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Rice Research in South Asia through Ages[1]

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Abstract

Domestication of rice (Oryza sativa; vrihi – *Sanskrit;* arise – *Tamil*) *that occurred more than 8000 years ago led to a series of developments in rice culture over millennia, making it the most important food item for more than half of the world's population. Compared to the documented information on rice culture of China, information on rice culture in South Asia is scanty. We are able to find information on rice culture covering the last 5000 years in Vedas, Samhitas, Puranas, Buddhist and Jain literature, Kautilya's Arthasastra, Krishi-Parashara, Kashyapiyakrishisukti, Watt's "A dictionary of the economic products of India", and a few others. Archaeological research also throws considerable light on rice culture. Farmers and intellectuals of many succeeding generations to innovate, develop, and adopt practices and technologies carried out empirical research on rice. Aspects such as (i) selection of phenotypically similar seeds suitable for a given region and for specific purposes; (ii) selection of soils and preparing them for growing broadcast, line-sown, or transplanted crop; (iii) innovative nursery management; (iv) organic topdressing; (v) weed management; (vi) water management at different stages of crop growth and at maturity; and (vii) harvesting, threshing, and storage were worked out and fine-tuned to the local needs. Extending over millennia, several thousand varieties were developed through selection. These included varieties based on differences in the size, shape, color, cooking quality, fragrance, taste, etc. Empirical research also led to claims of medical properties of rice types that need investigation. Processing of the harvested grains into food was worked out. This paper briefly highlights the knowledge of rice culture gained, especially in the last three millennia in South Asia and lists a few research areas that need serious attention.*

The word "science" was included in English language in the 14th century AD, from the Latin word *scientia*, which means having knowledge. Webster's Collegiate dictionary defines "scientific method" as "Principles and procedures for the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses." Empirical science then is having knowledge through "experience or observation alone without due regard for system or theory". Present-day scientists would feel comfortable if we qualify that the rice research carried out by our ancestors in the ancient and medieval

periods was empirical. It would be fair to state that the basic rice cultivation practices in South Asia, which we follow today, were worked out before the word "science" was coined in the English language.

Rice is an ancient crop of South Asia and other parts of the world. Archaeological evidence pre-dates any literary evidence on rice culture. In comparison to China, archaeological as well as literary evidences available on the rice culture of South Asia are meager. However, it is possible to trace evolution of rice culture from the ancient past to the 21st century with the help of available sources of information. The contents of the paper are grouped on the basis of chronology.

Archaeological evidence

Mehra (2002) has reviewed archaeological findings of the Indus-Saraswati civilization. He pointed that wild rice was eaten in the advanced Mesolithic or pre-Neolithic (c. 8080 ± 115 BC) period at Chopani Mando. Prolific use of rice (cultivated – *Oryza sativa*; wild annual – *Oryza nivara*; and wild perennial – *Oryza rufipogon*) husk and chaff as pottery temper at Koldiwah (c. 6570 ± 210 BC) and Mahagara (c. 5440 ± 240 BC), and the discovery of the grains of cultivated rice at *Mahagara* establish the cultivation of *Oryza sativa*. Incidentally, all three locations, Chopani Mando, Koldiwah, and Mahagara are in the Ganga region of central Uttar Pradesh in India.

Rice cultivation apparently diffused in all directions from the Ganga valley. We could obtain more information on the diffusion of cultivated rice to other parts of India if archaeobotanical investigations are carried out in Bihar, Orissa, and southern India.

The Vedas (c. 3700–2000 BC)

Most scholars seem to agree that the oldest Veda, the Rigveda, does not contain any reference to rice, and that a subsequent Veda, the Yajurveda has reference to rice. f one reads Rigveda, one cannot miss noting the word *dhana*, which according to Sanskrit dictionaries means rice. Words such as *dhana* (IV.24.7), *dhanaa* (I.16.2), and *dhanya* (V.53.13) are found in Rigveda, and all these have been interpreted as the words for cereals in general. Susruta, a sage of the ancient era and whose work is described later, recognizes only rice as *dhanya* (also supported by Monier-Williams, 1899) and others as *kudhanya*, literally lesser or minor cereals. Wheat and barley are mentioned at the very end. Charaka who lived before Susruta, also gave much more details about rice than wheat. Sayanacharya (1400 AD) of Vijaynagar, in his commentary on Rigveda I.16.2 uses the word *tandula*, which, most scholars agree, means rice (Sontakke and Kashikar, 1983). Why scholars want to believe that Rigveda has no reference to rice is a riddle, which needs more discussion. It is true that Rigveda refers to *yava* (barley) far more frequently than any other cereal, but then scholars accept that the Harappans in the same region used very little rice.

Commentaries on Vedas were written in periods extending over centuries. These are found in the Brahamanas (ritual texts), Aranyakas (ritual and meditational texts for forest dwelling ascetics), and Upanishads (esoteric texts; gnostic treatises) (c. 2500–1000 BC). While Rigveda has several verses that reveal the existence of basic plow agriculture and animal husbandry, we cannot find any specific information on rice culture, or for that matter on any specific crop culture, in any of the above texts, except reference to cultivated rice (*vrihi*) and a wild rice (*nivara*). The *nivara* rice was especially recommended for ascetics (Dwivedi, 1959).

Ayurvedic treatises (Pre-400 BC)

Ayurveda, the science of human health, supplemented the fourth Veda, the Atharvaveda (2000 BC). Two treatises (*samhitas*), one by Charaka (c. 700 BC) (Vidyalankar, 1994) and the other by Susruta (c. 600–400 BC) (Krishnamurthy, 1991) are available today. Both these mention rice varieties in the context of their effects on human health.

