Visiting Sweet Potato from a Breeding Perspective: An Update

Shankar B[1] and Prashant Kaushik[2,3]
1. S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati-517502, Andhra Pradesh.
2. Kikugawa Research Station, Yokohama Ueki, 2265, Kamo, Kikugawa City, Shizuoka 439-0031, Japan; E-Mail: prakau@alumni.upv.es
3. Instituto de Conservación y Mejora de la Agrodiversidad Valenciana, Universitat Politècnica de València, Valencia, Spain
* Correspondence: Prashant Kaushik; E-Mail: prakau@doctor.upv.es

Abstract

Sweet potatoes are a crucial crop for Asian and African countries. Its nutritional content and capacity to keep you healthy have increased in recent years. Moreover, sweet potatoes' fibre also keeps your gut happy. Most sweet potato varieties don't bloom. Due to pollination issues, sweet potatoes are also incompatible with each other. Sweet potato blooms are self-sterile, so they don't mix well in breeding programmes. Traditional and modern breeding procedures didn't always work with sweet potatoes, but some did. Using molecular biology methods, some individuals become more resistant to illnesses by eliminating particular genes. The crop's nature and growth should be improved. All of this should be done to acquire new characteristics in sweet potatoes by crossing them. Sweet potatoes are a superb tuberous crop, but they have issues with pollination and adjusting to new breeding procedures. Modern breeding and biotechnology methods can be used to get the most out of this crop. These are "chronological" ways to get the most out of farming.

Keywords: sweet potato, breeding, genetics, genomics, health

Introduction

A nutritional diet is particularly vital in today's world to prevent numerous diseases such as cancer, diabetes, heart difficulties, mental disorders, and, more recently, the coronavirus. All of these diseases target the body's immune system and leave the person prone to various infections by degrading the overall immunity system in the body, sometimes leading to death [1]. In terms of such diseases, several super foods, such as green and fresh vegetables, various fruits, and dry nuts, are known to boost the body's resilience against a variety of ailments. Many tuberous vegetables are similarly nutritious, and sweet potatoes, which are less well-known, have recently acquired prominence owing to their remarkable health advantages. Although sweet potatoes are the least consumed, least known, and least valued of all vegetable crops, their benefits in promoting increased immunity in humans against a variety of diseases are enormous [2].

Sweet potatoes are members of the Convolvulaceae family, as is morning glory. This sweet potato is a huge, pumpkin-sized, sweet-tasting vegetable that is also known as yams [3]. This plant contains a maximum of 1000 species and more than 50 genera. These plants are valuable in a variety of breeding schemes. Ipomea batatas is the sole significant plant in this species named Ipomea batatas, which is technically followed by Ipomea aquatica called Kang Kong, which is utilised locally [4]. I. batatas is the more important of the two species because of its health advantages and useful qualities. Except for these two species, several other genera are known to be extremely poisonous [5].

The nutritional value of several sweet potato varieties varies. Sweet potatoes are typically found in subtropical climates with mild temperatures. This sweet potato requires a temperature of 25–28 °C for half of its life and a modest rainfall of 110 cm [6]. This plant typically completes its life cycle and is available for harvest 120-130 days after seeding. The seeds are retrieved during blooming and are not used for planting. In general, slips are used to grow sweet potatoes. These seeds are removed from the fruits and used for sprouting. These sprouts are then transferred or transplanted [7].

Sweet potatoes are known to be subjected to a variety of biotic stresses during their brief life cycle, including heat, soil salinity, drought, and chilling temperatures, all of which cause plants to produce lower tuber yields [8]. Along with these, many diseases are known to attack this tuberous crop, such as fusarium wilts and rots, which cause holes in the leaves and reduce food production, ultimately affecting tuber growth. Furthermore, pests such as weevils devastate the crop by attacking the leaves and subterranean rhizomes. As a result, despite being subjected to both biotic and abiotic stressors, this crop exhibits some resistance to specific stresses up to a certain degree [9].

Many of the nutritional components in sweet potatoes are particularly advantageous to human health, such as strengthening immunity and increasing brain function [10]. This crop is also known to improve eyesight and lessen blindness because of its high B-carotene content. Sweet potatoes are also believed to offer cancer-fighting effects and increase muscular stiffness, which makes a person stronger. Aside from that, sweet potatoes are known to contain a variety of nutritional qualities, including the highest quantities of Vitamin A, C, and K when consumed in the appropriate form. Sweet potatoes are also an excellent source of nourishment since they include a variety of minerals, dietary fibres, essential proteins and fats, and other nutrients [11].

