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Chapter

Visiting Potato from a Breeding Perspective: Accomplishments and Prospects

Navjot Singh Brar, Sat Pal Sharma and Prashant Kaushik

Abstract

Several enhancements to the conventional potato breeding are possible though they have encouragement as well as limitations. I n this direction, the marker-assisted selection may be utilized to stack major genes as well as QTLs. Whereas the genetic transformation and genome editing methods accelerate the process of ricking of genes/transgenes. Moreover, these methodologies supplemented with the next-generation sequencing (NGS) platforms and pipelines further aid in reaching the potato ideotype. Here, we overviewed the critical topics that are related to potatoes, from general background, breeding behavior, breeding approaches employed to the potato improvement. Overall, this information complied might serve as background information that is important for potato breeders.

Keywords: Potato, varieties, heterosis, heterosis, polyploidy, wild relatives

1. Introduction

Potato is among the most important food staples that rank overall fourth after cereals (maize, wheat and rice), belonging to one of the largest genus Solanum (over 1500 species) of family Solanaceae [1, 2]. Solanaceae family comprises of about 90 genera consisting of 3000–4000 species. Potato offers a considerable component of the world's food source. From unknown until the sixteenth century in the six following centuries, potato cultivation had spread from its centre of origin, in South America into the rest of the world [3, 4]. The genetic diversity is harboured in wild relatives and landraces considered to be valuable sources of deviation for genetic enhancement and crop improvement because the genetic foundation of the modern cultivated potato is quite narrow [5]. At present, the collected developed to guarantee the long-term upkeep of potato hereditary resources and reaffirms the benefits of potato genetic resources [3]. Collaboration between potato researchers and gene bank curators promotes the utilization of the genetic resources [6].

Moreover, there are over 5000 cultivar varieties of potato-based on its size, color, shape, texture, flavor, taste, storage quality and cooking quality [7]. These varieties are differing in physiochemical properties (carotenoids and ascorbic acid content) because of the location, agronomy practices, climatic and degree of stress conditions of that area [8, 9]. The potato crop is affordable (the poorest and most undernourished households can afford), high in quality nutrients (potential high food security crop), matures rapidly (4–6 months), need moderate care (irrigation at an interval of 6–7 days), easy to cook, protect itself against microbes (impermeable to gases,

water and chemicals), feed entire populations from hunger (high food security crop), easy to digest (quick breakdown with high glycemic index), used for some byproducts production (starch and alcohol) and also consumed by the animal as fodder [10]. Potato has high dietary fibers, magnesium, manganese, potassium, phosphorus, amino acids, proteins, carbohydrates, minerals, moisture, starch content, vitamins (Vit-C, B_6) as well as other antioxidants like polyphenols and carotenoids and low in fats [11, 12].

Worldwide, economic losses occur in potato because of diseases like late blight although these diseases are controlled by regular application of fungicides [13, 14]. Recent improvement in next-generation sequencing (NGS) technologies has resulted in a major reduction in the sequencing costs that makes genotyping with NGS systems cheaper and achievable [15]. Massive genotyping of the gene bank collections as well as posting the info will be a strategy to show the prospective utilization of germplasm collections in gene banks. Some gene banks have started distribution of germplasm collections together with all the genotyping information by NGS datasets [16]. NGS technologies are particularly helpful in the taxonomy that depends considerably on the herbarium specimen conceived from wild plants from the wild [17]. In this review, we have gathered the information from the general background, breeding behaviour, conventional breeding, genetic engineering to NGS methodologies employed to the potato improvement. This information is going to be a useful resource for potato breeders, offering information about the development made and prospects of reading a potato ideotype.

2. Taxonomy

S. tuberosum further diverges into two subspecies:

a. *andigena*: It is a diploid grown mainly in the Central and South American regions and is adapted to short day conditions.

b. *tuberosum*: It is a tetraploid potato with worldwide cultivation [18–20]. A general belief is that the subspecies *tuberosum* has descended from subspecies *andigena* introduced to Europe that later adapted to longer day lengths [21].

The section Petota is splits in to 8 cultivated and 228 wild species of potato, which are further grouped into 21 taxonomic series (19 tuber bearing+2 non-tuberous) [22]. Out of the cultivated species, only *S. tuberosum* ssp. *tuberosum* is extensively cultivated all around the globe, while others are cultivated especially in the Andean nations.

