PROGRESSES ON THE NATURE AND BIOTIC STRESS OF POTATO (SOLANUM TUBEROSUM L.)

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Geliş Tarihi / Received: 20.09.2021
Kabul Tarihi / Accepted: 17.11.2021
Araştırma Makalesi/Research Article
DOI: 10.38065/euroasiaorg.756

ABSTRACT

Potato (Solanum tuberosum L.) is the third largest crop in terms of consumption by human, most important tuber crop in the world and a vital plant for global food security. Instead, potato breeding is slow compared to other crops. Transforming potato into a diploid F1 hybrid crop is a hopeful method to increase potato genetic gain. Studies on breeding and genetics of potato has big potential to solve many problems exist in potato. Another potential area for these studies are diseases which are seriously targeting this crop worlwide started from Irish potato famine which effected whole Europe continent. Here in this review, some of latest significant problems and approaches related to potato production are given below.

Keywords: Potato, Solanum tuberosum L., breeding, genetics, diseases, pests

1. INTRODUCTION

Potato (Solanum tuberosum L.) is the third largest crop in terms of consumption by human (Taylor, 2018) and is the most important tuber crop in the world (Zhou et al., 2020). Potato is vital for global food security. It is economically stable than rice, wheat and maize. Potato markets didn’t change when international wheat market prices doubled in 2008 and in 2010 (McIvor, 2011). This secies originates from the Andes in South America and evolved for tuber formation strategy under short day conditions for vegetative propagation (Kloosterman et al., 2013).

2. POTATO BREEDING AND GENETICS

Instead of its importance, advances in potato breeding is slow compared to other crops (Taylor, 2018). Cultivated potato is propagated asexually and is tetraploid. Conventional breeding of potato focuses on quantitative phenotypic traits selection (Guo, 2021a). Genetic gain for potato is hindered by the genome (heterozygous tetraploid) of cultivated potato. Transforming potato into a diploid F1 hybrid crop is a hopeful method to increase potato genetic gain. A diploid germplasm may allow efficient self-fertilized seeds and development of inbred lines of potato (Eggers et al., 2021). Re-domestication of potato into inbred lines has also inhibited by self-incompatibility (Ye et al., 2018). Inbreeding depression reduces fitness between offsprings of genetic relatives. Potato suffers from serious inbreeding depression and big part of the genetic basis of the inbreed depression of potato is unknown (Zhang et al., 2019). Efforts are continuing to convert potato from a clonal tetraploid into a seed-based inbred-line-hybrid, but scientists need understand potato genome more (Zhou et al., 2020).

Fig. 1. Potato plants growing in aeroponics in the greenhouse in China (Wang et al., 2017)

Wild potatoes, is a dynamic source which si well adapted to diversified environments and conditions and is a strong reservoir of genes for breeding aims (Villano et al., 2020). Wild tuber-bearing Solanum species genomes are key to understand the evolution and adaptable diversification of potato (Lyu, 2017). As a powerful plant functional genomics tool, genome editing allow multiallelic-targeted-mutagenesis in potato (Sevestre et al., 2020).

3. PROBLEMS TO BE SOLVED BY BREEDING AND GENETICS

Nitrogen is the most important nutrient for potato growth and development (Galvez et al., 2016). High tuber yield requires high dose of nitrogen. Excess application of nitrogen increases pollution and production costs. Knowledge related to genes and regulatory elements is required to improve researches on nitrogen metabolism of potato crop (Tiwari et al., 2020).

Potato is a major food but produces toxic, solanidane glycoalkaloids (α-chaconine and α-solanine). Controlling the glycoalkaloid levels in potato is a major focus in potato breeding (Akiyama et al., 2021). Steroidal glycoalkaloids are neurotoxic defence chemicals exist in many members of the Solanaceae. Potato has high levels of steroidal glycoalkaloids which may make potato tuber consumption harmful. Steroidal glycoalkaloids levels of tubers depend on genetic factors. Certain stress and environmental conditions can increase its levels (Nahar et al., 2017).

The corky periderm of potato is a protective tissue formed via cambial activity of the phellogen cells when outer epidermis gets damaged. Periderm formation at correct time is critical to block water loss and pathogen invasion. At early tuber development stages, phellogen gets active and produces the skin of potato. Then, at tuber maturation, it gets inactive and skin stick to the flesh of tuber (Vulavala et al., 2019). Huge amounts of food potato get lost in the supply chains as a result of post-harvest applications. Sprouting during storage is a major post-harvest storage losses source for potato (Guo, 2021b).

Potato growth is heavily suppressed worldwide by salt stress and the molecular mechanisms of salinity tolerance of potato is still unclear (Li et al., 2020).