Because of these health benefits and advantages, these crops are developed in various ways to minimise pest and disease incidence [12]. In addition, many sweet potato varieties are designed to decrease the impact of biotic stressors, resulting in maximum yields. In addition, thanks to plant breeding techniques, colourful sweet potatoes were also available on the market [13]. There are several sequencing techniques available today, such as Illumina sequencing, which is used to detect viruses and their antibodies, which may then be synthesised prior to a viral assault. When a plant exhibits an immunological response to a specific illness, this strategy assists it in avoiding the greatest losses caused by that disease [14]. Several biotechnological methods were also used, including gene sequencing, herbicide resistance, and gene cloning. Most importantly, virus-resistant plants are being developed through genetic engineering, making these plants more resistant to biotic and abiotic stresses [15, 16].

This study covers all of the information on sweet potatoes, their applications and value as daily sustenance, plant breeding strategies, as well as various biotechnological features and sequencing approaches for improving the growth and yield aspects of this nutrient-rich tuberous crop. All information on this crop is carefully gathered in order to offer breeders, farmers, and the general public knowledge about its uses and importance in order to encourage the increasing growth and consumption of sweet potatoes.

2. Taxonomy

There are almost 400 different varieties in sweet potato so far. Although many varieties of sweet potato are edible but many are not to be chosen on table. These are tubers of high economic and nutritional importance[17].

Table 1: Varieties of sweet potato and their ploidy levels[18]

Varieties	Origin	Ploidy level
Ipomea ramosissima	Columbia	2x
Ipomea tabascana	Mexico	4x
Ipomea tiliacea	Mexico	4x
Ipomea trifida	South America	2x,4x, 6x

Ipomea batatas	Central America	4x, 6x

Many are the varieties in sweet potato with different ploidy levels and belongs to different origins. Out of all the important varieties in sweet potato *Ipomea tiliaceae* and *Ipomea tabascana* are very old and wild relatives. These varieties are not much selected for consumption and are also known for less or no flower.

3. Origin and Evolution:

Ipomea batatas is the main edible variety out of all the other species which is originated from Central or South America. This crop is being domesticated for about 5000 years in Mexico[19]. Also, *Ipomea trifida* which is a diploid species also the closest relative of Ipomea batatas was obtained from a cross between *I. littoralis* (tetraploid) and *I. leucantha* (diploid) parents. Based on the cytogenetical study it was assumed that *I. littoralis* (4x*), I. trifida*-(3x)-6x, *I. trifida* (6x) and I. batatas (6x), sweet potato, are autoploids derived from the doubling of a set of 15 chromosome pairs (genome B) of *I. leucantha* (2x) than from segmental alloploidy [20].

This crop was most common to many countries for preparing several cuisines and also for its several health benefits. Also, this crop was observed in a very old caves of chilaca canyon, south central to Peru in a radiocarbon dating technique in which it was noted to be around 8000 years of age. This makes a complete sense regarding the usage and the importance of the crop for its benefits from a very old time[25].

Though these species are originated in South and Central America these species are known to spread all over the world even extending to the Caribana due to the increase in the usage and it nutritional advantages. Also, from America this crop was known to be extended towards the inner parts of Europe, Asia, and some parts of China. By the end of 16^{th} century sweet potato was almost in every part of the world and is used in different ways like curries, baked, fries, bakeries and sweet dishes[26].

In Philippines the cultivation of sweet potato has increased tremendously making it one of the most important dishes in that place. Also in Japan sweet potato was the only staple food there during the tough famine times. Also, in Seoul sweet potato was cultivated, domesticated and improved with many nutritional qualities after learning about its importance for health and wellbeing[27]. Especially in India almost every part of the country enjoys the savoury and curries of sweet potato. This can be served as a snack either by boiling them or frying, Therefore, sweet potato is a very important, nutritional tuberous crop with many health benefits and ease of digestion[28].

