Int.J.Curr.Microbiol.App.Sci (2020) *9*(4): 773-782

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 4 (2020)**
Journal homepage: http://www.ijcmas.com

Review Article https://doi.org/10.20546/ijcmas.2020.904.092

Intragenesis as a Sustainable Crop Improvement Method: A Review

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Keywords

Genetically modified organisms, Intragenic modification, Sexually compatible gene pool

Article Info

Accepted:
07 March 2020
Available Online:
10 April 2020

A B S T R A C T

Our society has a great concern about transgenic crops regarding mixing of genetic materials between species whose hybridization is not possible naturally. Different public policies on the development and use of genetically modified organisms (GMOs) are of high concern with defining proper risk management strategies. Researchers are in agreement that this technology ‘‘tampers with nature’’ in an unacceptable manner. This has been recognised as an objection to the crossing of species borders in generation of transgenic organisms. There are recent projects of genetic modification which is aimed at accommodation of the above mentioned concerns by alteration of expression of endogenous genes rather than introduction of genes from other species. Several surveys show higher public acceptance of intragenic/cisgenic crops compared to transgenic crops. Therefore, although the intragenic and cisgenic concepts were internationally introduced only in last decade, several different traits in different variety of crops have recently been modified according to these concepts. The main moral reason for intragenic modification, is the requirement to respect the ‘‘otherness’’ of nature.

Introduction

The area of agricultural land utilized for the production purpose of transgenic (genetically modified or GM) crops has augmented at an unprecedented swiftness as the journey of these crops were commenced about 22 years ago. Even though the introduced Genetically Modified crops have been exceedingly triumphant, it is evident that only a part of the potential of genetic modification of crop plants is being grasped (Holme *et al*., 2013).

The technological as well as economical inconveniences are, however, only a fraction of the dilemma. Worldwide, the GM-technology has been met considerable scepticism among the common people and in effect thereof by the producers also, the industry along with the retailers.

Various studies evidently demonstrate that one of the chief anxieties of the public about transgenic crops is the combination of genetic elements artificially derived from diverse organisms that are not crossable by the natural means (Gaskell and Bauer, 2001; Bauer and Gaskell, 2002; Lassen *et al*., 2002).

This reluctance is linked time and again to a kind of respect for mother nature and also comes into view to be inter-linked with worries for impending health jeopardies and for the scattering of novel gene-combinations into the environment.

Bearing public worries about safety issues in mind concerning the GM crops in addition to the aspire of meeting these doubts and at the same time certifying an environmentally sound and resourceful plant production, the concept of intragenesis was developed as an efficient substitute to the transgenic crop development (Jacobsen and Schouten, 2007).

The concept is based on the elite utilization of genetic material from the same species or genetic material from the species that are closely-related and able to perform sexual hybridization.

This is in distinguishing to transgenesis where the genes as well as DNA sequences can be shifted between any species (Rommens *et al*., Jacobsen and Schouten, 2007).

Issues associated with traditional plant breeding

Unintentional transfer of undesirable genes

In their hard works to have room for the evolving requirements of growers as well as consumers, plant breeders take up any accessible tool to recognize the strongest feasible traits. In one application, a quantity of the genetic diversity that is obtainable within a sexually compatible group is captured by making crosses between the cultivated varieties and the wild relatives and screening the consequential F_1 hybrids for a novel trait. Through performing extensive backcrossing, a part of the wild DNA, representing at least ~1% of the whole genome and encompassing the selected trait, is introgressed into the existing varieties.

Significantly, the DNA segment that is introgressed may include one or numerous genes that are linked with detrimental characteristics. Over and above frequently observed linkage yield drag (Kopisch-Obuch *et al*., 2005), introgression can consequence in ambiguous alterations linked to lower quality of food. For example, transfer of “crisp chip” and “high starch” traits from *Solanum chacoense* to cultivated potato (*Solanum tuberosum*) augmented the levels of glycoalkaloid in the resultant variety Lenape to approximately twice concentration of the highest allowed limit (354 µg kg^{-1}) (Akeley *et al*., 1968; Zitnack *et al*., 1970).

