International Journal of Genetics
ISSN: 0975-2862 & E-ISSN: 0975-9158, Volume 10, Issue 2, 2018, pp.-360-364.
Available online at http://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000226

Review Article

A REVIEW ON POTATO (*Solanum tuberosum* L.) AND ITS GENETIC DIVERSITY

REDDY B. J.[1], MANDAL R.[2*], CHAKROBORTY M.[1], HIJAM L.[1] AND DUTTA P.[3]

[1]Department of Genetics and Plant Breeding, Uttar Banga Krishi Vishwavidyalaya, Cooch Behar, West Bengal 736165, India
[2]Regional Research station, Terai Zone, Uttar Banga Krishi Vishwavidyalaya, Cooch Behar, West Bengal 736165, India
[3]Department of Seed Science and Technology, Uttar Banga Krishi Vishwavidyalaya, Cooch Behar, West Bengal 736165, India
*Corresponding Author: Email- rup.biotech@gmail.com

Received: March 14, 2018; Revised: March 24, 2018; Accepted: March 25, 2018; Published: March 30, 2018

Abstract- Potato (*Solanum tuberosum* L.) is an annual herbaceous, self-pollinated species. Potato belongs to family *solanaceae* and the genus S*olanum* with a basic set of 12 chromosomes (x = 12). It is used as vegetable and in industries for manufacturing starch, alcoholic beverages and other processed products like French fries, chips etc. Afresh potato contains 16-20% carbohydrates 2.5-3.2% crude protein. Even though potato contains little amount of protein, nutritional quality of potato is better than cereals. Potato has potential to produce more calories and protein per unit land area with little time and water than most of the major food crops. Therefore, understanding its genetic diversity is important for the improvement of this crop and as well as for effective utilization of germplasm. Diversity analysis based on molecular characterization is better than morphological characterization as it is highly influenced by the environment. Hence, in-depth studies based on both morphological and molecular markers will help in better understanding the genetic diversity of potato germplasm.

Keywords- Potato, Morphological Marker, Molecular Marker and Genetic Diversity.

Citation: Reddy B. J., *et al*., (2018) A Review on Potato (*Solanum tuberosum* L.) and its Genetic Diversity. International Journal of Genetics, ISSN: 0975- 2862 & E-ISSN: 0975-9158, Volume 10, Issue 2, pp.-360-364. DOI: http://dx.doi.org/10.9735/0975-2862.10.2.360-364

Introduction

Potato (*Solanum tuberosum* L.), is the most commonly cultivated tuber crop and fourth most important food crop in the world, after wheat, rice and maize [1]. Potato belongs to family solanaceae and genus *Solanum*, with a basic set of 12 chromosomes (x = 12) [2]. Potato is not only a widely used vegetable but also used for making processed foods. Potatoes are also used in industries for manufacturing starch, alcoholic beverages. Development of varieties with agronomically important traits, and good keeping quality is one of the challenges for potato breeders. The assessment of genetic diversity is prerequisite for any crop improvement programme and made it possible to select parents for successful hybridization. The assessment of genetic diversity within and between plant populations of potato is generally done using following techniques; (i) morphological, (ii) biochemical evaluation (allozyme) and (iii) molecular marker analysis [3]. Molecular markers play an important role in genetic diversity assessment as commercial potatoes has narrow genetic base [4]. Appropriate DNA markers (polymorphic) should be at the DNA level and can be expressed in all tissues, organs, and various developmental stages of crop. Molecular markers can increase the efficiency and effectiveness of breeding programs when compared with traditional breeding programs. Various molecular techniques, such as RAPD, SSR (Microsatellite markers) [5-[7], AFLP, chloroplast RFLP, nuclear RFLP, etc. are utilizing for genetic diversity assessment and other purposes in potato breeding. Hence, in-depth studies on genetic diversity based on morphological and molecular markers is required in understanding the germplasm of potato for the analysis of population structure, identification, conservation and utilization of authentic and superior crop materials.