4. Domestication of Sweet potato

Sweet potatoes (*Ipomoea batatas*) are root plants, maybe first domesticated somewhere between the Orinoco River in North Venezuela and the Yucatan Peninsula in Mexico. The oldest forms of sweet potatoes were found in Peru about 200 BC. Sweet potato remains were also discovered in Polynesia at the end of the 15th century on Cook's Island, Hawaii, and the eastern islands. Many countries, like Europe and Africa, started the domestication of *Ipomoea trifida* in 1500 BC. Sweet potato cultivation began in well-known Asian countries such as China at the end of the 16th century, and it has since been domesticated. Also, the pollen, phytoliths, and many residues were obtained in South Auckland at the end of the 16th century [29]. Many other parts of the world, including Middle Eastern countries, domesticated the highly yielding and available sweet potatoes.

Also, in India, these sweet potatoes were cultivated and domesticated some 5000 years ago. I. batatas was the most common cultivar used in almost every part of the world, including India

[30]. It was also believed that these sweet potatoes were transmitted to different countries through people, animals, and birds. Primarily, the Portuguese and Spanish people started the transmission of this sweet potato towards Europe. Also, the seeds of sweet potatoes were transmitted from the south coast across the Pacific by Golden Plover birds as a natural transmission method [31].

Many scientists believe that this transfer of seed materials and pollen from one place to another through birds or by sailors across the coast of the Pacific is the main evidence for the spread of sweet potatoes across the world and their increase in cultivation. Also, this pollen transfer, which has been evidential and useful in promoting mating between different types of species, may result in a new hybrid variety with improved characteristics. All this understanding and this habitual cultivation in different parts of the world makes sweet potatoes a very important tuberous crop with multiple nutrients beneficial for the human body. This could be the strong reason for the adaptation of this crop in many areas around the world and in preparing several cuisines, making this crop the most useful and ever-developing tuberous crop in the world [32].

5. Floral Biology

Sweet potato flowers are commonly seen in the Pacific islands, many other tropical countries, and a few temperate regions. These flowers grow and are typically white to pinkish in colour and faded in appearance. In temperature regions where the climatic conditions are unsuitable for flowering and seed formation, grafting or girdling is usually used instead of flowering and seed formation. Also, the seeds obtained from the flowers take a long time to germinate and undergo dormancy, especially in temperature regions. These issues are uncommon in tropical regions where sweet potatoes are grown [33]. The flowering of this tuberous crop is not common in all the cultivars and has been observed in very few cultivars. The inflorescence observed was Cyme, which is again divided into two axillary peduncles, each of which bears flowers. But this is not always observed in all the varieties where single flowers are also formed. The joining of flower buds to the pendule is called a pedicel, which is the thick part of the stem and very short. All the three flowers, pedicel and peduncle, differ in size and colour, from green to a purple-pinkish colour [34].

Table 2: Sweet potato inflorescence details[35]

Parts of flower	Types
Inflorescence	Cyme
Flower	Bisexual
Calyx	Contains 5 sepals, 2 outer and 3 inner, that stay attached to the floral axis
Corolla	Contains 5 petals that are fused forming a funnel, generally with lilac or pale purple limb and with reddish to purple coloured. Some flowers are white in colour too.
Androecium	Contains five stamens with filaments that are covered with glandular hairs and that are partly fused to the corolla.
Gynoecium	Contains superior ovary, two carpels, two locules and two ovules, short style.

Fruits	Capsule, which turns brown when matured. Sometimes fruits are hairy.
Seeds	One or four seeds in each capsule, endosperm protected by thick and hard Testa.
Storage root	Adventitious roots.

The bloom is normally bisexual in all sweet potato varieties; however the colours range from pink to pale. These blooms have five sepals and five petals (Table 2) and are grouped in whorls, with the sepals remaining connected to the pedicel even after the petals fall off during maturity. The 5 stamens are placed around the style, which is in the centre of the flower. However, these flowers are self-sterile, which means that pollen from the same bloom does not fertilise the ovary of the same flower. The fruits are known as tubers, which are edible in a variety of cuisines, and the seeds obtained are difficult to grow in natural habitats for a variety of reasons. Scarification is required for these seeds to germinate. Furthermore, the vitality of the seeds lasts for many years. The storage root is a regular flattened, thick adventitious root that is commonly taken as a tuber but is correctly preserved for cultivar propagation and is produced as a mother stem (Table 2).