Persistent incidence of plant-produced toxins or allergens

More than 99% of the total dietary intake of toxins has been estimated to be generated by the food crops themselves (Ames *et al*., 1990). Products, for example, acrylamide, exhibit properties of being toxic as well as carcinogenic and gather in, such as, bread crusts along with the surface of potato chips in addition to French fries (Tareke *et al*., 2002). The normal acrylamide dietary intake level is 28 µg day^{-1} (www.cfsan.fda.gov/~dms/acryexpo.html.) and it could be lessen to slight quantities by the use of wheat and potato varieties accumulating stumpy levels of asparagine.

Unfortunately, breeders have not yet selected for low asparagine, and there are no acceptable varieties available at present that unexpectedly demonstrate this trait. Thus, labours to produce low-asparagine potato or wheat would necessitate both identification of source and introgression of trait, a procedure that may take a long time of 20 years (Rommens, 2007).

The availability of genes in crops of these days that are allergen-encoding is an even more vital concern. A solitary peanut can be menacing to people's life liable to budding allergy reactions, and the consumption of bread often injures the intestinal lining of 0.8% of the Americans unintentionally that suffer from gluten sensitivities (Harrison *et al*., 2007).

Although a number of allergen-encoding genes have been inactivated through the use of mutagenesis, it would be complicated to get rid of all 20-80 genes from the crops such as rice, wheat, soybean, peanut, and apple that encode allergens or suspected allergens (Gendel and Jenkins, 2006).

The regulatory agencies resist the deliberate utilization of genes that are identified to generate toxins, allergens, or anti-nutritionals (Kaeppler, 2000) but can accomplish petite to stop the unchecked transfer of such genes through conventional breeding (Bradford *et al*., 2005). There is another major issue of dormant traits activation.

Intragenesis

Rommens introduced the definition of the concept of intragenic transformation in the year 2004. In intragenesis, diverse plant genetic components are recombined *in-vitro* to raise an expression gene construct that is then introduced into a plant falling within the same sexually compatible gene pool (Rommens 2004; Rommens *et al.,* 2007).

Thus, the source of the genes for the genetic modification in case of intragenesis is from the same or a species that falls within crossable limit. Intragenes are hybrid genes. Selected genetic elements from various genes can be merged together in intragenesis (Rommens *et al.,* 2007). Intragenesis permits for the design of cassettes uniting definite genetic elements from plants belonging to the identical sexually compatibile gene pool. So, coding regions of one gene (with or without the introns) can be combined with the promoters and the terminators from various genes from the same sexually compatibile gene pool.

Moreover, silencing constructs can be designed by merging a number of different genetic elements from the group having the same sexual compatibility. When employing *Agrobacterium*-mediated transformation, the T-DNA border sequences should derive from the sexually compatible DNA pool (P-DNA borders). The phenotype of a plant achieved through the intragenesis is not attainable through the approaches of traditional breeding as the expression profile of the freshly accumulated gene may vary from that detected naturally (Schaart and Visser 2009; Devi *et al.,* 2013). Antisense or RNA interference (RNAi) can be utilized for achieving the purpose of silencing the gene(s) in case of intragenesis (Schaart and Visser 2009) (Table 1 and 2).

Table.1 Examples of traits that can be incorporated into a plant by either transferring or modifying the expression of native genes