Crop History

Potato is among the oldest crop plants cultivated for the food purpose. The botanical name, *Solanum tuberosum* was given by Linnaeus in his book "Species Plantarum" [8]. The history of potato started from Andes Mountains of South America about 8000 and 5000 BC near Lake Titicaca which is located at 3,800 m (12,500 ft) above sea level on the border between Bolivia and Peru. Wild potatoes from the humid coastal plains of South America were probably first eaten by people as early as 13,000 years ago. Many wild potato species show resistance to insects and diseases as they contain compounds like glycoalkaloids (solanine and chaconine), but they impart bitter taste and are toxic to humans at high enough levels, so choosing of non bitter potatoes for cultivation was first step in domestication. A technique called freeze-drying as found in Andes to remove bitterness from potato tubers but gradually selection and propagation of non-bitter tubers as made to eliminate bitter tubers. The communities of hunters and gatherers who had first came to the South American continent at least 7,000 years before starting of domesticating wild potatoes that grew around the lake in abundance. For many years after adaptation of potatoes in USA, they were used potatoes as food for horses and animals. Near Lake Titicaca Planting of tubers remains the most important operation of the farming year, where the potato is known as Mama Jatha (mother of growth) [9].

Origin, Distribution and Domestication

Western South America is the primary center of the origin of the potato and its wild relatives [1]. Where it grows wild in nature and presents the widest diversity of forms like tuber shape, size, colour, taste etc. Probable ancestor of all cultivated potatoes is *Solanus stenotonum*. From South America potato tardily started its travel across the continent, but it acquired great importance in 1530s when Spanish conquistadors searched for gold in Peru. They brought potato to Europe between the years of 1570 and 1593. The potato was introduced in India from

Europe in early 17th century, only 40 years after introduction in Europe by Portuguese. In 20th century, potato became one of the most beloved and produced food sources in the world. United States of America was the last major country who adopted potato. Now potato is cultivated throughout the world more than 100 countries including Europe, North America and countries of the former Soviet Union, Asia, Africa and Latin America [10].

GROWTH HABIT

Potato is an annual herbaceous plant cultivated under temperate, subtropical and tropical conditions. It is essentially a "cool weather crop". Temperature is the main limiting factor for potato production. In the temperatures below 10°C (50°F) and above 30°C (86°F) tuber growth is sharply inhibited. The optimum soil temperature is 16-19°C Where mean daily temperatures are 18 to 20°C their optimum yields are obtained. Potato requires continuous supply of water and adequate soil aeration. Potatoes usually grow a height of 3.5 feet. Tuber formation starts from 25 days after planting. For flowering potato requires long day period therefore under field conditions potato may give flowers or not. Potato can be harvested at any time after about 60-70 days after planting till 100-110 days it depends on duration of variety.

CROP BOTANY

Huaman, (1986) [11], gave detailed botanical and morphological description of potato crop. Potato is an annual and herbaceous plant that produces edible underground tubers that are used as vegetable [12]. Potato belongs to Solanaceae family, with a basic set of 12 chromosomes (x = 12). It belongs to the genus *Solanum*. *Solanum tuberosum* L., which is tetraploid (4n=48), is the most commonly cultivated species [13]. According to the latest classification there are only four cultivated species namely *S. tuberosum*, *S. ajanhuiri*, *S. juzepczukii* and *S. curtilobum* [14], it was seven previously as reported by Hawkes (1990) [15]. *S. tuberosum* is most predominant and widely grown species. The roots are fibrous and the tubers are enlarged portion of underground stem called stolons. The stem is angular, branched and bears pinnately compound, alternate leaves up to 30 cm long with small interjected leaflets between the main pinnae. The inflorescence is cyme and flowers are of varying colours like yellow, white, red, blue, pink or purple with yellow stamens inserted on short corolla tube but are rarely produced under conditions in which day lengths are short and temperatures are high. Potato is autogamous, but some amount of cross pollination occurs mostly by insects (Bumblebees). The fruits are small inedible berries and contain poisonous alkaloids (Solanine)[16]. Generally white flowered varieties produce white skinned tubers and pinkish skinned tubers are produced by varieties with colored flowers [17]. Potatoes are propagated through tubers, cut pieces of tubers with at least one or two eyes and "true seeds".