6. Pollination

Pollination is a difficult task in the case of sweet potatoes, where self-pollination is not possible due to the self-fertile nature of the plants, whereas cross-pollination is not encouraged as it causes cross-incompatibility in the varieties. For these very reasons, the selfing of the flower is highly difficult and the pollination should be done by another flower from other plants or from another variety [36]. To avoid many issues like varietal mixing, cross incompatibilities, and many other crossing problems, hand pollination is more commonly employed in sweet potato for hybrid production. Proper care and precautions were taken before and after hand pollination of sweet potato flowers. Insect pollination, air, tools, and many other modes of pollination are avoided in sweet potato by bagging the plants before the receptive stage of the stigma. In general, the stigmas of these flowers are receptive in the early hours of the morning [37]. Therefore, hand pollination is the best and best option for combinations of characters in sweet potatoes, which is a method employed in plant breeding. Most of the sweet potatoes were cultivated by root cuttings, stem cuttings, grafting, etc. to avoid all the possible problems caused by cross pollination and to maintain the purity of the variety [38].

7. Wild relatives of the sweet potato

Sweet potatoes are well known for their multiple advantages, like medicinal leaves, tuberous roots, and beautiful flowers, that offer many health benefits when consumed. In the olden days, very few cultivars were known that were of old type and were propagated only through grafting or through adventitious storage roots. But due to the increase in economic importance and cultivation in many areas, domestication is well adapted along with the production of new cultivars [39]. There are almost 7000 different cultivars of sweet potato and nearly 400 varieties obtained through breeding programs. All these species are unique in their characteristics and economic importance. whereas only 13 wild relatives are found in Ipomea batatas, 12 of which are found in South America and Mexico, with the exception of I. littoralis, which is often referred to as an old-world species [40]. Also, *Ipomea trifiida* was known as the closest wild relative of I. batatas, which is still being used for cultivation with improved genetic characteristics. There are many other wild relatives of sweet potatoes that have been proven to have adapted characteristics through several plant breeding techniques. These wild relatives usually act as diverse gene pools which contain many useful traits [41].

Many wild relatives are sometimes crossed with normal cultivated species in order to attain resistance against certain diseases and stresses. It was observed that *I. trifiida* was known for its resistance to biotic and abiotic stresses and is considered a model plant for the present cultivated species like *I. batatas*. Also, *I. littoralis* is a wild relative that contains certain characters like resistance against biotic stresses, especially drought and heat stress. Therefore, these varieties are sometimes crossed in order to attain resistance against certain stresses. In addition, many other wild relatives of sweet potatoes were widely used in plant breeding programmes to obtain advantageous characteristics. Certain South American wild species were known to have higher nutritional qualities than modern cultivars, allowing the importance of wild relatives to be studied and understood. Moreover, proper study of the wild relatives paves the way for promoting breeding methods in order to improve the required qualities in present-day cultivars as well as wild relatives [42].

8. Fertility issues in sweet potato breeding

Many factors affect the fertility issues in sweet potato cultivars, which are caused by the variety itself, ploidy level, genome constitution, mutations and many other reasons in plants. Some important reasons, like environmental issues, soil status, plant breeding methods, different stresses, etc., also affect the growth and fertile conditions in plants that promote varietal formation and hybrids that are of improved quality [43]. Certain stresses have an effect on sex determination, reproductive organ formations, storage organ production, fruit ripening, rooting, senescence, and other important metabolic processes in plants, which ultimately affect pollen formation and fertilization. In case of sweet potatoes, where the flowers are self-sterile, self-pollination is highly unlikely.

Whereas the flowers should be fertilised with the pollen from other flowers of another plant or another species in order to attain proper availability of characteristics in the progeny [44]. Often, sometimes in sweet potato, cross pollination through natural means is avoided in order to protect the crop from cross incompatibility and mixing of unwanted characters. Therefore, under such circumstances, usually hand pollination is done in order to reduce the unwanted traits in the progeny. Added to this, there is one more disadvantage in which the flowers of sweet potato open early in the morning and the pollen shed occurs after anthesis, which is also a hindrance for selfing [45]. Certain species like *I. trifiida* and *I. littoralis*, which were considered model plants for sweet potato breeding, were crossed in order to obtain new characteristics compared to other available varieties in sweet potato breeding.

