MEASUREMENT OF RAINFALL IN ANCIENT INDIA

T. M. Srinivasan

National Commission for the Compilation of History of Sciences in India,
Indian National Science Academy, New Delhi 110001.

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This brief survey indicates that the first measurements of the amount of rainfall with the help of the raingauge were made in India as early as the fourth century B. C., and continued to be practised until the end of the tenth century A. D. It is interesting to note that the internal sources do not yield any evidence to attest that the vessel was made of such and such material. In forecasting the quantity and distribution of rainfall, Kauṭilya is the only author who treats this aspect in a nutshell covering the whole of the Indian subcontinent. On the contrary, the Hindu astronomers or the weather prophets of the later period had relied on the position of stars to ascertain the quantity and distribution of rainfall. Nevertheless, many facts in the field of weather science were undoubtedly known to the ancients in India who certainly attempted to develop a system or practice for measuring the amount of precipitation with the use of the raingauge.

1. Introduction

The amount of precipitation in the form of rain is usually determined from the accumulation of water collected in a rain gauge ; and several types of recording instruments are routinely employed for the purpose. It is generally believed that the rain gauge is of Babylonian origin ; but we have no strong proof to warrant this assumption. Passages from Hebrew texts by Vogestian show that rain gauges were in use from the second century A.D. onwards. In China the chief evidence for this is to be found in the mathematical book *Shu Shu Chiu Chang* by Chhin Chin Shao of 1247 A.D., which contains problems on the shape of rain gauges called *thien chhih tsheyu*. After a lapse of nearly two hundred years several Korean rain-measuring instruments known as *tshe yu chhi* appear to have been in bronze set up in 1442 A.D. and concerning which the relevant imperial decrees are preserved in Korean historical texts[1,2]. But that the use of rain gauges was known to ancient Indians is amply evident from references to measurement of rain and rain gauges in indigenous literary works dating from the fourth century B.C.

2. Rain Gauge (Varṣamāṇa)

There is adequate archaeological evidence to testify that the Harappans of the Indus Valley were well aware of the seasonal rainfall and flooding of the river

Indus during the period between 2500 and 1700 B.C.[3] which is corroborated by modern meteorological investigations[4]. But our knowledge of the use of rain gauges by them still remains uncertain in the absence of specific pottery type or other indications. On the contrary the Vedic Aryans had a flair for transforming natural phenomena into mythological figures. Although the subject of weather phenomena is closely linked with the realms of mythology, the early Vedic texts contain much information on the meteorology of the north-west Indian subcontinent. But the same tests do not offer any information regarding the measurement of rainfall and the type of gauge used.

As already stated the earliest known literary reference to the existence and use of rain gauges goes back to the fourth century B.C. The celebrated grammarian Pāṇini in his *Aṣṭādhyāyi* (340 B.C.) refers to the measurement of rainfall as *varṣa pramāṇa*[5]. In the *Arthaśāstra* of Kauṭilya (c. fourth century B.C.) we find the mention of rain gauge as *varṣamāṇa*. We also note that with the development of instrumentation the first observation station was set up during the Mauryan period in the fourth century B.C. Similarly, Varāhamihira (c. sixth century A.D.) spells the name of the rain gauge as *varṣamāṇa* in his treatise *Bṛhat Saṃhitā*. We also come across accounts of rain gauge by Parāśara by way of interpolation in the *Bṛhat Saṃhitā* and the author of the *Kṛṣi Parāśara* an important work on the subject of agriculture written between A.D. 950 and 1000. And the information drawn from the above texts and the *Purāṇas* and literary works in Tamil is rather limited but sufficiently informative as to build up some material for the present investigation.