Charaka writes that *Raktashali* (red), *Mahashali* (large and fragrant), *Kalama* (thick stem), *Shakunarhita* (curved), *Turnaka* (quick maturity), *Deerghashuka* (long awned), *Panduka* (yellowish), *Langula* (tall ?), *Sugandhika* (fragrant), *Lohawal* (red), *Shariva* (pointed ?), *Pramodaka* (fragrant), *Patanga* (resembling grasshopper/locust ?), and *Tapaniya* (golden or maturing in hot weather) are all excellent *shali* (rices maturing in winter) rices. They have the following effects: refrigerant, tasty, causing slight flatulence, somewhat sticky, nourishing, semen augmenting, and diuretic. *Raktashali* (red) was claimed to be the best. It quenched thirst and corrected humoral (three body humors: *vata*, *kafa*, and *pitta*) imbalance. The next best were *Mahashali* and *Kalama*; the rest were rated lower.

Shavak (barley-like), *Hayana* (golden), *Panshu* (dusty), *Vapya* (oblong), and *Naishadaka* (from Nishadha country, i.e., modern Kumaon hills) were also considered *shali* rices having similar but inferior properties to the above.

Shastika (60-day) rices were considered cool, tasty, and rectifiers of humoral imbalance. White rices of this group were the best. The next best was a dusky one.

Vrihi rices matured in four months [maturity in the *Sharad* (October–November) season]. These were either white or red (*Patala*) grained. *Vrihi* rices, though tasty, were claimed to increase hyperacidity as well as frequency of excretion.

Susruta, who pioneered plastic surgery, also wrote a treatise and mentioned several varieties of rice. Some names were common.

Shali varieties: *Lohitaka* (red husk), *Kardamaka* (growing in slimy soil), *Panduka* (yellowish), *Sugandhaka* (fragrant), *Shakunarhita* (curved), *Pushpandaka* (resembling ovary of flower), *Pundarika* (white), *Mahashali* (large and fragrant), *Shitabhiruka* (cold sensitive), *Rodhrapushpaka* (red), *Dirghashuka* (long awned), *Kanchanaka* (golden

husk), *Mahishamastaka* (resembling buffalo head), *Hayanaka* (golden), *Dushika* (rice resembling pencil), and *Mahadushika* (?).

Shastika varieties: *Shastika* (60-day), *Pramodaka* (fragrant), *Mahashastika* (large seed, 60-day ?), *Kedaraka* (from mountains), *Pitaka* (yellow grain), and seven others, which were probably not rice but some other short-duration crops.

Vrihi varieties: *Krishnavrihi* (black), *Jatumukha* (freckled), *Nandimukha* (shape like bullock face), *Lavakshaka* (curved grain ?), *Twaritaka* (early rice), *Kukkutandaka* (oval), *Paravataka* (small, oval), and *Patal* (red).

Wild varieties: *Nivara* and two others, which may not be rices.

All *shali* varieties were considered "strength-giving", s*hastika* varieties astringent in taste, and *vrihi* varieties were considered astringent and sweet.

Both Charaka and Susruta treated rice in detail, giving names of varieties and their effects on human physiology. No other cereal, including wheat, received so much attention in their treatises.

Some interesting observations by Susruta were, "Rice of once transplanted paddy plants and of those transplanted several times in succession are easily digested and comparatively more nutrition efficient." Yet another observation, "Rice from the stubbles of a previous harvest is parching. It suppresses evacuation of stools." Also, "The use of new rice tends to increase secretions of internal organs, while that of one year maturity is light. Two-year old rice is excellent in quality" (Kumar, 1988).

The preceding paragraphs prove that considerable empirical research had been done prior to Buddhist era on the rice cultivation, varietal development, and medical properties. Varieties were classified on the basis of geographical indications, duration for maturity, method of cultivation (direct growing and transplanted), color, size, and shape of rice with and without husk, possession of fragrance, etc. Clearly the practice of transplanting seedlings had been worked out before 400 BC.

Buddhist literature

The Jatakas (stories of the former births of Lord Buddha – c. 300 BC) contain references to (i) hill rice, (ii) tanks for irrigation, (iii) red husked rice (*Rattasalivam*), (iv) word, *tandula*, meaning dehusked rice, (v) scented rices, (vi) liquor from rice, and (vii) medical properties (Kumar, 1988).

Resource management (Arthasastra) by Kautilya (321–296 BC)

This treatise has 15 Books and in Book 2, Chapter 14, duties of *Sitadhyaksha*, i.e., the Superintendent of Agriculture (for crown lands) are given. Some of the paragraphs reproduced below give substantial information on rice culture (Nene, 2002).

1. “When one-third of the requisite quantity of the rain falls both during the commencement and closing months of the rainy season [*Sravana* (July/August) and *Kartika* (October/November) and two-third in the middle [*Bhadrapada* (August/September) and *Ashwin* (September/October)], then the rainfall is considered very even.”

   The optimum distribution of rainfall during a season for crop growth and high yield has been indicated. Clearly this must have been based on keen observations over many years; perhaps these observations might have been made much before Kautilya’s time. The Vedic Indians had already observed the duration of monsoon rainfall to be approx. 4 months, which holds true even today (Nene and Sadhale, 1997). Thus the tradition of making keen observations in relation to crop cultivation must have continued since the beginning of the Vedic period to Kautilya’s time. Today, we accept the seasonal distribution of Northwest monsoon, along the lines suggested by Kautilya, to be optimal for the rainy season crops.

2. “Three are the clouds that continuously rain for seven days; eighty are they that pour minute drops; and sixty are they that appear with the sunshine – this is considered good, well distributed rainfall. Where rains interspersed with wind and sunshine is such that cow dung cakes can be dried three times (during the rainy season), reaping of a good harvest is certain.”

