



Impact of Climate Condition on Flowering, Fruiting, Kernel and Nut-yield In Newly Added Potential Growing Areas of Cashewnut in India- A Review

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ABSTRACT: *Cashew is now an important Horticulture plant for India and now India is exporting cashew at a good scale. Traditional Indian growing area comprises the parts of Karnataka, Maharashtra, Goa, West Bengal, Odisha, Andhra Pradesh and Tamil Nadu states. However, now new areas are coming up with good potential for cultivation such as Gujarat, Jharkhand, Chhattisgarh, Andaman and Nicobar island, North Earsten Hilly States. Cashew cultivars are recommended based on geographical distribution, climate, soil based on these flowering and fruiting time. Cashew nut yield and kernel weight can be different for different varieties and so on its quality with shelling can vary. Flowering and fruiting is greatly influenced by rain because it starts flowering after monsoon, which is greatly influenced by the onset and offset of Indian monsoon that India varies from state to state as India has north-east monsoon and south-west monsoon. Moreover, soil characteristics across India varies widely. Integrated effect of soil, rainfall and temperature drives the optimum growth of cashew trees, which resulted in the change in yield and quality of cashew nuts. The present review paper addresses many of these drivers and their impact on cashew produce in India.*

Keywords: *Cashew Cultivar, India, Climate, Geographical distribution, Morphology assessment*

1.0 Introduction

Cashew (*Anacardium occidentale* L.) is a perennial tropical tree of the Anacardiaceae family. The cashew is an important crop for semi-arid agriculture, which contributes to the social and economical development of numerous world regions (Bezerra *et al.* 2007). Though, it is native to tropical America, the West Indies, Brazil and Peru, cashew is one of the most important crop in India because of significant profits from its exports. In India, cashews were first introduced by the Portuguese 500 years ago to Goa and then spread to other regions. The term "Cashew" has originated from the Brazilian name "acajaiba" and the Tupi name "a caju", which the Portuguese converted into "Caju" and is commonly known as "kaju" in India (Saroj *et al.* 2014). Despite its first purpose of introduction, presently cashew has been



widely grown for its nuts to be used as food, medicine, and source of income in mainly tropical regions with the major coverage found in Brazil, India, Vietnam, Indonesia, and numerous countries in West and East Africa (Tola and Mazengia 2019).

India is the first country in the world to benefit from the international trade in cashew nuts in the early 20th century. Currently, cashews are planted on an area of 8.93 thousand hectares, which produces 6.95 thousand tons of cashew nuts per year (Bhat *et al.* 2010). Cashews are also known as wild goldmine (Dasmohapatra *et al.* 2013, Jayasankar *et al.* 2018). Commercial cultivation began in the early 1960s, and over time, cashews became a high value-added crop, earning the status of an export-oriented commodity, bringing significant money to the country.

World production of raw cashew nuts has also grown to 4.9 million tons in 2016, which was just 0.29 million tons in 1961 (Tola and Mazengia 2019). Cashew production is affected by variability of climatic factors (Balogoun *et al.* 2016). In recent years, considering the possibility of global climate change, an increasing emphasis on world food security and its regional impacts became a key issue for the scientific community (Mall *et al.* 2006). Under normal conditions, Crop growth, development, water use and yield are largely determined by the prevailing weather during the growing season. Any change from 'normal weather' has an effect over the crop production and cashew plantation is also not immune to these changes. This paper reviews the possible impact of climate change in Indian cashew growing regions.