Kauṭilya says that 'in (front of) the store-house a bowl (*kuṇḍa*) with its mouth as wide as an *aratṇī* (24 *aṅgulas* or finger-breadths = 18 ins.) shall be set up as rain gauge (*varṣamāṇa*)' : '*koṣthagare varṣamāṇam aratṇīmukham kuṇḍam sthāpayet*'. Varāhamihira's account is still more detailed and runs thus : 'the quantity of rainfall should be determined through a gauge whose diameter is one cubit (*hasta-viśālam*) ; and when it contains 50 *palas* it will be equal to one *āḍhaka*' : '*Hastaviśālam kuṇḍakam adhikṛty-āmbu pramāṇa nirdeśah ? pañcāśat, palam adhakam anena minuyāi-jalam patitām*[7]. However Parāśara specifies that the vessel intended for measuring the rainfall should have a circular mouth of diameter 20 *aṅgulas* (15 ins.) depth 8 *aṅgulas* (6 ins.) and capacity one *ādhaka* (50 *palas*) when the vessel is filled to the brim : *same vimśaṅgul-ānāhe dvi-catusk-āṅgul-occhrite bhānde varṣati sampūrṇam jñeyam ādhaka varṣaṇam*' (vide Parāśara as quoted by Utṛāla in the *Bṛhat Saṃhitā*)[8]. According to the author of the *Kṛṣi Parāśara* the dimensions of the container or vessel as the rain gauge should be 12 *aṅgulas* (9 ins.) for its length width and depth. Here the length may refer either to the base or mouth of the vessel[9].

From the above-cited passages we gather that the authors of the works differ from one another from the point of view of the type and dimensions of the vessel.

We shall enumerate some of the salient features of the gauge as well as the points of difference as contended by the authors in the following pages. Kauṭilya and Varāhamihira stress that the mouth of the vessel should have a diameter or width of 24 *aṅgulas* (18 ins.) or *aratṇī** or *hasta-viśālam* (one cubit). On the contrary Parāśara (who is quoted by Utpāla in the *Bṛhat Saṃhitā*) says that the mouth of the width of the vessl should be 20 *aṅgulas* (15 ins). The *Kṛṣi Parāśara* specifies that the width of the vessel should be 12 *aṅgulas* (9 ins.) and the same measurement stands for the length and depth of the vessel. In the latter case it is clear that the vessel must be cylindrical and having the same measurement for the length, width and depth. It is also discernible from the above information that the diameter or width of the vessel ranges from 9 ins. to 18 ins. Kauṭilya and Varāhamihira make no mention of the length and depth of the vessel; whereas Parāśara and the author of the *Kṛṣi Parāśara* do specify the length of the gauge as 20 *aṅgulas* (15 ins.) and 12 *aṅgulas* (9 ins.) respectively. And the latter work goes one step further by stating that the depth of the vessel should be 12 *aṅgulas* (9 ins.). Another interesting point which emerges from these accounts is the capacity of the vessel which is conspicuous by its absence in the *Arthaśāstra* of Kauṭilya. Varāhamihira and Parāśara stipulate that the capacity of volume of the container should be 50 *palas* or one *āḍhaka* when it is filled to the brim. The *Samāśa Saṃhitā* (as quoted by Utpāla in the *Bṛhat Saṃhitā*) describes this one *ādhaka* as *māgadhamāna* (.... *Jalamānammagadha-mānena hastamite*)[10]. This finds corroboration in the work of Kauṭilya who states that the *droṇa* measure of the state is equal to 200 *palas* and an *adhaka* is one fourth of it or 50 *palas*[11]. Thus this conventional weight of one *pala* is approximately 11 oz. or 37.76 gm; and 50 *palas* is reckoned at about 66.66 ozs., or 1.888 kg.** It may not be out of place to mention here that this peculiar system of measuring rainfall as mentioned by Kauṭilya and Varāhamihira must

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**Aratṇī*: cubit, according to *Śulbasutra* of *Baudhāyana*, this measure is equal to 24 *aṇgula* or 'finger-breadths'. This *Śatapatha Brāhmaṇa* (x.21.3) also mentions 24 *aṅgulas* as a measure but without reference to the *aratṇī*, see *Vedic Index*, (1912), A. A. Macdonell and A. B. Keith, London, Vol. II, p. 512 *Aratṇīkukham*: 'according to the commentary on *Bhāṣavyakhyānām* (in Malayalam) the gauge is square, each side being one cubit.....Perhaps the vessel was cubical in shape. The commentary *Jayamaṅgala* on Book I and *Cānakyatika* adds that the capacity of the vessel should be one *droṇa*, for rain is measured in *droṇa*.' 'On the basis of about 511 cubic inches in a *droṇa* and a cylindrical rain gauge with a surface area of about 254.3 sq inches '1 *aratṇī* about 18″ diameter, 2.5.7.), 16 *droṇas* amount to about 32″ of rain; if the gauge is understood to be square (18′×18″), they would amount to about 25″; *see* R. P. Kangle, (1963) *The Kauṭilya Arthaśāstra*, Part II, pp. 84 and 171, University of Bombay Publication, Bombay.