Sr No	Solanum species	Chromosome number	Ploidy level
1	*Solanum ajanhuiri* *Solanum goniocalyx* *Solanum phureja* *Solanum stenotomum*	2n = 2x = 24	Diploid
2	*Solanum chaucha* *Solanum juzepczukii*	2n = 3x = 36	Triploid
3	*Solanum tuberosum ssp. tuberosum* *Solanum tuberosum ssp. andigena*	2n = 4x = 48	Tetraploid
4	*Solanum curtilobum*	2n = 5x = 60	Pentaploid

3. Origin and evolution

Series *tuberosa* (containing *S. tuberosum*) and other series of subsection *potatoe* have two centres of diversity. One is a long-stretching Andean terrain in Argentina, Bolivia, Colombia, Ecuador, Peru, and Venezuela, while the other is in central Mexico [18, 23–31]. This theory is based on the fact that the plants originally introduced into Europe were late flowering and tuberising, and the morphological description [32]. Such transition can take place in a fairly short period of approximately ten years of selection [33]. An alternative school of thought is that, after the potato blight epidemic in Europe, new germplasm of *S. tuberosum subsp. tuberosum, which* originated from Chile was introduced into Europe [18].

Hawkes [18] and Grun [34] opined that the cultigenic species *S. stenotomum* is the most primitive and progenitor of all other cultivated material. *S. leptophyes* Bitt. has been theorized as the probable progenitor of *S. stenotomum* based on morphological similarity [18]. The first cultivated material of *S. stenotomum*, has also been considered to be domesticated from *S. brevicaule* complex genepool [25, 34–37]. With advent of molecular techniques seven different chloroplast haplotypes were distinguished in a selection of wild and cultivated species [38]. Kardolus et al. [39] revealed that *S. tuberosum* subsp. *tuberosum* forms a cluster with *S. multidissectum* and *S. canasense* in the Brevicaule complex. *S. tuberosum* is believed to be a straight tetraploid of *S. stenotomum* by some workers but some evidence strongly support the allotetraploid origin of *S. tuberosum* [40]. As per another report the cultivated species are in the same clade as the northern Brevicaule clade that consists of *S. bukasovii*, *S. ambosinum*, *S. canasense*, *S. leptophyes*, *S. achacachense* Card. and *S. multidissectum* [41]. Multiple origin from *S. stenotomum* is believed to be cause of rising of initial populations of *S. tuberosum* subsp. *andigena* [42].

To summarize, first diploid cultivated material (*S. stenotomum*) has probably descended from one of the species in the Brevicaule complex. Sexual polyploidization, accompanied by hybridization and human selection led to the development of tetraploid landraces (*S. tuberosum* subsp. *andigenum*). However, there is an absence of sufficient molecular data to point out a particular wild ancestral species.

4. Domestication of potato

Spanish conquerors introduced potato into the European countries by the 16th century [18, 43–46]. There are two competing theories about the nature of the first material to be introduced into Europe. Grun [34] and Hawkes [18] suggested the very first potato material brought to Europe consisted of *S. tuberosum* subsp. *andigena* from the Andes, quite probably from Colombia. The late blight epidemic in Europe during the 1840s led to the destruction of most of the original stock of potato. In the post epidemic period, new introductions consisted mainly of *S. tuberosum* subsp. *tuberosum.* Whereas Juzepczuk and Bukasov [47] were of the opinion that the subsp. *tuberosum* germplasm from Chile was already a part of early introductions in Europe, as morphology and growing conditions of early European plants and Chilean material bore similarities. Chilean potatoes were suitable for growing in Europe as they were adapted for tuberization under long-day conditions. DNA analysis of the historical herbarium specimens suggested that although Andean potato arrived first but Chilean potato was present long before late blight epidemics in Europe [44].

Introduction of potato to the Bengal floodplains, Nile delta, Morocco and Nigeria was made by European colonizers, colonial governors, missionaries [48, 49].

Emigrant farmers carried the potato to Australia and South America that led to the establishment of the potato in Argentina and Brazil. The tuber spread was along the old Asian routes through the Caucasus to Turkey, and from Russian federation to western China [31].

During the 20th century, potato emerged as a truly global food. After the Second World War, the potato was grown on a huge span of arable land in Germany and Britain, and potato has surpassed cereal production in Belarus and Poland. Since 1960s, cultivation of potato has been expanding in the ever-developing world [50, 51], it is grown as a cash crop in Bangladesh.