   Contents of this paragraph should be read along with the contents of paragraph 1. In paragraph 1, Kautilya mentions that two-third quantity of rain should be in the mid-season and one-sixth in the beginning and one-sixth toward the end of the crop season (6 months). In paragraph 2, Kautilya indicates distribution of rainfall in which long heavy spells of rain, drizzle, wind, and sunshine (i.e., break in rain) were considered to give good harvests. Surely, critical and detailed observations over a large number of rainy seasons must have been made to arrive at such a recommendation.

   Virmani (2001) analyzed the contents of paragraphs 1 and 2, using 30-year (1931–1960) rainfall data of Patna (Patliputra of Kautilya’s period was located on the outskirts of present-day city of Patna in the Indian state of Bihar) and concluded that Kautilya’s statements on the distribution and adequacy of rain match well with the needs of rainfed crops. These have stood the test of time.

3. “*Sali* (rice type), *vrihi* (rice type), *kodrava* (*Paspalum scrobiculatum*), *tila* (sesame), *priyangu* (*Setaria italica*), *udaraka* (a kind of millet ?) and *varaka* (*Vigna aconitifolia*) are to be sown at the commencement of the rainy season.”

   Two kinds of rice, *sali* (transplanted ?) and *vrihi* (broadcast) were grown as the major cereal.

4. “The seeds of grains are to be exposed to mist and heat for seven nights . . .”

The practice of exposing seed to dew in the night and drying it under sun during the day is certainly very interesting. Before systemic fungicides became available to farmers in 1960s to control internally seedborne smut diseases in cereals, soaking seed in water to activate fungal mycelia and drying the seed under hot sun to kill these activated mycelia was a recommended practice for wheat seed in northern India to control the loose smut disease. It is possible that the practice mentioned by Kautilya could be leading to activation of fungi and bacteria present on the seed surface or just under the seed coat and then followed by their death on exposure to sun, and thus the seed was freed from potential pathogens. It would be worth conducting experiments to verify this hypothesis. Incidentally, Watt (1891) has recorded the practice of exposing seed to dew and drying it under the sun for 3 days in case of the seed for irrigated, summer crop of rice in Burdwan district of West Bengal.

5. "The sprouts of seeds (seedlings), when grown, are to be manured with fresh haul of minute fishes and irrigated with the milk of *snuhi* (*Euphorbia neriifolia*)."

The recommendation in the first part of paragraph 5 consists of "topdressing" with tiny weed fish. Minute fish species were either cultured or found naturally in pools in large numbers. These were released in large numbers in plots of young rice seedlings with standing water. Milky extract from the *snuhi* plants was poured in the fish-containing plots. We know today that species of *Euphorbia* have fish-killing property because of the presence of diterpenes (ingenol-esters). The intention therefore was to release the fish and kill those to make nitrogen, phosphorus, calcium, etc. from the decomposing fish available to the crop. Clearly an ingenious method of topdressing rice with manure! I was surprised to find a recent record of this practice being followed in the Ranchi district of Jharkhand. Fish are allowed to die as water in plots recedes, thus avoiding the use of *Euphorbia* (ICAR, 2003).

There is no specific reference to transplanting of rice, but since transplanting technique had been worked out by that time, one could assume that transplanted rice seedlings was followed wherever irrigation facility existed and the word *shali* was used for transplanted rice.

Krishi-Parashara (c. 400–100 BC)

An English translation of eight verses (Sadhale, 1999), given below, gives us a clear picture of the status of rice culture in South Asia.

V.159. Uniform seeds produce excellent results. Hence every effort should be made to procure uniform seeds.

V.160. Putting the seeds in a strong bag, one should weed out grass that shoots out (in the field). If grass is not weeded it spreads later, growing all over the farm.

V.169. It is excellent to sow seeds in the hot season (April–May) for transplantation. Sowing in *Shravana* (July/August) is said to be bad and in *Bhadrapada* (August/September) the worst.

V.183. Seeds are of two types: those to be sown and those to be transplanted.

V.184. Paddy seedlings outgrown into plants in the nursery should not be pulled out for transplantation, as they are unproductive.

V.186. It is in *Aashadha* (June/July) or *Shravana* (July/August) that wise farmers construct small bunds for retaining water. If this is not done there is no difference between the seeds and the crops.

V.195. Here is a mantra for controlling grain diseases:

"Salutations to the feet of the revered preceptor. Let success prevail! The ever-victorious feet of Rama (i.e., Rama himself), the Lord of Lords, the Emperor of Emperors, the revered One, commands from his heavenly abode situated on the peak of the Himalayas, the slopes of which are white like the conch, the jasmine (*Jasminum* sp.) flower, the Moon – Hanuman, the son of Wind moving fast like wind, destroyer of invaders, standing on the seashore amidst hundreds and thousands of monkeys with his tail raised and claws harsh and strong, 'Let there be well being.' Winds are blowing with great force in a section of a farm belonging to so and so hailing from such and such family/group. If the destroyers of crops such as *gandhi, shankhi, pandarmundi, dhuli, shringari, kumari, madaka,* etc. and goats, wild boars, pigs, deer, buffaloes, parrots, sparrows, winged insects, etc. do not leave that farm by your order, you shall strike them hard with your tail strong like thunderbolt."

"*Om am ghan ghin ghun gha!*"

These words should be written with the red lac-dye and should be tied to the crop. Thus there will be no danger from diseases, insects, wild animals, etc.

V.196. What hope of harvest can that foolish farmer have who has not made arrangements for preserving water for the crop during *Ashwin* (September/October) and *Kartika* (October/November)?

