Water and Irrigation Needs of Tuber Crops in Coastal Climates: A Review

Abstract

One of the most essential elements for plant growth is water. Large amounts of it are required by plants constantly throughout their life cycle. It significantly affects agricultural activities like irrigation, soil management, crop production, and chemical spraying environments, as well as plant processes like photosynthesis, respiration, absorption, transport, and use of mineral nutrients. This review examines the impacts of climate change on root and tuber crops, including rising temperatures, altered rainfall patterns, extreme weather events, and changes in pest and disease dynamics. These changes significantly affect root and tuber crop production, leading to lower yields, compromised quality, increased susceptibility to pests and diseases, and limited access to water resources. Adaptation strategies encompass various approaches, such as agronomic practices, crop diversification, improved water management, breeding for climate resilience, and agro ecological methods. In the world, the most significant root and tuber crops are cassava, sweet potatoes, and potatoes. Water will produce maximum production for root crops; however, water stress during critical stages might adversely affect the final output of root crops. The purpose of this article of review is to understand the water and irrigation needs of tuber crops (sweet potato, greater and lesser yams, aerial yams, elephant foot yams, xanthosoma, and cassava) that are effectively produced in Maharashtra's coastal climate. This review emphasizes the urgent need to address climate change impacts on tropical root and tuber crops. It highlights the critical role of adaptive measures in ensuring long-term sustainability and food security in a changing climate.

Keywords: Tuber crops, Climate change, Coastal Climatic,crop diversification, Water requirement, Irrigation requirement, potato, sweet potato, cassava

1 Introduction

Although agriculture consumes an important portion of water resources, the development of water-saving agriculture is essential to the management of water resources and the growth of agricultural output (Zhou et al. 2022). In India, agriculture consumes the largest amount of water (81%), and so productive and intelligent management of water in agriculture should be the top issue (Surendran et al. 2013). In India, the agricultural sector consumes 85% of the water resources poorly (Hans VB 2018). Comparing irrigation and rain fed agriculture provides for higher agricultural production, which is essential for global food security (FAO

Stat 2023). A reliable evaluation of the crop's water requirements is necessary for effective agricultural water management. Climate parameter estimates were useful in agriculture for making informed decisions that saved irrigation costs for crops (Rana et al. 2013).

Beta-carotene, antioxidants, dietary fiber, and minerals are all present in good amounts in tubers (Padmaja et al. 2013). In coastal conditions, tuber crops are extremely sensitive to climate variation. These crops grow across a variety of conditions, including long droughts and higher rainfall. In addition to being resistant to shade and drought, tuber crops are highly adaptable and may succeed in mixed cropping systems in marginal environments, low input situations and unfavorable soil conditions (Mhaskar et al. 2017). The major tuber crops include sweet potatoes, yams, cassava, and potatoes. Minor tuber crops include this plant, taro and tannia. These tuber crops, potatoes, account for a large portion of global production, while cassava and sweet potatoes are the most widely cultivated crops in India (Prakash et al. 2020). Cultivated starchy root and tuber crops are the world's second-most important source of carbohydrates, after cereals. They contribute significantly to the global food supply and are a major source of processed goods for both industrial and human usage, as well as animal feed.The Konkan region is somewhat blessed with soil and climatic conditions. The temperature in Konkan not crosses 35ºC to 36ºC with an average humidity of 50% around the year. The average rainfall is ranging from 2500 to 4000 mm and soils are high percolative. (Bhagwat et al. 2023).

2 Different types of tuber crops under coastal climatic conditions

2.1 Sweet potato

A crop that contributes significantly to global food security, sweet potatoes are grown on 8 million hectares and yield an estimated 106 million tons of yield annually. (FAO, 2016). This ranks third in important among root crops globally, after cassava and potatoes. (Naidoo et al., 2016). The Konkan Ashwini sweet potato kind generates large amounts of long, dark purple tubers in a short amount of time (105 days), and it operates best in coastal climates. (Haldavnekar 2005). In South West, the sweet potato needs 22.80 mm of water in the early season and 473.87 mm in the late season. Water is required in both the early and late growth seasons. (Ekanayake and Collins 2004). The highest yield per plant and hectare, as well as the greatest amounts of total, reducing, and non-reducing sugars and starch content in sweet potatoes, were obtained with an application of 75 kg K ha^{-1}, while the highest amount of protein in tubers was produced by 50 kg K ha^{-1} (Rizvi 1982).

