Grassroot Innovation, Laboratory Experiments and Modeling: Case Study of Appropriate Technology Development

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1 Introduction

Research Scientists and Engineers working in Government labs and Educational Institutions often doubt if interacting with people in the unorganised sectors such as Tribal villages can provide opportunities for innovation and, hence, refrain from such an interaction. There is ample evidence in the country that shows that such opportunities readily present themselves and successful innovations are possible. Such innovations also offer research opportunities whose successful pursuits can also be presented for career advancement. Interactions with organised industry or engagements in frontier research are not necessarily the only ways to engage in satisfying research activity.

The author was fortunate to be presented such an opportunity by the Bhumiputra Pratishthaan, an NGO in Thane District. Next section describes the innovation process which alerted the author to the need for carrying out systematic laboratory experiments as well as theoretical modeling for design optimisation.

The academic investigations aptly corroborated the contributions of the Tribal people to the innovation process. These contributions highlighted the need to respond to the beneficiary-concerns in a practical design because these concerns address the limit situations of the people in the unorganised sectors. Such new constraints lead to new innovations.

2 The Innovation

2.1 The Setting

On a rainy day in August 1973, the author paid a visit to village Kondhaan, Taluka Manor, Dist: Thane, Maharashtra where an NGO called Bhumi-Putra Pratishthaan (BPP) had initiated tribal development work in 1972 in con- sultation with National Inst of Bank Management (NIBM). The NIBM had conceptualised Farmer's Service Society (FSS) to enable otherwise non-credit worthy small and marginal farmers to obtain bank loans through group loans lent to the FSS to carry out cooperative activities. The NGO, the local branch of Bank of Maharashtra (BoM) and workers of a local people's movement Bhumi Sena (BS) were the partners in the project. In order to ensure recovery of loans, procedures were jointly laid out and several economic activities were to be supported through appropriate technological interventions. The organisational strength of BS, the spirit of service of the NGO and the financial strength of BoM were considered important attributes of the partners.

One major problem faced by the tribal farmers was that of *Khavti* loans taken at exorbitant rates from money-lenders. The need for such loans arose because by end-of-July, the farmers ran out of food stocks from the previous year's harvest (about 600-800 kg / acre). As such, to carry out the hard tasks of Paddy cultivation during transplanting and subsequent harvesting operations, farmers had to borrow money to buy rice from the market. In July, the prices are high and when the new crop arrives in September/October, the prices fall. As such, farmers ended up effectively making repayments at high interest rates.

In order to address this problem, NIBM proposed introduction of *Quick- Yielding Variety* (QYV) of rice invented at International Rice Research Inst (IRRI), Manila. QYVs mature in 90-100 days as against 120-135 days for middle- and late-varieties traditionally cultivated by the farmers. The introduc- tion of QYVs would thus not only obviate the need for *Khavti* loans but will also vacate the land for leguminous or vegetable crops to be taken during the remaining 30 days of monsoon. The leguminous crops fix Nitrogen in the soil whereas cash incomes can be realised from vegetables.

The QYVs, however, have a short dormancy period (up to 72 hours after harvest) and if not dried quickly after maturity, the paddy begins to germinate. Since sun-drying is not possible during the latter part of monsoon, farmers lost 30 to 40 per cent of their crop through germination. It is for this reason that farmers did not opt for extensive cultivation of QYVs. The need to cultivate QYVs, however, is particularly great for small and marginal farmers. In the absence of suitable means of drying their crop, small and marginal farmers agreed to commit only a part of their (typically 2.5 acres and less) land to QYVs. If a mechanical dryer were available not only would crops be saved, but farmers would also be encouraged to take two crops from their total land.

There were 3 more reasons why farmers were reluctant to commit larger portions of their land to QYVs. These were

1. The harvested paddy was difficult to thresh using their traditional method because of its high (26 %) moisture content as against about 13-16 % in traditional sun-dried varieties. They did not have a mechanical thresher

2. QYVs required use of Chemical fertilizers which they had never used

3. The straw of QYV plant was shorter (only about 1 ft high) than traditional variety. This, they felt, will require too much straw for thatching roofs and more closely spaced rafts and bamboo perlins will be required.

In spite of these reservations, many farmers had agreed to commit 10 Gunthas of land for QYVs. In Aug 1973, therefore, when the crops had arrived, the chief of the NGO requested the author, during his visit, for a design of a suitable Dryer after being told that the author possessed a PhD in *Heat Transfer*[2].