These verses reveal: (i) the process of selecting phenotypically similar seed had started, which in turn must have led to establishing better varieties of rice; (ii) emphasis on seed purity; (iii) classification of varieties into two groups, viz., direct sowing types and transplanted types; (iv) ensuring availability of water during the growing season; and (v) identification of pests.

A treatise on agriculture by Kashyapa (Kashyapiyakrishisukti c. 800 AD)

The text was obviously written for areas with assured high rainfall, where rice culture could be practiced with relative ease. This is the only Sanskrit text (kashyapiyakrishisukti) that gives us a clear idea about the state to which rice cultivation had evolved until more than 1000 years ago (Ayachit, 2002). In fact, it is the text that every rice scientist should read.

Planting time and selection of land for different crops (Chapter I. Verses 323–340)

Before doing anything else Kashyapa suggested to "develop yielding capacity of the fields" regardless of the crops chosen for cultivation (323). This is a very significant statement with clear implication on sustainability of the land. The planting should be commenced with the beginning of the rainy season in several "countries" listed (324–326). These were: Kasmira (Kashmir), Vanga (West Bengal and Bangladesh), Nepala (Nepal), Panchala (parts of western Uttar Pradesh – Bareilly, Budaun, Farrukhabad), Kosala (Oudh in central Uttar Pradesh), Kuru (Delhi and upper Gangetic region), Virata (a region in northern Bengal), Avanti (Malwa and Nimar regions of western Madhya Pradesh), Malwa (south western Madhya Pradesh), Saka (east of Iran ?), Sindhu (Sind in Pakistan), Sauvira (lower Indus Valley, east of the river), Surasena (present Agra division of Uttar Pradesh), Chedi (eastern part of modern Bundelkhand of Uttar Pradesh and Madhya Pradesh), Konkana (present Konkan on western coast of India), and Andhra (deltas of Godavari and Krishna rivers). No "country" south of the Krishna river has been specifically mentioned. In most of these "countries", the Southwest monsoon constitutes the rainy season. Kashyapa has mentioned taking a crop even in summer if water was available (326–328).

Kashyapa divided arable lands into two major categories; viz., lands suitable for growing rice (paddy) and lands suitable for other crops. Basically, low-lying lands that could be irrigated easily were meant for rice, whereas the uplands where water supply was limited were meant for other crops such as pulses. Rice fields were to be of higher fertility than fields under other crops (330–332) and were to be bunded to retain water but the bunds had to have openings to allow excess water to flow elsewhere. Rice soils were to be clayey and rice fields close to each other and to the threshing ground (332–334). Rice fields were always to have standing water (338).

Varieties of rice (Chapter I. Verses 362–373)

In the verse 362, Kashyapa considered three main varieties of rice; viz., *shali, kalama,* and *shastika*. In the next two verses (363–364), he stated: "*Kalama* is slightly thick, white, and with a surplus sap. *Shastika* is made tasteless by the creator. *Shali* rice is said

to have twenty-six varieties depending on the quality of land in different regions." In verse 365 it is stated that "sowing of these various seeds has to be undertaken in seasons suitable for a particular variety." These verses can be interpreted thus; there are three groups of rice varieties, *shali, kalama,* and *shastika*. *Shali* rice varieties apparently were favored more than the other two. *Kalama* was small-grained, and *shastika* (60-day variety) was clearly an inferior type. Kashyapa mentioned that different varieties of rice were to be grown on different kinds of soil and under different weather conditions.

All this makes sense. However, in verse 364, Kashyapa mentioned that *shali* rice has 26 varieties. But when one reads the names of these 26 varieties, one gets confused after noting names of *kalama, vrihi, sambaka,* all mixed up with *shali* (362–373).

Vrihi is considered to be the oldest name for rice. We find *Shuklavrihi* (white rice) mentioned in Krishna Yajurveda (c. 3000 BC). In the same Veda, *Krishnanamvrihini* (black rice), *Asunamvrihinam* (fast growing, 60-day rice), *Mahavrihinam* (large-seeded rice), and *Naivaram* (wild rice) have been mentioned. In the subsequently compiled Atharvaveda, *Naivaram* became *Nivara* and in addition to black rice, red rice and the 60-day rice were mentioned. A new name for rice appeared in the Atharvaveda; i.e., *tandula* (for dehusked rice). The word *vrihi* for rice was used in Upanishads. *Shali* was used for those rices that were planted at the beginning of the rainy season and harvested in winter; these were probably the 6-month varieties (Kumar, 1988). *Vrihi, shali, nivara, shastika* as well as a new word *kalama* appeared in Susruta Samhita (400 BC) and Amarkosha of Amarsimha (c. 200–500 AD) (Jha, 1999). Buddhist literature commonly used the word *shali* for rice. In Apte's Sanskrit-English dictionary, the definition of *kalama* is similar to that of *shali*; i.e., sown in May–June and harvested in December–January. However, another meaning of the word *kalama* is pen. In the same dictionary, the word *sambaku* means "to plow twice". Susruta mentions *vrihi* as rice and considers the word to be arising from the word *vrihi* that means to "throw" or "hurl" (Krishnamurthy, 1991).

Taking the above discussion into consideration, I would like to suggest that the oldest word, *vrihi* for rice (paddy) meant rice that was broadcast in the field for sowing. As the transplanting was introduced and the duration of the crop increased, the word *shali* was coined, and it became the most commonly used word. *Kalama* also means "a reed for writing". I am tempted to suggest that the name *kalama* was used for *shali* varieties, which had strong, thick tillers, which in old times could be used as pens for writing. The word *sambaka* apparently has originated from *sambaku,* which means, as pointed out before, "to plow twice". This may be a reference to an old practice of double transplanting of long-duration varieties to reduce the duration. Today rices with names as *samba* (Tamil), *sambavu* (Telugu), and *sambanellu* (Kannada) usually refer to fine, superior varieties. The word *samba* is also used for a rice season (15 July to 14 January) in Tamil Nadu (Arumugasamy *et al*., 2001).

