chemistry with ICP–MS. Ore textures with several classical illustrations were the highlight of the talk delivered by G. S. Roonwal (Delhi). N. C. Pant (GSI, Faridabad) dealt with the role of electron microprobe analysis in petrography and the significance of REE and accessory minerals in chemical dating of rocks in two separate lectures.

Practical sessions were conducted with the help of a micro-image display system. Excellent thin-section slides were shown by several resource persons. Presentations by the participants on their research findings followed by discussions were an integral part of the course. Participants were also evaluated by a few resource persons through oral/written assignments. On the penultimate day, S. Mukherjee (GSI, Faridabad) shared his experience of the Antarctica expeditions through photos/slides.

The chief guest at the valedictory function T. V. Ramakrishnan (Indian Academy of Sciences, Bangalore) distributed certificates to each participant. A few participants spoke on the occasion. A volume containing all the lecture material was also published. The participants were of the opinion that this course on petrography was timely and that more such courses should be conducted in different parts of the country to help young scientists look at rocks through the eyes of a petrographer and mind of a petrologist.

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COMMENTARY

Flowering asynchrony can maintain genetic purity in rice landraces

Debal Deb

Although contribution of genes from wild relatives has over centuries enhanced the genetic base of rice, genetic 'contamination' from modern rice cultivars, especially hybrids incorporating genes from *japonica* and *indica* varieties of cultivated rice (*Oryza sativa*), may cause loss of many characteristics (like aroma, slenderness or colour of grains) of an established landrace preferred by folk farmers. Transgenic rice varieties may further enhance chances of contamination of farmers' landraces with alien or incompatible genes[1], and raise concerns of biosafety[2].

Genetic impurity in rice varieties is caused more frequently from anthropogenic seed dispersal during planting than due to cross-pollination at flowering[3,4]. With the erosion of traditional practices regarding careful separation of seeds of different varieties, mixing of breeders' seeds is a frequent phenomenon. Most modern farmers in the global South have either forgotten or tend to neglect the traditional practice of 'roguing' for retaining genetic purity of their preferred landraces. Roguing is the removal of off-type rice plants from both parents[5], on the basis of morphological characters (like plant stature, leaf length and width, flag leaf angle, panicle shape and panicle size). With the erosion of the knowledge and practice of rouging, physical and genetic mixing is now commonplace in most local rice varieties.

An apparently uncontrollable source of varietal intermixing is cross-pollination, which occurs at a considerably low frequency between the cultivated rice and its wild relatives (especially *O. rufipogon*), and between landraces of the former. The frequency of out-crossing does not exceed 1%, even when panicles of donor rice plants were clipped with those of the acceptors, and when the acceptors had longest stigmas and highest degree of stigma exsertion[6]. The principal factors that physically reduce cross-pollination frequencies include a short style and stigma, short anthers, limited pollen availability, short-lived pollen, progressive decline of pollen viability, and a brief period (between 30 s and 9 min) between opening of florets and release of pollen[4,7]. Rice flowers often remain open for periods of less than 3 h, and only during daytime[8], which further delimits the scope of out-crossing.

Nevertheless, low rates of cross-pollination can occur in cultivated rice when plants with synchronous or overlapping flowering times grow in close proximity[9,10]. In order to prevent the risk of cross-pollination, rice researchers recommend a spatial isolation of about 110 m from seed production plots to other rice varieties[10,11]. Some authors[5] recommend an isolation distance of up to 200 m for male sterile (A line) multiplication, while for other varieties, it is sufficient to keep an isolation distance of 3 to 5 m.

However, it may not be feasible for small and marginal farmers in South and South East Asia to leave gaps of 110 m – or even 5 m – between plots of rice crops on their typically small farms growing two or more local rice landraces. Besides, a spatial gap of 5 m may not ensure zero out-crossing, as far as wind-borne transmission of pollen is concerned. The alternative measure of maintaining barrier isolation with sorghum, pigeonpea or sugarcane, with 30–40 m distance[10] is not an economical option for small farmers. Besides, plant barriers often have wide holes sufficient to allow pollens to fly across into plots on both sides.

As a more practicable alternative, I suggest here to maintain a temporal distance between cultivars in terms of flowering time. Some scholars recommend keeping a gap of at least 30 days between the flowering stage of the parental lines in the seed-production field and that of other varieties grown within the area to avoid contamination by pollen[5]. However, I argue here that a temporal separation by 12 h between the onset of flowering of one cultivar and the beginning of the milking stage of its neighbour is sufficient to check out-crossing.

The rice flower biology ensures that a small time gap between pollen release

Table 1. Days until flowering (DUF) and duration of flowering (DF) of selected landraces of *O. sativa*

Landrace	State of origin	Country	DUF	DF
Aswin Jharia	West Bengal, Jharkhand	India	85	9
Bansh Phul	Jessore	Bangladesh	109	10
Gadaba	Orissa	India	71	13
Garam Masala	Maharashtra	India	82	6
Geti-sal	West Bengal	India	95	10
Komal	Assam	India	102	13
Meghnad-sal	Jharkhand	India	109	11
Noichi	West Bengal	India	80	12
Rangi Haitta	Tripura	India	49	8
Rosa Marchetti	Tuscany	Italy	47	9
Sada Dhepa	Dinajpur	Bangladesh	110	12
Sada Mota	West Bengal	India	127	9
Sekara	Orissa	India	51	11
Shatia Bhadoi	West Bengal	India	45	12
Sonam	Bihar, Jharkhand	India	97	12
Tulsibhog	West Bengal	India	130	8
Velchi	Maharashtra	India	74	12

and the opening of florets be enough to minimize chances of cross-pollination. The rice pollen is typically short-lived, and cannot remain viable beyond 30 min after release from the anther. *O. sativa* pollen has the fastest decline in post-release viability, and loses 100% of its viability about 30 min after anther dehiscence[2]. Furthermore, even when flowering periods of two cultivars overlap[8], cross-pollination is often unsuccessful because rice florets remain open for periods of less than 3 h. Finally, rice florets do not open during night hours. Thus, a 12-h gap between the opening of florets of a given cultivar and anther dehiscence of its neighbouring cultivars seems adequate to entirely eliminate chances of out-crossing between them.

