

Table 1. Comparison of techniques used by Yoshizaki and Pandian

General technique	Transcloning (Yoshizaki)	Androgenesis (Pandian)
Donor	<i>Onchorhynchus mykiss</i>	<i>Puntius conchoniensis</i>
Recipient	<i>O. mosou</i>	<i>P. tetrazona</i>
Germplasm source	Primordial germ cells (PGCs)	Spermatozoa
Transfer technique	By microinjection of PGCs	Natural fertilization/activation
Requirements	Isolation of PGCs Marking with <i>vasa</i> and GFP Tracing the marked PGCs in recipient	Collection of cadaveric sperm from post-mortem specimens preserved at -20°C Incubation of milt in 2.5% PEG for 10 min to promote dispermy Genome inactivation of the recipient eggs by UV irradiation
Advantages	Restoration of nuclear and mitochondrial genomes	Restoration of nuclear genome alone

earlier introduced. On my suggestion, he has chosen the Siamese fighting fish *Beta splendens*, an airbreathing fish amenable to microsurgery. The idea is to use the sterile gonad of the recipient species as a surrogation chamber for exogenous gonad to function normally and to produce its sperm. Much of our understanding of the role played by one or other sex steroid was based on surgical removal of testis or ovary of fish. Surgical removal of gonad in *B. splendens* resulted in regeneration of the entire gonad (see ref. 8); briefly, the gametes, from which progenies could be derived through fertilization, can more easily be obtained by transplantation of the essential fraction, i.e. 'stem cells' of the gonad of the donor, rather than transferring the PGCs, as has been made by Yoshizaki.

The techniques of Yoshizaki and Strussmann pose great challenges to taxonomists and immunologists; How do the fry and adult of a recipient species tolerate the presence and/or proliferation of PGCs and pieces of testis of donor species, respectively, especially in the absence of immuno-suppressants like cyclosporin? It is assumed that the

basal laminar layer of testis prevents the entry of phagocytes. Incidentally, there are also claims for *ex situ* culturing of human sperm in the rat gonad, using the technique which Strussmann conceived 10 years ago and is now engaged in. Controversial claims have also been made in a report by Sofikitis *et al.*⁹.

When so many advances are made in Japan, what is the status in India? Well, a beginning has been made at Madurai Kamaraj University. Choosing the rosy barb *Puntius conchoniensis* as a model fish, we have induced dispermic interspecific androgenesis, a simple technique to restore genome of a fish species, for instance, rosy barb using its sperm drawn from postmortem preserved specimen and genome-inactivated eggs of tiger barb *P. tetrazona*¹⁰. A simple and widely practicable method of obtaining live sperm from specimens, that were preserved at -20°C for 240 days has been reported earlier¹. Table 1 presents a comparison between the highly skilled sophisticated method of Yoshizaki, and the simple, widely practicable method of ours.

1. Koteeswaran, R. and Pandian, T. J., *Curr. Sci.*, 2002, **82**, 447–450.
2. Iyengar, A., Muller, F. and Maclean, N., *Transgenic Res.*, 1996, **5**, 147–166.
3. Yoshizaki, G., Takeuchi, Y., Kobayashi, T., Ihara, S. and Takeuchi, T., *Fish Physiol. Biochem.*, 2002, **26**, 3–12.
4. Takeuchi, Y., Yoshizaki, G., Kobayashi, T. and Takeuchi, T., *Biol. Reprod.*, 2002, **67**, 1087–1092.
5. Takeuchi, Y., Yoshizaki, G. and Takeuchi, T., *Biol. Reprod.*, 2003, **69**, 1142–1149.
6. Yoshizaki, G., Takeuchi, Y., Sakatani, S. and Takeuchi, T., *Int. J. Dev. Biol.*, 2000, **44**, 323–326.
7. Takeuchi, Y., Yoshizaki, G., Tominaga, H., Kobayashi, T. and Takeuchi, T., In *Aquatic Genomics* (eds Shimizu N., Aoki T., Hirono I. and Takashima F.), Springer, Tokyo, 2003, pp. 310–319.
8. Pandian, T. J. and Sheela, S. G., *Aquaculture*, 1995, **138**, 1–22.
9. Sofikitis, N. *et al.*, *Human Reprod. Update*, 2003, **9**, 291–307.
10. Pandian, T. J. and Kirankumar, S., *Curr. Sci.*, 2003, **85**, 917–931.

T. J. Pandian is in the School of Biological Sciences, Madurai Kamaraj University, Madurai 625 021, India. e-mail: tipandian@eth.net

COMMENTARY

Rainwater harvesting, a time-honoured practice: Need for revival*

B. P. Radhakrishna

'Rainwater harvesting' and 'groundwater recharge' are now two catchwords which are commonly used by most people, without realising their full significance. Harvesting of rainwater through impounding

it where it falls by means of ponds, check dams and in large-sized tanks is a well-understood technique practised for at least the last 1000 years. The landscape, especially of South India, is virtually studded with such structures. Unfortunately, village communities deprived of ownership rights have lost all interest in their upkeep, with

the result that the tanks have remained neglected, become filled with silt and incapable of harvesting water to any significant extent.