Although Kashyapa mentions 26 varieties of *shali* and *vrihi* rices (364, 373), the names given in verses 366–372 reveal 4 varieties of *shali* group, 5 of *kalama* group, 4 of *sambaka* group, 11 of *vrihi* group, and 2 of *nivara* group.

It is possible that as rice cultivation technology improved further after Kashyapa's time, agronomic practices of one group of rices might have been applied to another. Thus *vrihi* types, which were originally meant for broadcast, might have been transplanted in later times.

Attempts made by Kashyapa and his predecessors to classify rice types using planting method, duration, color of paddy husk, taste, shape and size of grain, extent of swelling after cooking, and medicinal properties deserve full appreciation and recognition.

Golden rice (Chapter I. Verse 367, 372)

Currently there is a talk about the genetically modified "golden rice", which is claimed to be a potential solution to eliminate vitamin A deficiency among the poor people of South Asia. While the issue is being debated, I am wondering if *Peetvarnavrihi* (yellow rice) (372), which Kashyapa claimed to improve digestion, or a *sambaka* variety called *Hema* (golden) (367) could have been sources of β-carotene. Also Sri Bhavamisra (mentioned elsewhere) claimed that red *shali* improved eyesight. Can we take another look at our existing rice germplasm and analyze "golden colored" genotypes for β-carotene content? I am aware of the fact that carotenoids in bran are often removed in the rice mills. However, those who support the genetically engineered golden rice should evaluate the pros and cons. Whether people eat "golden colored rice" or colored rice with bran, they will have to be educated to give up the habit of eating white rice. Also it is worth mentioning that red kernel and red bran are found in certain varieties, e.g., *Mahadi* and *Rata* (Gupte and Raje, 1896).

Rice varieties – other aspects (Chapter I. Verses 374–410)

Some of the other highlights under the topic on collection and preservation of seed are: (i) it is the king's (government in today's context) responsibility to ensure seed supply (375); (ii) seed must be properly dried in sun (374); (iii) giving a gift of seed is a superior act (376); (iv) different varieties of rice mature at different times taking 3 to 8 months (377–379); (v) farmers should respect traditional knowledge of the region and use it (379–380); (vi) seeds of all kinds of other crops should be likewise collected, dried, and stored in pots, heaps of husk, or bowls (403–404); and (vii) seed must be protected from rabbits, rats, and moisture (405).

One verse (407) beautifully explains the importance of seed. "Taking care of good seeds religiously is conducive to the benefit of farmers [as has been] said by great sages."

Cultivation practices (Chapter I. Verses 428–525)

Practices described are similar to the practices followed today. Some of the highlights of this sub-section are: (i) rice crop grown in the "country" of Kosala (Oudh in central Uttar Pradesh) was considered to be the best (428); (ii) among different rices, *kalama* rices were to be planted first (probably these were of long duration) (429); (iii) wherever a

reservoir was shared, all the concerned farmers were to carry out operations in groups, using 10 pairs of bullocks (440–443), a good prescription for cooperation; (iv) arrangements to drain off excess water were to be made (437); (v) seedlings grown in nurseries were to be taken out, fastened in bundles, and transplanted in manured, puddled soil in lines by workers (433–436); (vi) gaps were to be filled in to ensure good plant stands (439–440); (vii) seedlings normally established in 17 days (445–446) and growth was evident in about a month (448–449); (viii) weeding was to be carried out thoroughly, especially grasses like *Erianthus munja* (*munja*) (450–456); (ix) water was to stand in fields all the time till the grain-filling stage was over (468–472) and then drained afterwards (478–479); (x) protection from parakeets at grain-filling stage (467) as well as from rats, insect pests, and other animals (475, 481); (xi) harvesting to be done with nippers and then drying and threshing using animals, and followed by winnowing (483–495); (xii) storage of grain in containers, masonry or grass structures, glass vessels, or underground space to protect from moisture, storage insects, and thieves (497–501); (xiii) leftover crop residue to be stored for use as dry fodder for animals (503–508); and (xiv) raising a second crop of rice in the same field if water was available (514–525) following the procedures highlighted above. Special mention to additional application of manures including green manure has been made (518) for the second rice crop.

Indian materia medica (Bhavaprakasa Nighantu) of Sri Bhavamisra (16th century AD)

This text is considered as one of the last in the series of materia medica belonging to ancient Indian heritage (Chunekar and Pandey,1986). Sri Bhavamisra essentially uses *vrihi* for 4-month and *shali* for 6-month rices. Most of the names are the same as we find in the texts of Charaka and Susruta referred earlier. However, Sri Bhavamisra also states that the number of rice varieties was too large and thus could not be included in the chapter of his treatise.

Compared to Charaka and Susruta, we find more information on rice varieties in the context of human health. The information is summarized below:

Rice maturing in October: Oily, constipating, tasty, voice-improving, virility enhancer, blood enhancer, slightly flatulent and cough producing, refrigerant, acidity reducer, diuretic.

Rice produced in* rabbed *(parched) soil Digestible, laxative, diuretic, cough reducer.

Rice from plowed land: Less flatulence and acidity, virility enhancer, constipating, memory and physical strength enhancer.

Volunteer rice: tasty, reduces acidity and cough, appetite enhancer, flatulent, acrid taste.

Transplanted rice: easily digested, semen enhancer.

Ratooned rice: acrid, constipating, physical strength enhancer.

***Raktashali* (red rice):** best for health, good for skin, improves eyesight, diuretic, voice-improving, semen enhancer.