2.2 Greater yam

The type of yam that is cultivated the most intensively worldwide is the bigger yam. Its adaptability to non-staking situations and clarity of cultivation make it the popular variety (Neina, 2021). The greater yam variety "Konkan Ghorkand," distributed for the Konkan region by DBSKKV, Dapoli, is a vertical plant that yields 16 t ha^{-1} of round, transparent tubers with a purple tint and attractive taste. (Mhaskar 2013). The technique produced better greater yams and offers an easy and cheap way to grow plants. It also presents an opportunity to reduce the cost of producing greater yams.

2.3 Lesser yam

Most tuber species are cultivated worldwide, particularly in the tropical regions of Asia and Africa. The lesser yam, or *Dioscorea esculenta L.*, is one of the significant yam species grown in Maharashtra's Konkan region. The most significant species that is commercially grown in the tropics is the lesser yam (Dioscorea esculenta L.), although it is mostly produced in South Eastern Asia. The component of the lesser yam that is most economically used is the tuber. Unlike most other yams, the tubers are tiny and typically born in clusters per each plant. 5 to 20 tubers are produced by each plant. Every tuber has rounded ends and is nearly tubular (Onwueme, 1978). It is a significant tuber crop that is produced in the Konkan region of Maharashtra on sloppy or well-drained soil during the Kharif season. In the Konkan region, this yam is known to as Kangar or Kate kanke in susceptible languages. It has a lot of carbs and other beneficial components (Mhaskar et al., 2015).

2.4 Aerial yam

The aerial yam, or the species bulbifera, is a species of yam which is native to Asia and Africa. It is commonly referred to as air potatoes. It is one of the yams that is most popularly consumed worldwide. The aerial bulbs of bitter yam like potatoes, in comparison to normal yam. A freshly developed aerial yam variety called Konkan Kalika (KKVDb-1) has been developed by the D.B.S.K.K.V., Dapoli, Dist. Ratnagiri. It is made available for cultivation in Maharashtra's Konkan region and produces a high marketable output, cooking quality, good taste, and resistance to pests and disease. The bulbs have a pale yellowish flesh color. The enhanced cultivar offers 4–5 tonne/ha production potential. It has been found that aerial yam offers nutritional and medicinal benefits. It has an excessive amount of nutrients, fiber, and protein. They work effectively for conventional traditional medicine. (Onwueme, 1978; Walter, 2010).

2.5 Elephant foot yam

The elephant foot yam is a tropical tuber crop that is reproduced vegetatively. Because of its high net returns, greater shelf life, and production capacity, it is a favorite vegetable in many tasty diets. As such, it has good potential for adoption as a cash generator. The tuber is rich in potassium, phosphorus, calcium, iron, manganese, zinc, antioxidants, and flavonoids in addition to being a high-energy source. Based of the blood-purifying qualities of the tubers, they are used in medications to treat stakes, the condition, sickness, and other stomach issues (Sarkar et al 2024).

2.6 Xanthosoma

Members of the Araceae family of herbaceous crops include the tropical root Xanthosoma sagittifolium (Wada et al., 2021). Because of its resistance to disease and pests, xanthosoma was carried over the Pacific and into Asia, where it reached minor crop status, frequently at the expense of other root crops. (Plucknett, 1976). The corms provide easily digesting starch and are known to contain significant amounts of protein, vitamin C, thiamine, riboflavine, and iron; the cormels are used for human consumption (Offei et al., 2004).

2.7 Cassava

Cassava (Manihot esculentaCrantz.) is a widely grown tuber crop, mainly in tropical regions, supplying and supporting more than 800 million people, mostly in Africa (Muiruri et al 2021). Climate change is predicted to have a major impact on cassava productivity in growing regions of Africa and the world. (Muiruri et al 2021). The drought is predicted to continue and be a challenge for cassava productivity because it will lower tuber output (Muiruri et al 2021).