5. Floral biology

Potato inflorescence is terminal comprising 1–30 (but usually 7–15) flowers, depending on the type of cultivar [52–55]. The inflorescence is cymose, and flowers are actinomorphic and hypogynous. Arrangement of floral parts is regular. Five petal arrangement of the flower gives it a star shape [56]. Depending upon the cultivar, shape and size of lobes of sepals vary. The androecium comprises of five stamens alternating with the petals. The anthers collectively form a cone shaped structure to conceal the ovary [55]. Anthers are bright yellow or orange coloured except in case of male sterile plants in which the colour of anthers is light yellow or yellow green [57]. The ovary is superior and bilocular with ovules arranged at the periphery of the placenta.

Details of the *S. tuberosum* inflorescence are given below:

Inflorescence	**Solitoryor cymose**
Flower	Bisexual, actinomorphic
Calyx	Sepals five, united, persistent valvate aestivation
Corolla	Petals five, united, velvate aestivation
Androecium	Stamens five, epipetalous
Gynoecium	Bicarpellary syncarpoes, ovary superior bilocular, placenta with many vacuoles
Fruits	Berry or capsule
Seeds	Many, endospermous

Colour of the corolla varies from white to complex range of blue, red, and purple [53]. Opening of flowers start near the base of the inflorescence and proceed upward at the rate of about 2–3 flowers each day [54]. Long day length accompanied by high humidity and low temperature are conducive for potato flowering [57, 58]. Flower production and berry setting is favoured by 12–14-hour photoperiod and night temperature of 12-15°C [59, 60]. Short day duration at the time of flowering may result in abscission of floral bud [58]. Flower and fruit production in potato is influenced by several factors such as genotype, temperature, photoperiod, inflorescence position, plant/stem density, competition between flower and tuber, precipitation, date of planting and nutrient level [61–65]. Flowers remain open for 2–4 days, and out of this duration, pollen production and stigma remains receptive for about 2 days [57]. The fruit type is a berry, and are spherical to ovoid in shape, about 14 cm in diameter. Berries are green in colour or green-tinged, and upon ripening bear white or purple spots or bands [53, 66].

Floral bud abscission occurs in case of short days at the time of flowering, hence giving the impression of poor flowering of a cultivar [58]. Thus, conditions favourable for flowering and fruiting in tropics and subtropics can be found at higher altitudes (1500 m above sea level) [67]. Characteristics like days to flowering, flowering duration, the intensity of flowering and fruit set have wide genetic diversity [60]. A survey on flowering behaviour, male sterility and berry set was conducted across 25 countries by Gopal [67]. Flowering initiated after 6–15 weeks of planting and duration of flowering ranged from 1 to 10 weeks. The setting of berries ranged from 0 to more than 5 berries/plant, while there no setting in 31.8% of accessions in blooming. Production of flowers and fruits is influenced by several factors like temperature, photoperiod, genotype, inflorescence position, plant/stem density, flower and tuber competition, precipitation, date of planting and nutrient level [61–65]. The number of primary flowers increased with increase in plant density while the proportion of flowers on lateral stems reduced [62].

6. Pollination

Potato is predominantly a self-pollinated plant and is occasionally cross-pollinated [54, 56]. Generally, diploid wild species are insect-pollinated and cross-breeding in nature. Presence of insects is imperative in facilitating cross-breeding and selfing in potato. Bumblebee species like *Bombus terricola* and *B. impatiens* are particularly good pollinators for potatoes [68, 69]. European honey bee (*Apis mellifera*) and *B. fervidus* do not contribute to the pollination of potato, as the flowers are devoid of nectar [70]. Despite the lack of pollinator resources provided by the crop, a great diversity of bees was recorded in a potato-dominated agroecosystem [71]. Wind does not play any role in the pollination of potato, and no seed set was observed [68]. There are no detailed studies of pollination behavior of potato in India. Controlled pollination can be achieved under field or greenhouse. However, crosses made under the field conditions are prone to losses from the environmental factors like wind, rain, heat and drought. Therefore, breeders prefer crossing in the greenhouse. The crossing should preferably be done during the early morning hours when the temperature is moderate [54].

7. Wild relatives of potato

Comprehensive taxonomic treatment by Hawkes [18] found there are 235 potato species in total, 228 outdoors and 7 cultivated potato species. Various studies, implementing advanced molecular resources with a considerable amount of samples covering a broad range of species have advised that a reconsideration of the taxonomic classification is necessary [72]. As previously, potato species are hugely sophisticated in taxonomic classification. A broad area of distribution, together with an extensive selection of altitudinal division, from sea level up to 4500 MSL, indicates a broad range of adaptation this has resulted in the huge diversity and adaptations in the potatoes [73].