We should note that rices produced on *rabbed* soil were noted separately for their properties. Plowed paddy might mean *beushened* paddy. As pointed out earlier one of the properties of *Raktashali* (red rice) is to improve eyesight. Rice ratooning was common. Practice of ratooning rice was recorded by Watt (1891) and continues even today in Faizabad (Uttar Pradesh) region (ICAR, 2002). Some of the rices have been claimed to be man's fecundity. It should be noted that the people living in the so-called developing world are predominantly rice eaters. Rice is known to contain selenium, which is implicated in man's sperm-forming process.

Ain-i-Akbari (1590 AD)

By the 16th century, the Mughal rule was well established in northern India. We find an excellent document in Ain-i-Akbari written by Abul Fazl Allami around 1590 AD (Blochman, 1927; Jarret, 1949). The following paragraph gives an idea of how rice cultivars were obtained for the "imperial" kitchen during Akbar's period.

". . . at the beginning of every quarter, the *Diwan-i-buyutat* and the *Mir Bakawal* collect whatever they think will be necessary; e.g. *Sukhdas* rice from Bharaij (present-day Bahraich in Uttar Pradesh), *Dewzira* rice from Gwaliar (Gwalior in Madhya Pradesh), *Jinjin* rice from Rajori (Kashmir ?) and Nimlah . . ."

In a table in Ain-i-Akbari giving "prices of certain articles", we find references to cultivars of rice and their prices. The prices give us an idea about the superiority of certain cultivars (Table 1).

Table 1. Cultivars of rice mentioned in Ain-i-Akbari.

Cultivars	Price per maund (37 kg) of rice
Mushkin[1]	180 d[2,3]
Sada[4]	160 d[3]
Sukhdas[5]	100 d
Dunaparsad	90 d
Samjira[4]	90 d
Shakarchini[4]	90 d
Dewzira[6]	90 d
Jinjin	80 d
Dakah	50 d
Zirhi	40 d
Sathi	20 d

1. *Mushkin* cultivar is described as small white rice with fragrance and "pleasant to taste", perhaps with musky scent; musk is *mushk* in Persian.
2. d = dam (40 dams = 1 rupee).
3. Price was mentioned for paddy and not rice; conversion factor — 63% grain recovery — was used to arrive at the price given in the above table.
4. Cultivars *Sada*, *Samjira*, and *Shakarchini* are still grown in West Bengal, India.
5. *Sukhdas* was cultivated in Oudh (Kannauj to Gorakhpur in Uttar Pradesh, India). This is white-grained, delicate, and scented rice "scarcely to be matched". *Sukhdas* may have its origin in: *Sugandhaka* → *Sukhanda* →*Sukhda* → *Sukhdas*. During the 19th century good rice was considered synonymous with *Sugdasi* in the language of Sind (Pakistan).

6. *Dewzira* could be *Dahijira* of West Bengal or ***Devjira.***

Source: Nene (1998).

European traveler's account

One of the earliest European travelers who mentioned rice of the Bombay (Mumbai) area (Maharashtra, India) was, perhaps, Jean Baptiste Tavernier, who described the rice field seen by him on a march south from Surat (Gujarat, India) in 1654 (Watt, 1891). He makes special mention of the musk-scented rices of Surat. His remarks are quoted: "All the rice which grows in this country possesses a particular quality, causing it to be much esteemed. Its grain is half as small again as that of common rice, and when it is cooked, snow is not whiter than it is, besides which, it smells like musk, and all the nobles of India eat no other. When you wish to make an acceptable present to anyone in Persia you take him a sack of this rice."

It is interesting to note that this popular rice cultivar was small-grained, white, and with a musky scent. This description fits well with the description of the cultivar *Mushkin* described about 50 years earlier in Ain-i-Akbari. Surat was the port from where scented rices were exported. This rice must have been produced in the Thane region of Maharashtra. We find that the musk-scented rice cultivar called *Gandh-kasturi* was grown in Jessore (now in Bangladesh) towards the end of 19th century (Nene, 1998).

First record of basmati rice

In the famous poem in the Punjabi language, Heer Ranjha, the poet Waris Shah (1725–1798) referred to several rice cultivars such as *Basmati*, *Begumi*, *Satthi* (60-day rice), and several others (Padam, 1977; Ahuja *et al.*, 1997). It seems this might be the first documented record of the cultivar named *Basmati*. Waris Shah also mentioned *Sathi* of Akbar's period. To get names of rice cultivars in a poem, the cultivars should have been well known over an extended period. It is therefore safe to assume that *Basmati* and *Begumi* mentioned by Waris Shah in c. 1766 must have been in cultivation for at least 50 to 60 years earlier; i.e., around 1700 AD.

Information on 19th century rice as culled from Watt (1891)

Multitude of rice varieties

According to an estimate, more than ten thousand varieties must have existed in India. Ability of farmers to recognize varietal differences was marvelled as is evident from the following paragraph:

Mr. O B Clarke, an experienced and accurate botanist, remarking on the marvellous intuitive knowledge which the hereditary cultivators possess, in the forms of rice, while dealing with the *uri* (wild) says, "I do not know how, in the young state, the cultivator tells *uri* from the *aman*; I cannot."

In another paragraph related to Rangpur, now in Bangladesh, Watt (1891) states, "Almost every considerable village has a variety of its own, and every year sees the extinction of some of the old varieties and the appearance of some not known before."

There was an interesting report from the erstwhile Bengal (now West Bengal in India and Bangladesh) on certain rice varieties producing two or three grains in one spikelet. However, names of varieties were not given.

