BIOLOGICAL CONCEPTS AND AGRICULTURE IN ANCIENT INDIA

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There are some inherent difficulties which are of interpretative and correlative nature between the written and unwritten (archaeological) records, in reconstructing the history of sciences in ancient India. For a proper assessment of information from the written records, it is necessary to exercise considerable caution.

The observations and interpretations of the biological phenomena by the ancient Indians range from the humblest to the complex ones. Several of them are of the nature of a true scientific enquiry; but most of them are not beyond the mere impressions of innocent minds concerning the novelties of nature.

The domestication and economic exploitation of wild plants provided the ancient Indians with a deep insight into their morphological and differentiating characters as well as their economic utility leading eventually to philosophical speculations concerning the origin of life, divergence of life into plants and animals and their responses to environment. Surprisingly many of their superficial observations and even the philosophical speculations, such as the existence of life in the plant kingdom and the concepts of organic evolution and the like, find attestation by modern science. Howsoever primitive their methods might have been, their knowledge of plant and animal life around them and their practice relating to the selective use of plants and animals for food or fodder, oils and fibre as a means of transport in the field were really of a high degree. The same may be said about the domestication of cereals, legumes, oil-yielding and fibrous plants, proper times of sowing, preparation of land and use of fertilizers, practice of rotation of crops, methods of weeding, etc.

The influence of the alien culture on the development of scientific thought in ancient India has also been discussed.

INTRODUCTION

The historical development of science in ancient India cannot be appraised properly unless the two sources—the literary and the archaeological—are understood in their right perspective and are chronologically well established. The unknown span of time comprising the period prior to the writing of the literature enhances further the difficulties of exactly knowing the time of the origin of scientific observations. The order of the progressive development of written literature is believed to commence with the *Ṛksaṃhitā* followed gradually by the later *saṃhitās*, the *Brāhmaṇas*, the *upaniṣads*, the *sūtras*, the *Rāmāyaṇa*, the *Mahābhārata* and the *purāṇas*. Within this order some parts of the same literature were composed at different times as, for instance,

the tenth *maṇḍala* in *Ṛgveda* is believed to be of later origin.[1, 2] Consequently, an overlap in time and contents cannot be ruled out.

The postulated long and short chronologies create further difficulties. A consensus of opinion dates the *Ṛgveda* to about 1000 B.C. and the advent of the Aryans into India to about 1500 B.C. But the chronological scheme based on the *purāṇa*s and the Aihole inscription of Pulakesin II (seventh century A.D.) places the Bhārata War to about 3000 B.C. Pargiter, however, places the Bhārata War to *c.* 950 B.C. From other sources another date suggested is 1400 B.C.[3] The latter two dates approach almost the date assigned to *Ṛksaṃhitā* or the arrival of the Aryans.

The devastating flood recorded in *Śatapatha Brāhmaṇa* is dated to 3100 B.C. in analogy to a similar event recorded and dated in Mesopotamia but such a correlation lacks supporting evidence. The possibility, that this was perhaps merely a local feature than a universal one, cannot be ruled out.

Against these conservative estimates of dates of prehistoric events, there are now available several radiocarbon dates in the country. The C^{14} dates are tied with the prehistoric human cultures, the recognition of which is based on the use of stone and metals (copper, bronze, iron). There is hardly any mention of use of stone implements in the Vedic and subsequent literature. Amongst the metals, copper, bronze, gold and silver are frequently mentioned together with iron.[4, 5] The knowledge of iron together with copper and bronze archaeologically reveals that the *Ṛgveda* belonged to the Iron Age. From typological grounds and C^{14} dates, the beginning of Iron Age in India is dated to 800–1000 B.C.[6]

Prior to the Iron Age, India was inhabited by the non-Aryans who, as the anthropological evidence[7] suggests, were comprised by the Negrito people and the proto-Australoids. The latter had extended their sway into Australia. The backwashes of immigrations of the Melanesians and Polynesians into India later contributed new cultures such as pottery perhaps unknown to the Negritos. They are believed to have introduced agriculture into India and were responsible for the neolithic development of the late Palaeolithic or Mesolithic cultures in the country. The proto-Australoids characterized by agriculture were followed by the Mediterraneans, the Orientals, who believed in City culture and international trade. The pre-Iron Age archaeological discoveries have already provided evidence of Mediterranean influence in India. The Mediterraneans probably ushered in the Chalcolithic period in India, the proto-Australoids, the Neolithic period and the Negritos—the hunters and food gatherers—lived in the Mesolithic period. From this, it would appear that the Indian scientific thought developed during the Neolithic and Chalcolithic-Bronze Ages must be of substantial value and should hardly be overlooked. It will, however, be interesting to note as to how far their scientific knowledge had influenced the scientific thought of the Aryans.

Besides the chronological jumble in ancient Indian literature, there remains a great difficulty in interpreting the records. There is no dearth of attempts made to show the existence of scientific knowledge in ancient India. Nevertheless, we have not been successful in identifying the Munjawant Range in the Himalayas, the source of *Soma* plant and the *Soma* plant itself. The same applies to *yava*, interpreted as barley, which remains largely unsupported by archaeobotanical discoveries. A very large number of plants mentioned in old Sanskrit language have been recognized with the modern plants[8] but their reliability is far from established except in cases where the old Sanskrit names, undergone recognizable changes, are still retained in modern Indian language. In inferring biological knowledge of the ancient Indians it is, therefore, very imperative to be cautious, rather than be carried away by over-enthusiasm. Any attempt towards giving an ultra-modern aspect to the knowledge of the ancients would certainly do injustice to the cause of building up the history of ancient science in India.