Globally most commercial potato varieties are susceptible to late blight disease (Phytophthora infestans) and yields of potato sharply reduces due to this diseases. But many wild potato species have variation for tolerance/resistance and are potentially source for resistance genes (Witek et al., 2016).

Phytophthora infestans is an oomycete pathogen and is responsible for the Irish potato famine (1845–1849) which caused persistent and devastating outbreaks of late blight diseases in whole Europe. Still, genome of the pathogen strain is entirely unknown (Martin et al., 2013).

Potato ring rot disease (Clavibacter michiganensis subsp. Sepedonicus) is a significant bacterial pathogen of potato. Rapid diagnosis of C. michiganensis is important to prevent serious harvest losses. Low sensitive serological tests exist but are not widely used in diagnosis of C. Michiganensis. DNA-PCR methods are sensitive but are not suitable for on-site diagnosis and require expensive laboratory equipments. Alternative amplification methods for DNA-based diagnostic methods are required (Sagcan & Kara, 2019).

Fig. 2. Aeroponic potato production technique (photograph by Paul Demo) (Demo et al., 2015).

4. CULTIVATION AND BIOTIC STRESS FACTORS OF POTATO

China applied a policy to increase potato production and increase low yields significantly (Liu et al., 2021). Water deficit is a major limiting factor in crop production zones in arid and semi-arid areas in China. Humic acid is normally a soil conditoner but was applied on potato foliage to reduce drought damage in northern China. Humic acid increased potato plant growth, photosynthesis parameters and fresh potato tuber yield under drought conditions in green house tests (Man-Hong et al., 2020).

Plant diseases cause significant yield losses (Chinchilla et al., 2019). Viruses are serious plant diseases resulting in high crop yield losses worldwide (Kumari et al., 2020). PVX (Potato virus X) is a RNA plant virus from Alphaflexiviridae family which effect potatos (Grinzato et al., 2020). AMV (Alfalfa mosaic virus) causes significant crop losses in potato and is distributed worldwide via wide host range (Abdelkhalek et al., 2020). Every year worldwide potato farmers inform sharp yield losses sourced from PVY (Potato virus Y) (Huhnlein et al., 2011). New tactics and strategies are needed to control pathogens without environmental harms (Chinchilla et al., 2019). Terpenoid phytoalexins are defense compounds effecting pathogens from broad spectrum and pests of plants (Li et al., 2015). Phytohormones are diverse chemicals regulation plant growth and development. They are capable to manage biotic stress responses (Wiesel et al., 2015). Protection of potatoes from pathogens is a major problem. Usage of synthetic hydrogels filled with peat, humates and plant protection products is needed to be developed for potato crop. Introduction of swollen gel into potato rhizosphere may optimize water supply and tuber yield, protect potato tubers from pathogens, fix pesticides in the rhizosphere, protect them from leaching and damaging environment (Smagin et al., 2019). This method may be useful to apply insecticides, too.

Control of insects is mainly basing on insecticide chemicals. But pests develop insecticide resistance which is a increasing problem in management of pests of potatos. Insecticide resistance mechanisms function by elevated activity of detoxifying enzymes and xenobiotic transporters which destroy and excrete insecticide molecules (Kaplanoglu et al., 2017). Root knot nematode (Meloidogyne chitwoodi) is an important pest of potato in major potato production zones like Northwest of the US (Zhang & Gleason, 2020). Colorado Potato Beetle is an invasive and serious pest of potato native North America but now distributed in Eurasia zone. First determined as pest in 1864 and rapidly spreaded to Europe and Asia (Wang et al., 2017). Potato cyst nematodes (Globodera pallida and G. Rostochiensis) make important economic losses in potato. These nematodes are hard to manage due to ability to stay dormant in soil for years (Duceppe et al., 2017).

CONCLUSIONS

Here in this review, some of latest significant problems and approaches related to potato production are given. Potato is a very important source of calorie for global human populations and animals in some countries like Russia. Instead of importance of potato, many problems exist which are needed to be solved.

Transforming potato crop from a clonally propagated form into seed-propagated F1 form is the main target of big scaled breeding organisations. Other major problems are concentrated on diseases and pests of potato.

As a conclusion, it can be said that the main problems to be solved related to potato as mentioned in high quality international articles are : 1) development of seed-propagated F1 potato forms and 2) diseases and insect resistance/tolerance in the cultured potato genotypes.

LITERATURES

Abdelkhalek, A., Al-Askar, A. A., & Behiry, S. I. (2020). Bacillus licheniformis strain POT1 mediated polyphenol biosynthetic pathways genes activation and systemic resistance in potato plants against Alfalfa mosaic virus. Scientific Reports, 10(1), 1-16.