Trait	target plant	target gene	approach	Year	Reference
Extended shelf life	tomato	Pg	fruit-specific silencing	1988	Sheehy *et al.*, 1988
Extended shelf life	tomato	Acc oxidase	fruit-specific silencing	1991	Oeller *et al.*, 1991
Extended shelf life	tomato	Acc synthase	fruit-specific silencing	1998	Liu *et al.*, 1998
Increased vitamin-E content	Arabidopsis	gmt	seed-specific overexpression	1998	Shintani *et al.*, 1998
Reduced glycemic index	potato	Sbe I + Sbe II	tuber-specific silencing	2000	Schwall *et al.*, 2000
Increased xanthophyll content	tomato	Lcy + Chy	fruit-specific overexpression	2002	Dharmapuri *et al.*, 2002
Heat-stable vegetable oil	cottonseed	Fad2	seed-specific silencing	2002	Liu *et al.*, 2002
Increased zeaxanthin content	potato	Zep	tuber-specific silencing	2002	Romer *et al.*, 2002
Increased anthocyanin content	tomato	Ant1	fruit-specific overexpression	2003	Mathews *et al.*, 2003
Increased vitamin-C content	strawberry[a]	GalUR	constitutive overexpression[b]	2003	Agius *et al.*, 2003
Increased vitamin-E content	soybean	Vte3 + Vte4	seed-specific overexpression[c]	2003	Van-Eenennaam *et al.*, 2003
Late blight resistance	potato	RB	use of original promoter	2003	Song *et al.*, 2003
Reduced allergen content	soybean	Gly m Bd 30 K	constitutive silencing[d]	2003	Herman *et al.*, 2003
Enhanced aroma	potato	Cgsb	constitutive overexpression[b]	2003	Di *et al.*, 2003
Increased flavonol content	potato	Chi	tuber-specific overexpression	2004	Lukaszewicz *et al.*, 2004
Heat-stable vegetable oil	soybean	Fad3	seed-specific silencing	2004	Fillatti *et al.*, 2004

Bruise tolerance	potato	Ppo	tuber-specific silencing	2004	Rommens *et al.*, 2004
Increased carotenoid and flavonoid content	tomato	Det1	fruit-specific silencing	2005	Davuluri *et al.*, 2005
Reduced allergen content	apple	Mal d 1	constitutive silencing[d]	2005	Gilissen *et al.*, 2005
Reduced allergen content	peanut	Ara h 2	constitutive silencing[d]	2005	Dodo *et al.*, 2005
Extended shelf life	tomato	Dhs	constitutive silencing[b]	2005	Wang *et al.*, 2005
Increased â-carotene content	potato	Lcy-e	tuber-specific silencing	2006	Diretto *et al.*, 2006
Enhanced aroma	tomato	Aadc1A	constitutive overexpression[b]	2006	Tieman *et al.*, 2006
Enhanced flavor	potato	R1 + PhL	tuber-specific silencing	2006	Rommens *et al.*, 2006
Reduced heat-induced acrylamide content	potato	R1 + PhL	tuber-specific silencing	2006	Rommens *et al.*, 2006
Reduced lignin content	alfalfa/feed	C3H	silencing in vascular tissues	2006	Ralph *et al.*, 2006
Reduced allergen content	tomato	Ltpg1 or Ltpg2	constitutive silencing[d]	2006	Le *et al.*, 2006
Increased folate content	tomato	Acds	fruit-specific overexpression	2007	Diaz de la Garza *et al.*, 2007
Reduced heat-induced acrylamide content	potato	Apg1	tuber-specific overexpression	2007	Rommens, 2007
Reduced heat-induced acrylamide content	potato	Asn1 + Asn2	tuber-specific silencing	2007	Rommens, 2007

[a]Concept demonstrated inArabidopsis. [b]Molecular strategies may be improved upon by employing tissue-specific promoters. [c]Gene isolated from Arabidopsis. [d]Multigene silencing constructs may be used to simultaneously inactivate various allergen-encoding genes.