Also, crosses between diploid varieties of sweet potatoes and tetraploid varieties didn't give many beneficial characteristics for the breeding. But when diploid is crossed with a hexaploid cultivar of sweet potato, the results were very small compared to the previous cross. According to this, present-day cultivars are known to give good yields and characteristics in offspring compared to their wild relatives [46]. Crosses between *I. batata*s and *I. purpurea*, which are present-day cultivars, gave good results compared to the involvement of wild relatives. Therefore, it was concluded that crossing is quite a difficult task in sweet potatoes due to their self-incompatibility issues.

Also, it is more important to follow certain breeding techniques to attain new varieties of sweet potatoes. Although crosses between present-day cultivars and wild relatives did not show much improvement in the fertility of the plants, certain important characteristics like tolerance and resistance against certain stresses were achieved [47]. The use of wild relatives in breeding has been shown to improve plant nutritional qualities, resistance to certain stresses, and the characteristics of their offspring.

Since fertilisation is the major obstacle to sweet potato cultivation, many parts of the world cultivate this crop through vegetative propagation rather than seeding. Seed production is extremely difficult, if not impossible, in new varieties that have been previously crossed to obtain useful characteristics. grafting, storage root, and girdling were the methods most commonly used in sweet potatoes due to their incompatibility in fertilisation and production of new and improved varieties. To lower the fertility barriers in sweet potatoes, many breeding programmes were carried out in order to increase the resistance against many stresses. Also, many breeding programmes were conducted to maintain the nutritional qualities of the cultivars due to improper fertilisation [48]. Therefore, in sweet potatoes, hand pollination through improved breeding programmes is the only method to achieve important characters from other cultivars which are grown. Seeds were collected and trails were conducted in order to observe the improvement in the progeny [48].

9. Compatibility issues

This is a major problem in sweet potatoes, as they are self-sterile and cannot pollinate themselves. Unilateral incompatibility indicates the blockage of the pollen tube in the style, stigma, or ovary. This can be due to self-incompatibility, cross-incompatibility, or interspecific incompatibility in general. But in the case of sweet potatoes, the cross between two identical cultivars was not 100% successful due to self-sterility, which leads to unilateral incompatibility [49]. It was also observed that the mating between two different cultivars of sweet potatoes in opposite or reciprocal directions was not possible and showed incompatibility where the pollen tubes were obstructed in the styles of the flowers and did not reach the ovary. Even when pollen tubes reach the ovary, fertilisation does not always occur due to incompatibility [50].

Many are the reasons for incompatibility in sweet potatoes, which can be due to the selection of incompatible parents, improper crossing procedures, breeding techniques, etc., which would affect the plants and avoid fertilisation. The incompatibility system in sweet potatoes is still under study and not understood completely till now. Although there are many other crops that are self-incompatible like sweet potatoes, which include tobacco, solanum species, and petunia, they show incompatibility in many cases as the crosses between the already fertilised flower and the male parent [49,50].

Several other crops similar to sweet potatoes show self-incompatibility not because of any environmental issue but due to genetic divergence. It is quite well understood that this unilateral incompatibility is quite common in crops that are unable to fertilise themselves and depend upon pollen from other cultivars. It was also observed that this incompatibility occurs due to different morphological, genetic, physiological, and biochemical barriers in plants. Also, this incompatibility is supported by the genotype of the sporophytic tissue from which the pollen was obtained. Also, for several other reasons, like the interactions between pollen and stigma, pollen and style, and pollen and ovary interactions, the compatibility between the plants is known to be affected [51].

Therefore, sweet potatoes were highly proven to be unilaterally incompatible as one cross is more fertile than the reciprocal cross with the same varieties. It was also observed that the mating was highly compatible only in one direction and was very low or non-compatible in the opposite direction. This unilateral incompatibility, especially in sweet potatoes, can be explained by [52] promoting out-breeding and new gene combinations. Reduces homozygosity Checking for normal seed set even after cross pollination transfer of required characters through cross-pollination Selection of superior-quality parents is possible. Although many are the reasons for understanding unilateral compatibility in sweet potatoes, a few techniques help in overcoming this problem in sweet potatoes as well as other plants.