Genetic diversity of the germplasm and usefulness has been the drive to incorporate wild genes into cultivated types. The achievements of the application of wild relatives for genetic improvement relies a great deal on crossability with developed species. The gene pool is essentially the most often used concept determining the level of relatedness between species [74]. Though the genepool concept has been generally accepted, efforts to utilize the genepool concept to the potato was also

presented [75]. Manipulation methods to alter the ploidy level in potato have been discovered. Even important genes from the tertiary genepool could be unveiled using bridge species in the crossing, embryo rescue, and somatic hybridization [76]. Currently, potato genetic materials are preserved in gene banks around the planet and therefore, are offered for potato breeders as well as researchers [77]. Cultivated potatoes are conserved primarily as clonal collections, like a tuber, *in vitro* and cryopreservation; on the flip side, wild potato species are primarily gathered up and also retained in the type of botanical seeds [78, 79].

8. Fertility issues in potato breeding

Potato is propagated sexually by seeds and asexually by tubers [80]. Most of *Solanum* species are diploid in nature with obligate allogamy (cross-pollination) which is result of multi-allelic gametophytic self-incompatibility (S) locus, thus preventing self-fertilization among Solanum species. In contrast to this, tetraploid cultivated potato (*Solanum tuberosum* ssp. *tuberosum* L.) [81]. However, their highly heterozygous nature (interlocus and intralocus) with tetrasomic inheritance pose difficulty in genetic complexity and challenge in potato breeding, and this is further aggravated by, high genetic load due to accumulation of deleterious alleles as a result of its vegetative propagation. Severe inbreeding depression is anticipated upon selfing, which results in the reduction of seedling germination and many reproductive complexities like reduction in flowering [57].

Conventionally potato varieties are developed through hybridization and selection, with a huge investment of time and resources because of its complex multi-locus inheritance and tetraploid genome. Successful hybridization programme between different potato populations have to deal with many barriers like pre-zygotic barriers including pollen and pistil incompatibility and post-zygotic barriers like embryo and endosperm abortion, sterility and hybrid breakdown in segregating generations [82], that leads to the hindering of the breeding programmes [60]. In male-sterile plants, flowers do not produce functional anthers or viable pollen, but the ovaries usually function [57]. The failure to produce pollen may be an inherent characteristic with sterility being dominant over fertility [83]. Even after successful fertilization by overcoming these issues, development of seeds requires proper endosperm development.

Male sterility is the result of nuclear cytoplasm interactions; the predominant Ms. gene interacts with the cytoplasm, for instance, the diploid hybrids between *S. tuberosum* Group Tuberosum haploids × Group Phureja yield all or perhaps nearly all-male sterile progeny [84]. The occurrence of male sterility typically leads to issues for potato breeders, as the option of parental lines can limit the introgression of characteristics [85]. The frequency of male fertile offspring in a hybrid between the group Tuberosum and Phureja are different because of their different ploidy levels [86–88].

In the last couple of years, a pattern emerged in a group of potato breeders to reconsider the pick as a diploid species constructed from a compilation of inbred lines that capture the favourable genetic diversity accessible in cultivated and wild potatoes [89]. Inbreeding due to selfing might be useful for organizing the entire gene pool into different favourably interacting and healthy epistatic systems. Whatever the nature of its, self-compatible 2x cultivars will offer an even more appealing self-compatible source than *S. chacoense* since they will avoid the undesirable linkage drag regarding the usage of an untamed species within the development of 2x inbred lines. Loss of S-RNase functionality is a standard route to self-compatibility [90].

9. Unilateral compatibility

The endosperm balance number (EBN) seems to be very likely that a mechanism related to a loss of protein functionality results in the formation of 2n gametes. Although it is not complete, the consistency of the self-incompatible self-compatible rule indicates a link between inter- and intraspecific pollen rejection [91, 92]. The EBN concept was helpful to elucidate the nature of the pollinator result in haploid removal. The triploid block is a reproductive screen resulting from endosperm malfunction due to the epigenetic event of genomic imprinting. Evidence implies that the endosperm dosage devices are imprinted within the gametes; therefore, the similar gene being functionally different in paternal and maternal chromosomes [93].