2.0 Geographical distribution

Globally cashew growing regions are located between 28° N and 28° S (Salam and Peter 2010). In India, it grows along the entire coastal strip from 8° N to 28° N. Major Indian traditional cashew growing regions are found in the states located along the west coast (Maharashtra, Goa, and Karnataka) and east coast (Tamil Nadu, Andhra Pradesh, Odisha, and West Bengal) in southern parts of India (Rejani *et al.* 2013, Polisetty *et al.* 2018). However, nowadays, cashews are spreading rapidly in the nontraditional regions such as Dharampur-Kaprada talukas of Gujarat (Shah *et al.* 2018, Ghadage *et al.* 2016). Malhotra *et al.* (2017) reported for the cashew plantation in Jharkhand, Chhattisgarh (Bastar district), North Eastern Hilly (NEH) states, Andaman and Nicobar islands, plains of Karnataka, North Eastern Hilly (NEH) states Meghalaya, Tripura, Manipur and Nagaland. Moreover, some parts of Assam and Mizoram are likely to cultivate on industrial bases. In the state of Gujarat, it is observed that cashew plantations are also being grown on a trial basis in the parts of Dang, Narmada and Tapi districts (Shah *et al.* 2018). Scattered new plantations were



also observed in Saurashtra region (including Junagadh, Rajkot, Bhavnagar, Amreli and Surendranagar districts). Shah *et al.* (2018) have reported that considering the taste, whiteness and crunchiness of the produce, cashew from South Gujarat is superior as compared to cashew from Goa.

3.0 Environmental and soil suitability

In most cashew growing regions of the world, climate is characterized by high temperatures with low and irregular precipitation, providing insufficient water for plants over the larger part of the year (Bezerra *et al.* 2007).

3.1 Dependence on climate and soil:

The appearance of cashews is strongly influenced by the elevation of the place where they are being grown (Malhotra *et al.* 2017). Flowering time depends on the latitude, hence low temperatures at high altitudes adversely affect harvest. It is reported that the maximum altitude suitable for planting cashews depends on the latitude. Cashews were planted at an altitude of about 1000 m, but in Assam, India, 250 m to the north, it was found that elevations above 700 m were not suitable for harvesting. This could be due to the fact that the lower temperature at higher altitude has an effect on the development of the cashew trees. Cashews are sunny trees that cannot tolerate excessive shade. The sunny period on the west coast of India averages more than 9 hours a day from December to May, while there is less sunshine in the southwest and Northwest from June to November. This variation in sunshine hours has an impact on the quality of cashew produce. The dependence of the growth of cashew plantation on the climate and soil parameters are shown in Figure 1.

It is observed that the region receiving rainfall below 300 mm per year is not suitable for growing the cashew, which results in the lower yield of cashew nuts. Loamy red & lateritic soil, red & black mixed soil, Alluvium derived soil, sandy loams & loams, coastal sand and loamy & silt loam are the types of soil that are best suitable for the healthy growth of cashew plantation.

Cashew trees are larger and yield more in deep, strongly weathered soils (Ngatunga 2001). Widiatmaka (2014) studies that 76% of cashew production variability is influenced by effective soil depth. Poorly drained soil, or soil with lower than 45 cm depth, is not suitable for better growth. Generally, well drained, red sandy loam and light coastal soil with high water holding capacity and rich in organic matter is preferred (Jena and Panda 2020). Desirable soil depth is 90 cm but 45-90 cm soil depth is also good (Rejani *et al.* 2013). All around, depleted soil is must to dodge water logging and root decay, with pH going from 5.8



to 6.8 (Desai *et al.* 2014). According to Venugopal and Khader (1991) soil salinity higher than 2% is unsuitable for normal growth. Expected yield may exceed 1000 kg per hectare, if all the parameters influencing the growth are favorable.