Religion and philosophy coupled with spiritual outlook so much preoccupied the minds of the ancient Aryans that no separate treatise on Biology and Agriculture was written until about A.D. 400–600; or later as attested by Varāhamihira's *Bṛhat Saṃhitā, Agnipurāṇa* dealing with topics of *Vṛkṣāyurveda* and *Gulma—Vṛkṣāyurveda* in *Arthaśāstra* by Kauṭilya and science of agriculture, *Kṛṣiparāśara*, by Khanā. The medicinal use of plants, however, is predated to 800 B.C. (Dhanvantari, Bharadwāja, Ātreya) and more precisely to 600 B.C.–200 B.C., the dates assigned to Suśruta and Caraka. The sixth century B.C. may be taken as an important time in the history of sciences in India when scientific methodology, classification of plants and animals and agriculture were really given a scientific basis. This is the period of real scientific enquiry as contrasted from humble and innocent observations that preceded this period so far as the Aryans are concerned.

The alien influence during this period perhaps commenced from 600 B.C. with the Achaemid Persians who through their conquest of Syria, Phoenicia, Egypt and Greek establishments in Asia Minor must have influenced the Indian scientific thought. Later the advent of the Greeks into India dated to 327–326 B.C. and subsequent commercial exchanges and exchange of scholars as narrated by Aristoxenes (320–300 B.C.) continued until the third and fourth century A.D.[9] Similar exchanges during the rule of the Mauryas, the Śakas, the Kuṣāṇas and the Guptas until the sixth and seventh century A.D., and during the later part of this period the exchanges with China as attested by the Chinese pilgrims such as Fa-Hien (fifth century A.D.), Yuan Chawng (A.D. 629–649) and I Tsing (A.D. 675–685) left behind their impact on the Indian scientific thought. The visit of the students from Korea, Mongolia, Tokhara, Japan and Tibet to the Indian Universities and of the Indian Buddhist *bhikṣus* to other countries, during this period, shows widespread exchanges.

The exchange of Indian scientific thought also took place with the Arabian countries where the Indian Sanskrit literature was first translated into Persian and then Arabic. The earliest record of this dates to A.D. 753–774 during the rule of Khalif Mansur in Sindh, and thereafter during A.D. 786–808 during the time of Harun.

The period of decline followed the Muslim invasions directly and indirectly influencing the growth of science in this country. Perhaps the new environment drove the Indians from the materialistic to spiritual attitudes. The overtaking of scientific attitude by religious philosophy, the pattern of archaic secrecy, rigidity of caste system, drift from Sanskrit literature, the concept of pseudo-superiority, denial of exchange and incorporation of new ideas and discoveries, lack of royal patronage, destructive attitude of the invaders equally contributed towards an over-all decline of scientific thought. Nevertheless some scholars continued devotedly to enrich the Indian science by their contributions as, for instance, Mādhavakār and Vṛnda (A.D. 1000), Bhāva Miśra (A.D. 1550) and Ānandarāya Makhi (A.D. 1600). There is a contrasting renaissance in the European countries during this period of decadence in Indian science.

As stated above the information of the Biological concepts and Agriculture of ancient India is inferred and collected from the Archaeological and Literary sources. Equating the Aryans with the Iron Age, all the pre-Iron Age cultures are referred to pre-Aryans.

The biological concepts and agriculture of the pre-Aryans, as deduced from Archaeological discoveries, are described first. This is followed by the information concerning the Aryans and derived from the ancient literature dealt with in chronological order. The overlap in the informations for pre-Aryans and Aryans is not factual since the pre-Aryans (the pre-Iron Age ancient Indians) are believed to have preceded the Aryans.

In contrast to stray observations in *Early Literature*, copious and exhaustive information has been found in the *Later Literature* written a few centuries before the birth of Christ. From this it has been possible to segregate and assort observations of general nature as given under 'General Biology' from more specific ones as given under 'Classification of Plants', 'Classification of Animals' and 'Agriculture'. In this attempt some overlap has crept in owing to the fact that the same observation has been found equally valuable to the particular sections under which it has been given.

Biological Concepts and Agriculture Among the pre-Aryans

In the absence of any written records or whatever has been discovered being undecipherable, the knowledge of biological concepts and agriculture of the pre-Aryans can only be inferred from the archaeological discoveries. The acquaintance of the Mesolithic Indians, the Negritos or the Hamitic Negroids[10]

with the wild animals (cow, buffalo, horse, ox, sheep, goat, rat, fish and crocodile) which they had hunted and gathered for their subsistence is established from archaeology. It is much short of scientific knowledge. It is interesting, however, that most of the wild animals used as 'food' by the early Indians were subsequently domesticated for the purpose and continue till today the favourite animals, the flesh of many of which is eaten by mankind. It is, however, not easily understood as to why out of several other wild animals they had only preferred the above. Was any scientific knowledge involved in doing so, or was it just a matter of chance and availability ?

Agriculture, however, was unknown.