Spooner et al. [22] proposed a concept particularly for the Potato, implementing 5 crossability groups based on self-compatible/self-incompatible systems and endosperm balance number (EBN). The main genepool of potato contains *S. tuberosum* ssp. *tuberosum* with all cultivars and landraces. All the cultivated potatoes are tetraploid (2n = 4x = forty eight) with 4EBN. Potato has a vast secondary gene pool comprising of related wild species that gives a rich, distinctive, and different supply of hereditary variation. The EBN is a unit identifying the realizations of interspecific crosses [94]. Hybridization within every group is anticipated to achieve success rather than hybridization across groups, and therefore the executions of hybridization may be predicted. Whereas the genepool principle, as well as the EBN model, provides assistance in the utilization of wild genetic resources, additionally, they provide insight into phylogenetic connection and also taxonomy. Nevertheless, species crossability are always crucial to offer concrete evidence. Potato researchers have developed strategies to conquer the hybridization screen to transfer genes from wild species of the secondary and even tertiary genepool [95].

Haploids exhibited disomic inheritance, that implies that every chromosome combined with its homolog, thus giving means for simplifying genetic research in potato. They can furthermore be well utilized for research on natural mutation and chromosome pairing accumulated at the tetraploid fitness level. In this direction, the reason behind the generation of haploids was acquiring a genetic bridge between the different genomes of Solanum species [96]. Haploids from tetraploids usually don't flower and can also be male sterile because of inbreeding throughout the tasks of haploidization [97]. Selection of haploids can result in diploid breeding lines; additionally, a particular kind of haploids are accustomed for understanding the segregation of characteristics at the tetraploid level if numerous haploids are made of a single tetraploid genotype [98]. Whereas, tuberization in potato is controlled by day length [99, 100], and plant hormones, such as gibberellin and jasmonic acid also play a crucial role in defining tuberization. Although, specific potato genotype tuberizes under a particular day length condition along with specific physiological requirements that vary from genotype to genotype. In *in vitro* studies, no particular method of tuberization is found, and it's regarded as a complex trait. Utilizing the genome sequence [101] as well as info on Ft, it was determined that the potato genomic locus StSP6A, induces movable tuberization signal. The StSP6A signal led to the induction of tuber growth at the stolon termini. They've postulated that diverse allelic deviation of this gene is connected with the domestication of potatoes.

10. Breeding behavior of potato: from conventional to new breeding technologies

Potato breeding and improvement is an uphill task owing to its complex genetic structure and multi-allelic gene action arising due to its tetraploid genome [102].

Any breeding programme relies on the objective of the programme, germplasm availability and breeding method/technique. Genetic resources of potato are quite rich as compared to any other cultivated plant consisting of about 190 wild and primitive species [103], resulting in great amount of genetic diversity readily available for exploitation. Its rich variations are also attributed due to its reproductive biology which shows there can be 40% (range 21–74%) natural cross-pollination [104]. Besides this, its tetraploid nature (2n = 4x = 48) having four sets of chromosomes entirely homologous shows random pairing at meiosis [57] further adding to its diversity and genetic variations. This sexual reproduction generates ample amount of diversity by recombining the variants of genes that arose by mutation. As a consequence, potatoes are highly heterozygous individuals that display inbreeding depression on selfing and thus become the major impediment for the exploitation of its heterosis [105, 106].

Despite the broad genetic base, progress in efforts for potato breeding is quite slow, and its genetic gains are not fixable due to the obligatory out-breeding nature. Several conventional, as well as modern breeding techniques, have been utilized for improvement in yield, processing, storage-quality [107] and against biotic stresses [108, 109]. Although conventional breeding approaches like hybridization, clonal selection, irradiation/mutagens and introgression has been successfully employed [57]. But the progress is limited and slower due to demanding tasks of introgression and phenotypic characterization of better performing individuals in successive generations. Apart from this, intraspecific incompatibilities and inbreeding depression lead to failure of trait incorporations in the polyploid crop.

Although conventional breeding has played an important role in potato improvement by developing coloured potatoes and potatoes with improved nutrients [110], but the progress is very slow. In order to overcome these challenges, biotechnological, molecular breeding and genome editing tools, considered as new breeding techniques, have played an important role to facilitate interspecies crosses, and towards augmenting and broadening of the genetic base of gene pool of cultivated material. Biotechnological techniques like *in vitro* meristem shoot tips culture have been successfully eliminated potato virus Y [111]. This method was crucial and reliable for supplying pathogen-free seed potatoes to farm [112]. Embryo culture technique has been used successfully for improving resistance to potato leafroll virus so as to circumvent interspecific incompatibility [113]. Utilization of somaclonal variation resulting heritable phenotypic changes arise during the cell culture and regeneration of potato tissue culture was reported from leaf protoplasts of 'Russet Burbank' cultivar [114] along with improved resistance to pathogens like *Phytophthora infestans*; *Alternaria solani* [114, 115] and tuber morphology [116]. The somatic fusion of potato protoplasts with protoplasts of wild relatives has also been extensively exploited for introgression of novel sources of disease and pest resistance [105, 109, 117–119].