Table.2 Intragenic crops developed or currently under development

Crop	Type	Prom./term./spacer from	Gene	Trait	Reference
Potato	Silencing	GBSS/nos Spacer: GBSS-fragment GBSS/GBSS Spacer: GBSS-fragment	GBSS	High amylopectin	de Vetten *et al.*, 2003
Potato	Silencing	GBSS/Ubi3 Spacer: Ubi7-fragment	Ppo	Preventing black spot bruise	Rommens *et al.*, 2004
Potato	Silencing	GBSS/Ubi3 Spacer: Ubi7-fragment	Ppo, R1, PhL	Preventing black spot bruise. Limiting cold-induced degradation	Rommens *et al.*, 2006
Potato	Silencing	Prom.Agp/Prom.GBS* Spacer: Ubi7-fragment	StAs1,StAS2	Limit acrylamide in French Fries	Rommens *et al.*, 2008
Potato	Silencing	Prom.Agp/Prom.GBS* Spacer: Ubi7-fragment	StAs1	Limit acrylamide in French Fries	Chawla *et al.*, 2012
Apple	Expression	RbcS/RbcS	HcrVf2	Scab resistance	Joshi *et al.*, 2011
Strawberry	Overexpression	FaExp2/FaExp2	PGIP	Gray mould resistance	Schaart, 2004
Alfalfa	Silencing	PromPetE/PromPetE* Spacer: Comt-fragment	Comt	Reduced levels of lignin	Weeks *et al.*, 2008
Perennial ryegrass	Overexpression	n.m. but from species itself	Lpvp1	Drought tolerance	Bajaj *et al.*, 2008

*This type of 'convergent transcription' silencing construct with two promoters was shown to be very efficient (Yan *et al.*, 2006). n.m.: not mentioned

Present status of intragenic crops' regulation

The simplicity, timeframe and cost of endorsement of the intragenic crops are under development will be dependent upon the future regulations of these crops. In the majority of the countries, the release of intragenic crops falls currently under the regulatory guidelines as similar as the crops that are transgenic.

Limitations of intragenics

Although the intragenic technology is enlightening considerable advantages more than the transgenic counterpart, conversely, still there are a petite number of limitations present related to this novel tool. One of the chief disadvantages contributed by the intragenic approach compared to transgenic, is that characters that are outside to the sexually well-matched gene pool cannot be introduced. In addition, extraordinary proficiency and time are compulsory for successful development of intragenic crops as compared to the transgenic crops.

The application of intragenic practice boosts the opportunity to introgress the ideal favoured genes into the fresh cultivars, without troubling their constructive characteristics. Conventional methods in plant breeding rely on random modifications of genome and are not easy to apply to either eradicate undesirable features or activate the dormant traits. Moreover, improvements of definite characteristics could be coupled with inadvertent as well as unnoticed changes in genetic level that compromise quality of food. These issues are addressed efficiently by accurately recombining native elements *in vitro* and introducing the resulting expression cassettes into plants using marker-free and all-native DNA transformation. An evaluation of these low-risk crops should be focused on any potential safety issues to the consumer. We propose to lessen the regulatory yoke for intragenic crops as compared to transgenic crops.

References

Agius F, González-Lamothe R, Caballero JL, Muñoz-Blanco J, Botella MA, Valpuesta V. Engineering increased vitamin C levels in plants by overexpression of a D-galacturonic acid reductase. Nature biotechnology. 2003 Feb; 21(2):177-81.

Akeley RV, Mills WR, Cunningham CE, Watts J. Lenape: a new potato variety high in solids and chipping quality. American Potato Journal. 1968 Apr 1;45(4):142-5.

Ames BN, Profet M, Gold LS. Nature's chemicals and synthetic chemicals: comparative toxicology. Proceedings of the National Academy of Sciences. 1990 Oct 1;87(19):7782-6.

Bajaj S, Puthigae S, Templeton K, Bryant C, Gill G, Lomba P, Zhang H, Altpeter F, Hanley Z. Towards engineering drought tolerance in perennial ryegrass using its own genome. In6th Canadian plant genomics workshop 2008 Jun 23 (Vol. 62).

Bauer MW, Bauer MW, Gaskell G, Durant J, editors. Biotechnology-the making of a global controversy. Cambridge University Press; 2002 Sep 5.

Bradford KJ, Van Deynze A, Gutterson N, Parrott W, Strauss SH. Regulating transgenic crops sensibly: lessons from plant breeding, biotechnology and genomics. Nature biotechnology. 2005 Apr; 23(4):439-44.