Importance

Potato (*Solanum tuberosum* L.), is the most commonly cultivated tuber crop and fourth most important food crop in the world, after wheat, rice and maize [1]. In most of the developing countries, and more specifically in urban areas, increasing levels of income are driving a "nutrition transition" toward more energy rich foods and processed food products. That's why demand for potato is rising. In South Africa, potatoes are staple food in urban areas. Potatoes are nonfattening, nutritious and wholesome food that supplies many important nutrients to the diet. Freshly harvested potatoes contain about 75-80% water, 16-20% carbohydrates, 2.5-3.2% crude protein, 0.8-1.2% minerals, 0.1-0.2%crude fats, 0.6% crude fiber and some vitamins [18]. Although potato contain only relatively little protein, their nutritional quality is better than cereals. Potatoes contains fair amount of essential amino acids such as isoleucine, leucine and tryptophan [19]. Potatoes also contain dietary antioxidants, which may play a part in preventing diseases related to ageing, and dietary fiber, thiamine, iron and folic acid. It is used as vegetable and in industries for manufacturing starch, alcoholic beverages and other processed products like French fries, chips etc. It is also used for some medicinal purposes like gastrointestinal and hepatic infections.

Taxonomy and Nomenclature

The potato is a dicot plant belonging to family solanaceae and the genus S*olanum*. This is a largest genus of angiosperms and comprises nearly 2,000 species. Genus S*olanum* has been divided into two sub genuses namely *Pachystemonum* and *Leptostemonum* as per the latest classification. *Pachystemonum* has been further divided in to five sections of which section Petota, contains most of the tuber bearing species. Section petota has been divided under two subsections, namely Estolonifera and potatoe. All cultivated species grouped under the series *Tuberosa* of subsection potatoe [20]. About 72 % of the species are diploid (2n=24) and nearly 12% tetraploid (2n=48). The rest are triploid (2n=36), pentaploid (2n=60) and hexaploid (2n=72). The widely cultivated potato belongs to tetraploid species *Solanum tuberosum* L.

Scientific classification

Kingdom : Plantae
Division : Magnoliophyta
Class : Magnoliopsida
Subclass : Asteridae
Order : Solanales
Family : Solanaceae
Genus : Solanum
Species : *S. tuberosum*

Agronomical Aspects

Potato is short-duration crop and fits well in different multiple and intercropping systems. Potatoes can and are grown in wide range of soil (alluvial, hill, black, red and laterite) having pH in the range of 5 to 7.5[20]. Well drained coarse or sandy loam to loamy soils is good for the growth of roots, stolons and tubers as they supply sufficient oxygen. Soils with high organic matter are perfect for potato cultivation. Good crop growth is observed when days are sunny and nights are cool with temperature not more than 23°C. Tuber formation starts from 20 to 25 days after planting [2]. Highest tuber formation takes place when day temperature 20°C and night temperature 14°C [21]. Potato crop is taken in autumn/inter/spring seasons in the plains and during summer/autumn in the hills. However, planting time depends somewhat on the cultivar and environmental conditions. The fields are ploughed to a depth of 20-35cm and clods are broken. Hot weather cultivation by ploughing field deep and giving one or two turnings of soils in the summer months in the plains and keeping it fallow helps in checking the problem of soil-borne pathogens and also perennial weeds [20]. Before planting, fields are ploughed followed by one or two tillings. Potato is traditionally propagated through tubers. Seed tubers are cut into 30-40 g weight and 3.5-5 cm diameter in such a way that each piece should contain 2-3 healthy eyes [21]. Ridge and furrow method is most popular method of planting. Potatoes usually grow a height of 3.5 feet. There should be adequate amount of soil cover the tubers and therefore, proper earthing should be done after 30 days of planting using double mould board plough or ridger. Blossom is in white to purple colour. Under adverse weather conditions the flowers will drop off. Total water requirement varies between 350-550mm depending upon soil type, climate and crop duration [21]. Being short duration crop, potato can be harvested at any time after about 60-70 days (early varieties) after planting till 100-110 days (late varieties). Harvesting of potatoes is done before the temperatures rise above 30°C. The crop is harvested 10-15 days after stoppage of last irrigation. Potato has potential to give 20 to 25 t/ha in case of early varieties and 30 to 35 t/ha in case of late varieties [21].