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[2] The author's PhD work involved solution of Partial Differential Equations of mass, mo- mentum and energy transfer in a particular situation. He had never dried anything!

2.2 The Problem Statement

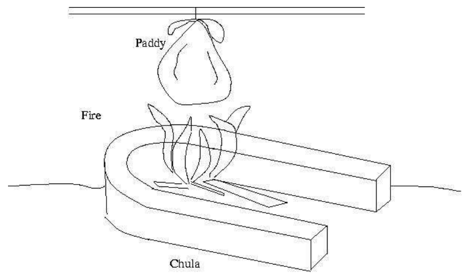
Work on finding an appropriate technology solution to the Drying problem began at IIT Bombay in 1973. Currently, the farmers obtained about 100 kg/acre of QYVs and the total yields were 800 kg to 1000 kg/acre. The farmers live in small hamlets with populations varying between 100 to 500 and land holding varying between 25 and 100 acres. The yield of the early variety of paddy thus varied between 2 and 10 tons per hamlet. This much paddy must be dried in ten days. It was quite possible that, if farmers were satisfied with the drying technique proposed to them, they would prefer to plant greater quantities of QYV paddy. Therefore, the Dryer design must be amenable to an augmentation in its scale (to about 25 to 100 tons of paddy in ten days) without excessively increasing its cost and sophistication. The farmers would also be interested in using the Dryer for late varieties (which are dried in the sun and which have poor milling characteristics, in addition to incurring considerable handling loss and loss to rodent attacks in the fields) which mature in late October, to obtain greater yields after milling. All these constraints and requirements emerged through a dialogue and therefore the technical specifications for the Dryer were as follows:

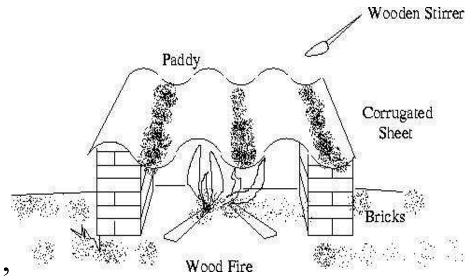
1. Capacity per day: 0.5 tons to 10 tons.
2. To be simple to construct and operate by farmers themselves.
3. When the demand for the Dryer increases, the smallest-capacity unit must be amenable to an increase in the scale of operations without greater sophistication and without additional constructional and operational difficulties.
4. Since drying is a once-a-year operation the capital cost of the Dryer must by as low as possible.

2.3 Alternative Solutions

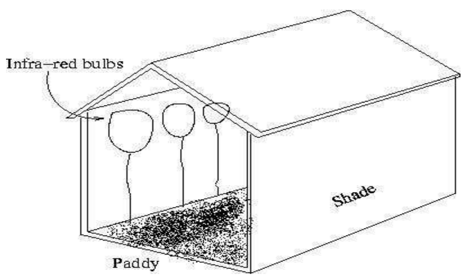
After specifying the problem in technical terms, the spectrum of drying techniques was scanned in terms of capacity/batch, drying time, area requirement, uniformity of drying, mechanical and constructional sophistication, ease of operation, possibilities of self-help in construction at operation, suitability to purpose (consumption, market or storage), known users of each technique, pressure-drop and heat-mass transfer characteristics for paddy grains, Figure 1 shows the alternative solutions.

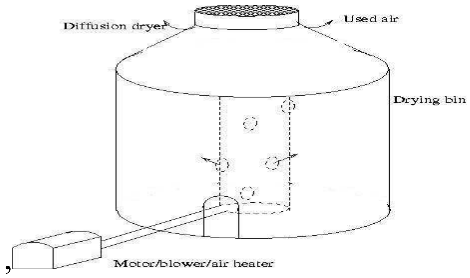
Figure 1a shows the solution developed by the farmer's themselves. Freshly threshed wet paddy was tied in a cloth and hung on top of the Chulas. Unfortunately, this did not result in even drying and, in fact, the paddy at the bottom got *cooked.* Therefore, the present author along with workers from the NGO assembled a *direct-contact dryer* (Figure 1b) from corrugated GI sheets that



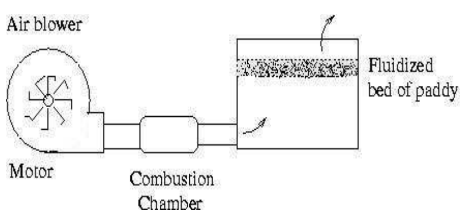


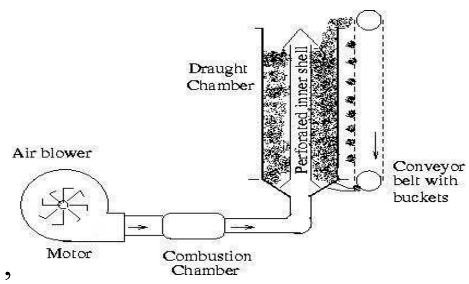
(a) Solution by farmers , (b) Solution by the NGO





