitoid

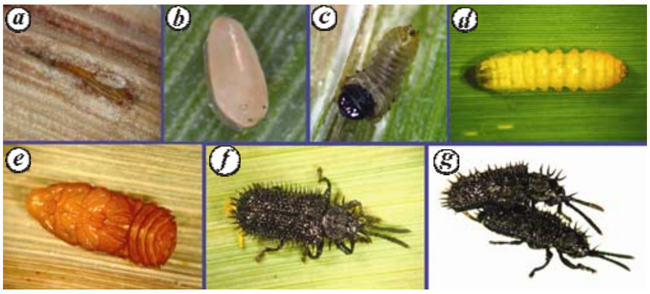

Figure 2. Life stages of *Asamangulia cuspidata* in sugarcane: ***a***, egg inserted in the epidermis; ***b***, egg extracted from the slit; ***c***, young and ***d***, grown-up grubs; ***e***, pupa; ***f***, adult; ***g***, mating pair.

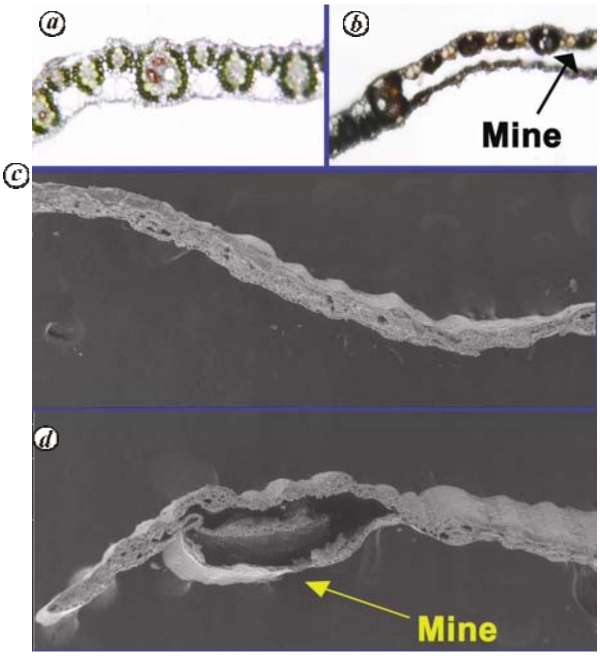

Figure 3. Sectional view of healthy and *Asamangulia cuspidata* infested sugarcane leaves. Light microscopy sections of (***a***) healthy and (***b***) mined leaves in early stage of mining. SEM sections of (***c***) healthy and (***d***) mined leaves in late stage of mining.

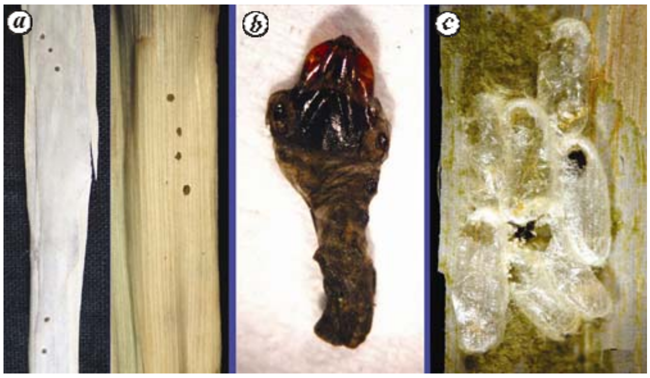

Figure 4. Type-I parasitism in *Asamangulia cuspidata* infesting sugarcane: ***a***, dispersed parasitoid emergence holes on the mine surface; ***b***, shrivelled carcass of parasitized grub; ***c***, a group of seven cocoons of the parasitoid inside the mine.