Manuring

It is recorded that farmers everywhere were aware of the importance of manuring rice crop, but quantities available were inadequate. Many European observers expressed surprise at moderate yields obtained consistently year after year over centuries. In a statement recorded, "Liebig (Justus von: 1803–1873) says that the reason why rice can be

grown in Bengal every year in the same fields without manure is because the rivers annually replenish the soil by a layer of rich silt." The Director of Land Records, around 1880, sums up his observation, "Compared with the advantages of a proper supply of water all other questions in its cultivation, namely the quality of seed used, the nature of the soil on which it is grown, the manures applied, and the mode of cultivation adopted, are things of very minor importance."

Though it was observed that manuring in fields was seldom done, there are several references to heavy manuring of the nurseries all over India. Organic wastes of all kinds constituted the manure.

Two reports (1884–1885) from the erstwhile Bombay Presidency need to be highlighted. One relates to what became known as the Salsette Experiment and the other to the *rabbed* nurseries.

The Salsette Experiment

This experiment is highly noteworthy and was carried out in 1884. Watt (1891) states, "A field specially selected for test-reaping was located at Salsette (near Mumbai). The seed sown per acre was 100 lb, the yield of grain from the same 4220 lb (4.8 t ha^{-1}) and of straw 14,253 lb, the total value of the produce having been put down at Rs 73-12-0 (Rs 73.75)." The remark made against that experiment states that the crop was obtained from "unirrigated, un-*rabbed* (field not parched) rice, grown every year on a land reclaimed from the sea-side and sweetened by heavy sweepings from the Bandra slaughter-house at 120 cartloads per acre."

The information is most striking, but not surprising in the context of recommendations made repeatedly in ancient vrikshayurveda to apply preparations (e.g., *kunapa*) made from animal flesh, marrow, etc. to obtain high yields of quality produce from fruit and flowering trees (Sadhale, 1996).

Rabbing (parching) nursery soil

The word *rab* in Marathi (possible origin: Sanskrit with *raksha* meaning ash) signifies burning. This is a practice of burning refuse to parch the soil reserved for raising nurseries before the advent of monsoon. The steps taken were: (i) elevated land for nursery, bunded to prevent surface washing; (ii) 2.5 to 5 cm thick layer of broken dung cakes (when plentifully available); (iii) a layer of leaves or chopped loppings (preferably of *Terminalia tomentasa* to provide intense heat); (iv) a layer of dry grass; and (v) a layer of finely-divided straw or husk to close openings between the stems of the coarse grass and prevent the earth (final layer) falling through. To prolong burning the fire was started on the lee side.

The system was commonly practiced in the Thane district of erstwhile Bombay Presidency. The ash provides nutrients and the weeds are reduced. Seedlings grow

vigorously. Farmers also find the nuisance of weeds, pests, and diseases greatly reduced in the transplanted crop from *rabbed* nurseries. This method was documented earlier in 1787 by a botanist Dr Hove (Watt, 1891).

In the last 30 years, we have gained good knowledge on the role of silica in rice plant growth and development. Dr N K Sawant and Dr S Y Daftardar (Maharashtra) proved that the rice husk ash (RHA) contains 91% silica. Seedlings of rice absorb high quantities of silica, which provides resistance to the blast and yellow stem borer infestation (Joshi, 2002).

Since the original Thane Report (was not available to me), I could not get to actual yield figures. However, a paragraph from Watt (1891) reads, "On the page 19 of the Thane Report it is stated that the yield of the experimental plots manured with dung gave 50.9% of the standard (the cow dung *rab* plot), while the unmanured and unrabbed plots showed 60.3% and 73.5%." This clearly establishes the superiority of the *rabbing* method. It is intriguing why most rice researchers in the last 50 years have outrightly dismissed the practice of *rabbing* on the grounds of "wasting" organic matter. It is interesting, however, to note that *rabbing* nursery soil was recently reported from Karimnagar (Andhra Pradesh), Dang (Gujarat), Shimla (Himachal Pradesh), and Sindhudurg (Maharashtra) (ICAR, 2003).

Watt (1891) made an interesting report of occasional topdressing of rice crop with earth impregnated with salt petre (potassium and sodium nitrates) in Varanasi area of Uttar Pradesh.

Weeding

Weeding was the major concern reported. Besides the manual weeding, there were some interesting regional practices. As pointed out earlier, *rabbing* was one method to control weeds in nurseries. Another method was adding *basuti* (*Adhatoda vasica* Nees; *vasa, vasaka*) leaves and twigs in flooded fields to kill weeds in the Punjab. A special implement, used generally in southern India and called *hodata* in Thane, was used to press ground firmly against the young rice seedlings. *Hodata* is a mud roller with a broad bar of wood hollowed on the lower side in the direction of its length. This reduces excessive growth of rice plants and keeps the weeds down.

A practice called *beushening* is followed for weed control (Watt, 1891; Singh, 2002). *Beushening* is an old practice followed in some parts of Uttar Pradesh, Jharkhand, Madhya Pradesh, Chhatisgarh, and Orissa, especially where the rainfall is uncertain. It combines direct dry seeding of rice in a well-prepared field, wet plowing of the young seedlings 20 to 30 days after emergence, laddering of the field, and seedling redistribution. The practice has different local names such as *baug* (Jharkhand), *bidauni* and *bidhaini* in Uttar Pradesh and Assam, and *biasi* in Madhya Pradesh. Apparently these words have their origin in the Sanskrit word, *vidhavanan*, which means shaking or agitating. The letter 'v' is often pronounced as 'b' and the word *bidhaini* comes very

close to the Sanskrit word *vidhavanan*. The anglicized version of the word is likely to be *beushening*. I have so far not come across specific mention to this practice in any of the available old texts except in Watt (1891) in which the practice in Jharkhand region followed for weed control is mentioned. But it must be a practice belonging to the period when Sanskrit was still the language used, thus taking us back to 1500 AD or earlier.