Chawla R, Shakya R, Rommens CM. Tuber- specific silencing of asparagine synthetase- 1 reduces the acrylamide- forming potential of potatoes grown in the field without affecting tuber shape and yield. Plant biotechnology journal. 2012 Oct;10(8):913-24.

Davuluri GR, Van Tuinen A, Fraser PD, Manfredonia A, Newman R, Burgess D, Brummell DA, King SR, Palys J, Uhlig J, Bramley PM. Fruit-specific RNAi-mediated suppression of DET1 enhances carotenoid and flavonoid content in tomatoes. Nature biotechnology. 2005 Jul;23(7):890-5.

de la Garza RD, Quinlivan EP, Klaus SM, Basset GJ, Gregory JF, Hanson AD. Folate biofortification in tomatoes by engineering the pteridine branch of folate synthesis. Proceedings of the National Academy of Sciences. 2004 Sep 21;101(38):13720-5.

de Vetten N, Wolters AM, Raemakers K, van der Meer I, ter Stege R, Heeres E, Heeres P, Visser R. A transformation method for obtaining marker-free plants of a cross-pollinating and vegetatively propagated crop. Nature biotechnology. 2003 Apr; 21(4):439-42.

Devi EL, Chongtham SK, Holeyachi P, Kousar N, Singh M, Behera C, Telem RS, Singh NA, Wani SH. Cisgenesis and intragenesis: twin sisters for crop improvement. Res J Agric For Sci. 2013; 1:22-6.

Dharmapuri S, Rosati C, Pallara P, Aquilani R, Bouvier F, Camara B, Giuliano G. Metabolic engineering of xanthophyll content in tomato fruits. Febs Letters. 2002 May 22;519(1-3):30-4.

Di R, Kim J, Martin MN, Leustek T, Jhoo J, Ho CT, Tumer NE. Enhancement of the primary flavor compound methional in potato by increasing the level of soluble methionine. Journal of agricultural and food chemistry. 2003 Sep 10;51(19):5695-702.

Diretto G, Tavazza R, Welsch R, Pizzichini D, Mourgues F, Papacchioli V, Beyer P, Giuliano G. Metabolic engineering of potato tuber carotenoids through tuber-specific silencing of lycopene epsilon cyclase. BMC plant biology. 2006 Dec 1;6(1):13.

Dodo H, Konan K, Viquez O. A genetic engineering strategy to eliminate peanut allergy. Current allergy and asthma reports. 2005 Jan 1;5(1):67.

Gaskell G, Bauer MW, editors. Biotechnology 1996-2000: The years of controversy. London: Science Museum; 2001.

Gendel SM, Jenkins JA. Allergen sequence databases. Molecular nutrition & food research. 2006 Jul;50(7):633-7.

Gilissen LJ, Bolhaar ST, Matos CI, Rouwendal GJ, Boone MJ, Krens FA, Zuidmeer L, van Leeuwen A, Akkerdaas J, Hoffmann-Sommergruber K, Knulst AC. Silencing the major apple allergen Mal d 1 by using the RNA interference approach. Journal of allergy and clinical immunology. 2005 Feb 1; 115(2): 364-9.

Harrison MS, Wehbi M, Obideen K. Celiac disease: more common than you think. Cleveland Clinic journal of medicine. 2007 Mar 1; 74(3): 209.

Herman EM, Helm RM, Jung R, Kinney AJ. Genetic modification removes an immunodominant allergen from soybean. Plant physiology. 2003 May 1;132(1):36-43.

Holme IB, Wendt T, Holm PB. Intragenesis and cisgenesis as alternatives to transgenic crop development. Plant Biotechnology Journal. 2013 May; 11(4):395-407.

Jacobsen E, Schouten HJ. Cisgenesis strongly improves introgression breeding and induced translocation breeding of plants. Trends in biotechnology. 2007 May 1;25(5):219-23.

Joshi SG, Schaart JG, Groenwold R, Jacobsen E, Schouten HJ, Krens FA. Functional analysis and expression profiling of HcrVf1 and HcrVf2 for development of scab resistant cisgenic and intragenic apples. Plant molecular biology. 2011 Apr 1;75(6):579-91.