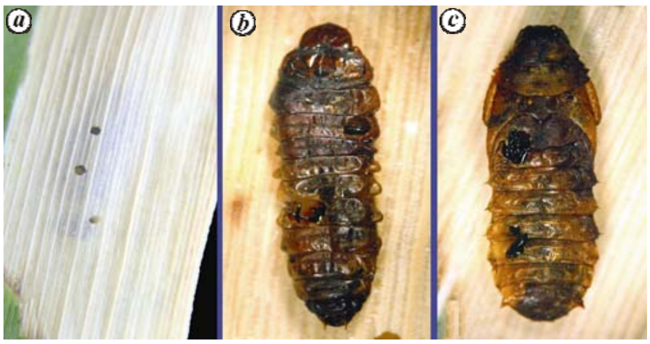

Figure 5. Type-II parasitism in *Asamangulia cuspidata* infesting sugarcane: ***a***, parasitoid emergence holes on the mine surface with visible mummified grub inside the mine. ***b***, ***c***, mummified grub (***b***) and pupa (***c***) with parasitoid emergence holes.

Figure 6. Parasitoids recovered from *Asamangulia cuspidata* infesting sugarcane: ***a***, *Bracon* sp.; ***b***, ***c***, *Pediobius* spp.; ***d***, *Eurytoma* sp.

emerged from each hole. The number of parasitoid adults that emerged from sampled mines ($n = 15$) generally varied from 1 to 5, though 15 parasitoids were observed in one sample. The presence of dead parasitoid adults in some grub/pupal remains indicated either failure to emerge under intense superparasitism or the occurrence of hyperparasitism.

While an apparent hyperparasitoid emerged from the mines that harboured *Bracon* cocoons, the recovery of two species of *Pediobius* and one species of *Eurytoma*, both genera with records as hyperparasitoids in sugarcane[16], suggested multipleparasitism or hyperparasitism even in type-II parasitism. Type-I with *Bracon* sp. and type-II with yet-to-be discerned parasitoids contributed in the ratio of 70 : 30 to the overall field parasitism ($n = 50$ parasitized mines). Detailed taxonomic identification and description of all four species, elucidation of biology of parasitoid complex in both types and assessment of extent of hyperparasitism would not only facilitate precise determination of their relative role as primary or secondary parasitoids in the natural control of the miner, but also prevent underestimation of the role of the parasitoid complex.

The two species of *Pediobius* recovered in the present study apparently constitute new records as suggested by the lack of earlier reports of their occurrence on *A. cuspidata*. The *Bracon* sp. observed in the present study, could be the same as or different from that included in earlier compilations[11,12]. The predominance of *Bracon* sp. with 70% contribution to the total parasitism could partly be due to its early occurrence as a parasitoid of grubs alone, unlike the parasitoids in type-II parasitism where both grubs and pupae appeared to serve as target stages. Despite the possibility of hyperparasitism, the overall 40% parasitism observed in the two types in the present study is comparable to the 38% reported due to a *Microbracon* sp.[11], despite the suggestion that it could be a misidentification of *A. harleyi*[14]. However, in contrast to the sequential occurrence with higher levels of parasitism by the later parasitoids[11], the three genera occurred concurrently in the present study. Although not examined, the possibility of entomopathogens as a mortality factor cannot be ruled out despite the protection provided by the mines, since egg slits can serve as entry points.