Certain plant breeding techniques like mixed pollination, intra-ovarian pollination, test-tube pollination, treatment with chemicals, treating styles of female plants with heat, etc., are used so far in many plants, but very few are successful in the case of sweet potato due to its less adaptation. The techniques employed to overcome incompatibility are to promote crossbreeding or outcrossing for seed setting for the development of new and improved varieties [53]. In general, this sweet potato does not need any sort of these techniques if cultivated through vegetative propagation methods. Therefore, sweet potato, which is a very nutritious tuberous plant with many health benefits, is highly incompatible and was also observed to be unilaterally incompatible since several outcross programmes were conducted for seed setting and a few methods like grafting and vegetative propagation were employed for easy cultivation and growth [54].

10. Breeding behaviour of sweet potatoes from conventional to new breeding technologies

Proper breeding and following breeding procedures on a long run-in sweet potatoes is quite difficult due to their genetic make-up and the type of pollination they receive. Because there were so many cultivars and ploidy levels in sweet potatoes, breeding programmes could be risky in terms of yielding fruitful results.For any breeding programme to be successful, the plant must be self-pollinated and should be adaptable to cross-pollination as well. But in the case of sweet potatoes, selfing is not possible to self-sterility and cross pollination sometimes leads to incompatibility, which does not produce any hybrids.

Therefore, proper breeding, trails, and observation of the hybrids is a difficult task and needs a lot of improvement to develop many cultivars that are suitable for growth and cultivation [55]. Many of the breeding procedures that were carried out for sweet potato breeding were successful, but not all due to improper fertilisation in sweet potatoes. Most of the sweet potato varieties produce few flowers or no flowers at all, which leads to a lack of genetic variability due to the lack of proper pollination in sweet potatoes. Also, there are many other problems involved in sweet potatoes, like increasing nutrient content, stress escape, yield content, etc. Many breeding procedures were employed, both conventional methods and new breeding methods, that were aimed at improving the quality and development of new varieties of sweet potatoes [56].

To initiate the breeding procedures in sweet potatoes, proper selection of parents is the first and most important step. The parents that were suitable for the breeding programme and showed less incompatibility and were highly adaptive to any environmental conditions were to be selected. After this, the selection of parents for crossing is to be done in order to observe the genetic diversity and also to increase the genetic resources [57]. After crossing, certain outcrosses were also to be conducted to check the ability of the sweet potato cultivars with other varieties. This selection of parents and just making a few crosses to obtain the seed comes under the new breeding methods of fertilisation in sweet potatoes. To achieve this outcross in the proper way, hand pollination is employed so that the compatible and targeted pollen will be used for pollination. If not handled properly, hand pollination requires a lot of attention and care. If not handled properly, mixed crosses would result in cross incompatibility in sweet potatoes [59].

Many modern techniques in biotechnology and molecular biology like genome sequencing and gene editing would be preferable as these techniques involve a complete understanding of the genomes of sweet potatoes. Although the sweet potato genome size is large, nearly about 1.6 Gb, and is very complex in understanding, proper care should be taken in order to analyse the genomes of different sweet potato cultivars as they vary in their genome sizes and their ploidy levels. Also, genome editing has gained much importance in recent years to eliminate unwanted segments of a gene, which could also be employed in sweet potatoes to eliminate disease-causing genes and viral genomes [57].]

The most important genome editing tool, called CRISPR/CAS, has gained much importance in recent years in identifying and eliminating unwanted segments of the gene in the entire sweet potato genome. Therefore, not only conventional and plant breeding methods, which are highly time-consuming, but certain biotechnological procedures can also be employed in order to reduce the time and effort in developing the genomes of sweet potatoes [56,57]. New breeding methods that were successful old methods of breeding like collection, evaluation, and selection of germplasm are not very useful as they do not involve the identification of new genes and outcrossing will be very difficult due to certain molecular biology techniques that could be employed in order to understand the nature of genes [59].

Therefore, it is understood that sweet potato breeding is multifaceted, and it is very complex to acquire the required characters from different cultivars while dealing with incompatibilities. Many countries were working hard to improve the nutritional qualities of sweet potatoes and make cross pollination easier. Furthermore, few companies in America were testing flowering varieties so that seeds could be developed and used easily. Therefore, plant breeding through conventional or new methods is quite a task in sweet potatoes due to their ploidy levels and pollination issues [60].