(c) Solution by Agr Res station , (d) Diffusion Dryer





(e)Solution in a Text Book , (f) Moving bed Dryer - IIT Kgp

Figure 1: Alternative Drying Solutions for Paddy

were readily available with the NGO. This required continuous stirring to pre- vent cooking and was found to be very cumbersome although during one night of continuous work, nearly 6 bags (about 500 kg) of paddy was saved from germination.

While such *impromptu* solutions must be invoked in an emergency, a more reliable design must be sought. Further field work then brought to notice a solution practiced at the Agr Res Station (AGR) near Khopoli in Raigad Dist. The AGR used Infra-Red bulbs for *radiation drying* in a large shed on the floor of which Paddy was continuously stirred (Figure 1c). Obviously, such a solution will require a very large area.

Figure 1d shows the *Diffusion Dryer* routinely used on American farms. In this dryer, grains are stored in a bin and hot air infiltrates the stagnant grain mass through central perforated pipe. Diffusion drying is a slow process and therefore not suitable for rapid drying required to prevent germination of paddy. Diffusion dryers are used mainly to prevent fungal attacks during long-term storage. Library search showed that *Fluidised Bed Dryer* (Figure 1e) [1] may be used. The drying rate of such dryers is of course high but the area required tends to be large for the same quantity of grains. Also, for maintaining fluidisation, large air flow rates are required. Finally, Figure 1f shows a *Moving Bed Dryer* developed at IIT Kharagpur. Hot, upward flow of air is bled through a central perforated pipe closed at the top. The air penetrates a downward flow of grains which are collected at the bottom and raised to the top outside the Dryer by means of a conveyor belt. The Dryer thus requires two driving motors; one for the air blower and the other to drive the conveyor. Although, counter-current moving bed dryers achieve a fast rate of drying with minimum area, there is considerable constructional and operational complexity and cost is high for application in a Tribal village.

2.4 Innovation Process

Since, none of the solutions listed above appeared to meet the requirement of rapid drying in a tribal village situation, it was decided to build on the field experience at Kondhaan. Experiments were initiated in the Mechanical Engg Dept of IIT Bombay.

Initially, a small quantity of grain were put in a conical hopper bin as shown in figure 2. A screen was inserted between the hopper-bottom and the connecting pipe to prevent grain from falling. The pipe was connected to an air blower. The intention was to stir the grain as in figure 1b while the air flow would bring about convection drying which will be faster than diffusion drying. To his surprise, as soon as the blower was started, the paddy grain flew into the face of the author! A colleague[3] then pointed out that it was nothing but a *spouted bed* that he had seen in USSR for combustion of coal.

This discovery of Spouting led the author to consult book on *Fluidization* by Leva [2]. This book, in a small half-page section on spouting, showed the principle of spouting as shown in figure 3 (left). Spouting is carried out in a cylindrical container with a hopper-bottom. When the air-blower is started, the upward moving air through the stagnant grain mass experiences increasing pressure drop while a spout is formed in the center of the vessel. The momentum of the air-jet penetrates further up the grain mass creating a *dilute phase* in the core while the surrounding annular *dense phase* descends due to gravity. The downward flow of grain is *entrained* in the dilute phase where it travels up the spout. Ultimately, if the air supply pressure is adequate to overcome the bed pressure-drop, the spout *ejects* out of the bed-top creating a fountain. The grains, after loosing their momentum, begin to *free-fall* back into the vessel. Thus, a grain circulation is established while the air is let off to the atmosphere.

