org/wiki/List_of_countries_by_population and GDP data from http://en.wikipedia.org/wiki/List_of_countries_by_GDP_(nominal).

Both sources were accessed on 10 December 2012. If C is the number of 'champion works' and P is the zeroth-order indicator of size (we use here population in millions and GDP in trillions of US dollars respectively), then the second-order indicator[2] is $X = C^2/P$. Tables 1 and 2 show GDP-based and population-based second-order performance indicators for the top 10 in each list, as well as Finland, Norway, South Africa and the BRIC countries.

1. Mahesh, G., *Curr. Sci.*, 2012, **103**, 1260–1261.

2. Prathap, G., *Curr. Sci.*, 2010, **98**, 995–996.

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Bt brinjal: a risk assessment worth taking?

The *Bt* brinjal debate seems to have regained momentum. Several new reports and articles have been made available[1–4], and an FAO e-mail conference on GMOs[5] has attracted a number of participants who have voiced ideas and opinions on *Bt* brinjal. Concern over the potential consequences for biosafety if this transgenic crop is commercialized, is a recurrent theme in many of the views put forward.

In a recent article, Gupta[3] outlines the major environmental risks which are generally perceived to be associated with the commercialization of genetically modified crops. These include transfer of transgenes to wild species due to pollen transfer (or pollen-mediated transgene flow). The view that certain environmental risks, including pollen transfer, have no scientific basis, is put forward. In this light, he suggests that the appropriate regulatory tests can therefore be dispensed with. In stark contrast, the Thirty-seventh Report of the Committee on Agriculture[1] recently noted that there were strongly expressed concerns over the scope and adequacy of the evaluation of certain environmental hazards associated with the release of *Bt* brinjal. Such hazards include risks to wild relatives (which can arise as a consequence of pollen-mediated transgene flow).

In the course of the on-going international crop improvement programme for brinjal, over 50 different sexual hybridization studies have been undertaken. These have employed pollen transfer techniques, with the majority looking at the potential for hybridization between brinjal and its wild relatives. Some studies reported an extremely high crossing success rate, e.g. in the cross between brinjal and *Solanum violaceum* Ortega (a common weed); this gave a successful two-way cross, producing vigorous, highly fertile F_1 hybrids[6]. A number of other studies have looked at hybridization between brinjal and cultivated relatives, such as *S. aethiopicum* L. and *S. macrocarpon* L. (sometimes cultivated in India and other parts of Asia). These are relevant considerations in our understanding of potential transgene transfer from *Bt* brinjal during outcrossing, and several useful summaries of the hybridization studies are available[7–9]. At this point it is important to note that six wild-relative species and four cultivated *Solanum* species found in India are known to be able to cross with brinjal to produce reproductively fit hybrids[2].

It has been suggested that the chances of natural hybridization (as opposed to artificial hybridization via hand-pollination, described above) taking place are low. However, pollination in brinjal may consist of up to 47% natural cross-pollination, with up to 70% of fruit set arising as a consequence of pollination by insects – many trials indicate that insects play a major role (see Quagliotti[10]). Brinjal has thus been described as 'an often cross-pollinated crop'[11]. Some pollen leaves the apical pores of the anthers on its own accord upon dehiscence, but physical contact is known to facilitate the exit of pollen. In spite of this, some reports have described the role of insects in pollination of *Solanum* flowers as 'insignificant'[12]. Cross-pollination of brinjal in Asia is by insects such as bees and, regionally, may be as high as 48% (ref. 13). Pollen is collected and transferred by bee species using 'buzz-pollination'[14]. The release of pollen from the anther pores of one flower is thereby encouraged by vibrations set up by rapid beating of the bee's wings. It is then transferred to the stigmas of other flowers as the bee moves on. It seems that where buzz-pollinating bees are present, pollen transfer is virtually inevitable. It is not surprising then, that there is a considerable body of opinion that adheres to the idea that brinjal and its closest wild relatives can freely interchange genes by natural hybridization (e.g. refs 15 and 16).

It is of note that two main studies were undertaken to determine the risk of pollen transfer from *Bt* brinjal hybrids to non-*Bt* brinjal. These took place in 2003 and 2009 on experimental farms in Karnataka, Maharashtra and Andhra Pradesh, and studied the incidence of outcrossing from spiny *Bt* brinjal lines to spineless untransformed varieties. It was discovered that almost 3% outcrossing was possible, with pollen transferred up to 30 m away from the transgenic plants[11]. In both studies, honey bees were used as an integral part of the methodology and

Figure 1. Details of brinjal flower, showing the yellow, poricidally dehiscent anthers (photograph by the author).

were observed as they pollinated the flowers. However, honey bees are unable to buzz-pollinate, unlike, for example, bumble bees (*Bombus* spp.), which show a preference for flowers such as those of *Solanum*, with poricidally dehiscent anthers (Figure 1). So, although outcrossing (via cross-pollination) was demonstrable in the two studies, it is likely that the use of an appropriate insect vector would have favoured a more realistic and considerably higher incidence of outcrossing.