Sugarcane in tropical India plays host to an array of pests, some of which are of subtropical origin. Pests such as top borer *Scirpophaga excerptalis* (Walker) (Lepidoptera: Crambidae) and leaf-hopper *Pyrilla perpusilla* (Walker) (Hemiptera: Lophopidae) that occur endemically in subtropical sugarcane reach damaging levels only occasionally in the tropics. In the milder and more conducive climate, and temporally and spatially contiguous semi-perennial crop-pest system in the tropics, fortuitous or planned introduction and establishment of the most effective natural enemies led to natural regulation of these predominantly subtropical pests[16,17]. The most recent example is the woolly aphid *Ceratovacuna lanigera* Zehntner (Hemiptera: Aphididae) that invaded sugarcane in tropical Indian states. The aphid was not controlled effectively by the predator *Dipha aphidivora* (Meyrick) (Lepidoptera: Pyralidae) that accompanied the pest, but was ultimately regulated by the introduced parasitoid *Encarsia flavoscutellum* Zehntner (Hymenoptera: Aphelinidae), preventing further crop losses[18]. The present report of the occurrence of leaf mining hispa *A. cuspidata*, yet another minor pest restricted to a few states of subtropical India hitherto, perhaps was not recorded at Coimbatore before, as the absence of any published report except for the indirect reference to its occurrence in south India indicates[4,6]. The pest has maintained minor status and remained restricted to a narrow geographical area in subtropical India over the past few decades, possibly due to the activity of effective natural enemies[10,11,14]. Several subtropical or tropical sugarcane pests, more so the former, apparently possess the adaptability traits to colonize the other region, as exemplified by top borer, pyrilla and woolly aphid. However, their introduction and proliferation had been restrained by natural and man-made barriers such as geographical isolation, varietal composition, crop management practices, etc. The expansion of sugar industry and cane cultivation area, spatial and temporal crop contiguity, changes in local cultivation practices, and movement of harvested cane, seed and germplasm material have not only promoted the spread of pests such as *A. cuspidata* in sugarcane crop belts, but also colonization of sugarcane crop islands by new pests in the recent past[15,19,20].

The present preliminary field survey/study revealed low incidence levels of *A. cuspidata* at Coimbatore

primarily due to the activity of the parasitoids that accompanied the pest, besides other reasons. Absence of records of *Pediobius* sp. and *Eurytoma* sp. on sugarcane pests in India, except as hyperparasitoids[16], and the possibility of the *Bracon* sp. being a new species indicated that these parasitoid genera could be established associations in the home of the pest and not new associations in the present study site. It is possible that these parasitoids remained undetected in the places where the pest was originally reported, which could be one of the four states, namely
Bihar, UP, Punjab[4] and West Bengal[8], and arrived in the current study site as parasitized grubs or pupae in the mines. The high parasitism rates reported for parasitoids including *Microbracon* sp.[11], whose identity was questioned based on specimens collected at Muzaffarnagar[14], and similar levels of parasitism caused by the three different parasitoid genera in the present study indicated that the pest may have been introduced from any of the three states where the parasitoid complex either changed and/or has not been updated since the earlier reports[10,11].

Asamangulia cuspidata passed through 3 or 4 cycles and was most active during June–August in north Bihar[5] and June–September with a leaf infestation rate of 30% in New Delhi[11]. The miner is unlikely to maintain such narrow temporal range in the present study site or tropical India. The more uniform climatic conditions and continuous crop availability in the tropics may allow year-round proliferation of the pest as indicated by its activity at Coimbatore during May–December 2014, albeit at the present lower leaf infestation level (20.00%) than that observed in New Delhi[11]. The suggestion to collect affected leaves in the beginning of June to prevent its breeding as a control measure[5], though may not have been practised, would have interfered with the natural control brought about by parasitoids in the same area a couple of years later[10]. The invasive woolly aphid rapidly spread and ravaged sugarcane for a few years in the southern states apparently due to adaptive advantages such as high reproductive rate and telescopic generations typical of aphids. Despite the huge foliage biomass providing an ideal niche, *A. cuspidata* is less likely to attain such menacing levels due to its long life cycle and the presence of parasitoids. Variable size of parasitized mines, obviously due to parasitism in different stages of the grub and the consequent reduction in feeding damage, indicated loss of some productive leaf area even under parasitoid activity. The considerable levels of parasitism observed in the present study site by the three parasitoid genera, despite the possibility of hyperparasitism among them, indicated that these parasitoids have a complementary role in maintaining the current low levels of the pest. However, constant monitoring of the dynamics is needed to ascertain the occurrence of such natural control. High levels of parasitism observed by Anwar[11] indicated the potential of the parasitoids despite the ambiguity expressed about the identity of one of them[14]. The introduction of these parasitoids from the original home of the pest, after confirming the identity, may be contemplated if the three parasitoid genera observed in the present study site fail to maintain the low levels of the pest owing to possible competitive interaction among them.

