understanding of the subject is lacking in the new breed of teachers, who are products of the same system.

Science teaching is already suffering from lack of funds; continuous escalation in costs of equipment, chemicals and consumables have further made the conditions depressing. In botany a major portion of practical work includes study of lower plant forms, viz. algae, fungi, bryophytes, pteriodophytes, gymnosperms, etc., provided to students in preserved forms. These plants are collected from their natural habitats by scientific suppliers and sold to universities at exorbitant prices. Commercially inclined suppliers who have no respect for biodiversity or its conservation make these collections. Overharvesting of natural resources leads to depletion of irreplaceable flora of regions, viz. Darjeeling, Shillong and other North East regions, Pachmarhi in MP, Nilgiris, Western Ghats, coastal marine areas, etc.

Upgradation of the botany syllabus by UGC has led to the indictment of several practicals in the molecular field, which vouch for costly instruments and consumables. No consideration has been shown to upgrade the staff, teachers, laboratories and library facilities. With most of the universities under immense teaching load, under-equipped staff and meagre funds, designing expensive practicals for a larger number of pupils is not feasible. Thus trained students, when they enter the field of research and academics, cannot deliver the quality of teaching and work needed for the purpose.

Various funding agencies, viz. UGC, DST, DBT, etc. initiate new courses like industrial microbiology, environmental sciences, etc. But after a few years, they meet the same fate due to lack of maintenance. Several instruments and facilities are thus rendered useless either due to untrained staff or poor maintenance; laboratory grants sanctioned by UGC for state universities cannot cater for even the basic necessities of laboratories. Population pressure initiates increase in number of seats without any consideration for grants and infrastructure capabilities; thus the very basic objectives of a science curriculum and work are defeated. Personal initiatives by staff at departmental level cannot solve the problem. But drastic steps have to be taken; otherwise, practical work will lose its credibility in times to come.

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Identifying dietary source of *Helicoverpa armigera* using carbon isotope signatures – A critique

At the outset, I submit my appreciation to the authors[1] for initiating a novel line of entomological research in India. However, I seek clarifications from them on a few aspects presented in the article, which may benefit readers of *Current Science*.

(1) There appears to be a mistake where the authors claim that, 'Such studies (of using the differences in carbon isotope signatures to infer feeding behaviour) have not been attempted for determining the feeding habits of insects (prior to their study)'. They may have overlooked the work of Gould *et al.*[2] (which has been cited by the authors in their article) who have shown that differences in the carbon isotope signatures between C_3 and C_4 plants are clearly reflected in the insect (another polyphagous species, *Helicoverpa zea*, which is closely related to *H. armigera*) that feeds on them, and further, have used this as a baseline data to show movement of *H. zea* across different host plant species.

(2) The authors[1] seem to restrict their experimentation to verify if *H. armigera* carries the isotope signatures of its host plants. Therefore, it appears that they have attempted to investigate a well-established fact in animal ecology that carbon isotope signature in the food (plant or animal) is reflected in the organism that feeds on it. A common statement used by animal ecologists in case of isotope signatures of carbon is, 'you are what you eat' because of only a slight enrichment in ^{13}C along the trophic chain[3] (while in the case of nitrogen, it is 'you are what you eat +3‰')[3], which appears to be the same that the authors[1] are claiming. Hence, the readers may be benefited if the authors would clearly mention their objective.

(3) Isotope signatures obtained from samples made from pupae may not be very reliable due to the problems posed by parasitization and/or microbial infection, especially when pupae have been collected from an open field as has been done in one of the situations in the study[1]. Although the authors would have taken enough care to check that the pupae were alive and apparently healthy, one cannot rule out the possibility of a parasitoid or an infection developing inside the pupal body. Isotope signatures of samples made from parasitized or infected pupae would not reflect the true signature of the species in question. Another point is that the moth is the one involved in migration in case of *H. armigera*, and therefore may be the most logical stage to be investigated for isotope signatures. I would like to mention the work of Gould *et al.*[2], where the wings of the moths of *H. zea* were used to determine the isotope signature (the probability of contamination is also reduced by using wings). Hence, it is difficult to understand why the authors[1] did not wait for moths to emerge from pupae before drawing samples? It would benefit the readers if they would explain the rationale for using pupae in their study[1].

(4) As the authors have not mentioned about the statistical test performed for the data presented in table 1[1], I 'believe' that they have compared all the five treatments (bendi – lab experiment; maize, chickpea, tomato and bendi – field collected) together to arrive at, what they mention in the text, 'The $\delta^{13}C$ differed significantly among the several host plant species with maize…'. This, I presume, also means that there was no significant difference in the $\delta^{13}C$ values

across the C_3 species, because at a later stage, the authors mention that the technique may not be sensitive to differentiate C_3 host species. However, the mean and standard deviation values of $\delta^{13}C$ for pupae of *H. armigera* (table 1)[1] developed on different C_3 species, for instance, bendi – field collected ($\delta^{13}C = -22.36 \pm 0.16$) and tomato ($\delta^{13}C = -27.93 \pm 0.15$) suggests a possible significant difference, which could be detected by applying a statistical test that compares two treatments at a time (it may be noted that the coefficient of variance in both these cases is <1%). In case this is true, it would be of interest to know the authors' interpretations.