3. Climate change condition and tuber crop response

Climatic change refers to long-term changes in Earth's climatic system related to human activities such as burning fossil fuels and deforestation. These activities create greenhouse gases, trapping heat and gradually improving global temperatures(Saravanan and Gutam 2023).Since changes in (CO_2) have a major effect on crop output, many studies have specifically examined how different crops respond to (CO_2). Another reason is that human activity has an apparent measurable, and predictable impact on the earth's atmosphere, which is the reason there is an increase in CO_2, ozone, and SO_2. Since the 1960s, there has been sufficient testimony (Keeling et al 1995) Since the amount of carbon dioxide in the atmosphere is rising, and plant scientists have shown time and time again that this increase is probably already responsible for significant increases in the photosynthesis of leaves in C3 species (Sage 1994).

3.1 Photosynthesis

Increasing atmospheric CO_2 affects C3 plants to photo respire less because it increases carboxylation and decreases saturation of the photosynthesis enzyme Rubisco. (Sage 1994). Increased photosynthetic rates are the result of this change as well as the increased CO_2 diffusion differential into the leaves. On the other together, it showed that this effect was not sustained over time in certain cases. There are sometimes reports of reduced photosynthetic capacity in the leaves of C3 plants exposed to increased [CO_2] for extended periods of time. This behaviour, called adaptation or down-regulation of photosynthetic capability, has been the topic of various investigations (Long and Drake 1992, Sage 1994). For the purpose to understand and evaluate the possible impacts of this adaptation on growth and yield, a mechanistic simulation model of potato growth was developed. (Spitters et al., 1986; Schapendonk et al., 1995) was used. 192 F's biochemical model was used to simulate the gross CO_2 assimilation of leaves(Miglietta et al. 1996, Farquhar et al. (1980) and Caemmerer and Farquhar (1981)).

3.2 Development and phenology

The drought, temperature variations in the air, and [CO_2] changes can all have an impact on crop phenology. Crop behaviour might be impacted by the expected increase in [CO_2] in two separate ways. The crop's surface temperature may rise as a result, and higher photosynthetic rates under higher [CO_2] conditions may be attained. A greater reduced-carbon gradient from the leaves to the sink organs and a higher CO_2 gradient from the source to the chloroplast will probably result in better photosynthetic rates. This will result in the sinks filling up more quickly and possibly even early leaf senescence. The primary reason of variations in the surface temperature of a crop growing in elevated CO_2 conditions is the presence of a physiological feedback impact of stomatal conductance on the crop's surface energy balance. It is established that a rise in the inter or substomatal [CO_2] (C_i) is caused by an increase in the external [CO_2]. (Farquhar et al., 1980) and that increased C_i reduces the aperture of the stomatal pores (Morison, 1987). It has been theoretically shown that this physiological response system favors higher crop surface temperatures under most weather situations (Raupach, 1998).

3.3 Biomass and yield

If tuber sink strength is reduced due to a down-regulation of the absorption rate, the beneficial effects of the addition of CO2 on tuber yields may be reduced (Wheeler et al., 1991). Under short-day and low-light conditions, by 27% and 19% under short-day and high-light conditions, by 9% and 9% under long-day (24 h) and low-light conditions, and by 9% and 9% under long-day and high-light conditions, respectively, the addition of CO2 increased tuber yield and total biomass dry weight in this experiment. This demonstrates that the response to enhanced [CO2] was constrained in cases where tuber growth was restricted, whether by longer days that slowed tuber initiation and growth or by higher irradiation (from high light intensity and/or long days). In other studies, yields of carrot and kohlrabi (Sritharan et al 1992, Mortensen 1994, Wheeler et al. 1994) grown with a doubling of [CO2], even though there were substantial interactions between the [CO2] and phosphorus availability.

4 Application of tuber crop in food change

Although their nutritional value, tuber crops have been neglected everywhere in the world. These crops offer a varied diet of energy, vitamins, and nutrients, hence improving food and nutritional security in tribal regions. Of the 30,000 kinds of edible plants found globally, 30 crops provided 90% of the calories used in the human diet. Rural and tribal groups commonly use certain types of tubers and tuber crop products as sources of food (Arutselvan et al 2023).