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Minerals of cactus (*Opuntia dillenii*): cladode and fruit

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Cladode (modified stem) and fruit of cactus (*Opuntia dillenii*) were analysed for their mineral content, following ashing and analysis by ICP-AES and Atomic Absorption Spectroscopy (AAS). Values are expressed as mg per 100 g dry weight of the material. Cladode was analysed at three stages of growth; differences were noticed for K, Ca, Mg, P and Na, and also for Al, Ba, Cr, Mn and Pb contents. Cladode was observed to be a good source of K, Ca, Mg, Na, Fe and Zn. Toxic elements such as Cd, Cu, Cr and Ni were well within the permissible limits; Pb and As were below detection levels. The fruit was found to contain 34%, 36%, 4% and 26% of pulp, peel, seed and waste (including spines) on fresh weight basis. Pulp was found to be a good source of K, Na, Ca, Mg and Fe. Toxic elements such as Pb, As, Hg and Se were below detection levels/within permissible limits. These values of pulp were compared with the mineral contents of fruit peel and seed. Accordingly, both cladode and fruit can be used for edible purposes as food supplements, without endanger of toxicity from the angle of mineral constitution. The scope for their possible use in food formulation is highlighted.

Keywords: Cactus, cladode, fruit, mineral content, spectroscopy.

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IN the light of global desertification and declining water resources, *Opuntia* spp. is gaining even more importance as an effective food production system, including both vegetative and fruit parts. At present, *Opuntia* plants are grown in more than 30 countries on about 100,000 ha area[1,2]. These include Mexico, the Mediterranean (Egypt, Italy, Greece, Spain, Turkey), California, South America (Argentina, Brazil, Chile, Columbia, Peru), the Middle East (Isreal, Jordan), North Africa (Algeria, Morocco, Tunisia), South Africa and India[1,3,4]. For cladodes, mean hectare yield of 30–80 tonnes can be achieved annually[5,6]. Mexico is the only country planting cladodes for commercial use on 10,000 ha, with a total production of 600,000 tonnes per annum[7].

Cacti have a special carbondioxide fixation pathway, known as crassulacean acid metabolism (CAM), and can have a four-to five-fold greater efficiency in converting water to dry matter than even C4 plants such as maize[8]. Being water-use efficient, they should be useful in arid and semi-arid regions[9]. As a CAM plant, *Opuntia* spp. are characterized by a high water-use efficiency of 4–10 mmol CO_2 per mol H_2O compared to C3 and C4 plants with 1.0–1.5 mmol and 2–3 mmol CO_2 per mol H_2O respectively. Through succulence, the ability to store considerable quantities of water, the plant may survive despite harsh environmental conditions[10]. Furthermore, *Opuntia* exhibits the highest production rate of overground growing plants[11,12]. Interestingly, the biomass production was even found to increase in atmospheric CO_2 concentrations[2,13,14], thus counteracting the green house effect[15].

Opuntia is a large genus of succulent shrubs with over 360 species, widely grown in the warmer parts of the world. It is commonly known as prickly pear and belongs to the family Cactaceae. Many species of cactus are found growing as wild plants in arid (less than 250 mm annual precipitation) and semiarid (250–450 mm annual precipitation) regions of India. *Opuntia* plants show high ecological adaptivity and can therefore be encountered under all climatic conditions: the Mediterranean, North, Central and South Africa, North, Central and South America, the Middle East, Australia and India[15].

Opuntia dillenii (ker-gawl) Haw, commonly seen in the southern parts of India, is popularly known as pear bush, tuna, Indian fig. This plant is a spreading fleshy shrub usually growing 50–200 cm tall. The stem is much branched and consists of flattened, fleshy segments called