The Neolithic period is characterized by manufacture of handmade pottery and the cultivation of grain and domestication of animals. There is nothing on record how this was achieved except the remains of plants and animals that are cultivated and domesticated today. The recognition in the remains of plants of rice (Baidipur, Orissa); ragi, *Eleusine coracana* (Hallur, Mysore); Kulti, *Dolichos biflorus* (Tekkalkota in the Karnatak) and weeds (*Lithospermum arvense, Lotus corniculatus, Medicago denticulata, M. falcata, Trifolium* sp., *Ipomoea* sp.) usually associated with wheat and barley cultivation together with the crop-cutting implement from Burzahom, Kashmir Valley, reveals the Neolithic agriculture in India.[11, 12, 13, 14] That the Neolithic Indians were agriculturists and cattle breeders is further attested by huge ash mounds in Raichur and Bellary districts and other parts of the country.[15]

The biological and agricultural knowledge of some standard did exist in the country during the Neolithic period. Was this introduced into the country or was it originated here ? The radio-carbon assay has revealed diffusion of agriculture into other countries from the Middle East or South-West Asia where the earliest records have been dated to 8,500–9,000 years (Jericho in Mesopotamia). To reach farther countries it, however, took three to four millenniums. In India the Neolithic is dated to about 4,000 years. The diffusion of the agricultural trait can, however, not be denied but strangely enough the crops (wheat, barley) cultivated in Iran, Iraq and Anatolia were not diffused into India but for the indirect evidence of wheat cultivation in Kashmir. The domestication of rice and millet probably originated in India or was introduced here by the back waves of the proto-Australoids from Polynesia and Melanesia as held by Chatterji[16], who attributes the commencement of the Neolithic period in India to these people.

It is quite conceivable as expressed by Chatterji[17] that the domestication of tropical fruits and vegetables such as the banana, the coconut, the betel, the egg-plant, the pumpkin, the lime, the rose apple and the cotton and the silk cotton and of tropical animals such as the fowl, the peacock, the elephant and some breed of horse or pony had been already achieved here prior to the arrival

of Aryans from the temperate regions. The pre-Aryan Austric speakers or the Palaeo-Mediterraneans or Mediterraneans or the Orientals in India must be accredited with the scientific knowledge involved in their domestication and economic uses. In contrast to the proto-Australoids who were agriculturists, the Orientals, the probable architects of the Chalcolithic cultures in India, had material culture decidedly of higher degree than that of the nomadic Aryans. They knew the art of weaving, spinning and dyeing. Recent archaeobotanical researches have shown that they introduced wheat and barley into the rice-millet culture previously existing in India, knew the use of linseed also and besides cereals they consumed legumes such as lentil, *mung*, *urd*, *mattar*, etc.[18]

It is, however, not possible to assess properly the advance in the scientific knowledge of biology and agriculture as evidenced by their cultures based on highly advanced plant economy. Considerable experimentation must have preceded before the domestication of wild plants and animals must have been perfected. Their cultural contacts as revealed by archaeological discoveries suggest that they shared their scientific knowledge with the people in the Mediterranean region in the West and with the Melanesians and Polynesians in the East.

Biological Concepts and Agriculture Among the Aryans

The advent of the Aryans in the middle of second millennium before Christ introduced a very spiritualistic Homa-Cult into the country. Through their conflicts and contacts with the local people they soon imbibed the local traits of cultures which got so intricately mixed up with their own that linguistic palaeontology has been pressed into their recognition. In the literature composed later, considerable biological knowledge from the local sources must have entered it. It is, however, difficult to separate the local from the extra-local knowledge in written literature but, in attributing all that to the Aryans, we will be doing injustice to the authors of great cultures that preceded them.

The written records are decidedly of greater advantage since they readily help in proper assessment of the knowledge of the ancient Indians. Biological concepts and the agricultural knowledge have been very carefully sifted from amongst the philosophical speculations in ancient treatises by Majumdar,[19] Seal[20] and lately Ghosh,[21] Apte[22] and Jaggi[23]. The information that follows is largely drawn from these sources.

The Ṛksaṃhitā

The reference to a dragon, the lowing of cows, the tame and horned animals in the Indra hymn (*Ṛksaṃhitā* I.32); the continuity of life; the production of food through ploughing (X.117); the reference to four-footed

beasts (I.148); reference to birds, weaving of thread, rope (II.28); reference to trees, bull, lashing of horse by a whip, lions' roar, the shooting up of plants, the advantage of rainfall to the seeds, sowing of the seeds (II.83); an oblique reference to the domestication of cattle (VI.75); licking of a calf by the cow (III.33); reference to cruel wolves (X.15); hibernation and croaking of frogs at and subsequent to rainfall (the famous frog hymn: VII.103); the use of leeches for the sick, reference to seasoned timber, the feathers of birds, the grinding of corn and striving for the cattle to attain wealth (IX.112) constitute simple and humble observations in the *Ṛgveda*.

There seems to be personification of Nature, natural phenomena and constituents of nature as gods. The dwelling, the field, the furrow are also personified as gods. The cosmic circulation of water is beautifully described through the involvement of personifications.[24] Further, the mention of goats, antelopes, boars and buffaloes; the division of universe into earth, air and heaven, and *Soma* as lord of plants and of the wood are also mentioned.

The subject of evolution, the origin of universe, is discussed in *Ṛgveda* with a mixed feeling of divine creation and natural evolution (*Ṛv.* X, 190: origin of night, ocean and year in succession from heat; the rise of Hiraṇyagarbha from the great waters and creation of the world by him from the pre-existing matter, *Ṛv.* 121). A hymn to Viśvakarman (X.82) states that the waters contained the primordial germ, the floating world egg, from which arises Viśvakarman, the first-born of the universe, the creator and maker of the world. The *Puruṣa Sukta* (X.90) considers the body of *Puruṣa* as the original material from which the world is created through the agency of gods.