Area and Production

Potato is annually cultivated in about 20 million hectares with approximate production of 320 million tones globally [1] [22]. China is now the leading potato producer, and almost a third of all potatoes are produced in China and India. Whereas the main African countries are Egypt, South Africa, Algeria, and Morocco in that order producing more than 80 percent of all the potatoes in the continent. According to Haan and Rodriguez (2016) [1] the potato production has rapidly overtaken all other food crops in Africa and Asia since the early 1960s. Potato production in the world is undergoing major change. In Europe, North America and countries of the former Soviet Union until the early 1990s, most potatoes were

grown and consumed. For the first-time potato production of developing countries is greater than developed countries as per the FAO data in 2005. A total of 381,682,000 tonnes is estimated in 2014 (FAOSTAT, 2017).

Table-1 *Top 10 Potato Producing Countries in the world (FAOSTAT 2015) [10]*

Rank	Country	Potato Production in the year 2013 [tonnes]	% of world total
1	China	95,987,500	25.4
2	India	45,343,600 12%	12
3	Russian Federation	30,199,100	7.99
4	Ukraine	22,258,600	5.89
5	United States	19,843,900	5.25
6	Germany	9,669,700	2.56
7	Bangladesh	8,603,000	2.27
8	France	6,975,000	1.84
9	Netherlands	6,801,000	1.7
10	Poland	6,334,200	1.6
World total potato production		**377,863,333.33 tonnes**	

India ranks second in potato production in the world [10]. The main potato producing states in India are Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal, Gujarat and M.P. The potato production during the year 2015-16 estimated to be around 481.0 lakh MT from the area of 20.85 lakh ha in the country as per the 1st estimate of Govt. of India [23].

Genetic Diversity and Its Importance

Genetic diversity is the all the variability occurring among the individuals of a species. In the hierarchy of diversity genetic diversity is situated after ecological and species diversity. Genetic diversity is essential for survival of crop plants and their improvement. Diversity in plant genetic resources provides opportunity for plant breeders to develop new and improved varieties with desirable traits, such as high yield potential, pest and disease resistance abiotic stress resistance and photo insensitivity, etc. Genetic variability present in nature has been exploited within crop species from the beginning of agriculture, to meet subsistence food requirement. Later the focus shifted to produce excess amount of food for increasing populations. Presently the focus is on both yield and quality aspects of major food crops to meet the requirements of growing population to provide balanced diet. With changing climatic scenario, development of varieties which can withstand to climatic changes is becoming more important. The existence of genetic diversity in the form of land races, obsolete cultivars, cultivated varieties, breeding stocks, mutant lines etc. serve as the source of desirable alleles for developing climate resilient varieties with traits like tolerance towards potential new insect-pests and diseases, extreme heat, extreme cold, and towards various pollutants [24]. Breeding goals are keep on changing, so different genes should be reserved in the germplasm. To widen the genetic diversity of potato breeding varieties, introgression of genes between wild and cultivated species is necessary [25]. Genetic diversity between two parents is prerequisite for heterosis and to obtain transgressive segregants. Knowing of genetic diversity is essential to select the best parents and to design proper crossing techniques and selection strategies and it also facilitates development of new lines for non-conventional uses like biofuel production from agricultural crops like sorghum, maize etc.

Genetic Diversity Analysis in Potato

The assessment of genetic diversity within and between plant populations of potato is generally performed using following techniques; (i) morphological, (ii) biochemical evaluation (allozyme) and (iii) molecular marker analysis [3]. Markers can show similar modes of inheritance, as we observe for any other characters, that is, dominant/recessive or co-dominant. In general, co-dominant markers (genetic pattern of homozygotes can be differentiated from that of heterozygotes) are highly informative than the dominant markers.

I. Morphological markers

Morphological markers are based on visually observable characters such as plant height, stem colour, flower color, growth habits, pigmentation etc. Morphological characterization does not require expensive technology but huge amount of land area is often required for these field experiments, it becomes more expensive than molecular assessment.