Kaeppler HF. Food safety assessment of genetically modified crops. Agronomy Journal. 2000 Jul 1;92(4):793-7.

Kopisch-Obuch FJ, McBroom RL, Diers BW. Association between soybean cyst nematode resistance loci and yield in soybean. Crop science. 2005 May 1;45(3):956-65.

Lassen J, Madsen KH, Sandøe P. Ethics and genetic engineering–lessons to be learned from GM foods. Bioprocess and Biosystems Engineering. 2002 Jan 1; 24(5): 263-71.

Le LQ, Lorenz Y, Scheurer S, Fötisch K, Enrique E, Bartra J, Biemelt S, Vieths S, Sonnewald U. Design of tomato fruits with reduced allergenicity by dsRNAi- mediated inhibition of ns- LTP (Lyc e 3) expression. Plant biotechnology journal. 2006 Mar;4(2):231-42.

Liu C, Tian Y, Shen Q, Jiang H, Ju R, Yan T, Liu C, Mang K. Cloning of 1-aminocyclopropane-1-carboxylate (ACC) synthetase cDNA and the inhibition of fruit ripening by its antisense RNA in transgenic tomato plants. Chinese journal of biotechnology. 1998; 14(2): 75.

Liu Q, Singh SP, Green AG. High-stearic and high-oleic cottonseed oils produced by hairpin RNA-mediated posttranscriptional gene silencing. Plant physiology. 2002 Aug 1; 129(4): 1732-43.

Lukaszewicz M, Matysiak-Kata I, Skala J, Fecka I, Cisowski W, Szopa J. Antioxidant capacity manipulation in transgenic potato tuber by changes in phenolic compounds content. Journal of Agricultural and Food Chemistry. 2004 Mar 24; 52(6): 1526-33.

Mathews H, Clendennen SK, Caldwell CG, Liu XL, Connors K, Matheis N, Schuster DK, Menasco DJ, Wagoner W, Lightner J, Wagner DR. Activation tagging in tomato identifies a transcriptional regulator of anthocyanin biosynthesis, modification, and transport. The Plant Cell. 2003 Aug 1; 15(8): 1689-703.

Moradpour M, Abdullah SN. Cisgenesis and Intragenesis as new strategies for crop improvement. In: Crop Improvement 2017 (pp. 191-216). Springer, Cham.

Oeller PW, Lu MW, Taylor LP, Pike DA, Theologis A. Reversible inhibition of tomato fruit senescence by antisense RNA. Science. 1991 Oct 18; 254(5030): 437-9.

Ralph J, Akiyama T, Kim H, Lu F, Schatz PF, Marita JM, Ralph SA, Reddy MS, Chen F, Dixon RA. Effects of coumarate 3-hydroxylase down-regulation on lignin structure. Journal of Biological Chemistry. 2006 Mar 31; 281(13): 8843-53.

Römer S, Lübeck J, Kauder F, Steiger S, Adomat C, Sandmann G. Genetic engineering of a zeaxanthin-rich potato by antisense inactivation and co-suppression of carotenoid epoxidation. Metabolic engineering. 2002 Oct 1;4(4):263-72.

Rommens CM, Bougri O, Yan H. Rommens CM, Humara JM, Ye J., Yan H., Richael C., Zhang L., Perry R., and Swords K. Crop Improvement through Modification of the Plant's Own Genome. This article has been retracted at the request of the authors. Retraction is based on three inaccurate statements of facts that are associated with a plant-derived transfer DNA. Two of the inaccuracies were described on p. 422.

Rommens CM, Haring MA, Swords K, Davies HV, Belknap WR. The intragenic approach as a new extension to traditional plant breeding. Trends in Plant Science. 2007 Sep 1; 12(9): 397-403.