Power of hearing in plants is mentioned in *Ṛv.* X.97.23. Further, plants were known to cure diseases as the entire hymn, X.97, is addressed to them for their curative powers. Here as many as 107 applications of plants are referred to.

Grain *yava* was cultivated but not rice. There is mention of edible fruits and honey. Fermentation and distillation were practised in the preparation of some juice and *surā* (liquor) from grain. Besides the deer skin used as garments, clothes were woven and woollen clothing was in vogue. Some sort of oil was prepared and used.

Tilling comprised the cutting of furrows with the wooden ploughshare drawn by bulls. Seeds were sown in furrows, crop was cut with sickle, which was threshed, sifted and finally winnowed. Cultivation was helped by irrigation and wells. The Aryans were primarily pastoral people and the cattle comprising cows and bullocks were their most valued possession. Warm milk of the cow was considered cooked and was a wonder and the dark or red cow was believed to give shining milk (*Ṛv.* III.93, 13). Wood was used to make carts and chariots for agriculture and transport, for dug-outs, oars, vessels and for houses. Beams were made of bamboo. The oxhide was

tanned and used for bow strings, thongs, reins and the lash of the whip (*Ṛv.* VI.75, 11; I.121, 9; VI.47.26; 53, 9). Mats from grass and reeds were also made.

Later Saṃhitās

There is a reference to serpents, tiger and tiger-skin in *Atharvaveda.*[25] Plants conceive and multiply is mentioned in *Av.* XI.6.10. The *Bhūmi Śukta* (*Av.* XII.1) refers to snowy mountains; forest; brown, black, red and multiform earth. There is recognition of energy (if the word *agni* be so interpreted), in water, man, stones, plants and trees (*Av.* III.21). The uses of rice, beans, sesame and curd are additions in the later *saṃhitās* over our knowledge of vegetable foods of the *Ṛgvedic* Aryans. Liquor was prepared from rice, barley and grass.

A fact of considerable botanical and cultural importance during the *Brāhmaṇa* period is that the real Soma plant was difficult to obtain and its substitutes were being used (*Pañcaviṃśa Brāhmaṇa,* IX.5.3). To increase the yield of the plant as juice it was kept in water to swell—a distinct departure from *Ṛgvedic* practice of pounding the shoots of Soma plant between stones and straining the juice through sheeps' wool.[26]

Besides the woollen and cotton garments, clothes from silk were also manufactured. Boar-skin was used for sandals or shoes (*Śatapatha Brāhmaṇa*) and there was advancement in weaving such as the terms for 'warp' and 'woof' suggest. Saffron was used for dyeing the cloth (*Sāṅkhāyana Āraṇyaka,* XI.4). The quill of the porcupine was used for parting the hair and for annointing the eyes. Conch shell was used as amulet (*Av.*). There is mention of pearl in *Śadviṃśa Brāhmaṇa* (V.6).

Use of herbs in combination with spells and water (*Av.*) reveals elementary standard. Diseases were believed to have been caused by demons, but their symptoms are well described in *Atharva-veda.* Plant *Kuṣṭha* was known as a potent against *takman* (material fever) (*Av.*). Bites of snakes and of harmful insects are mentioned. Sand bags were used to stop bleeding. Dissection of animal was in vogue and sickness was observed to be prevalent at the junction of seasons (*Sāṅkhāyana Brāhmaṇa,* V.1).

Ploughs used in agriculture were large, driven by eight, twelve or twenty-four oxen (*Av. Śatapatha Br.*). 'The oxen were yoked and harnessed with traces and guided by the goad of the ploughmen'. Dung or cow-dung was used as manure. The plough had a lance-pointed handle. Ploughing was believed to have been introduced by Pṛthu Vainya (*Av.*). *Yava* sown in winter was harvested in summer, rice grown in rains ripened in autumn. Beans and sesame planted during summer rains ripened in winter. Wheat was also known. Pests were known; moles destroying the seed and others harming the shoots. Charms were used at the time of sowing and gathering

corn against these pests. Spells are described in *Atharvaveda* to avert drought and excessive rains.

Pasture lands were maintained with sheds for the cattle. Hunting, fishing and catching of birds were in vogue. Elephant was known. Pens for cattle and sheep were created in the houses made up of wood with ribs of bamboo cane with thatching. Bundles of grass finished with reed work were used to fill the walls.

The evolution of the universe was believed from Prajāpati apparently divine creation.

The Upaniṣads and the Sūtras

During the period of *Upaniṣads* and *Sūtras* (800 B.C. to 300 B.C.), rice and barley became the staple articles of diet. Wheat became unpopular. Beans (*māṣa*), kidney beans (*mudga*), mustard seed (*sarṣapa*), sesame and millets were known. Camel, ass, deer and dog are the animals mentioned. There is reference to hempen cloth also besides cotton, woollen, linen and silken. Garments were dyed with the juice of lodhra flowers, madder or indigo. Staff was made of the wood of *palāsa, bilva* or *nyagrodha.* Porcupines' quill was the hair comb. Sandalwood was frequently used as a perfumed pellet.

There is mention of appearance of herbs during the rainy season—a humble observation.