Table-2 *Details of different studies about the genetic diversity in potato using morphological characters*

Parameters /Characters studied	Material(s) used for study	References
Plant emergence (%), plant height (cm), number of leaves Plant-^{1}, number of branches Plant-^{1}, number of shoots Plant-^{1}, dry matter content of shoots (%), dry matter content of tubers (%), number of tubers plant-^{1}, tuber weight per plant (kg), marketable tuber yield per Plant (kg) and unmarketable tuber yield per Plant (kg).	39 F_1C_1 clonal progenies of potato.	Nirmodh Prabha, *et al.* 2018 [26].
Plant height(cm), Number of stems per Plant, Number of leaflets/compound leaf, Leaf area (cm^{2}), Foliage coverage per plant, Fresh weight per plant (g), Tuber dry matter (%), Number of tubers per plant, Single tuber weight per plant (g) and Total tubers weight per plant(g) were studied to determine genetic diversity.	31 potato genotypes grown in Bangladesh.	M. Nasiruddin, *et al.* 2017 [27]
Fifteen qualitative characteristics of stem, berry, tuber, and flower were studied.	624 Andigena accessions were studied for morphological characterization of Andigena population.	Berdugo-Cely, J *et al.*2017 [28]
different characters *viz*., plant emergence per cent, plant height, number of compound leaves plant-^{1}, number of leaves plant-^{1}, number of shoots plant-^{1}, plant canopy per cent, fresh weight of shoots plant-^{1}, dry weight of shoots plant-^{1}, number of tubers plant-^{1}, fresh weight of tubers plant-^{1}, dry weight of tubers plant-^{1}, harvest index per cent, marketable tuber yield ha-^{1}, unmarketable tuber yield ha-^{1} and total tuber yield ha-^{1} were observed.	25 genotypes were evaluated to estimate genetic variability, heritability and genetic advance for important yield component characters in potato.	Sunidhi Mishra, *et al.* 2017 [29]
Stem colour, shape of stem cross section, abaxial and adaxial leaf pubescence, leaf dissection, leaf size, leaf color, growth habit and branching habit, flower color, degree of flowering, and tendency to premature flower abscission, tuber skin color, tuber flesh color, tuber skin texture, secondary tuber color, tuber shape, and storability were taken into consideration.	44 local Ethiopian cultivars were studied to find out genetic diversity and relationship of Ethiopian potato varieties to germplasm from North America.	Semagn Asredie Kolech, *et al.* 2016 [30]
A number of morphological and yield parameters including plant height (cm), number of aerial stems/plant, tubers number/plant, tubers weight (kg)/plant and total yield/hectare (ton) were observed for anatomical analysis	9 cultivars growing in Egypt.	H.A.M. Mahgoub, *et al.* 2014 [31]
Days to emergence, days to flowering, days to maturity, plant height (cm), number of stem/plant, tuber diameter (cm), tuber yield (kg), tubers number per plant, biological yield(kg), harvest index, small tuber percentage, medium tuber percentage and big tuber percentage were studied to determine Genetic variability and association between agronomic characters.	9 potato varieties which were released by the regional and national research institutions at different times and 4 local cultivars in SNNPRS, Ethiopia.	Addisu Fekadu, *et al.* 2013 [32]
A study was conducted on 78 characters to obtain morphological, ploidy, and microsatellite (SSR) data needed to set up a useful subset of the collection of cultivated potatoes and closely related wild species.	Russian National cultivated potato collection comprises 238 accessions of seven cultivated species of	Tatjana Gavrilenko, *et al.* 2010 [33]
Percent emergence, days to flower, plant height (cm), plant spread (cm), leaf area (4th cpd)(cm), number of main stems per plant, number of small sized tubers per plant, weight of small sized tubers per plant (g), number of medium sized tubers per plant, weight of medium sized tubers per plant (g), number of large sized tubers per plant , weight of large sized tubers per plant (g), total number of tubers per plant, total weight of tubers per plant (g), total tuber yield (t ha-^{1}), tuber specific gravity (g/cc), tubers dry matter (%), marketable tuber yield (g/plant), marketable tuber yield (t ha-^{1}), total sugar (mg /100g raw tuber), reducing sugar (mg/100 g raw tuber), non-reducing sugar (mg /100 g raw tuber) and Chips recovery (g /100g slice) were studied to determine genetic variability.	100 potato genotypes obtained from CPRI Shimla.	D. Regassa and Basavaraj, 2002 [34]

These marker traits are often susceptible to phenotypic plasticity; conversely, this allows assessment of genetic diversity in the presence of environmental variation which cannot be avoided from the genotypic variation. These types of markers are still having advantage and they are mandatory for differentiating the adult plants from their genetic contamination arises from several ways like mechanical mixtures, natural out-crossing etc. in the field, for example, flower or leaf color variants.