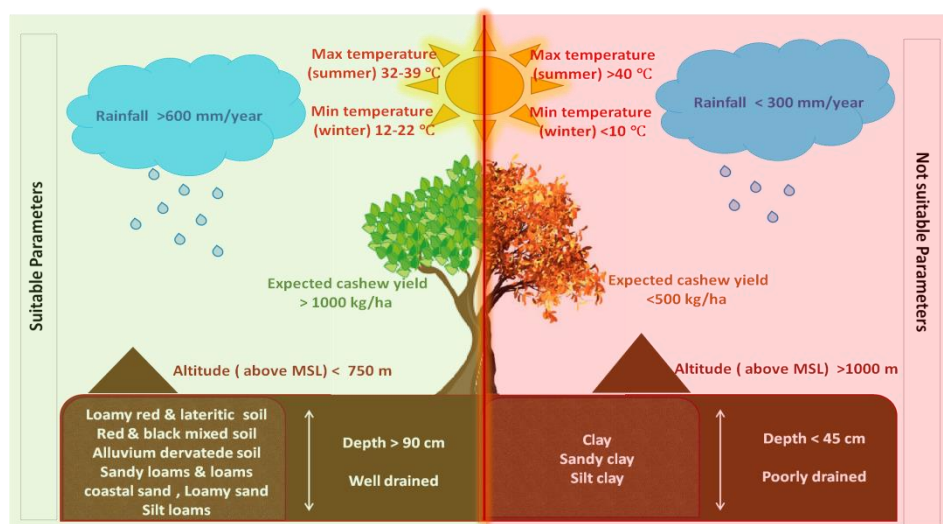


Figure 1: Suitability of climate and soil conditions for the growth of Cashew plantation
(prepared from the data reported in Rejani *et al.* 2013)

Cashews tend to grow further south in response to sunlight in the northern hemisphere. The maximum daily temperature in the main cashew producing regions is found within 25 °C to 35 °C. Bezerra *et al.* (2007) reported that the optimal temperature for cashew seed germination in Brazil is around 35°C. Blooming cashews need a cool winter, particularly lower minimum surface air temperatures, ranging from 16 °C to 20 °C, combined with humid nights. Onset of Indian monsoon varies from one region to another region. In the regions of Andhra Pradesh, Karnataka, North East Hilly regions, Goa and West Bengal onset of monsoon is observed in June. Maharashtra, Odisha, Chhattisgarh has onset of monsoon in mid June. Generally in Gujarat monsoon arrives at the end of June. Mostly monsoon season is around 4 months in India. As the onset of monsoon varies from state to state, variation in the offset is also observed from one state to another state located in different parts of India. Monsoon offset occurs at the end of October in Maharashtra, Goa, West Bengal, Chhattisgarh, Andhra Pradesh, Odisha and Karnataka. Monsoon offset observed for NEH is in Mid October and that for Gujarat is in the end of September. It is to be noted that Kerala, Tamilnadu and Andaman Nicobar have two monsoon. In these regions one South West Monsoon retreats from the area and Northeast monsoon gets established. These



variations in monsoon onset, offset and associated rainy days vary widely within India, which also has an impact on the variation in the phenology of cashew trees and quality of the cashew produce.

Abnormal rains between November-December slow down the breeding stage of abnormal late flowering varieties. Moreover it was observed that cashews require a climate with a precisely defined minimum drying time of 4 to 5 months. A climate with a spell of 4 to 6 dry months and period along with monsoon period of 1,000 to 2,000 mm rainfall is suitable for commercial cashew cultivation (Malhotra *et al.* 2017). Widiatmaka (2014) observed that the number of dry months, which are strongly correlated with a level of productivity above 80%, is 5 to 10 months.

Average rainfall distribution in the cashew region ranges from low rainfall (300 to 600 mm in Gujarat) to high rainfall (2700 to 3500 mm on the west coast and in the NEH regions). Little rainfall during the months of January to March increases the yield of cashew production. Heavy rains adversely affect the yield (Widiatmaka 2014), which leads to poor and early dropping of nuts. Light rain during flowering will not damage the blooms, but heavy rain during flowering will affect harvest. Coincidence of flowering with high rainfall or excess humidity leads to incidence of pests and diseases (Bhoomika and Rani 2018). Water deficits and changes from the optimal values of salinity and prevailing temperatures are the most likely environmental factors limiting the cashew production (Bezerra *et al.* 2007).