In consideration of the above, pollen transfer should be regarded as a major factor in generating biosafety risks associated with *Bt* brinjal. The neglect of pollen transfer tests would thereby disregard this potential hazard. Furthermore, any investigations into this factor should involve a wide range of potential recipient species, including cultivated *Solanum* relatives, other than brinjal. For a thorough assessment to be possible, data which are extensive, interpretable and unambiguous must be made available.

At the moment, consideration[1] is being given to post-moratorium information[17] relating to the scope and adequacy of the environmental risk assessments undertaken during the development of *Bt* brinjal. The outcomes and implications for biosafety remain to be seen.

1. Ministry of Agriculture, India, Committee on Agriculture 37th Report: cultivation of genetically modified food crops–prospects and effects, August 2012; http://164.100.47.134/Isscommittee/Agriculture/GM_Report.pdf
2. Samuels, J., Genetically engineered *Bt* brinjal and the implications for plant diversity – revisited, Novel Solanaceae Crops Project, UK, 2012; http://www.greenpeace.org/seasia/ph/PageFiles/415937/GE-Bt-brinjal-revisited.pdf
3. Gupta, P. K., *Curr. Sci.*, 2012, **103**, 995–1002.
4. Shelton, A. M., *GM Crops*, 2012, **3**, 175–183.
5. FAO moderated e-mail conference, GMOs in the pipeline in the crop, forestry, livestock, aquaculture and agro-industry sectors in developing countries, 5 November–2 December 2012; http://www.fao.org/fileadmin/user_upload/biotech/docs/conf18msgs.pdf
6. Rao, S. V. and Rao, B. G. S., *Theor. Appl. Genet.*, 1984, **67**, 419–426.
7. Daunay, M.-C., Lester, R. N. and Laterrot, H., In *Solanaceae III: Taxonomy, Chemistry, Evolution* (eds Hawkes, J. G. *et al.*), Royal Botanic Gardens, Kew, 1991, pp. 389–412.
8. Kashyap, V. *et al.*, *Sci. Hortic.*, 2003, **97**, 1–25.
9. Rao, N. N., In *The Biology and Taxonomy of the Solanaceae* (eds Hawkes, J. G. *et al.*), Academic Press, London, 1979, pp. 605–614.
10. Quagliotti, L., In *The Biology and Taxonomy of the Solanaceae* (eds Hawkes, J. G. *et al.*), Academic Press, London, 1979, pp. 399–419.
11. Singh, M., Centre of origin, interrelationship and crossability in *Solanum melongena* (Brinjal), Research report, Division of Vegetable Improvement, Indian Institute of Vegetable Research (IIVR), Varanasi, 2009.
12. Genetic Engineering and Approval Committee, Minutes of the Second Expert Committee on *Bt* brinjal, Ministry of Environment and Forests, New Delhi, 2007; http://www.envfor.nic.in/divisions/csurv/bt_brinjal.pdf
13. MoEF, Biology of Brinjal, DBT, New Delhi, 2010; http://dbtbiosafety.nic.in/guidelines/brinjal.pdf
14. Buchmann, S. L., In *Handbook of Experimental Pollination Biology* (eds Jones, C. E. and Little, R. J.), Van Nostrand and Reinhold, New York, 1983, pp. 73–113.
15. Meyer, R. S., Karol, K. G., Little, D. P., Nee, M. H. and Litt, A., *Mol. Phylogenet. Evol.*, 2012, **63**, 685–701.
16. Weese, T. and Bohs, L., *Taxon*, 2010, **59**, 49–56.
17. Andow, D. A., *Bt* brinjal: the scope and adequacy of the GEAC environmental risk assessment, Department of Entomology, University of Minnesota, USA, 2010.

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Phoenix rupicola in the Eastern Himalaya

Endemic to the Eastern Himalaya, the scarce Cliff Date Palm (*Phoenix rupicola* T. Anders.) is under serious consideration for immediate conservation measures and redemptive action in Sikkim today. Recent count has revealed a total of 121 individuals within an estimated 11,000 sq. km of the Sikkim Himalayan expanse and under ca. 1.5 sq. km of actual area of occupancy (AOO). This makes it a strong contender for being labelled as Critically Endangered species under the IUCN Red List of Threatened Plants[1] (at present it is assigned Near Threatened category). These plants have been recorded earlier in the Sikkim Himalaya[2,3].

Among the few pinnate-leaved palms of India (total 14 species), only about 3 species grow in the foothills and submontane region, of which *P. rupicola* is in danger of total disappearance if recovery measures are not implemented soon. Encroachment in its natural habitat and related anthropogenic activities are causes for limiting its habitat and regeneration potential. These palms are normally found growing at the forest outliers, mostly close to the streams and characteristically over steep rocky slopes (L. *rupicola* = of the rocks). Of these three habitat classes, the first two are easily accessible and therefore more susceptible to disturbance and degradation. If proper conservation measures are not implemented, the species may soon become extinct.

As the trunk of the palm is rich in starch, it was earlier cut down for getting the sago-like pith by the natives, which was subsequently processed for human consumption. This practice has made a

Figure 1. *Phoenix rupicola* in natural habitat at Pashoke, ca. 1060 m amsl.