II. DNA (or molecular) marker analysis

The most widely used markers are molecular markers, due to their hyper variability, better genomic coverage, high reproducibility, amenability to automation, being neutral and free from environmental fluctuations. A molecular marker consists of specific molecules, identified using primer which, in virtue of its presence, differentiates unequivocally the chromosomic trait which it represents as well as the flanking regions at the 3' and 5' extremity. The variation that arises from deletion, duplication, inversion, and/or insertion in the chromosomes can be detected by these markers. Molecular markers located only near or linked to genes governing those traits, so they do not affect the phenotype of the characters of interest. These markers are inherited both in dominant and co-dominant patterns. Different markers have different genetic qualities like dominant or co-dominant, can multiply anonymous or characterized loci, can contain expressed or non expressed sequences, etc. They are stable and detectable in all tissues regardless of growth, differentiation, development, or defense status of the cell so they have advantages than conventional, phenotype-based alternatives. Additionally, they are unaffected by environmental, pleiotropic and epistatic effects. Many studies on genetic diversity were conducted using both morphological and molecular markers simultaneously.

Table-3 *Details of some major marker systems used for the genetic diversity analysis of potato*

Marker system	Primer/Isozyme details	Material(s) used for study	References
SNPs markers	-	809 Andigenum group accessions were studied for the genetic diversity and population structure.	Berdugo-Cely, *et al.* 2017 [28]
SSR and AFLP	10 AFLP primer combinations	288 potato germplasms from eight countries and the International Potato Center (CIP) were studied for the genetic diversity and population structure.	Jian WANG, *et al.* 2017 [35]
SSR	12 SSR markers used in the Genetic diversity assessment	93 potato accessions were used, which includes 63 potato clones from Eritrea, 18 and 12 varieties from Kenya and Rwanda.	Biniam Mesfin Ghebreslassie, *et al.* 2016 [6]
SSRs and EST-SSRs	25 microsatellite primer pairs	47 potato genotypes from America, Europe and Iran	Haleh Salimi, *et al.* 2016 [5]
SSR	55 pairs of SSR primers	192 diploid potato cultivars	Song, *et al.* 2016 [7]
SSR	24 pairs of SSR primers	85 cultivars were studied for genetic diversity analysis	Hong liao and Huachun guo, 2014 [36]
ISSR	ISSR-3, ISSR-10, ISSR-16, ISSR-18, ISSR-21, ISSR-24, ISSR-26, ISSR-27, ISSR-28 and ISSR-29	Molecular, biochemical and anatomical analysis of 9 potato cultivars growing in Egypt	H.A.M. Mahgoub, *et al.* 2014 [31]
RAPD	Seventeen RAPD primers	12 popular potato varieties in Bangladesh were used for molecular diversity analysis	M.E. Hoque, *et al.* 2013 [37]
SSR	10 potato specific microsatellite primers were used	38 accessions of potato for molecular characterization.	Patrícia Favoretto, *et al.* 2011 [38]
PCR-IRAP	Three primers namely P-Tst-1 , P-Tst-3 and P-Tst-6	20 most grown potato varieties	Alena Nováková, *et al.* 2009 [39]
RAPD	10 decamer primers of random sequence	Study of genetic diversity of 6 cultivars collected from Bangladesh Agricultural University.	Sabina Yasmin *et. al,* 2006 [40]
RAPD	Isozymes of peroxidase (PX), aspartate transaminase (AT), isocitrate dehydrogenase (IDH), phosphoglucomutase (PGM) were analyzed in leaves, and esterase (EST), phosphoglucomutase (PGM) and protein (PT) in tubers and 18 primers were used for screening.	27 potato genotypes including 19 potato cultivars and 8 breeding clones growing in the field at Embrapa Clima Temperado, Pelotas (31ºSL).	Eliana Antonia Silveira Collares, *et al.* 2004 [41]

Conclusion

Presence of genetic variability in potato is must for its further enhancement by providing options for the potato breeders to develop new varieties and hybrids. This can be achieved through morphological and molecular characterization of plant genetic resources. Development and utilization of subsets like core and minicore collection of large sized germplasm representing the diversity of the entire collection of the species is essential as it may limit their use in breeding. Molecular markers are very important tools for measuring the diversity of potato. Low assay cost, affordable hardware, throughput, convenience, and ease of assay development and automation are important factors when choosing a technology. Now quality data is generating in fast manner with the help of high throughput molecular marker technologies, so it is possible to characterize the huge amount of germplasm with less time and resources. NGS reduced the cost and time required for sequencing the whole genome of any organism. Nowadays assessing phenotypic and molecular diversity parameters is easy for potato breeders with available software packages to speed up the crop improvement.