4.0 Cultivar and Morphological assessment

India is a very diverse country in terms of regional variations in land use/land cover variations and meteorological conditions. The state-wise variation in cashew production and cultivars are given in Table-1 (Desai *et al.* 2010 , Gajbhiye *et al.* 2018, Hanumanthappa *et al.* 2014, Muthu Kumar *et al.* 2011, Nayak *et al.* 2020, Saroj 2015 , Shah *et al.* 2018, Tripathy *et al.* 2015, Vikram *et al.* 2013)

Table-1: State-wise production and cultivars

States	Production (2014-15) %	Preferable cultivars
Maharashtra	31.3	Vengurla-1 Vengurla-3, Vengurla-4, Vengurla-6, Vengurla-7 and Vengurla-8.
Andhra Pradesh	13.3	BPP-4, BPP-6 and BPP-8



Odisha	11.4	Bhubaneswar-I, BPP-8 and Dhana.
Karnataka	10.7	NRCC Sel-2, Bhaskara, Ullal-I, Ullal-3, Ullal-4, Vengurla-4, Vengurla-7, Madakkathara-2, Chintamani-1 and Chintamani-2.
Kerala	10.6	Madakkathara-I, Madakkathara-2, K-22-I, Kanaka, Dhana, Priyanka, Amrutha and VRI-3.
Tamil Nadu	8.9	VRI-1, VRI-3 and VRI H-1
Goa	4.3	Goa-1, Goa-2, Vengurla-1, Vengurla-4, Vengurla-6 and Vengurla-7.
Gujarat	3.3	Vengurla-4, Vengurla-7
West Bengal	1.7	Jhargram-I, Bidhan Jhargram-2 and BPP-8
NEH	4.4 (others)	Ullal-3, Ullal-4 , Vengurla-1, Vengurla-4
Chhattisgarh		Vengurla-4 , Indira kaju-1

4.1 Roots, leaves and canopy structure:

Cashew is a perennial polygamous and male evergreen plant. Generally, the cashew tree is tall and widespread, with a height varying from 8 to 15 m and a crown span up to 20 m (Bezerra *et al.* 2007). Generally the estimated life of the cashew trees are around 50 to 60 years and start bearing fruit in their third to fifth year (Tola and Mazengia 2019). There are two types of cashew nut growth, respectively intensive and extensive. Cashews have an extensive lateral root system with a tap root that penetrate deep into the soil. Generally the cashew leaves are dark green at the top with opaque green in the beneath (Malhotra *et al.* 2017). Both sided smooth cashew leaves are glabrous, thick, leathery, oblong to obviate and alternately located on the branches (Kumar *et al.* 2012, Mog *et al.* 2018). Leaves have a blunt top and slightly tapered bottom. Size of the leaves is around 10 to 20 cm long and 5 to 10 cm wide, varying in a ratio of 1.8:1. Generally, stem length is observed between 0.5 to 1 cm. Canopy-type of various hybrid or selection varieties, grown across India, are given in Figure-2 (Dasmohapatra *et al.* 2014, Malhotra



et al. 2017). Canopy structures can be classified as compact, open, upright & open, upright & compact, spreading, semi-spreading and highly spreading (Salam *et al.* 2010).

4.2 Flowering and fruiting:

Cashew is considered as an andromonoecious species (Saroj *et al.* 2014). Cashew flowers are small with white or light green colour, which are turning pink when opened. The conical, pyramidal or irregular in shaped inflorescence of cashew is called terminal panicle (Dendena and Corsi 2014). It bears both male (staminate) and hermaphrodite (perfect) flowers in the same panicle due to which it is considered as an andromonoecious and cross pollinated species (Bhoomika *et al.* 2018; Sethi *et al.* 2020). Flowers and fruits are borne on the outer extremity of the canopy due to the production of flowers at the end of the new shoots (Janani *et al.* 2020). In general, seedling cashew plants start flowering in three to five years. However, grafted trees come to flowering within 3 years. Normally flowering starts after the emergence of new growth flush at the end of monsoon. Timing and duration flowering are strongly influenced by the prevalent temperature. Across India, regional differences were observed in the flowering time. Generally, variety-wise flowering and fruiting time extends from November of the year to the June of subsequent year (Figure-2).