**The basic weight of ancient India was the *raktika*, the bright red seed of the *guñja*(*Abrus Precatorius*), which was conventionally reckoned at about 1.85 grains (0.118 gm). The goldsmiths scale given by Manu, which was probably the most widely followed, was:

5 *raktikas*=1 *māsa*,

16 *māsas* = 1 *karṣa*, *tolaka* or *suvarṇa*,

4 *karṣas* = 1 *pala*,

10 *palas* = 1 *dhararas*, *see* A.L. Basham, (1954) *The Wonder That Was India*, London, 505p..

have been introduced by the Mauryan rulers in the Magadha country (south Bihar) in the fourth or third century B.C. and continued to be practised effectively by the succeeding rulers until the end of the sixth century A.D.[12] It is therefore likely that this system of cubic measurement introduced by the Mauryan rulers must have been followed and popularised by the Gupta kings throughout the length and breadth of the country which came under their sway.

Many internal sources also give series of weights based on this *Māgadhamāna* measure and show that the standards varied widely with time and place. For example the *Purāṇic* sources mention that 13 *palas* make one *māgadha* measure (*jala-prastha*) ; and 4 of these measures equal to one *nalikoccaya* or *ghata*[13]. In the *Bṛhat Saṃhitā* it is stated that 64 *palas* make one *ādhaka* which in turn is equal to one *māgadhamāna*.[14] These weights of measures must have been in force only for measuring solids and liquids in ancient India. But for measuring the rain water an *ādhaka* was reckoned to consist of 50 *palas* based on *māgadhamāna* as stated by Kauṭilya and Varāhamihira. It then shows that the ordinary *ādhaka* probably belonging to the *kaliṅgamāṇa* consisted of 64 *palas ;* whereas in the case of the *māgadhamāna*, it was equal to 50 *palas*.[15]

3. Material of the Gauge

Now comes the important question of the material out of which the vessel was made. It is unfortunate that the internal sources do not yield any evidence to attest that the vessel was made of such and such material. Incidentaily Kauṭilya refers to the vessel as '*kuṇḍa*' which may mean anything like a bowl-shaped vessel, basin, pitcher, pot, etc., and in this context we may have to presume that it means either a bowl or pot. Possibly the corroborative evidence drawn from the archaeological finds may lend support to the type of pottery which was used by the people of northern India. The Iron Age in India has been associated with a black lustrous pottery called the Northern Black Polished ware dated from 500 B.C. They have been found in large numbers in different parts of northern India and hence its name. It has been ascertained that the N.B.P. ware appeared first in the regions of modern Bihar and eastern Uttar Pradesh and from whence it might have spread with passage of time to other parts of northern, central and southern India. It is therefore assumed that this black-to-gloosy-grey ceramic reputed for its metallic sound wide distribution and association with iron would have been selected by our ancients and the bowl-shaped flat-bottomed vessels would have been their first choice. Again the use of metal for making the vessel is not ruled out ; for the association of iron with the N.B.P. were in northern India would have also prompted them to make an attempt at it. But these suppositions have no archaeological basis. Further, we do not find even any accidental reference in literary texts to the use of iron or ceramic material in this case.

The *Kṛṣi Parāśara* is the only extant text which specifies wood as the medium for making the gauge. The author says that the vessel should be made of the wood

of *calita* (*Dillenia indica*), mango (*Magnifera indica*), or *Punnāga* (*Calophyllum inophyllum*) trees. He also stresses that the use of the wood of wood-apple (*Foronia dephantinum*), *Pakur Ficus infectonia*) or *nimba* (*Melia indica*) trees was forbidden for the making of measuring vessel. Since the author of the *Kṛṣi Parāśara* recommends only three species of wood without much details it has not been possible to ascertain to what extent such containers were adopted and made use of by observers.