Application of review: This review helps to provide proper information about various tools used in the genetic diversity analysis in potato to the breeders.

Review Category: Genetics and Plant Breeding

Abbreviations:

AFLP: Amplified fragment length polymorphism
ISSR: Inter simple sequence repeats
RAPD: Randomly amplified polymorphic DNA
RFLP: Restriction fragment length polymorphism
SNP: Single nucleotide polymorphism
SSR: Simple sequence repeats
IRAP: Inter-Retrotransposon Amplified Polymorphism

Acknowledgement / Funding: Author thankful to The Director of Research, Uttar Banga Krishi Vishwavidyalaya, Cooch Behar, West Bengal 736165, India. Author also thankful to In-Charge, RRSTZ, Uttar Banga Krishi Vishwavidyalaya, Cooch Behar, West Bengal 736165, India

***Research Guide or Chairperson of research: Dr Rupsanatan Mandal**
University: Uttar Banga Krishi Vishwavidyalaya, Cooch Behar, West Bengal 736165, India
Research project name or number: Nil

Author Contributions: All author equally contributed
Author statement: All authors read, reviewed, agree and approved the final manuscript

Conflict of Interest: None declared
Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

References

[1] Haan S. de, & Rodriguez F. (2016) Potato origin and production. In J. Singh & L. Kaur (Eds.), *Advances in Potato Chemistry and Technology* (2nd, pp. 1–32). London, UK: Academic Press, Elsevier.

[2] Kazuo Watanabe (2015) *Breed Sci*., **65(1),** 53–68**.**

[3] Govindaraj M., Vetriventhan M. and Srinivasan M. (2014) *Genetics Research International,* 2015, 14.

[4] Jansky S.H., Dawson J. and Spooner D.M. (2015) *Am. J. Bot.,* **102,** 1213–1215.

[5] Haleh Salimi, Masoud Bahar, Aghafakhr Mirlohi and Majid Talebi (2016) *Iran J Biotechnol*, **14**(4), 270–277.

[6] Biniam Mesfin Ghebreslassie, S. Mwangi Githiri, Tadesse Mehari, Remmy W. Kasili, Marc Ghislain and Eric Magembe (2016) *African Journal of Biotechnology,* **15**(35), 1883-1891

[7] Song X., Zhang C., Li Y., Feng S., Yang Q. and Huang S. (2016) *Horticultural Plant Journal*, **2**, 163-171.

[8] Linnaeus C. (1857) Species Plantarum. The Royal Society of London, London, UK.

[9] FAOSTAT. (2008) International year of the potato. African Perspective. Retrieved August 12, 2013, from http://www.fao.org/potato-2008/en/world/africa.html.

[10] FAOSTAT. (2015) *FAO Statistical Pocketbook: World Food and Agriculture*. Rome, Italy.

[11] Huaman Z. (1986) *Systematic botany and morphology of potato,* (6), Lima, Peru.

[12] Struik P. C. & Wiersema S. G. (2001) *Experimental Agriculture*, **37**(01), 125–134.

[13] Rosa P. M., Campos T., de Sousa A. C. B., de Sforça D. A., Torres G. A. M. & Souza A. P. de (2010) *Pesquisa Agropecuária Brasileira*, **45**(1), 110–113.

[14] Spooner D. M., Nunez J., Trujillo G., Herrera M. del R., Guzman F. & Ghislain, M. (2007) *PNAS*, **104(**49), 19398–19403.

[15] Hawkes J. G. (1990) *The potato: evolution, biodiversity, and genetic resources* (National g.). Washington D.C. Smithsonian Institution Press.

[16] Rice R. P., Rice L. W. & Tindall H. D. (1990) *Fruit and vegetable production in* 129 *warm climate*. Hong Kong: MacMillan Educational Crop.