It is only in recent years that there has been much talk of rainwater harvesting. Thanks to the crusading efforts of Anil Agarwal and his team at the Centre for

*Reproduced from *J. Geol. Soc. India*, Aug. 2003, vol. 62.

Science and Environment, New Delhi, sporadic attempts are being made, mostly by non-official agencies, at rainwater harvesting. Unfortunately, the governments, instead of lending massive support to such efforts, have shown scant interest. But now, suddenly, even that little interest has been diverted to the interlinking of rivers and the construction of further major dams at enormous expense. Such schemes of doubtful utilitarian value may benefit only the already affluent farmers living in river valleys. The large majority of the population, living on higher ground will be the last and the least benefited by these grandiose schemes. Drought conditions will continue and are likely to worsen, if timely action is not taken at conserving water and harnessing rainwater. If recurring drought conditions have to be prevented, the only course open is rainwater harvesting practised on a regional scale by arresting the rapid run-off of water, allowing it to seep downward and augment the groundwater reservoir. It is this process of maintaining the groundwater source and making it available throughout the year which is termed as groundwater recharge.

Special aspects of the outer envelope of planet earth

It will be pertinent here to draw attention to a few special features which characterize our planet. The earth appears to be the only planet in the solar system which has anything similar to the soil which covers almost the entire land surface in the form of a thin skin. Beneath this veneer of soil (in the hard rock region of Karnataka) is a layer of weathered and decomposed rock which may extend to a further depth of 30 m. Below this level, the rock becomes hard and almost impervious, except through fractures or fissures up to about 100 m depth. Such fissures become less and less at increased depth and beyond 300 m, the ground is impervious and mostly dry.

One other fortunate circumstance which characterizes planet earth is the presence of an atmospheric layer rich in water vapour. As a result of climatic changes, this layer becomes heavily charged with water vapour, the result of evapo-transpiration from the land and sea surface. The air so charged with water vapour moves towards the land surface and when it cools down gives rise to copious amounts of rainfall.

When this precipitation is heavy over a short period of time, as during the monsoon period, the soil soon becomes saturated, causing much of the rainwater to flow over the surface and into *nalas* and depressions forming local drainage systems. Most of the run-off water is eventually discharged, via rivers, into the oceans and is lost. In addition, due to denudation of forest cover, the run-off carries away to the oceans immense quantities of valuable soil, far more than that provided by rock decomposition in the same period, and eventually promoting desertification.

Natural groundwater recharge

The surviving thin soil cover however, absorbs a good part of the rain and stores it in the weathered mantle below. This water is not stationary but slowly moves to the lower sections of the valley and contributes to river flow in summer months. The bulk of the recharge and discharge therefore takes place in this 20 m zone and is reflected in the changes of water level in the wells. This is natural groundwater recharge which takes place imperceptibly and without human intervention or assistance.

It must be said to the credit of our forefathers that they had understood fairly clearly the availability of potable water below ground, within easy reach in almost all places, through this natural process of rainwater recharge every year. This understanding enabled them to utilize the resource in a satisfactory manner by developing a system of large-diameter open wells which not only provided a larger area for percolation, but also served as storage facilities. Nowhere else, perhaps, in the world was groundwater developed in such a systematic manner as in the peninsular part of India. Water was treated as a precious commodity, was used judiciously and being available at shallow depths, there was little effort or cost involved in well-sinking and lifting the water to the surface.

Large-scale exploitation of fossil groundwater since 1980 and its evil effects

The history of water found at depths greater than 100 m, which is being presently tapped indiscriminately by means of borewells, is different. It is certainly

not recent rainwater which has directly infiltrated underground, but its source must be far away and it must have taken decades or even centuries to accumulate. A great deal of research is needed to clearly understand the mode of occurrence and the source of groundwater in this zone, as our knowledge at present is far too inadequate.

The deeper one goes underground in search of water, the quantity encountered becomes less and less, and the movement of this water is so slow that it may take a century to recharge the fractured/fissured zone. At still greater depths of over 100 m and up to 300 m, recharge may take several centuries or even a millennium.

Correct weightage and appreciation of these basic facts and the necessity of avoiding over-exploitation of the precious resource of groundwater, does not seem to have been given in our zeal to exploit groundwater from increasing depths.

Encouraged by the copious amount of water struck in borewells, farmers, multi-storey building developers and industries have taken to drilling of deep borewells and pumping out enormous quantities of water, far in excess of the annual recharge. This senseless way of utilizing centuries-old accumulated water, aided through bank loans and supply of free electric power, has rapidly exhausted the 'fossil' water held in this zone, and many borewells which earlier yielded abundant water have gone dry. It is sad irony that advances in drilling technology and the availability of deep-well and submersible pumps while bringing prosperity to a few, have tended to exhaust a precious resource which can only be replaced by nature over a very long period of time.