4.1 Sweet potato

Children's vitamin A status improves with the consumption of 125 g orange-skinned sweet potatoes, which are high in carotenoids; this is especially true in underdeveloped nations. Sweet potato roots contain compounds that may have substantial antioxidant and anticancer properties. Additionally, the phenolic and flavonoid concentrations of sweet potato extracts are closely connected to antioxidant activity (Scott 1992). In addition to having significant levels of nutritional fiber, minerals, and vitamins, sweet potatoes also contain high levels of bioactive compounds including anthocyanin’s and phenolic acids, which contribute to the flesh's color.

Vitamins B, C, E, and K are all present in high concentrations in it and contribute to preserving and treat the body. Sweet potatoes are also high in dietary fiber, vitamins, minerals, and bioactive compounds including anthocyanins and phenolic acids which give the flesh its color. 125 grams of orange-skinned sweet potatoes, rich in carotenoids and improve children's vitamin A level. This is especially true for nations with lower incomes. Using genotypes of orange-fleshed sweet potatoes that give higher yields may improve farmers' economic and nutritional conditions. (Van Jaarsveld et al. 2006).

Bread, biscuits, hotcakes, gruel, noodles, candies, puddings, and other foods can all be made with sweet potato flour. If combined with wheat flour, it can be used to produce bread and chapattis. This flour provides stability to ice creams. In addition to having a high calorie content, sweet potatoes are a good source of dietary protein, vitamins (such as C, B complex, and beta carotene), minerals, and trace elements (Kulshrestha et al. 2018).

4.2 Yams

Yams are usually served boiling, mashed, or in pieces. Usually used in parts for soups and stews, crushed yam can also be cooked and fried into cakes or used as a substance to thicken food. Yam tubers include vitamins such as vitamin E and carotenoids as well as bioactive substances like mucin, which dioscin, allantoin, choline, which polyphenols, and the hypothesis was. (Iwu et al. 1990, Bhandari et al. 2003).

Chemicals found in tubers include vitamin C, a kind of antioxidant that supports the formation of collagen and anti-aging. Healthy eyesight, skin, hair, and bones are supported by the high amounts of protein, fat, carbohydrate, calcium, phosphate, iron, and vitamin A found in yams. Humans frequently consume the nutrient-rich peels from yams. They might also reduce the chance of a nutritional shortage. The yam products also include essential antioxidants that help prevent a variety of diseases. Yam extracts have been shown in numerous studies to have antioxidant, antimicrobial, and hypoglycaemic properties. Yams have the potential to increase the activity of digestive enzymes in the small intestine while promoting the formation of stomach tissue cells (Kelmanson et al. 2000). Yams are high in vitamin C, potassium, manganese, copper, and phytochemicals, among other minerals. Processors' most well-liked yam value-added products include pickles, roasted cubes, deep-fried chips, Payasam, Vada, chutney, cutlet, and pakoda(Ray 2015).

4.3 Aroids

Starch is the most essential component of taro, making up between 73 and 80% of the total. (Njintang et al. 2007). Taro tubers are generally low in protein and fat but high in carbohydrates, fiber, and minerals. About 11% of the protein in taro is made up of albumin, which is high in tyrosine and phenylalanine. Taro protein is high in all essential amino acids but deficient in lysine and histidine. These rhizomes have various beneficial components that are used in the food sector, such as starch, mucilage, and powders. Their ability to function as a thickening and binding agent contributed to their application in food preparation, food pastes, and drinks (Calle et al. 2021).

The production of completely different tuber products including elephant foot yam, Karunai kilangu, and taro, as well as the development of value-added tuber products to increase their potential usage in the food industry as a replacement for traditional forms and carbohydrates (Parvathi et al. 2016).