Diseases were still sought to be cured by propitiating the demons. Cow-dung was used for smearing the floors. Uncultivated corn (wild rice or grain) was also used. A ceremony of cattle breeding was also performed. Minor rites were performed when the cows were led to the pasture lands, when they ran about, when they returned and before and after their entry into the cow-pens.

Several forest products such as *vaṃśa, kuṭaja, ikṣu* (sugar-cane) were also known. Rush mats were made from *viriṇa* grass.

Life in plants was conceived as in human beings—all forms of life eat and drink and possess soul (*Aitareya Āraṇyaka* I.5, 1, 9; III.61.5), possess a sort of dormant and latent consciousness and are capable of pleasure and pain (*Manusaṃhitā* 1.49).

Evolution on earth is explained through five elements in the *Upaniṣads.* Ether springs from *Brāhmaṇ*; air from earth; fire from air; water from fire; earth from water; herbs from earth; food from herbs; seed from food and man from seed (*Varuṇa* in *Taittirīya Upaniṣad* II, 1). More or less similar views are expressed in other *Upaniṣads* (*Chāndogya* I, I, 2; *Bṛhadāraṇyaka* 4.6.1).

The Divine creation is mixed up with the thought that as from the seed springs up the fig-tree, so also from the ultimate minute reality precedes the

diverse world. It is noteworthy to mention that the *Chāndogya Upaniṣad* beautifully mixes up the theory of transmigration with evolution that the dead after sacrifice goes to the moon and abides there until his actions have been squared and returns to the earth first as a plant and then as a member of higher class of humans. To this may be added the statement from *Kauśitaki Upaniṣad* (I.2–3) that the dead return to various forms of earthly existence from man to worm. The concept of rebirth is nothing more than Divine creation, although the forms of life attained are dependent on the deeds.

Later Literature

Majumdar[27] and Jaggi[28] have sifted some valuable and more specific biological information largely from Kaṇāda, Suśruta (600 B.C.) and Caraka (200–300 B.C.), down to A.D. 500 and later. A critical appraisal of this information for the biological and agricultural knowledge is essential.

General Biology

There is much of elementary knowledge, such as concerning the early stages of germination of seeds and the factors governing it (proper season, good soil, water, vitality of the seeds and proper care); mention of plants seeds of which sprout in rainy season; ploughing the land sixteen times for successful cultivation of cotton, eight times for radish, four times for paddy and nil for betel (Khanā); the general morphology of the plants both external and internal: the external comprising various types of roots, shoots (creepers, trailers, twinners), epiphytes, saprophytes, a mention of mushroom; underground stems, morphology of leaf, number of leaflets, morphology of flower and inflorescence, the classification of fruits after the name of the plant and mention of seed coats, and the internal comprising bark, wood and pith of a stem, natural healing of plants from wounds.

Further the *scientific thought* comprises the distinction between fertile and sterile soil; absorption of food materials from the soil by the roots and the suction force involved (*Mahābhārata, Śānti Parva,* Ch. 184: 855); assimilation; belief that air and *agni* (energy) help in assimilation; prohibition of cutting of leaves of banana for they yield bread and clothes; flourishing of paddy in the sun and betel under shade; the development of paddy during day under the sun and at night by water; circulation of water up to the leaves not due to sun's rays (Kaṇāda 5.2–7) but by destiny; knowledge of the trees to be planted in a garden, house, temples, etc., and directions provided where the planting of a particular tree in the house may be auspicious; 'worshipping will result in luxuriant growth of trees and stars influencing the trees' (*Bṛhat Saṃhitā,* Ch. 514, Vol. II); planting of plants in various seasons: those with undeveloped branches in *Māgha* and *Phālgoona,* those with just developed

branches in *Agrahāyaṇa* and *Pouṣa*, those with well-developed branches in *Śrāvaṇa* and *Bhādra*, etc.; various methods of planting: from joints, buddings and cuttings (besmeared with cow-dung), grafting and transplanting (besmeared with oil, honey, milk and cow-dung) (*Bṛhat Saṃhitā*, Ch. 54, Vol. II, p. 743)[29]; distances to be maintained between individual trees: 20 cubits, 16 cubits, 12 cubits to avoid close planting and roots mingling together (*Bṛhat Saṃhitā*, loc. cit.); and prescription of time for watering the trees: morning and evening in summer, and during the day in winter, and when the earth is dried in rainy season (*Bṛhat Saṃhitā*, Ch. 54, 9; *Agnipurāṇa*, Ch. 281, *śloka* 7).

To promote flowering and fruiting, manures comprising sesame, excreta of goats and sheep, barley powder, beef soaked in water for seven nights in measured quantity were poured over the roots; a pretreatment of seeds comprised soaking them in an infusion of powdered paddy, bean, sesame, decomposing flesh and steaming with turmeric, or boiling in milk and clarified butter, then drying in sun. Fish water was also used. Such processes were repeated for several days, 20 or so, and then seeds sown in holes to which milk decoctions or fish water already added (*Bṛhat Saṃhitā, Agnipurāṇa*); sprinkling of oil over the roots of a dry barren tree helps them to flower and fruit (*Cikitsā-saṃgraha, śloka* 86: 293, 194).

Rotation of crops was practised—rice in summer and pulses in winter in the same field.

Etiolation and drying up of plants were believed to be due to cold climate, wind and sun or due to excessive heat or too much rain and amongst the remedies prescribed mud kneaded with ghee and *vidaṅga* were applied to the roots and later milk diluted with water was applied or *vidaṅga* mixed with rice, fish and flesh or decoctions of *kulattha, māśa, mudga, tila, yava* were given to the roots (Varāhamihira).[30]

Sleeping or passing under a tree during night was prohibited (*Manusaṃhitā*, IV.73). This does not suggest that the respiration in plants was known to the ancient Indians.