[17] Winch T. (2006) *Growing food: A guide to food production*. Dordrecht, The Netherlands: Springer.

[18] Schoenemann J.A. (1977) grading, packing and marketing potatoes, in: potatoes production, storing. Processing, Ora Smith, Ed., 2nd Edition. The AVI publishing company inc., west port, pp.470-505.

[19] Yadav S.K. and Srivastava A.K. (2015) *International Journal of Applied and Pure Science and Agriculture,* **1**, 26-34.

[20] Thamburaj S. and Narendra S. (2016) Text book of vegetables, tubers and spices. Indian Council of Agriculture Research, New Delhi, pp.320-341.

[21] Choudary B.R., Manphool S. Fageria and Dhaka R. S. (2009) A text book on production technology of vegetables. Kalyani publishers. India.

[22] Poczai P., Gorj, A. M., Nagy S., Taller J. & Polg Z. (2010) *American Journal of Botany*, **97**(12), 142-145.

[23] Department of Agriculture and Cooperation (Horticulture Division) http://eands.dacnet.nic.in/Publication12-12-2013/Agricultureat%20a%20Glance2013/ page128-185.pdf

[24] Singh B. D. (2015) Plant breeding principles and methods. Ed., 10th Edition. Kalyani publishers, New Delhi, India, pp.19-20.

[25] Gavrilenko T.A. and Yermishin A.P. (2017) *Vavilov Journal of Genetics and Breeding*., **21(1)**, 16-29.

[26] Nirmodh Prabha., H.C. Nanda and Suresh Kumar Sharma (2018) *Int. J. Curr. Microbiol. App. Sci.,* **7**(2), 3152-3157.

[27] M. Nasiruddin, M., Ali Haydar, FM and Rafiul Islam and AKM. (2017) *Int. Res. J. Biological Sci*., **6**(11), 1-8.

[28] Berdugo-Cely J., Valbuena R.I., Sánchez-Betancourt E., Barrero L.S. and Yockteng R. (2017) *PLoS ONE,* 12(3), e0173039.

[29] Mishra S., Singh J., Sharma P.K. (2017) *Biosci Biotech Res Asia,* **14**(1).

[30] Semagn Asredie Kolech, Donald Halseth, Keith Perry, David Wolfe, David S. Douches, Joseph Coombs and Walter De Jong (2016) Genetic Diversity and Relationship of Ethiopian Potato Varieties to Germplasm from North America, Europe and the International Potato Center. **93**, 609–619.

[31] Mahgoub H.A.M., Eisa G.S.A. and Youssef M.A.H. (2014) *Journal of Genetic Engineering and Biotechnology*, **13,** 39–49.

[32] Addisu Fekadu, Yohannes Petros and Habtamu Zelleke (2013) *International Journal of Biodiversity and Conservation,* **5**(8), 523-528.

[33] Tatjana G., Olga A., Anna O., Lubov N., Ekaterina K., Nina M., Galina P., Anna I., Natalia S., Stephan K., Ludmila K., Olga A and David S (2010) *Genet Resour Crop Evol.,* **57**, 1151–1164.

[34] Regassa D and Basavaraj N (2005) *Karnataka J. Agric. Sci,* **18**(1), 87-90.

[35] Jian WANG, LuHOU, Ruo-yuWANG, Miao-miaoHE and Qing-changLIU (2017) *Journal of Integrative Agriculture*,**16,** 2434-2443.

[36] Hong L. and Huachun G. (2014) *Series Botanica* 56/1, 16–27

[37] Hoque M.E., Huq H. and Moon N.J. (2013) *SAARC J. Agri,* **11**(2), 95-102.

[38] Patrícia F., Elizabeth A.V and Paulo C.T. de M (2011) *Hortic. Bras,* **29** (4).

[39] Alena N., Kateřina Š., Jan B and Vladislav Č. (2009) *Czech J. Genet. Plant Breed.* **45**, 1-10.

[40] Sabina Yasmin, Shahidul Md., Khondokerl., Nasiruddin Md and Md. Samsul Alam (2006) *Biotechnology,* **5**, 27-31.

[41] Eliana Antonia Silveira Collares, Eva Choer, Arione da Silva Pereira (2014) *Brasília*, **39**, 871-878.