4.4 Cassava

The cassava root is long and rounded, with a thick, uniform flesh enveloping a separate, difficult, and dark rind that is about 1 mm thick on the outside (Nassar et al. 2008). In addition to having a high starch content, cassava roots also contain substantial amounts of calcium (50 mg/100 g), phosphorus (40 mg/100 g), and vitamin C (25 mg/100 g) (Blagbrough et al. 2010). However, they contain some minerals and protein. A variety of bioactive compounds, such as hydroxycoumarins like this compound, cyanogenic glucosides like linamarin and lotaustralin, noncyanogenic glucosides, terpenoids, and flavonoids, are found in cassava roots. In contrast, cassava leaves offer a respectable amount of protein; they are low in lysine and methionine but high in lysine (Reilly et al. 2004).

Balagopalan et al. (1988) state that cassava is utilized in the production of industrial items, processed meals, and animal feed. Products made from cassava can be used more widely to promote the expansion of rural industries and increase producers', manufacturers', and dealers' profits. In addition, it can help improve the food security of people that grow and prepare their own food (Plucknett et al. 1998).

5 Irrigation and water management practices of tuber crop

Precision irrigation and other modern irrigation technologies are heavily promoting the use of tuber crops as a solution to problems with increasing crop output in the current climate. A potentially helpful tool for effective irrigation management to conserve water and reduce leaching potential is the variable rate irrigation (VRI) technology, an innovative system used in this study that applies varying rates of irrigation amount along the length of the centre pivots based on specific crop water needs, field conditions, and varieties (Hedley et al 2010). Because VRI better regulates soil water in the crop rooting zone, it also contributes to higher crop yields (Perea et al 2018). The current study demonstrated how VRI may be effectively applied to potato irrigation control. This instrument could be used in conjunction with techniques like soil mapping to lower total irrigation application without compromising tuber yield.

For the control of bacterial and fungal diseases in potato crops, such as bacterial ring rot, early dryness, late blight, hollow heart, mold, and others, irrigation management is essential. High levels of humidity that persist throughout the potato crop canopy are beneficial for the germination, growth, reproduction, distribution, and survival of diseases. (Adams 1990). Potato plants need to have adequate water management to prevent being placed in drought conditions because of their shallow root structure, which makes them extremely prone to water stress. (Yamaguchi 1990, Opena 1999, Onder 2005, Ahmadi et al 2011 and Quiroz et al 2012). For sustainable potato production, moisture content in the soil should be maintained above 50% of the total amount of water available (Singh 1969). (Jensen et al. 2010)revealed that the maximum amount of water that might be saved compared to the field's capacity was 30%. (Camargo et al. 2015) suggested that applying 80 to 100% of irrigation requirements helps to achieve high biomass accumulation.

6 Irrigation system of tuber crops

In several experiments, the results of different irrigation techniques—such as furrow, surface drip, subsurface drip, and spray irrigation—under tuber crops varied depending on the local climate and soil conditions (Onder 2005For tuber crops grown in Western climates, surface drip irrigation produced the highest water use efficiency and therefore is indicated. (Onder 2005, Weatherhead 1998). Because spray irrigation reduces water stress, improves nitrogen management, and lowers soil temperature than furrow irrigation, it results in better-looking tubers and a far lower frequency of sugar ends (Trout et al 1974).

The ideal amount of moisture must be present in the plant's roots zone for balanced tuber growth, and this can be achieved with modern irrigation techniques including sprinkler and drip irrigation (Pawar et al., 2002).The primary causes of the tuber crop's increased productivity while using micro-sprinklers are the reduction of nutrient leaching, the impact of whiteflies, and variations in soil moisture in the effective root zone. It was known that whitefly infection was less severe in crops that were watered by drip and furrow as opposed to fields that were irrigated by micro sprinkler systems. With regular irrigation using a micro-sprinkler, the whitefly infection was managed and the leaf canopy was thoroughly cleaned. Apart from that, micro-sprinkler watering might have created an environment that was better, promoting increased yields through improved photosynthesis, root aeration, and plant growth. (Holzapfel et al., 2000). Among different irrigation methods, sprinkler and drip irrigation resulted significantly higher potato tuber yield compared with furrow irrigation.