The phenomenon in plants of life, death, sleep, waking, disease, dragging, etc., and movements of plants such as expansion or contraction in response to touch were well known with examples such as sensitivity to touch in *Mimosa pudica* (*lajjāvatī*), movement of the sunflower to the sun, opening of the lotus with the sun rise, others in the evening and of lily with the rise of moon (Udayana, Gunaratna, Sankara Misra).[31]

Plants were known to live to a maximum of ten thousand years (Gunaratna).[32]

Plants were considered higher in scale than elemental lives (Maskarin Gosāla).[33] In *Śāntiparva, Mahābhārata* (Ch. 184), plants are believed to have sense of touch, sense of hearing, sense of sight, sense of taste, etc. More or less similar views are expressed by Udayana, Kaṇāda, and in *Bhāgavat Purāṇa*, etc.[34]

Seeds and flowers were believed to have been produced by the co-operation or union of different sexes (*Hārita Saṃhitā—Śirasthāna*, Ch. 1, p. 344). Plants of *vatsaka* with white flowers, large fruit and tender leaves are male and those with red and yellow flowers and small fruits are female according to Caraka (*Kalpasthāna*, Ch. 5, 3, p. 1031). Pollen was believed by Amara to be female menstruum (*Vanauṣadhi Varga*, 50). Distinction of male and female in reeds or palms is based on the compactness or greater amplitude of plants. The plant of *Ketakī* is always described as a couple—the male not producing fruits and having flowers with pollen dust and the female is described as yielding a golden harvest.[35]

Land was divided into the *jāṅgala* region (dry—wilderness—desert), *anūpa* region (abounding in swamps) and *sādhāraṇa* region by Caraka (*Kalpasthāna* I, *Madana Phala Kalpa* 6, 7 and 9 verses) and by Suśruta (*Sutrasthāna*, Ch. 35, verses 34–42) but in the nature of these regions both the authors differ, for instance, mountains are absent from the *anūpa* region as described by Caraka but according to Suśruta undulating chains of lofty hills traverse the area. A list of plants in each region is described by Varāhamihira and aquatics are listed by Amara (*Amarakoṣa*, *Pātālavarga*, 50–56). *Jāṅgala* region appears to be dry scrub-jungle, the *anūpa* region perhaps refers to a tropical wet but certainly not the alpine region from the identification of plants mentioned.[36]

Naming the place after the abundance of plant is much short of giving an idea of plant association. It merely indicates local dominance of a plant. Islands are similarly named after plant names such as Kuśadwīpa, Plakṣādwīpa, Śālmalidwīpa in *Purāṇas*.[37]

Nomenclature of plants is based on association with great men (e.g. *Aśoka*) or ritual (e.g. *yajñaḍumura*); medicinal property or domestic utility (e.g. *vānīra*, for making houses); characteristic morphological features: nature of the bark, number of leaves, colour of wood, shape and colour of flowers; geographical occurrence (e.g. *Śaubira*: indigenous of *Śaubir*; *Drāviḍaka*: indigenous of *Drāviḍ*); habitat (e.g. *jalaja*: growing in water; *maruvaka*, growing in desert); and other characteristics such as occurrence in a particular season (e.g. *māghya*) or haunted by ghosts (e.g. *bhūtabāsa*).

Plants were often known by more than one name based on morphological characteristics, medicinal or other properties such as *kṣīra kāṇḍaka* (stems with milk), *tulāphala* (woolly fruits) and *kharjjughna* (ringworm killer) are the names of the same plant interpreted as a species of *Calatropis*.

Classification of Plants

The classification of plants was based on botanical, medicinal and dietic principles. From the simple distinction into trees, shrubs and herbs and

creepers in the *Ṛgveda* (X, 97, 15) to an elaborate classification by Suśruta and Caraka between 600 B.C. and 200 B.C. is indeed an advancement.

The classification by Manu (*Manusaṃhitā* I, 46, 47, 48) of plants into the *oṣadhis* (annuals), *vanaspatis*, *vṛkṣas* and *gucchas* (shrubs), *gulmas*, *tṛṇas* (grasses), *pratanas* (creepers) and *vallīs* (twiners and climbers) is almost after the *Ṛgvedic* classification. Suśruta and Caraka, however, recognize only four groups with some differences, viz. *oṣadhis*, *virudhs*, *vānaspatyas* (*vṛkṣas*), *vanaspatis*, after the same old pattern. Later commentators, Dalvana for instance,[38] have, however, elaborated these systems and several subgroups are recognized with examples.

The *Vaiśeṣika* commentator Praśastapāda recognizes six major groups, viz. *tṛṇas* (grasses), *oṣadhis* (herbs), *vṛkṣas* (trees), *latās* (creepers), *avatanas*, (arboraceous shrubs) and *vanaspatis* (trees without flowers). Illustrations are provided by Śrīdhara in *Nyāya Kandali* and by Udayanachārya in *Kiraṇ-ārvalī*. *Bhāgavatpurāṇa* more or less follows the same pattern with some changes in names of groups (*Bhāgavatpurāṇa*, 3rd Skanda, 10th chapter, 19th verse). Amara's classification[39] is not much different from this pattern, though with some elaborations. In this system bamboo is considered a giant grass and palms are looked upon as tree grasses, and parasites are included in *latās*. In subsequent literature floating weeds (*plava*), mosses and lichens (*śaivāla*) are also referred to but not classified as the mushrooms.