[3] Late Prof A Jaganmohan, Mech Engg Dept

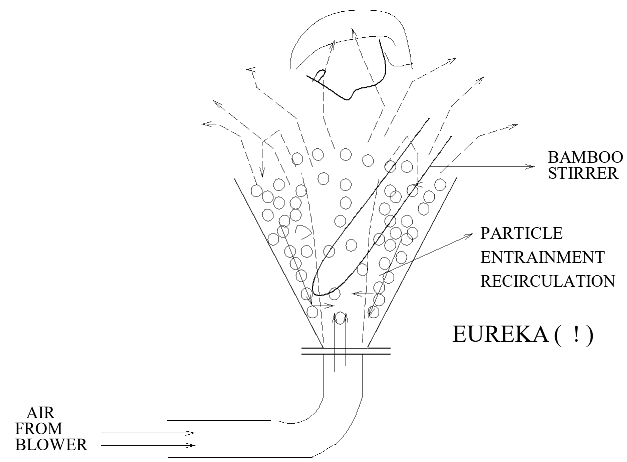


Figure 2: Eureka ! - Spouting Discovered

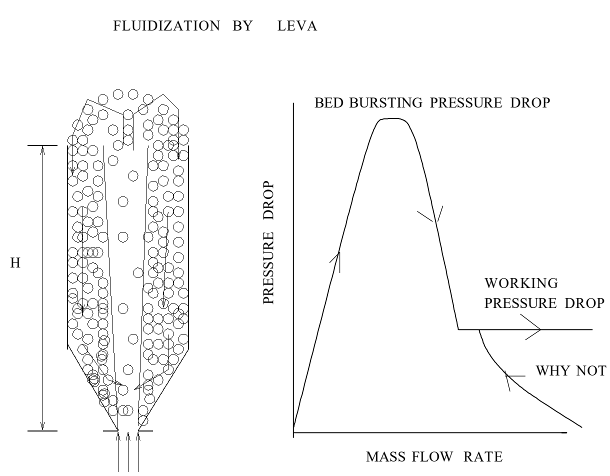


Figure 3: Principle of Spouting

The great advantage of this technique is that the hot-air used for drying itself brings about grain circulation and the need for a conveyor belt used in the moving bed dryer (see figure 1f) is obviated. Figure 3 (right) shows that till the spout penetrates the grain-bed, there is rise in pressure drop while the air mass flow rate increases. The pressure drop peaks and the value of this peak pressure drop is dictated by height H of the bed and the properties of the grain. However, after ejection through the bed, the pressure drop suddenly falls to a stable *working pressure drop* that hardly changes with increasing air flow rate. In practical dryers of this type, a separate *compressor* (a low mass flow - high pressure device) is needed to overcome the peak pressure drop whereas a blower (high mass flow - low pressure device) takes over during steady state operation [3]. Besides, the stability of spouting requires geometric precision to ensure *perfect verticality* of the vessel as well as *perfect axi-symmetry*. Failure to observe verticality and axi-symmetry results in collapse of spouting. This is of course not a desirable feature of Dryer used for village application. These shortcomings of the conventional spouting bed alerted the author to look closely at figure 3 (right) again. It was obvious from this figure to probe the question:

Instead of raising the pressure drop to a peak value and then dropping down to a low working pressure drop, why not start with a zero pressure drop and high mass flow rate and approach the working pressure drop with a lower mass flow rate ?

This question led to the a modification of the conventional spouted bed as shown in figure 4. In this dryer, an un-perforated draft tube (PVC) was held centrally by means of internal ring type locators. The bottom end of the tube rested on the screen between the air supply pipe and the conical hopper. The surrounding annular space is then filled with paddy to 1.2 m height (equal to 85 kg or 1 bag of rice). The air blower is started. Air experiences little pressure drop up its travel through the tube. The tube is then gradually *lifted* creating a space between the tube bottom and the hopper-bottom. The annular grain now entrain into the air-jet and travel up the tube. If not arrested by means of an *inverted conical cap*, the grains tended to fly-off. With the cap, the grains were directed downwards to fall onto the free surface of the annular grain bed. Thus, grain *circulation* was established. Further lift of the tube, increased the grin circulation rate further. However, after a certain lift, spouting ceased. This was because the supply pressure (about 18 cm of water) was not high enough to support spouting. An optimum lift height (h) was determined from working experience.

There were several advantages achieved in this new design. The Dryer was taken to village Damkhind (see figure 5(left)) in late August- early September 1974 and QYVs cultivated by the farmers were successfully dried in monsoon conditions.