Akiyama, R., Watanabe, B., Nakayasu, M., Lee, H. J., Kato, J., Umemoto, N., & Mizutani, M. (2021). The biosynthetic pathway of potato solanidanes diverged from that of spirosolanes due to evolution of a dioxygenase. Nature communications, 12(1), 1-10.

Chinchilla, D., Bruisson, S., Meyer, S., Zühlke, D., Hirschfeld, C., Joller, C., & Weisskopf, L. (2019). A sulfur-containing volatile emitted by potato-associated bacteria confers protection against late blight through direct anti-oomycete activity. Scientific reports, 9(1), 1-15.

Demo, P., Lemaga, B., Kakuhenzire, R., Schulz, S., Borus, D., Barker, I., & Schulte-Geldermann, E. (2015). Strategies to improve seed potato quality and supply in sub-Saharan Africa: Experience from interventions in five countries. Potato and sweetpotato in Africa: transforming the value chains for food and nutrition security, DABI, Wallingford, 155-67.

Duceppe, M. O., Lafond-Lapalme, J., Palomares-Rius, J. E., Sabeh, M., Blok, V., Moffett, P., & Mimee, B. (2017). Analysis of survival and hatching transcriptomes from potato cyst nematodes, Globodera rostochiensis and G. pallida. Scientific reports, 7(1), 1-13.

Eggers, E. J., van der Burgt, A., van Heusden, S. A., de Vries, M. E., Visser, R. G., Bachem, C. W., & Lindhout, P. (2021). Neofunctionalisation of the Sli gene leads to self-compatibility and facilitates precision breeding in potato. Nature Communications, 12(1), 1-9.

Galvez, J. H., Tai, H. H., Lagüe, M., Zebarth, B. J., & Strömvik, M. V. (2016). The nitrogen responsive transcriptome in potato (Solanum tuberosum L.) reveals significant gene regulatory motifs. Scientific reports, 6(1), 1-15.

Grinzato, A., Kandiah, E., Lico, C., Betti, C., Baschieri, S., & Zanotti, G. (2020). Atomic structure of potato virus X, the prototype of the Alphaflexiviridae family. Nature chemical biology, 16(5), 564-569.

Guo, Y. (2021a). Designing hybrid potato. Nature Food, 2(7), 453-453.

Guo, Y. (2021b). Sprouting control for potato storage. Nature Food, 2(5), 319-319.

Huhnlein, A., Schubert, J., Thieme, T., & Schliephake, E. (2011). Quantitative detection of Potato virus Y in potato plants and aphids-Discussion of diverse applications in potato research. Nature Precedings, 1-1.

Kaplanoglu, E., Chapman, P., Scott, I. M., & Donly, C. (2017). Overexpression of a cytochrome P450 and a UDP-glycosyltransferase is associated with imidacloprid resistance in the Colorado potato beetle, Leptinotarsa decemlineata. Scientific reports, 7(1), 1-10.

Kloosterman, B., Abelenda, J. A., Gomez, M. D. M. C., Oortwijn, M., de Boer, J. M., Kowitwanich, K., ... & Bachem, C. W. (2013). Naturally occurring allele diversity allows potato cultivation in northern latitudes. Nature, 495(7440), 246-250.

Kumari, P., Kumar, J., Kumar, R. R., Ansar, M., Rajani, K., Kumar, S., & Ranjan, T. (2020). Inhibition of potato leafroll virus multiplication and systemic translocation by siRNA constructs against putative ATPase fold of movement protein. Scientific reports, 10(1), 1-11.

Li, Q., Qin, Y., Hu, X., Li, G., Ding, H., Xiong, X., & Wang, W. (2020). Transcriptome analysis uncovers the gene expression profile of salt-stressed potato (Solanum tuberosum L.). Scientific reports, 10(1), 1-19.

Li, R., Tee, C. S., Jiang, Y. L., Jiang, X. Y., Venkatesh, P. N., Sarojam, R., & Ye, J. (2015). A terpenoid phytoalexin plays a role in basal defense of Nicotiana benthamiana against Potato virus X. Scientific reports, 5(1), 1-6.

Liu, B., Gu, W., Yang, Y., Lu, B., Wang, F., Zhang, B., & Bi, J. (2021). Promoting potato as staple food can reduce the carbon–land–water impacts of crops in China. Nature Food, 1-8.

Lyu, J. (2017). Unearthing potato evolution. Nature Plants, 3(12), 912-912.