The above systems are no more than the primitive systems lacking knowledge of floral morphology and jumbling of habit forms into the same and diverse groups. The inconspicuous and unshowy flowers were never recognized.

Variable forms or species within the same plant name were also recognized, such as *Kovidāra* interpreted as *Bauhinia* had plants with white flowers, others with yellow, red or with scented and unscented flowers. A primitive species concept or perhaps a method towards the recognition of differentiating characters between plants of the same name cannot go unnoticed. It may be likened to a primitive generic-specific concept.

Several groups of plants were recognized from the medicinal properties of plants into the purgatives and the astringents and each, further, subdivided by Caraka. Suśruta on the same principle recognized 37 sections of plants of medicinal use (*Sūtrasthāna*, Ch. XXXVIII). Similarly groups are recognized on dietic value by both Caraka and Suśruta. Far divorced from a primitive natural system these classifications served specialized purposes and reveal the enormous use of plants for medicinal and economic purposes.

Classification of Animals

Four principles, viz. (1) life on land, sea or air, (2) herbivorous or carnivorous nature, (3) use of flesh in diseases and (4) the mode of birth, were used

to classify animals by Suśruta and Caraka. The following four categories were recognized within the mode of birth, viz. (1) born with the placenta in the uterus, (2) born from eggs, (3) born out of moisture and (4) born out of vegetables (Caraka) or from the ground (Suśruta).

Amongst the asexually or sexually born animals, Praśastapāda includes those born with placenta and from eggs and the asexual ones included all those with or without bones, blood, easily crushable or not, etc.[40]

Around about A.D. 40 Umāsvāti in his *Tattvārthādhigama* employed the number of senses to classify animals.[41] He recognized four categories, viz. (1) those possessing senses of touch and of taste (five subgroups comprising worms, insects, molluscs and leeches); (2) those with senses of touch, taste and smell (seven subgroups comprising ants, red ants, bugs and fleas, weevils and lice, sprigtails, plant lice, termites); (3) those with well-developed and active senses of touch, taste, smell and sight (comprising five subgroups, viz. bees, crasps, hornets, flies, gnats, mosquitoes; scorpions and spiders; butterflies and moths; grasshoppers and moths); and (4) those with well-developed senses of touch, taste, smell, sight and hearing and these include fishes, reptiles, birds, quadrupeds and man. The latter category is further subdivided on the mode of reproduction into 3 subgroups, viz. (1) those reproduced from eggs (snakes, lizards, fishes and birds, etc.); (2) those born from placenta (man, cow, buffalo, goat, sheep, horse, ass, camel and the other mammals) and (3) all the other placental animals not included in the second subgroup, viz. porcupine, elephant, hedgehog, hare, rabbit, squirrel, bat, flying fox and vampire.

Umāsvāti's was an advanced attempt over his predecessors.

Agriculture

Agriculture was largely followed on the lines laid in the *Vedas* and *Saṃhitās*. By about the fourth century B.C. and earlier the regal authorities took more interest and a proper management and supervision by the State was introduced as given in *Manusaṃhitā* and *Arthaśāstra*. Typical advances made are the collection of rainfall data in various parts of the country—16 *droṇas* of rain in *jāṅgala* region, half in the *anūpanam* region, 13½ *droṇas* in *aśmakas*, 23 *droṇas* in *Avanti* and immense in *Aparāntam*, etc., and some means for the forecast were also discovered. Plants sown at the commencement of rainy season, during the middle of the season and thereafter are listed together with suitability of various kinds of lands such as river banks for *vallī-phala*; lands overflowing with water for pepper, grapes, sugar-cane; vicinity of wells for vegetables and roots; low ground for green crops; on spaces between the rows of crops, fragrant and medicinal plants, etc.[42]

More or less similar instruction for the cultivation of particular plants in specific seasons is also provided in *Kṛṣi-Parāśara* probably composed during

the fifth century A.D. It also gives an account of the construction of plough.[43] The same information more or less is contained in Khanā's maxims dated to about A.D. 500. This also gives means of predicting showers and the influence of timely and untimely rains on crops and economy, slection of soil for some crops and instructions on ploughing the land, proper seasons for sowing and on reaping. Some of the informations are given below.[44]

Rainfall in the months of *Māgha, Phālgoona* was considered good for prosperity. Drought in *Jaiṣṭha* and shower in *Āṣāḍa* are believed to be good for abundance of crop but heavy rains in *Āṣāḍa* on the ninth day of the full moon may cause drought. Sandy soil is good for *aus* paddy and clayey soil for jute. Ploughing as prescribed by Khanā be done for 16 times for radish, half the number for cotton and half of that for paddy and none for betel. Ploughing the field from the east will fulfil the aim. Prescription of precise times for sowing are given such as peas after the first 19 days of *Āswina* and within the first 19 days of *Kārtika*; mustards towards the end of autumn; paddy throughout the year and the first 12 days of *Bhādra*. Very interesting observations are recorded regarding ripening such as corn ripens within 20 days after the first appearance of the ear; 30 days after the first appearance of spike, 20 days after the first appearance of flower, etc.

