Figure 1. *Cymbidium whiteae*. ***a***, Habit; ***b***, Flowering branch; ***c***, Close-up of flower.

Biosphere Reserve (KBR) and is more than 50 km away from the previous localities. Moreover, the present population is on a completely different mountain ridge (at the base of KBR) and on a different aspect of slope. This natural refugium of endemic species needs to be conserved because the area is extensively under cardamom cultivation. More populations can be found in similar landscapes in Sikkim or near KBR after a thorough search. To mitigate direct or indirect threats to this species, it is imperative that the local community be mobilized to improve their understanding about this plant in particular and other endemic and endangered flora in general. For *in situ* conservation of this endemic and rare species, the area should be covered under the protected area network.

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Sustainable water management in India with reference to flow irrigation projects

I have read the article by S. K. Jain with interest[1]. Instead of spending space recounting the many relevant issues and points in it, I may be permitted to draw attention to a couple of relevant points missing in this review.

In discussing the impact on water-related sectors (p. 179) it is stated that, 'A major boost to agricultural production and also to productivity of water in agriculture (more crop per drop) was achieved with the green revolution in the 1960s … Hence, another crop productivity revolution with respect to water is required … Obviously, there is considerable scope for improving water productivity in India.' Here, the reference is to the physical productivity of the crop under irrigation (more crop per drop). What is totally missing is the value productivity per drop.

It is really sad that in India this aspect of the most economic use of water for irrigation has not attracted the attention of engineers as well as the agronomists advising them. The problem is not serious in regions endowed with more than adequate water, surface and underground, for the crops grown or to be grown. But, in regions characterized by severe shortage of water for agriculture (not to speak of all other needs), it is important to use the water such that this scarcest of the inputs of agriculture produces the maximum value per unit of water used. This is elementary economic logic. (Indeed, any farmer with very limited availability of water compared to the agricultural land under his control to be irrigated, understands this.)

In India more than 40% of the total agricultural land is located in what is called the dry agricultural region (with less than 40 inches of annual precipitation), located mostly in the non-coastal part of peninsular India. A very large part of it does not receive even 25 inches in the year. And, this is the region that is

also characterized by poor groundwater resource.

Engineers have estimated that in this region the waters flowing in the rivers running from west to east can irrigate at most about a third of the total land under cultivation, following the present pattern of use of canal water. Only two crops, sugarcane and paddy, consume the bulk of the canal water. Sugarcane, in the regions where this is the dominant irrigated crop, accounts for more than three-fourths of the total flow irrigation water. It is not very different in the paddy regions. But these two crops account for a small part of the total flow irrigated land. In view of the acute shortage of water for irrigation in the region, it would be logical to use the water such that maximum additional income per unit of irrigation water is generated in the region (*not* additional income per unit of irrigated land).

Using this elementary economic logic a research project was submitted early in 1978 to the Central Water Commission for a systematic examination of this question in two established flow irrigation projects in Maharashtra, Pravara and Neera (left bank canal). The report of the study was submitted to the Commission as well as the Government of Maharashtra.

The study[2] showed that canal water was most uneconomically used. A simple example will help understand the point: An acre of sugarcane requires 180 acre-inches of irrigation water, while an acre of irrigated hybrid jowar requires 18 acre-inches of irrigation water. So, roughly speaking, the irrigation water given to an acre of sugarcane can irrigate 10 acres of hybrid jowar. But the net value addition from irrigating an acre of sugarcane was much less than half the value addition from irrigating 10 acres of hybrid jowar. What is true of jowar is also true of all seasonal pulses, oilseeds, cotton, even wheat and, of course, spices, potato and horticultural crops. The study showed that if flow irrigation water is economically used, the additional income to the social economy will be at least twice the present and more widely distributed amongst the farming households. What is equally important, nearly 60% of the net cropped area (not 30%, as projected under the present use-pattern) will be irrigated when all flow irrigation projects are implemented and there will be greater stability to agriculture in this dry region. The total man-days of employment, household and hired, under the new use-pattern will be much larger than what the present use-pattern ensures. It will not mean the end of sugarcane farming in the region. For, a systematic plan of recycling the seeped groundwater in the command areas of the flow irrigation projects can help grow sugarcane (and rice), though of course with different area concentrations than under the present pattern.

I may also mention that a three-man committee (V. M. Dandekar, Datta Deshmukh and V. R. Deuskar) set up by the Government of Maharashtra in 1978–79, used the same logic to recommend a very different pattern of use of canal water under the flow irrigation projects in Maharashtra than followed at that time[3]. Why such use-pattern is not adopted by the farmers or the Government, despite the logic and the increased total social benefits is a different question that requires separate discussion. Suffice it to say that here the pattern of land holding in the command area of canals creates different land and water endowment at the individual and the social levels, leading to a conflict between social and individual welfare, and therefore needs social action.

All this has been raised and narrated here to make the point that there have been definitive studies to establish the logic of a very different type of use of irrigation water in the dry peninsular region that can lead to much better, wider and more beneficial use of available flow water of the region. However, the failure (unwillingness?) to exploit this approach has resulted in the highest technical authorities at the level of the Government of India spending tremendous technical man-power to design systems for transferring the *surplus* water from the Ganga–Brahmaputra basins and Mahanadi and Godavari to the drought-prone regions of peninsular India (the linking of rivers). That the engineers will be fascinated by this highly technical task is quite understandable. But there appears little concern and less understanding of the economic costs of the scheme. I may be permitted to recount an effort in this direction.

In 2003, a paper[4] was presented in an all-India conference organized by the Pune Chapter of the Institute of Engineers, which examined the economics of the project proposal, linking of rivers, based on the very limited data available in the project proposal, extracted by a senior member-engineer of the institute. The data listed were only the quantum of water that will be available for irrigation in the peninsular region and in the north in Rajasthan and upper Gujarat, the power likely to be generated at both ends and the estimated expenditure for these four parts of the project. Even the estimated time for execution of the project, the stages of completion and partial use, if any, of water and power, were not available.

With the available data the paper attempted an estimate of the annual capital cost of water (excluding the operation and maintenance expenses) at the farmer's field as well as the capital cost of an unit of power, assuming alternatively no interest on locked-up capital during the construction period of 20 years (assumed), and interest at 7% per annum for the period. The results were staggering: the annual capital cost of providing water to an acre of hybrid jowar at the field end, with zero interest on locked-up capital during the construction period, would be Rs 2015; with interest chargeable at 7% it would be more than Rs 4130 all at 2002 prices. For an acre of sugarcane it would be ten times these. If we compare this with the price of the gross output of the crop, we are simply floored. I may add that the paper presentation invoked only silence from the members of the Prabhu Committee.

Therefore, it is necessary that the economics of the use of flow water for irrigation in the dry regions of the country is noted as a relevant factor in the proper use of this very scarce resource of the economy. The matter should not be left to stray economists.

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