A plantation design based on asynchrony of pollen release and stigma exposure in different rice landraces is not difficult because the onset of flowering in rice takes a characteristic, landrace-specific length of time after sowing. The date of 50% flowering (when half of the panicle bears florets) is more or less landrace-specific and relatively photoperiod-invariant. The length of time until flowering (DUF), measured in days between the sowing date and the date of first flowering of a given cultivar, does not vary more than 5 days beyond the mean number of days, regardless of variations in temperature, humidity and photoperiod. The panicle inflorescence is completed between one and six days after the 50% flowering date, with low-land adapted landraces maturing later than those adapted to dryland conditions. The duration of flowering stage (DF) from the onset of flowering to the 'milk' stage, is also relatively landrace-specific. Thus, each rice landrace can be identified by its characteristic DUF and DF, which may serve as a helpful guide to design plantation of different landraces on a farm. Table 1 gives an illustrative list of selected rice landraces with their DUF and DF.

When the DUF and DF are known for different landraces, it would be easy for farmers to plant them on adjacent farm plots in a manner that would obviate cross-pollination between them. So long as the DF of a given landrace does not overlap with that of its neighbours, any possibility of cross-pollination between them is precluded. From Table 1, it is apparent that planting Shatia Bhadoi, for example, between plots of Sada Mota and Geti-sal on either side will have their flowering dates completely mismatching one another. I propose that no more than five heterochronous flowering periods would suffice to isolate a large number of cultivars adjacent to each other – a proposition akin to the 'four colour theorem' of colouring all possible adjacent vertices in a graph[12].

A cropping design based on flowering asynchrony between 360 rice landraces grown on adjacent plots of a small experimental farm of the Centre for Interdisciplinary Studies has proved effective in maintaining varietal purity over a period of five years. For each of these landraces, 18 morphological characteristics were recorded for comparison from the year 2000 to 2005. These characteristics include basal leaf sheath colour of the seedling, internode colour after transplanting, leaf length and width at late vegetative stage, flag leaf angle, panicle structure, panicle length, awning, threshability of grains, lemma and palea colour, lemma and palea pubescence, grain length and width, apiculus colour, seed-coat colour, brown rice length and width, and seed weight. Periodic examination of these descriptors of each landrace revealed that none had deviated from the standard record[13] of these characteristics.

Maintaining large spatial distance or physical barriers between cultivars is both expensive and impracticable for poor and marginal farmers in the global South, but the technique of spacing apart of varieties by means of flowering asynchrony can be effective in preserving genetic identities of different landraces. Because LF and DF are landrace-specific and relatively soil- and climate-invariant, growing landraces of non-overlapping flowering periods is a simple and sure means to prevent cross-pollination. This method would allow cultivation of a large number of rice landraces adjacent to one another on a small farm plot, with no risk of outcross. The method may also be useful to avoid genetic pollution from transgenic rice, and may be applied to prevent cross-pollination in many other open-pollinated crops.

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SCIENTIFIC CORRESPONDENCE

Crystal structure of $HgFe_2O_4$

Mercury contamination/poisoning is one of the most hazardous anthropogenic impacts that occurs in the environment. The literature survey reveals that because of the toxic nature of mercury, few researchers[1] had attempted the removal of mercury from water/wastewater. Though some were successful, disposal of the resulting highly saturated mercury sludge posed a problem for the ecosystem, because these methods involved only removal of mercury and none of them involved preparing a value-added product. The method described here not only removes mercury with greater efficiency than the prevalent methods quoted in the literature, but also converts it into a value-added product – $HgFe_2O_4$ (mercury ferrite). The porosity of $HgFe_2O_4$ was calculated from X-ray density and was observed to be –8.1. The ionic radii of both of its cations lie well within the range of spinel formation[2]. Therefore, it could be expected that this compound crystallizes in the spinel structure.

An important feature of the present study is in successfully locking the mercury as $HgFe_2O_4$ by an economic process of ferritization; co-precipitation of mercuric (Hg^{2+}) and ferrous (Fe^{2+}) ions was done with a dose of Fe^{2+} ions in the ratio of 1 : 2.5–3.2 with a solution containing Hg^{2+} ions, the pH of which was maintained between 9.5 and 10.2. The resultant solution was oxidized at 50°C by aeration. The resulting solution obtained after aeration contained precipitated hydroxides and this was further aerated. This aided the formation of the resultant compound, which crystallized by the process of ferritization[3]. The reaction time for the same was about 15 min. The ferruginous material thus obtained was then analysed by X-ray diffraction using CuK_a radiation (l = 1.5404).

Crystallographic data revealed that the compound crystallized in orthorhombic symmetry having a non-spinel $BaFe_2O_4$-type crystal structure[4] with lattice parameters a = 7.905 Å, b = 3.311Å and c = 4.876 Å. Preference of Hg^{2+} ions for tetrahedral sites was attributed to the sharing of their electrons with 2P electrons of the oxygen ions. The observed symmetry may be due to slight difference in electronegativity (<1.7) between Hg^{2+} and O^{2-} ions.

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