(5) The authors make an interesting point that isotope signatures of moths should be reflected in their eggs, which, by comparing with the host plant signature, could be used to 'conclusively' verify the presence of host biotypes in *H. armigera*. Although the idea is quite novel, I foresee a problem in it. As moths of *H. armigera* feed on nectar, which need not be from the same plant that it has fed as larvae, the eggs may also carry the signature of the nectar-contributing plant. Therefore, the isotope signature of their eggs may not truly reflect the signature of their mothers. Also, in species where males also contribute to the nourishment of eggs, isotope signatures of eggs would not reflect the signatures of the female moth; the problem gets compounded in polyandrous species (where a female mates with several males). Hence, it would be useful if the authors could explain their idea in this context.

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2. Gould, F., Blair, N., Reid, M., Rennie, T., Lopez, J. and Micinski, S., *Proc. Natl. Acad. Sci. USA*, 2002, **99**, 16581–16586.
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Response:

(1) The first report on the application of isotope signatures to identify the dietary habits of animals was made by Michael DeNiro and Samuel Epstein during the mid-seventies[1]. Subsequently, others have used this technique to assess the feeding habits in several other animals, including insects[2]. From this context, we may not be entirely correct by saying 'such studies have not been attempted…'. However, the major aim of our investigation reported in our paper is to apply the carbon isotope technique to evaluate the polyphagous nature of *H. armigera*. We have shown that the subtle yet significant variation in $\delta^{13}C$ among the C_3 species is fairly accurately reflected in the isotopic signature of the insect. The other new dimension of our results is that well within the life cycle of the larva diet changes, if any, would be reflected in the $\delta^{13}C$ signatures as larvae are voracious feeders. Such an approach has not been reported in the past.

(2) The isotopic signature of the food consumed by any animal is incorporated faithfully in the organic matter of the animal. Normally there would be a certain extent of isotopic enrichment in the animal compared to that of the food consumed. It is well known that the nitrogen isotope ratios are enriched by 3‰ while it is around 0.6 to 0.9‰ for carbon isotope ratios[1,3,4]. This is also evident from our data illustrated in figure 1. The intercept of the regression line between $\delta^{13}C$ of the pupa and the host plant is close to the expected value for the carbon isotope enrichment in the animal feeding over its host. This has been the basis of identifying the dietary sources of animals which was also our major objective. This aspect has been explicitly stated in the paper which the reader must have missed.

(3) The reader comments that using pupae is *not* a good option for isotopic analysis. He envisages the microbial infection or parasitization could alter the isotopic signatures. We had taken sufficient care and consciously selected only the healthy pupae free of parasitization or infection. The suggestion that one would be benefited using moths instead of pupae is well taken. However, since the pupae were healthy, we believe that the results would not be in any way different!

(4) We are aware of the statistical tools and their importance in explaining the observed results. We did observe significant differences between C_3 and C_4 species and also among the different C_3 species studied. It is well known that the carbon isotope ratios of C_3 and C_4 species are quite different and they seldom overlap. Thus, carbon isotope signatures offer a powerful tool to identify dietary preferences between C_3 and C_4 species. But such large differences among C_3 species (or even among C_4 species) are not noticed. Hence one needs to be cautious while interpreting $\delta^{13}C$ values of insects feeding on different C_3 or C_4 hosts. This is where we hypothesize that nitrogen isotope ratio can help in differentiating the C_3 host plants with similar $\delta^{13}C$. Experiments are under way to examine the validity of this hypothesis.

(5) It is of common understanding to an entomologist that *H. armigera* moths feed just before oviposition. Previous studies have clearly demonstrated that nectar feeding of *H. armigera* moths has an impact on crop selection for oviposition and distribution of eggs within the patch[5]. As female moths of *H. armigera* feed on nectar just before oviposition, most of the carbohydrates are utilized for generating the energy for flight than in getting assimilated in the body. Moreover, the eggs are completely matured at the time of nectar feeding by the moths. All these evidences completely exclude the possibility of carbon isotope signature of the nectar altering the isotope composition of eggs. Thus, to a large extent, isotopic composition of eggs should fairly well reflect the feeding habits of the adults. Hence, if one finds eggs of *H. armigera* carrying a specific carbon isotope signature on a host plant with a very different signature, it would provide clear evidences on the polyphagous habits or otherwise of *H. armigera*.

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5. Cunningham *et al.*, *Bull. Entomol. Res.*, 1999, **89**, 207.

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