Artificial groundwater recharge

Groundwater recharge can only mean the natural recharge of the shallow aquifer limited at best to a depth of 100 m below surface. This recharge of the aquifer is natural, for which no special efforts are necessary, except preparing the ground for impounding rainwater and thus promoting its percolation underground.

In recent years there has been much talk about *artificial groundwater recharge* through injecting water into abandoned borewells. First of all, where is the excess water available for recharging and what is the likelihood of success? Since percolation to and at greater depths is an extremely slow process, it is doubtful whether

borewells which have become dry can be made to recover and start yielding water through such artificial means. In addition, surface water is polluted in most cases and indiscriminate attempts at artificial recharge of groundwater in the hands of the uninitiated poses the great danger of polluting one of the few sources of unpolluted water on the planet. Once groundwater becomes polluted, there is no way of purifying it. *Our plea therefore is to abandon all talk of artificial recharge and concentrate on promoting and accelerating natural groundwater recharge by means of adopting rainwater harvesting methods.*

Indiscriminate groundwater exploitation in metropolitan cities

Over-exploitation of groundwater through borewells in metropolitan cities poses a great danger. A resource of inestimable value is irretrievably lost through profligate use by affluent sections of the community at the expense of others less well-placed. Severe restrictions must be imposed on such exploitation. There is, at present, no regulatory authority exercising control on the utilization of groundwater and it is essential that licensing borewells and

prescribing limits on water extraction be framed and introduced without delay.

Initiate a mass movement in rainwater harvesting

There is a vast extent of common land, generally classified as 'fallow' in village records, which must be converted into collection areas for rainwater harvesting. This is the only way of augmenting water resources for drinking and agricultural needs. Rainwater harvesting and groundwater recharge should be made to go hand-in-hand, with every member of the village community taking part in this effort. A mass movement in this direction is what is called for – (not the grandiose plans of politicians and bureaucrats of linking rivers) – which will solve local, state and national water shortages and make the land productive.

The sum and substance of the present analysis is to stress the inadvisability of sinking more borewells to greater depths for tapping water. The zone up to a depth of 100 m which contained fossil water accumulated over a period of years, has already been sucked dry and is no longer available for exploitation. Any talk of

recharging this zone through artificial means is a doubtful proposition because of the extremely slow process of recharge.

Wake-up call for groundwater authorities

If groundwater exploitation is allowed to continue in the same reckless manner in which it has so far been permitted without licensing and controlling the extraction, the one and only safe source of water which nature had provided us as an insurance against poor monsoons will soon be irretrievably lost, landing us in a deep water crisis of national proportions with no way open to remedy the situation. Immediate action is called for to bring in uniformly applicable legislative measures all over the country, in setting limits to groundwater tapping and prevent in particular, the commercial exploitation of groundwater for profit-making. The earth sciences community has a special role in compelling the politician and the policy-maker to initiate urgent action in this regard for the sake of posterity.

B. P. Radhakrishna is in the Geological Society of India, P.B. No. 1922, Gavi-puram P.O., Bangalore 560 019, India. e-mail: kitts@bgl.vsnl.net.in



Vol. XI] JULY 1942 [No. 7

The physics of the diamond

By reason of its remarkable properties, diamond is a substance of extraordinary interest to the physicist interested in the study of solids. It exhibits in a characteristically striking fashion, many phenomena which are scarcely noticeable with

other solids in ordinary circumstances. As an instance, we may recall the variation of specific heat with temperature. This was known as an experimental fact in the case of diamond for at least fifty years before it was recognised as a universal property of the solid state; the data for diamond published by Weber in 1875 formed the basis of Einstein's epoch-making paper of 1907 introducing the quantum theory of specific heats. History has a way of repeating itself, and the study of diamond should therefore appeal strongly to the experimenter seeking new avenues of research and to the theorist seeking new and fruitful lines of physical thought concerning the solid state.

For the reasons stated, I have since the year 1930 been deeply interested in physical investigations on the diamond. The difficulty of obtaining the material in a

form suitable for exact studies has, however, been a serious obstacle to progress. Indeed, in the early days, I was reduced to the expedient of borrowing diamond rings from wealthy friends who, though willing to oblige, were slightly apprehensive about the fate of their property! More recently, these difficulties have diminished as the result of the discovery that flat plates of diamond of excellent quality are not very expensive and can be purchased in useful sizes from many jewellers in India. The collection of diamonds got together in this way has enabled studies with this crystal to figure prominently in the Bangalore researches on the solid state. Results of fundamental importance have been reached by spectroscopic investigations on light-scattering, on absorption in the visible and ultra-violet, on fluorescence and phosphorescence, and

FROM THE ARCHIVES