4. Selection of Site

This is a matter requiring some judgement. It is a common practice that the gauge should be set up on the ground and not on structures of any kind ; and should be free from all possible obstructions. In this connection we have the reference of the *Arthaśāstra* of Kauṭilya who specifies that 'the bowl (*kuṇḍa*) with its mouth as wide as *aratnī* to be kept as rain gauge in (front of) the store-house'. But the does not offer any reasons for the selection of the 'store-house' as the rain gauge station. It is conjectured that in Kauṭilya's time many observation stations must have been set up in different parts of the country for the author speaks of the quantity of rainfall with reference to the area of distribution elsewhere in this work. It is interesting to note that during his time it was one of the duties of *Sannidhatr* (Chamberlain) to keep the gauge in front of the 'store-house' and collect annual rainfall statistics. Based on the information supplied by him the 'Superintendent of Agriculture' gave directions for sowing the seeds in different parts of the country. In addition, the State store-houses were very important in budgeting and the rain gauge records collected therein helped classify the land for revenue estimates.

5. Seasons of Rainfall

It is imperative to add a brief reference to the Hindu seasons and in particular the rainy season. Generally the Hindu calender contained twelve lunar months ; and a group of two such months formed a season (*ṛtu*). The six seasons were *vasanta* (spring March-May), *grīṣma* (summer May-July) *varṣa* (the rain July-September) *śarad* (autumn September-November) *hemanta* (winter November-January) and *śiśira* (the cool season January-March). Here the '*varṣa*' denotes primarily 'rain' and then 'rainy season' ; and we come across the use of this term frequently in the early Vedic texts. Similarly the term '*prā-vriṣ*' was in use in the *Ṛg Veda* and later texts to mean the rainy season. So also Pāṇini refers to the rainy season as '*prāvriṣ*' and '*varṣa*', the former was the first part of the season. These two parts were termed as *pūrva-varṣa* and *apāra-varṣa*. Besides, there are general terms such as *varṣa-kāla* and *varṣa-ṛtu* to mean only the rainy season. Generally it rains in some places during *Śrāvaṇā* (July-August) and *Bhādrapadā* (August-September) and in others during *Bhādrapadā* and *Āśvina* (September-October) ; and in others for a longer period. The *Milindapañho* or the Questions of King Milinda treats the seasons of rainfall in a lucid manner and with a scientific approach.

It refers to three kinds of well known rains—'that of the rainy season, that of the winter month (November-January) and that of the two months (*Āṣāḍha* and *Śrāvaṇa* June-August). If, besides these, any other rain falls that is not reckoned among the usual rains, that is called 'a rain out of season'. According to the *Ṛtu Saṃhāra* the rainy season is striking to the eye with copious dark clouds rumbling with thunder and dazzling with lightning and hanging low with the weight of water. The picture described in the *Ṛtu Saṃhāra* is conspicuously of central India because of several references to the Vindhyas.[24]

Rain was of course extremely important to the inhabitants of India since time immemorial as it is today from the point of agriculture. With such an intense interest in agriculture and allied problems the ancients had even timed the measurement of rainfall to see that it brought good results favourable to the growth of all crops. Varāhamihira emphatically states that the quantity of measurement of 'rainfall should be timed after the full-moon day in the month of *Jyeṣṭha* (May-June) when it has rained in the asterisms commencing with *Pūrvāsāḍha* (δ and ϵ Sagittarii). During this time he adds with a note of caution that 'the astronomer should judge the quantity and the good or bad effects of the rain'[25]. Gleanings from the *Samāsa Saṃhitā* as interpolated in the *Bṛhat Saṃhitā* are relevent in this connection : "The quantity of rainfall should be gauged on the day of the asterism during which there is rain for the first time through the (amount of) rain by which the earth is cleared of dust or the drops of water on the tips of blades of grass'.[26]

6. Quantity and Distribution of Rainfall

Now we shall discuss in detail the extent of the ancients' knowledge pertaining to the quantity and distribution of rainfall. Kauṭilya's account shows a clear understanding of the said problem. In the Chapter on 'The Superintendent of Agriculture' in his treatise on Polity he speaks of the following : 'The quantity of rain that falls in the country of *jaṅgāla* (desert countries or countries full of jungles) is 16 *droṇas ;* half as much more in *anupānām* (moist countries) ; as the countries which are fit for agriculture (*desavāpānam*) ; 13½ *droṇas* in the countries of *aśmakas* (Maharastra) ; 23 *droṇas* in Avanti (probably Malwa) ; and an immense quantity in *aparāntānam* (western countries the countries of Konkan) ; the borders of Himalayas and the countries where water-channels are made use of in agriculture'[27]. His method of classification of rainfall areas in relation to the annual average quantity is indeed remarkable and he is the only classical author who treats this aspect in a nutshell covering almost the whole of the Indian subcontinent. Further, it corresponds to the modern method of computation also. But the chief difference is that he expresses the quantity of rainfall in terms of weight or cubic measure ; whereas the modern meteorologists use linear measures for the purpose. Thus the ancient weight of the *pala* was approximately 11 oz. (37.76 gm.) and the *droṇa* 21 lb. (9.6 kg.). Discussing further the quantity of rainfall he adds that 'when one-third of the requisite quantity of rain falls both during the commencement and