Amarakośa in chapters on *Bhūmi Varga, Vanauṣadhivarga* and *Vaiśyavarga* and *Matsya Purāṇa* give further the classification of soils: fertile, barren, salt ground, waste land, etc., and their fitness for cultivation of crops, oil plants, etc., and an enumeration of implements such as harrow, goad, spade or hoe, sickle, a tie of yolk, body of plough, pin of yolk, pole of plough, the post of the threshing floor, pestle and mortars, winnowing basket, sieve, sack, etc.

Among other scientific observations made by the ancient Indians may be mentioned the prediction of the abundance and cheapness of crop of paddy or of all cereals from the abundant flowering of other plants (*Bṛhat Saṃhitā*, Ch. 29).[45] It is, however, unimaginable how the abundant flowering of *Śāla* (*Shorea robusta*) or *Aśoka* (*Saraca indica*) would indicate that. Apart from the cereals, similar observations also concern the legumes, oil plants, cotton and fruit trees (*Zizyphus jujuba*). Animals are not excluded from such observations as the prediction of cheapness of elephants and horses, molluscs (*śaṅkha*) and pearls. Gold, silver, human prosperity and even climate, fire, disease or epidemic and even the increase of prostitutes are not left out of consideration as predicted by abundant flowering and or overgrowth of plants. The graceful, entire, untorn leaves of trees, herbs and shrubs would suggest the coming of rains. Drought would be indicated by dry, ungraceful and torn leaves.

Another interesting observation is described in 115 *ślokas* of *Bṛhat Saṃhitā* (Ch. 53, Vol. II).[46] It concerns the prediction of underground water in a dreary region from the occurrence of a plant. A *vetasa* plant (*Calamus rotung*)

in a waterless tract is a sure indication of underground water about 7 ft. below the earth if ground is dug at a distance of 3 cubits to the west of the plant. Scores of such examples are quoted and in some cases the association of ant-hill with the plant has also been mentioned. Even if a frog is found below a tree it is a sure sign of the occurrence of water $4\frac{1}{2}$ *puruṣas* deep towards the north of the tree. Likewise prediction of water on the mountains is mentioned: all the grasses or trees, shrubs or herbs with milky juice found on the mountain would indicate water below 3 *puruṣas*. Stories in the *Jātakas* reveal how thirsty travellers were led by a clump of grass to water below it.

Conclusion

A glimpse into the ancient literature reveals that the ancient Indians were keen observers of nature and biological phenomena. Being agriculturists and philosophers their observations, always steeped in religious philosophy, were largely directed towards economic exploitation of plant and animal life. Judged from their face value, most of their observations seem to be of humble nature and these largely concern the plants and animals they were in close contact with in daily life. There is nothing of extraordinary scientific nature in these observations: they are common observations the like of which can be found among the humble folk in remote villages where the light of science has not penetrated yet. Together with charms, incantations and superstitions these humble observations speak of the primitive culture of the most ancient Indians. Howsoever the humble observations they had, the commencement of science can hardly be denied in them. Their philosophical speculations touched upon such complex problems as the origin and evolution of the universe and life on it but they are all steeped in divine creation mixed with observations of natural evolution. In their observations concerning plants and animals, analogy to man reigns supreme.

A real landmark seems to have been achieved a few centuries before the birth of Christ. A gradual shift from the spiritual to materialistic outlook becomes apparent; observations are more systematized and intensified. The humble observations are now replaced by a real scientific enquiry. No evidence of experimentation, however, becomes clear; the trial and error method or success and failure achieved are the chief sources for several advices contained in literature such as sowing of certain plants in particular seasons and avoiding close planting, etc.

It might, however, seem silly the kind of manures used by the ancient Indian, and the pretreatment provided to the seeds or perhaps stupid to sprinkle oil over the roots of a dry barren tree to help it to flower and fruit or the prediction of underground water from the occurrence of a particular plant. There are quite a few such observations which modern science may not account

for. It, however, remains to be established if these observations of the ancient Indians were backed by experimentation or not.

The classification of plants and animals is as primitive as of this period or later elsewhere and it is of considerable historical importance.

The problem of the origin of universe and evolution of life which occupied the minds of the *Ṛgvedic* Aryans continues to be solved by the later sages until, around seventh or eighth century A.D., Kapila propounds a very complex theory.

From humble observations to real scientific enquiry a progression in knowledge can be built up, provided the chronological jumble and the overlap in literature are straightened out. An impartial attitude to the ancient scientific thought reveals that the alien influences have affected it considerably. There is evidence of the imbibition by the Aryans of the indigenous scientific observations built up in India during the pre-Iron Age periods. During the period of landmark, a few centuries before the birth of Christ, the contacts made with the countries towards the West (Persia, Arabian countries, Greece, etc.) must have, through exchange of thoughts, influenced the scientific observations in the country. The anonymous author's 'Periplus of the Erythraean Sea' around A.D. 80, Ptolemy's geographical account of India in the second century A.D., and Pliny's account of Indian animals and plants in the first century A.D., and a few centuries later the records of India left by Sulaiman and Al Masudi, the Arab sailors, and the Chinese travellers down to eleventh century A.D. tend to show greater possibilities of alien influence on Indian thought. It may be held that there has been much more flow of knowledge out of India than India has received. While it may be true to a large extent, the contribution of alien scientific thought cannot be by any means very small.

From the thirteenth-fourteenth century A.D. the circumstances so shaped themselves that the history records an abrupt decline in Indian scientific thought although the tradition was still continued by a few scholars.

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