11. Nutritional Benefits of sweet potatoes:

Many are the health benefits involved in sweet potatoes which include high minerals, nutrients and many more. Sweet potatoes are rich in fibre, potassium, manganese and copper which are required in little amounts for proper functioning of human body[61]. Also, sweet potatoes are well known for high vitamin content especially Vitamin C, Vitamin B6, B5, B3 etc. Along with this another important compound called B-carotene was obtained from sweet potatoes which is a very important compound for improving eye sight. Apart from eye sight B-carotene was known to provide several other benefits on consumption of sweet potatoes[62].

Table 3: Nutrition composition per 100 gms of sweet potatoes:[63]

Type	Amount
Water	80%
Proteins	1.5gms
Calories	85%
Carbohydrates	21gms
Sugars	4.5gms

Fiber	3.5gms
Fats	0.5gms

Many were the improved nutritional factors present in sweet potatoes like fats, fibers, carbs and calories etc., (Table 3.). Out of all the factors calories occupies the maximum amount nearly about 85%, followed by water about 80%. With respect to carbohydrates sweet potato contain 21 gms in 100 gms which should be a check and also other factors like fibers are in needed amount like 3.5 gms which is of good value and is very useful for human body. Therefore, proper intake in required quantities is very much important regarding sweet potato.

12. Uses of B-carotene:

B-carotene has several advantages in the human body if taken under prescribed quantities, which will be highly beneficial in promoting a good immune system, good vision, and aid in improving the body's defence mechanism against severe stresses. Along with these benefits, B-carotene is known to improve the quality of skin, making it very healthy as well as improving the functioning of the mucous membranes. Although taking high doses of vitamin A through B-carotene might be toxic sometimes, the body uses the required quantity, and the rest is unused [64]. Therefore, many of the advantages of consuming sweet potatoes not only in improving eyesight but also in maintaining the body's health condition and protecting humans from many diseases. Even though this plant has many advantages for consumption and is well known in different parts of the world, due to its improper pollination, the development or generation of new varieties is not possible. Therefore, with the help of a few plant breeding techniques and molecular biology aspects, new genes were discovered in sweet potatoes, thereby resulting in the development of highly useful varieties with regard to yield, adaptation, and most importantly, improved nutritional benefits. Considering all these qualities, sweet potatoes can be consumed in a small quantity every day for proper body functioning [65].

13. Conclusion and prospects for the future directions

Without a doubt, sweet potato is a wonderful crop that belongs to the Convolvulaceae family, which also includes the famous and beautiful flower known as Morning Glory.This crop has gained much importance recently due to its important nutrient qualities and useful properties for maintaining good health. Even though this crop was not widely grown in the past, it has become an important part of the menu in almost all restaurants around the world. The nutritional benefits and certain therapeutic properties make this plant very useful for human consumption. Also, the fibre content in this makes the gut happy, which is also a major advantage of sweet potato consumption. In ancient India, sweet potatoes were used as a low-carb diet for weight loss and packed with energy.

A very small consumption of sweet potatoes a day gives nearly 400–500% of the Vitamin A that we need for a daily dosage. Also, this plant helps in the body's defence mechanism and maintains the health of bones. Similarly, heart problems, kidney and liver issues are all at bay with a little consumption of sweet potatoes. As we know, "too much of anything is bad." Therefore, the increased consumption of this tuber increases the risk of diabetes and stone formation in the kidneys. Due to this, the requirement for a little consumption of sweet potatoes per day helps in maintaining and balancing many important functions of the human body. Though there are several advantages to sweet potato consumption, there are certainly many disadvantages, like pollination. The majority of sweet potato cultivars produce very small flowers or do not produce any at all. Also, pollination is quite a problem in sweet potatoes, causing self-incompatibility and cross incompatibility as well. Apparently, this incompatibility in the flowers of this tuber crop due to their self-sterility poses many problems in breeding programmes of sweet potatoes.

Not all the conventional methods and new breeding techniques used for sweet potatoes were successful. Also, a few molecular biology techniques were helpful in promoting certain resistance by gene elimination against diseases. More focus should be diverted towards the improvement of the characteristics and development of this crop. Along with this outcrossing, the sources of outcross should also be increased in order to obtain new characters in sweet potatoes. Though sweet potato is a wonderful tuberous crop with certain disadvantages like improper pollination and adaptation to new breeding techniques, nevertheless, this crop can be upgraded by following certain advanced breeding procedures and biotechnological methods to gain maximum benefits from this crop.

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