during the closing months of the rainy season (*Śrāvanā* July-August; *Kārttikā* October-November) and two-thirds in the middle (*Proṣṭapadā* or *Bhādrapadā* August-September ; and *Ās'vayujā* or *Ās'vinā* September-October) then the rainfall is (considered) very even (*suṣumārūpam*)'.[28]

On the contrary the Hindu astronomers or the weather prophets of the later period had relied heavily on astrology in forcasting the quantity of rainfall. However, they had not specified the regionwise distribution of rainfall. Nevertheless they had predicted profuse rainfall confining to certain unspecified areas only. For example Kāśyapa and others opine that 'if there be rain in a certain area at the beginning there will be good rain throughout the season' ; while Devala maintains that 'if there be rain over an area of ten *yojaṇas* (70.20 km.) there will be plenty of rain during the whole season'. But according to Garga, Vaśiṣṭha and Parāśara good rain during the season should be predicted if there be rainfall over an area of not less than 12 *yojanas*[29]. Varāhamihira's system of prognostication is chiefly based on astrological computations. In other words it is reckoned in terms of the lunar mansions or *nakṣatras*. He devotes a separate chapter in his encyclopaedic work on the 'Quantity of Rainfall' in which he speaks of the amount and distribution of rainfall according to time in various lunar asterisms in four verses.[30] But the most disappointing factor in these accounts is that none of these authors could indicate the lowest measure of rainfall prevalent in those days. Pāṇini alone uses the term '*goṣpada*' to mean the measure of lowest rainfall without much details.[31] He also refers to the failure of rain or drought (*varṣa-pratibandha*) as *avagraha*.[32] So also we get scanty information from the *Rāmāyaṇa* regarding the climatic vagary or the absence of rainfall in a particular season.[33] But it is interesting to note here that the Buddhist *Jātakas* or Rebirth Stories refer to the role of wind in the distribution of rainfall which we come across in the narrative of the first *Jātaka* thus : 'We have just been told by some people that it is raining just on ahead in the belt of forest ; now how far does a rain-wind carry ?' 'A league, Sir'. 'And has this rain-wind reached any one man here ?' 'No, Sir'. 'How far off can you see the crest of a storm-cloud ?' 'A league, Sir'. 'And has any one man here seen the top of even a single storm-cloud ?' 'No, Sir'.[34]

7. Forecast of Rainfall

The position of the stars and planets is not used by meteorologists to forecast the rainfall. On the other hand we notice that to a great extent the astronomers and weather prophets of olden days relied on the position of stars to ascertain the future agricultural prospects of the land. Kauṭilya says that 'a forecast of such rainfall can be made by observing the position motion 'pregnancy' (*garbhadhāna*) of the Jupiter (*Bṛhaspati*), the rising and setting and motion of the Venus (*Śukra*) and the natural or unnatural aspect of the sun'.

There are a good many references in the Sangam Tamil classics belonging to the early centuries of the Christian era to the forecast of rainfall which also bring

to light the people of South India had certain well-set notions about the rainfall based on the system of astronomy in those days. They knew that, after the summer, the exact combination of planets would cause rain and this is detailed in the *Paripādal*.[56] If 'Venus (*Śukra*) descends on the north it was likely to cause rain.[37,38] It was also the belief that monsoon rain was the direct result of the planetary movements or conjunction.