Potato is a model crop in which transgenic or genetic engineering technology has been exploited to the maximum extent, and it is one of the first crops for which transgenic plants were regenerated [120]. Genetic engineering is an important and highly effective tool for incorporating single gene or pyramiding gene into elite potato cultivars with minimal or no disturbances to their genetic background [121]. Numerous transgenic genotypes have been developed for a wide range of traits, including pest and disease resistances; abiotic stress resistance; quality attributes for improved processing, nutrition and appearance etc. Gene silencing is another novel technique which uses RNAi for traits like increased carotenoid content and reducing cold-induced sweetening [122–124].

Apart from transgenics/genetic engineering techniques, marker-assisted breeding (MAB) has been successfully demonstrated in tetraploid potato [125]

for potato cyst nematode resistance trait. Several other examples like resistance to the nematode *Globodera rostochiensis*, resistance to potato virus X and resistance to potato wart [126] are the success stories of the application of MAB in potato. But the progress in MAB is negligible as compared to other crops due to its complex tetrasomic inheritance and high allelic variation [127]. However, in the current era of genomic breeding, prediction of genomic information is the best method to use for making breeding decisions [128]. Rather than using only significant marker-trait associations to build a prediction version, genomic prediction makes simultaneous usage of all markers [129]. In potato, genomic selection (GS) models are being utilized for predicting the accuracies of prediction models for various traits like for maturity [130], tuber starch content and chipping quality [131], *Phytophthora infestans* infection, plant maturity, tuber starch yield and tuber yield have been successfully predicted using GS models [132].

For the successful application of genome editing technologies, the first and foremost requirement is the availability of efficient transformation systems. Since potato has excellent availability of genomic resources as well as genome sequence and efficient transformation systems, several workers used various genome editing approaches *viz.* zinc-finger nucleases (ZFNs) [133–137] for improving traits like herbicide resistance, modification of starch, bio-fortification and reducing anti-nutritional factors to enhance overall increased quality of produce. Earlier for targeting traits like insect resistance, proteins, vitamins and carotenoids, transgenic technology was extensively used. Still, due to their off-target, copy number variations and other drawbacks, the trend has been shifted towards these new breeding technologies whereby TALENs and more recently CRISPR/CAS9 genome editing technologies were used for targeting traits like alteration of starch composition or hormonal expressions, reduction of anti-nutritional elements, imparting herbicide resistance, improving starch quality and overcoming self-incompatibility issues.

11. Conclusions and future prospects

The genetic improvement of potato depends on germplasm sources. In the genomics era, germplasm development can be easily performed by incorporating noval alleles from wild species, landraces, cultivated varieties, and even from distantly related species. In corporating the genomics equipment will substantially enhance the effectiveness of introgressing multi genic characteristics. Introgression may be possible through sexual hybridization, or molecular manipulations. In the context of molecular manipulations, different breeding technologies as TALEN and CRISPR/Cas9 are already used to improve the potato ideotype as per the market requirements. Moreover, the potato genome sequence, as well as useful potato hereditary transformation strategies, have hugely facilitated potato genetic engineering. The commercialization of these engineered goods is challenging because of regulatory/ethical restrictions and consumer preferences.

Breeding objectives like bio-fortification, as well as the removal of anti-nutritional factors like steroidal glycoalkaloids as already achieved. Additionally, incorporation of abiotic (environmental, salinity, drought, temperature) anxiety resistance that comes with improved nutrition can facilitate potato to acclimatize in varied agro-ecological zones, therefore impeding food shortage in less fertile/water deficit farming lands. Further expansion of food studies can establish several preliminary values to rationalize the health advantages of potato derived foods. Indeed, the potato genome sequence has facilitated the relative genomic analyses to determine the genes helpful for improving several agronomically significant characteristics as tuberization, damage of bitterness, along with ailments opposition.

Whereas, the studies concentrating on food safety and protection can offer considerable means to meet up the soaring food demands, particularly in the food-deficit countries. The rapid advancement of growing genetic engineering has supplied brand new exciting resources to produce crops with nutritional traits and enhanced yield. In this particular context, potato harvest has potential that is enormous to help with food security as it can offer inexpensive, energy food that is high at a sustainable basis.

Conflicts of interest

The authors declare no conflict of interest.

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