7 Water requirement of major tuber crops

7.1 Potato

Potato (Solanum tuberosum L.) is a winter crop with a shallow root structure among tuber crops. Tubers' water needs vary depending on a number of variables, including soil, climate, cultural practices, etc. Vegetable water requirements were related to planting dates; early-sown tubers needed 212.5 mm of water, whereas late-sown tubers needed 226.7 mm (Vishnoi et al 2012). In the potato growth cycle, several stages require varying amounts of water. Stolonization, tuberization, and tuber growth are the essential stages. (Begum 2018). Tuber yield is reduced during these crucial times of moisture stress (Iqbal et al 1996). The result from different investigations clearly shows the positive yield response of potato to water management practices during their critical periods of growth.

7.2 Sweet potato

Studies on the water requirements of sweet potato tubers (Ipomoea batatas) also showed that when soil moisture levels were high enough, tuber output increased. Various studies on drought resilience have indicated that sweet potato plants are suitable in locations prone to drought in terms of survival rate, and their leaves are resilient to up to 1.3 MPa of dying pressure (Pushpalatha 2023). The study by showed that the maximum root output resulted when the maximum number of irrigations were combined with a higher dose of fertilizer (Nedunchezhiyan et al 2012). In south-western Nigeria, sweet potatoes are estimated to require 22.80 mm of water in the early season and 473.87 mm in the late season. The study also found that additional irrigation is required all through the early and late growth seasons (Ekanayake 2004).

7.3 Cassava

The species Manihot esculenta Crantz or cassava, is a widely grown tuber crop, especially in tropical regions. For more than eight hundred million people, mostly in Africa, it supplies food and income(Muiruri et al 2021). Because the drought will reduce tuber output, it is predicted that cassava productivity will continue to be reduced (Muiruri et al 2021). When compared to rainfed crops, crops cultivated under irrigation have yield increases of 150–200%, and furrow irrigation with 25 mm of water at 100 mm CPE is suggested (Kerala Agricultural University 2016). When cassava is irrigated during dry months, the yield increases. A drip irrigation system using 20 mm of water records a two-fold increase in root yield when the daily cumulative pan evaporation value reaches 40 mm (Polthanee 2018).

7.4 Amorphophallus

Elephant foot yam is the common name for the tropical tuber crop Amorphophallus (Amorphophallus paeoniifolius). Its growth is appropriate for medium-textured, well-drained soil that receives 150 cm of yearly rainfall throughout the cropping season (Kerala Agricultural University 2016). Although amophophallus tolerates soil water stress, it is best to avoid it as it might negatively impact yield. It has a greater production capability of 50–80 tha-1, and plant development and corm yield are influenced by water availability (Ravi 2011). The need for irrigation water in tuber crops is critical, and water-smart techniques like mulching and ground cover mats allow the growth of elephant foot yams with less irrigation without compromising corm production. The amorphophallus production varies significantly depending on the amount of fertilizer and irrigation used. The highest corm output (47.66 t ha-1) was recorded when 100% of the prescribed fertilizer dose was applied together with 100% CPE irrigation (Venkatesan et al 2014).

7.5 Taro and Tannia

Important aroids that are grown and eaten as staple or subsistence foods in tropical climates are taro (Colocasia esculenta (L.) Schott.) And tannia (Xanthosoma sagittifolium (L.) Schott.). Popular vegetable taro was cultivated for both medicinal and nutritional uses. Compared to potatoes, it offers 135 calories per 100 grams of food, more than twice as many (Patel 2023). According to research on lowland taro's water requirements and irrigation schedule, drip irrigation at 100% crop evapo-transpiration produced the highest cormel output and water use efficiency, and the plant's ideal water need was 618 mm over the course of six months. Of the edible aroids, Tannariacormels has the largest percentage of starch, and the nutritional value of the leaves is similar to that of spinach (O Hair 1993).

Conclusions

In Maharashtra, the coastal climate is suitable for growing tuber crops like sweet potatoes, greater and lesser yams, elephant foot yams, xanthosoma, aerial yams, and cassava. In the most severe situations involving climatic abnormality, the production technology related to variety development, planting procedure, sensible nutrient management, suitable development, and harvesting can be helpful for the sustained production of tuber crops under coastal agroclimatic conditions.

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