Varāhamihira follows a different method which is quite interesting. He says that rainfall could be forecast by careful observation in the dark half of *Āṣāḍha* of the size brightness colour direction of the moon when in conjunction with *Rohiṇī* (Aldebaran). For this purpose a brahmin astrologer was commissioned to do this task. He went to a place north or east from the town and stayed there for three days fasting and worshipping the sacred fire; then drew a diagram of the planets and asterisms occupied by them and worshipped them with oblations coupled with incense and flowers. He then sanctified all sorts of seeds with the hymns of *mahāvrata* and immersed them in water containing gold and *garbha* (sacred grass) in the pot. It is further stated in his work that only those of the seeds and their parts which got sprouted during the moon's conjunction with *Rohiṇī* would be expected to thrive and flourish during the year and not others. The four water-pots which were kept in the north, south, east, and west and where named after the lunar months *Śrāvanā Bhādrapadā Ās'vinā* or *Ās'vayujā* and *Kṛttikā* in the dextral order were regarded as indicative of rainfall in that particular month. 'If any of the pots be full of water, the particular month signified by that will have good rain; while the empty pot indicated that month will have no rain. The amount of rain in the particular months would have to be guessed from the quantity of water left in the pots'.[39] This method seems to be more cumbrous and less efficient and scientific in approach than the other method which he himself advocates.

Well aware of the idea that the winds govern the weather, the ancient Indians used wind flags in order to measure the velocity and direction of wind. According to Varāhamihira it could be determined by observing the direction of the wind by means of a very black flag four cubits in length and hoisted on a staff of 12 cubits at the time of the moon's conjunction with *Rohiṇī*. For this purpose four watches (3 hour-periods) of the day were regarded as representing four months beginning with *Śrāvaṇā* respectively; and parts thereof corresponds to the days in their months. 'When two contrary winds blow from two directions that which shows firmness is more powerful and it is from this wind alone prediction should be made'. It seems probable that the use of flags was strictly enforced for the measurement of rainfall. The author of the *Kṛṣi Parāśara* also advocates the use of a flag for the determination of the direction and course of the wind. It is thus suggestive of the use of wind vanes, primitive to be sure, in India as early as the sixth century A.D. Varāhamihira in his *Bṛhat Saṃhitā* and the *Mayūracitraka* and the author of the *Kṛṣi Parāśara* speak at length on the symptoms and signs or conditions that were believed to determine immediate rainfall. Unfortunately,

a verification of these signs, which are of such great antiquity, is not made. However, many of these beliefs are still current in different parts of India.

Conclusion

This brief survey indicates that the empirical knowledge pertaining to the regular succession of seasons and observation of major anomalies in the weather had reached a sufficient level to be of practical use by the ancients for purposes of weather prediction. We do not know exactly when the first attempts were made to forecast whether there would be abundance of rainfall or famine but it is known that they date back to very ancient times. But there is enough evidence to corraborate that the first measurements of the amount of rainfall with the help of the raingauge were made in India as early as the fourth century B.C. and continued to be practised until the end of the tenth century A.D. As early as the fourth century B.C. the science of astrology which included astronomy was given considerable attention by the ancients in forecasting the quantity and distribution of rainfall for the entire year on the basis of the motion of the celestial bodies. But how far such weather forecasts were made use of by the ancients in augmenting the agricultural produce is not clearly known. It is equally unfortunate that the contribution made by the ancients to the science of meteorology during the first millennium of our era has still not been studied adequately. Nevertheless many facts in this field of science were undoubtedly known to the ancients in India who certainly attempted to develop a system or practice for forecasting the amount of precipitation with the use of the raingauge.

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References

[1] Needham, Joseph, with the collaboration of Wang Ling, (1959), *Science and Civilization in China*, 3, P. 471, Cambridge.

[2] Wada, Y. (1911), 'A Korean Rainguage of the Fifteenth Century', *Quaterly J. Royal Meteorological Society*, 37, p. 83.

[3] Wheeler, Sir R. E. Mortimer, (1953) *The Indus Civilization (Cambridge History of India)*, *Cambridge*, p. 5.

[4] Ramaswamy, C. (1968) 'Monsoon Over the Indus Valley During the Harappan Period', *Nature*, London, 217, (6120), pp. 628-629.

[5] *Aṣṭādhyāyi*, II, 4.32 ; *see* V. S. Agrawala, (1953) *India as Known to Pāṇini*, p. 203, I ucknow.

[6] *Arthaśāstra*, Bk. II. Ch. 5.7., (1929) Tr. R. S. Shamasastri, Mysore, p. 56.