Man-Hong, Y., Lei, Z., Sheng-Tao, X., McLaughlin, N. B., & Jing-Hui, L. (2020). Effect of water soluble humic acid applied to potato foliage on plant growth, photosynthesis characteristics and fresh tuber yield under different water deficits. Scientific reports, 10(1), 1-10.

Martin, M. D., Cappellini, E., Samaniego, J. A., Zepeda, M. L., Campos, P. F., Seguin-Orlando, A., & Gilbert, M. T. P. (2013). Reconstructing genome evolution in historic samples of the Irish potato famine pathogen. Nature communications, 4(1), 1-7.

McIvor, C. (2011). All eyes on the potato genome. Nature. https://doi.org/10.1038/news.2011.407

Nahar, N., Westerberg, E., Arif, U., Huchelmann, A., Guasca, A. O., Beste, L., ... & Sitbon, F. (2017). Transcript profiling of two potato cultivars during glycoalkaloid-inducing treatments shows differential expression of genes in sterol and glycoalkaloid metabolism. Scientific reports, 7(1), 1-13.

Sagcan, H., & Kara, N. T. (2019). Detection of Potato ring rot Pathogen Clavibacter michiganensis subsp. s epedonicus by Loop-mediated isothermal amplification (LAMP) assay. Scientific reports, 9(1), 1-8.

Sevestre, F., Facon, M., Wattebled, F., & Szydlowski, N. (2020). Facilitating gene editing in potato: a Single-Nucleotide Polymorphism (SNP) map of the Solanum tuberosum L. cv. Desiree genome. Scientific reports, 10(1), 1-8.

Smagin, A., Sadovnikova, N., & Smagina, M. (2019). Synthetic gel structures in soils for sustainable potato farming. Scientific reports, 9(1), 1-15.

Taylor, M. (2018). Routes to genetic gain in potato. Nature plants, 4(9), 631-632.

Tiwari, J. K., Buckseth, T., Zinta, R., Saraswati, A., Singh, R. K., Rawat, S., ... & Chakrabarti, S. K. (2020). Transcriptome analysis of potato shoots, roots and stolons under nitrogen stress. Scientific reports, 10(1), 1-18.

Villano, C., Esposito, S., D'Amelia, V., Garramone, R., Alioto, D., Zoina, A., ... & Carputo, D. (2020). WRKY genes family study reveals tissue-specific and stress-responsive TFs in wild potato species. Scientific reports, 10(1), 1-12.

Vulavala, V. K., Fogelman, E., Faigenboim, A., Shoseyov, O., & Ginzberg, I. (2019). The transcriptome of potato tuber phellogen reveals cellular functions of cork cambium and genes involved in periderm formation and maturation. Scientific reports, 9(1), 1-14.

Wang, C., Hawthorne, D., Qin, Y., Pan, X., Li, Z., & Zhu, S. (2017). Impact of climate and host availability on future distribution of Colorado potato beetle. Scientific Reports, 7(1), 1-9.

Wang, K., He, W., Ai, Y., Hu, J., Xie, K., Tang, M., ... & Zaag, P. V. (2017). Optimizing seed potato production by aeroponics in China. Philippine Journal of Crop Science, 42(1), 69-74.

Wiesel, L., Davis, J. L., Milne, L., Fernandez, V. R., Herold, M. B., Williams, J. M., ... & Hein, I. (2015). A transcriptional reference map of defence hormone responses in potato. Scientific reports, 5(1), 1-12.

Witek, K., Jupe, F., Witek, A. I., Baker, D., Clark, M. D., & Jones, J. D. (2016). Accelerated cloning of a potato late blight–resistance gene using RenSeq and SMRT sequencing. Nature biotechnology, 34(6), 656-660.

Ye, M., Peng, Z., Tang, D., Yang, Z., Li, D., Xu, Y., ... & Huang, S. (2018). Generation of self-compatible diploid potato by knockout of S-RNase. Nature Plants, 4(9), 651-654.

Zhang, C., Wang, P., Tang, D., Yang, Z., Lu, F., Qi, J., ... & Huang, S. (2019). The genetic basis of inbreeding depression in potato. Nature genetics, 51(3), 374-378.

Zhang, L., & Gleason, C. (2020). Enhancing potato resistance against root-knot nematodes using a plant-defence elicitor delivered by bacteria. Nature Plants, 6(6), 625-629.

Zhou, Q., Tang, D., Huang, W., Yang, Z., Zhang, Y., Hamilton, J. P., ... & Huang, S. (2020). Haplotype-resolved genome analyses of a heterozygous diploid potato. Nature genetics, 52(10), 1018-1023.