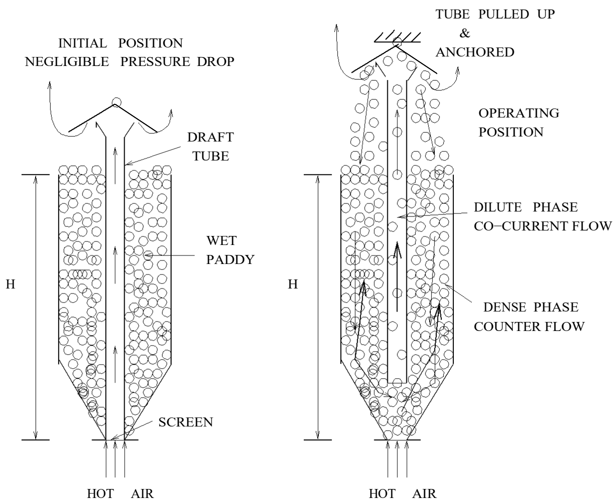


Figure 4: Spouted Bed dryer with a Draft Tube

Figure 5: Dryer in use at Village Damkhind, Taluka Manor

The cylindrical vessel was 40 cm dia, cone angle 40^0, supply pipe and draft tube had same diameter = 50 mm. The air was heated in *an internally baffled box* which was placed above a wood-fire. 1 HP blower (eff ▾ 30 %) was used. Figure 5 (middle) shows a bag of wet paddy being emptied in the dryer. Figure 5(right) shows villagers performing *the biting test* to determine whether the paddy was dried or not. This was necessary in the field conditions because there were no means to measure the moisture content of the dried paddy. Villagers experience came handy! Later, the approved dried paddy was collected in a Polythene bag and its moisture content determined in IIT Bombay. It was found to be 12.8 % ! (close to required 13 %). 85 kg of paddy was typically dried in 2 hrs 30 min under monsoon conditions (or, approximately, 0.7 Tons in 24 hrs).

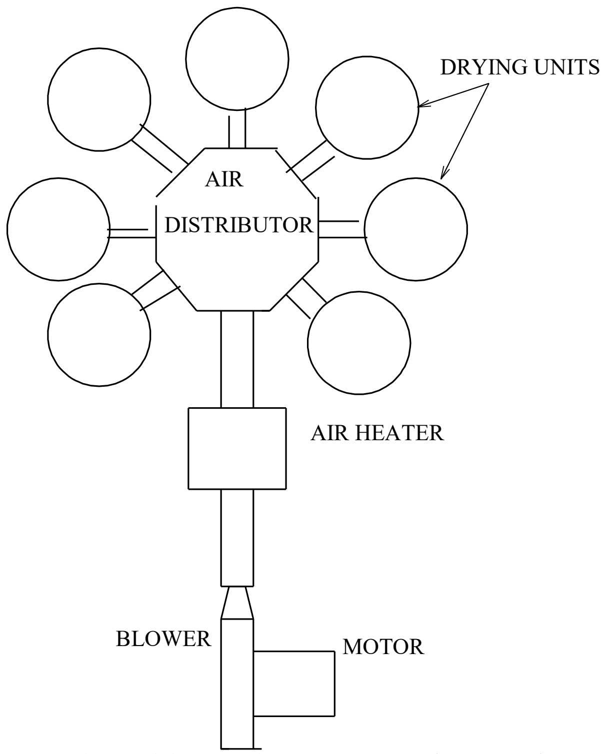


Figure 6: *Make it like a Flower*! - People's Scale-up Design

2.5 How to Scale-up ?

The villagers were satisfied with drying performance and soon queries began about scaling up issues because, in a single village, nearly 10-20 tons of paddy would have to be dried in subsequent years. Following a typical engineer's instinct, the author began to dream of a big, tall dryer[4]. However, the villager in figure 5(middle) quickly intervened, drew a picture on the ground by using a stick and said:

Do not build a big dryer. Instead make it like a *Flower* **!**

His suggestion is depicted in figure 6. The figure is self-explanatory and subsequent calculations showed that a 3.5 HP motor-blower with 6 drying bins operating in parallel will achieve drying rate of 5.4 tons / day using villager's design. The author was hugely impressed by the villager's power of expression. It showed that not only a *technical product* was transferred to the village but, in fact, the *Technology* was also transferred. This distinction between *technique or product* and *Technology*[5] is of paramount importance in Appropriate Technology Development.

[4]Such tall spouted bed dryers are used in Canada for drying wheat and peas (see, for example, [4])

The villager's suggestion for a parallel-design stemmed from the fear that a *big dryer will lead to quarrels*! He, therefore, preferred a Dryer in which each individual brings his bag(s) of paddy, loads it himself and takes away the dried paddy - no mixing which will require weighing before and after drying with inevitable *cheating* and hence, quarrels. Besides, in a large-bin dryer, there is no guarantee that the villager will get back paddy grown on his farm. Such apprehensions are very real and it is incumbent on the engineer to respect them.

ACKNOWLEDGEMENT:

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