[7] *Bṛhat Saṃhitā*, Adh. XXIII, sl. 2., (1947) Tr. V. Subramanya Sastri and M. R. Bhat, Bangalore, Vol. 1, p. 222.

[8] *Ibid., Adh.* XXI, *Sl.* 32., *op. ci.*, p. 217.

[9] Shastri, Ajay Mitra, '19) 'Textual Evidence Bearing on Rainfall in Ancient India', *J. Oriental Institute*, Baroda, 9, pp. 407-418.

[10] *Bṛhat Saṃhitā, Adh.* XXIII, *Sl.* 2., *op. ci* ., p. 221.

[11] *Arthaśāstra, Bk.* II, *Ch.* 24.5., *op. ci* ., p. 143.

[12] Shastri, Ajay Mitra, *op. ci* ., p. 417.

[13] *Brahmāṇḍa*, (IV.1.217), *Vāyu* (100.220), *Viṣṇu* (VI.3.8) ; see *The Purāṇa Index* (1951) V. R. Ramachandra Dikshitar, Uni. of Madras, Vol. I, p. 642.

[14] *Bṛhat Saṃhitā, op. ci* .

[15] Shastri, Ajay Mitra, (1969) *India as seen from the Bṛhat Saṃhitā of Varāhamihira*, Delhi, p. 341.

[16] Banerjee, N. R., (1965) *The Iron Age in India*, Delhi, p. 241.

[17] *Kṛṣi Parāśara*, verse 220 ; see Ajay Mitra Shastri, *op. ci* .

[18] *Arthaśāstra*, Bk. II, Ch. 5.7 ; *op. ci* ., p. 56.

[19] *Ibid.*

[20] Basham, A. L., (1954) *The Wonder That was India*, London, p. 494.

[21] Macdonell, A. A. and Keith, A. B. (1912) *Vedic Index of Names and Subjects*, Vol. II, p. 272, London.

[22] *Aṣṭādhyāyi*, (IV.3.26 ; VI.3.14 ; and VII.3.11) see V. S. Agrawala, *op. ci* p. 203.

[23] *The Milindapanho; The Questions of King Milinda*, (IV.1.36), (1965) Tr. T. W. Rhys Davids, New York, Dover Publications, part I, p. 171.

[24] *Ṛtu Saṃhāra*, 11.1 ; and 11.3.19 ; see B. S. Upadhyaya (1968) *India in Kālidāsa*, New Delhi, p. 28.

[25] *Bṛhat Saṃhitā, Adh.* XXIII, *Sl.* 1, op. cit., p. 221.

[26] *Ibid., Adh.* XXIII, *Sl.* 3., *op. ci* ., pp. 221-222.

[27] *Arthaśāstra*, Bk. II, Ch. 24.5., *op. ci* ., p. 143.

[28] *Ibid.*, Bk. II, Ch. 24.6, *op. ci* ., p. 144.

[29] *Bṛhat Saṃhitā, Adh.* XXIII, *Sl.* 649., *op. ci* ., p. 222.

[30] *Ibid., Adh.* XXIII, *Sl.* 6-9 ; *op. ci* .

[31] *Aṣṭādhyāyi*, VI. 1. 145., *op. ci* .

[32] *Ibid.*, III. 3.5., *op. ci* .

[33] *Rāmāyaṇa*, (1915) Tr. R.T.H. Griffith, Benares, I.9.9.

[34] *Jātakas* (1895-1907) Tr. E. B. Cowell *et al.*, Vol. I, No. 1, p. 7, Cambridge.

[35] *Arthaśāstra*, Bk. II. 24. 7.8, *op. cit.*

[36] *Paripāḍal*, verse 11.

[37] *Padiṟṟuppattu*, 24 : 25.

[38] *Puranānūru*, 34 : 6-8 (1923) Ed. U.V. Swaminatha Iyer, Madras.

[39] *Bṛhat Saṃhitā, Adh.* XXIV. *Sl.* 4-8, & 26., *op. cit.*, pp. 225, 226 and 233.

[40] *Ibid., Adh.* XXIV, *Sl.* 9 and 10., *op* : *cit.*, p. 227.

[41] Raychaudhuri, S. P., (1953) *Agricultural Practices in Ancient India*, Indian Council of Agricultural Research, Review Series, No. 4, p. 31, F.N. 2.