Plant protection

There is very little information available on protecting rice from diseases and pests. Some of the common pests and diseases with local names have been mentioned. Krishi-Parashara (400–100 BC) gives a mantra for protection of crops and we find the same practice mentioned in the texts written between 1000 and 1600 AD. Watt (1891) reported smoking of rice plants with *ajwain* (*Trachyspermum ammi*) or mustard oil by carrying along the tops on a lighted cow dung cake to control a moth (*tirha*) in the Bareilly region of Uttar Pradesh. Occasionally non-filling of grains was reported. Methods using herbals to control pests of fruit crops were known.

Yield of rice

It has not been possible to get any hard data on rice yields per unit area in any of the ancient texts. Fortunately the documentation by Watt (1891) covering almost the whole of 19th century gives us a clear idea about the paddy yields in South Asia. Various reports quoted by Watt (1891) from different regions of the Indian subcontinent reveal that the average yields ranged between 1 and 2 t ha^{-1}, the full range being from 0.5 to over 4.8 t ha^{-1}. As pointed out before, these yields were obtained with little manuring, but where manuring was done, the yields often were 3 t ha^{-1} or more. Results of the Salsette Experiment, described earlier, were a pointer towards the effect of manuring, especially at the nursery stage. Also rice from *rabbed* nurseries of Thane, well-managed rices in Karur (near Coimbatore), Tamil Nadu, possibly in Coorg (Karnataka), and in Bhandara area (near Nagpur), Maharashtra gave yields of more than 4 t ha^{-1}. It is pertinent to point out that in 2001–2002, the all-India average rice yield was approximately 2 t ha^{-1} (approximately 54% area under irrigation), with only Punjab and Tamil Nadu (99% and 93% area under irrigation, respectively) producing an average of more than 3 t ha^{-1}.

The main reason given for not manuring rice fields was their unavailability in sufficient quantities. Yet another reason, sometimes mentioned, was the presence of too many weeds in manured fields. Lodging of rice plants due to manuring was not reported.

Processing rice for food

Boiled rice was an important food item since the Vedic period. This would mean techniques to dehusk rice were worked out at that time itself. Being non-glutinous the *indica* types are most suited for eating with fingers. In the Vedic period, the cooked rice was called *odana*, but later called *bhata* or *batha*. Rice with milk was *kshira* (now *kheer*)

and with sesame seed and milk was *krsara* (later *khichari*). Boiled rice was eaten as such or with curd, ghee, sesame seeds, *mudga* (mung bean), *masha* (*urd*, black gram), or meat preparations. Rice was parched (*prthuka*) or puffed. According to Achaya (1998), parboiled rice is termed *pulungalarisi* in Tamil, and the earliest reference is found in *Siruppanarupudai* of the late Sangam period (later than 300 AD). Liquor called *sura* from barley or wild rice flour was prepared and consumed since the Vedic period. Even today rice is used for making *sura*. There is an interesting anecdote concerning *sura* in Watt (1891). It states, "In an appeal to the king of Portugal, John Huyghen Van Linschoten (1596) deplored the extent to which the Portuguese soldiers in India were acquiring spirits in place of wine of their own country, and feared that the army would be demoralized."

From that stage onwards, we know the usage of rice has been highly innovative.

Exchange of technologies

With contacts between the people of different regions within South Asia and between those of South Asia and other parts of the world, information on rice culture spread far and wide, and local innovations were made to successfully grow the crop. History tells us that the spread of technology should be need-based. I shall give two examples of technology transfer attempts, one unsuccessful and the other successful, and let the readers draw conclusions.

1. It seems, "India gave towards the close of last century (18th century) a mere handful of rice seed to America (Americans however believe that rice was introduced in 1685 possibly by slaves from Madagascar – author). Cultivation in the hands of European planters resulted in the New-World, not only becoming a rice-producing area, but in the finest and most profitable of all known rices being those developed by American enterprise." This Carolina rice was introduced on Government farms in India, but failed. The conclusion was "On the whole, it would seem that the Carolina rice seed was too widely and too indiscriminately distributed." Readers are referred to Watt (1891) to know why the Carolina rice failed; the reasons were many.

2. South Asia had been growing short-duration rices for millennia. Historically it is pertinent to mention that revolutionary changes in land utilization started with the introduction in Fukien province of China of an early-maturing and relatively drought-resistant rice cultivar (*indica* type) from the Kingdom of Champa in Central Indo-China (now Vietnam and Cambodia). The Kingdom of Champa which existed from the 2nd to 17th century AD was under strong cultural influence of India. It is most likely that short-duration cultivars were taken to Champa from India. In 1012 AD, when there was a drought in the lower Yangtze valley and Huai Ho regions of China, 30,000 bushels (appox. 818 t) seed of Champa cultivars were distributed. While the normal Chinese rice cultivars took 150 days, the Champa rices matured in 100 days after transplanting. The Chinese made further improvements and reduced the maturity

period to 50–60 days by the 18th century. Introduction of these short-duration rices made it possible for the Chinese to grow two or even three crops a year instead of one crop (Encyclopaedia Britannica, 1993).

Lessons from the rice heritage study

There are many lessons, which any student of agricultural heritage will be able to draw from the meager information available. I have tried to enumerate just a few that occurred to me at this stage of my study.

1. Respect traditional knowledge because it is based on countless observations and empirical research over millennia. Our future research should relate to traditional knowledge.
2. Research results should be made available to farmers through direct contact. In turn farmers should decide how they will utilize the knowledge. This should apply to new varieties as well.
3. South Asia needs research in both high input and low input rice culture. The emerging scenario in world agricultural markets must not force us to ignore low input rice culture.
4. A concurrent "crop management revolution" is needed, especially in view of non-substantial increases in per hectare yields even after the "green revolution."

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