No.	Variety	Hybrid/selection	Canopy type	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Apple Colour	Juice%
1	MADAKKATHARA - 1	Selection	Compact	Flowering												Yellow	72
2	DHANA	Hybrid	Compact													Yellow	72
3	K-22-1	Selection-Kottarakkara22	Compact													Red	68
4	VENGURLA-4	Midnapur RedxVetore56	Open													Red	76
5	VENGURLA-6	Vetore-56 xVengurla-1	Compact													Yellow	85
6	VENGURLA-7	Vengurla-3 x VRI-1	Compact													Yellow	86
7	BPP- 4	Epurupalem selesion	Upright and open													Yellow	60
8	BPP-6	Selection	Upright and open													Yellow	65
9	BPP-8	T.NO x 1 T.NO 40	Upright and compact													Yellow	66
10	VRI (Cw) H1	Hybrid	Semi Spreading													Pink with yellow tinge	77
11	ULLAL-3	Variety	Highly Spreading													Pink Red	75
12	ULLAL-4	Variety	Spreading													Yellow	70
13	GOA-1	Selection from Balli-2	Semi spreading													Yellow	68

Figure -2. Variety-wise flowering, fruiting, apple colour and juice characteristics

By and large the anthesis is observed between 9 am to 2 pm in India. Approximately 80 percent of the perfect flowers open between 10 am and 12 Noon. The peak period of dehiscence of anthers was observed between 9.30 to 11.30 am. Generally, rate of dehiscence was slightly higher on the sunny side of the tree as compared to that on the shady side (Malhotra *et al.* 2017, Saroj *et al.* 2014). Figure-2 also shows the description of canopy structure, apple colour and juice percentage for different hybrid/selection varieties grown across India. Cashew apple is generally still of minor economic



importance, however, cashew apple juice was found to contain the highest amount of vitamin C compared to some of the tropical fruits like pineapple, orange, grape, mango and lemon (Akinwale 2000).

The cashew fruit comprises a kidney-shaped nut and a pseudo-apple (Akinwale 2000). The whole cashew fruit consists of two parts: the bottom part (nuts) and the top part (falls fruit). The grey coloured nuts have kidney shaped achene with a dry one-seeded indehiscent fruit with the seed distinct from the fruit wall (Saroj *et al.* 2014). Nuts generally consist of epicarp, mesocarp, endocarp and a kernel wrapped by a peel (testa). The skin is smooth, corrosive, gray or greenish-gray, forms the epidermis. The spongy mesocarp is the thickest of the three layers. It has alveoli containing Cashew Nut Shell Liquid (CNSL), which is a sticky, gummy, corrosive oil rich in phenolic compounds (Gandhi *et al.* 2012, Akinhanmi *et al.* 2018). Endocarp consists of a hard, dense mass of sclerenchymatous cells (Saroj *et al.* 2014). These three layers form a thick crust, i.e. pericarp, and make up 45-50% of the pith. Nuts, the edible part, are made up of two cotyledons, which make up 20 to 22% of the nuts. Brown film (crust) covering the nuts make up about 5% by weight of the nuts.

Cashew apples were bred from artificial and hypertrophied pistils. The ratio of nuts to apples is usually 1:8. Bright apples are green, lavender or light green and turn green. When the apples are ripe, they turn red or yellow or faded. This is an indicator that the nuts can be harvested. Ripe apples have a peculiar smell. Ripe apples contain about 60-85% juice (Figure-2).

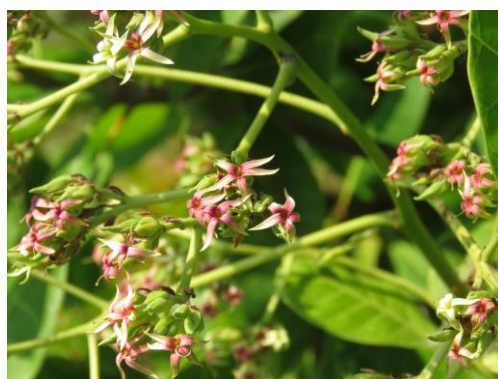


Fig: 3 Flowering in February 2020 at Dharampur in Valsad district of Gujarat, photograph courtesy to Dhruva Jani , student at Department of botany , Gujarat University

4.3 Kernel and nut yields:

The kernel of cashew nut is edible, economical and processed part (Sreenivas *et al.* 2016, Balasubramanian 2015). It has a wrinkled surface and is covered by a reddish brown as pink testa. The white coloured kernel is having high nutritional quality. The



variety or growing conditions have an influence on kernel composition (Malhotra *et al.* 2017). Moreover, quality of yield also depends on the shelling operations. Shelling is the operation of removal of shells protecting the style of the kernels, which produce whole crack-free kernels. Only with a little care, one can produce an annual average of 50 to 75 kg of apples and nuts per tree, yielding up to 4 kg of cashew kernels (Ona *et al.*, 2017). Figure-4 shows the variety-wise characteristics of cashew nuts and kernels. It is observed that the export grade of the produce is inversely proportional to the shelling percentage for the different varieties. Despite a lower nut weight of BPP-8 compared to Vengurla-7, per tree yield is higher for BPP-8. As observed from the figure, maximum yield is found for the BPP-8 variety, whereas Goa-1 has the lowest yield per tree. Despite a lower nut weight of BPP-8 compared to Vengurla-7, per tree yield is higher for BPP-8.

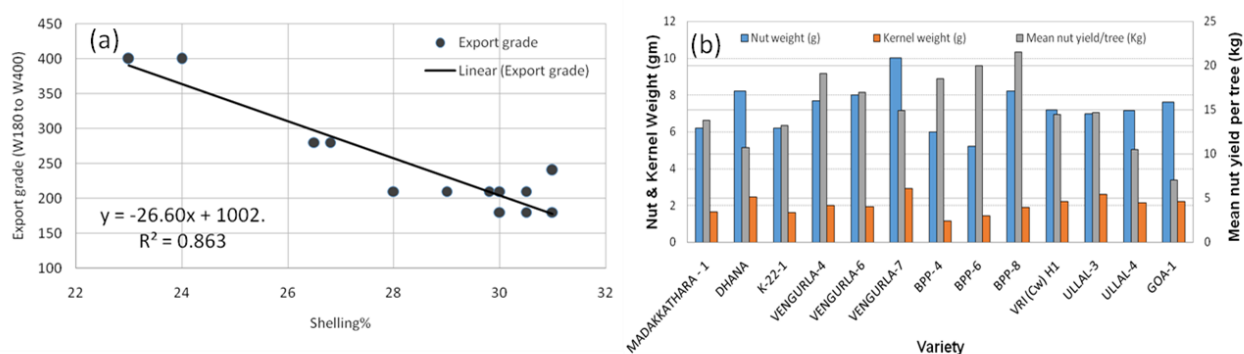


Figure 4. variety-wise characteristics of cashew nuts and kernels (a-The regression analysis performed using the data reported by Malhotra *et al.* (2017), Salam *et al.* (2010)

5.0 Conclusion

Cashew is one of the very important plants, which not only resist erosion it has tremendous commercial and medical value. In India, cashew areas are located mainly in southern and eastern parts but the growing region is now expanded in western parts also. As India is one of the most diverse country in terms of agro-climatic variability, cashew production is also varying from one region to another region. Moreover, region-to-region variation was observed in the quality of the produce. Analysis of the variety-wise characteristics revealed that the quality of cashew nuts is significantly correlated with the percentage of shelling.

Out of the selected varieties, maximum yield is found for the BPP-8 (mainly in Andhra pradesh and Odisha) variety and lowest for Goa-1 (mainly in Goa) variety. Optimum values of the climatic parameters, which are a driving force for the variation in cashew



phenology, health and quality of produce are described in this paper. The review highlighted the possibility of expansion of cashew areas in the region, where they are presently being grown on an experimental basis. Moreover, review also brought out the fact that despite being rich in vitamin C, cashew apple juice is not being produced on an operational basis. This is one of the potential produce from the cashew cultivation in India, which can help to boost the economy.

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