Rommens CM, Humara JM, Ye J, Yan H, Richael C, Zhang L, Perry R, Swords K. Crop improvement through modification of the plant's own genome. Plant Physiology. 2004 May 1; 135(1): 421-31.

Rommens CM, Yan H, Swords K, Richael C, Ye J. Low- acrylamide French fries and potato chips. Plant biotechnology journal. 2008 Oct; 6(8): 843-53.

Rommens CM, Ye J, Richael C, Swords K. Improving potato storage and processing characteristics through all-native DNA transformation. Journal of Agricultural and Food Chemistry. 2006 Dec 27; 54(26): 9882-7.

Rommens CM. All-native DNA transformation: a new approach to plant genetic engineering. Trends in Plant Science. 2004 Sep 1; 9(9): 457-64.

Rommens CM. Intragenic crop improvement: Combining the benefits of traditional breeding and genetic engineering. Journal of agricultural and food chemistry. 2007 May 30; 55(11): 4281-8.

Rommens CM. Intragenic crop improvement: Combining the benefits of traditional breeding and genetic engineering. Journal of agricultural and food chemistry. 2007 May 30; 55(11):4281-8.

Schaart JG, Visser RG. Novel plant breeding techniques. Consequences of new genetic modification-based plant breeding techniques in comparison to conventional plant breeding. Cogem; 2009.

Schaart JG. Towards consumer-friendly cisgenic strawberries which are less susceptible to Botrytis cinerea. 2004.

Schouten HJ, Krens FA, and Jacobsen E. Cisgenic plants are similar to traditionally bred plants. EMBO Rep. 2006; 7: 750–753.

Schwall GP, Safford R, Westcott RJ, Jeffcoat R, Tayal A, Shi YC, Gidley MJ, Jobling SA. Production of very-high-amylose potato starch by inhibition of SBE A and B. Nature biotechnology. 2000 May; 18(5): 551-4.

Sheehy RE, Kramer M, Hiatt WR. Reduction of polygalacturonase activity in tomato fruit by antisense RNA. Proceedings of the National Academy of Sciences. 1988 Dec 1; 85(23): 8805-9.

Shintani D, DellaPenna D. Elevating the vitamin E content of plants through metabolic engineering. Science. 1998 Dec 11; 282(5396): 2098-100.

Song J, Bradeen JM, Naess SK, Raasch JA, Wielgus SM, Haberlach GT, Liu J, Kuang H, Austin-Phillips S, Buell CR, Helgeson JP. Gene RB cloned from *Solanum bulbocastanum* confers broad spectrum resistance to potato late blight. Proceedings of the national academy of sciences. 2003 Aug 5; 100(16): 9128-33.

Tareke E, Rydberg P, Karlsson P, Eriksson S, Törnqvist M. Analysis of acrylamide, a carcinogen formed in heated foodstuffs. Journal of agricultural and food chemistry. 2002 Aug 14; 50(17): 4998-5006.

Tieman D, Taylor M, Schauer N, Fernie AR, Hanson AD, Klee HJ. Tomato aromatic amino acid decarboxylases participate in synthesis of the flavor volatiles 2-phenylethanol and 2-phenylacetaldehyde. Proceedings of the National Academy of Sciences. 2006 May 23; 103(21): 8287-92.

Van Eenennaam AL, Lincoln K, Durrett TP, Valentin HE, Shewmaker CK, Thorne GM, Jiang J, Baszis SR, Levering CK, Aasen ED, Hao M. Engineering vitamin E content: from Arabidopsis mutant to soy oil. The Plant Cell. 2003 Dec 1;15(12):3007-19.

Wang TW, Zhang CG, Wu W, Nowack LM, Madey E, Thompson JE. Antisense suppression of deoxyhypusine synthase in tomato delays fruit softening and alters growth and development. Plant physiology. 2005 Jul 1;138(3):1372-82.

Weeks JT, Ye J, Rommens CM. Development of an in planta method for transformation of alfalfa (*Medicago sativa*). Transgenic research. 2008 Aug 1; 17(4): 587-97.

Yan H, Chretien R, Ye J, Rommens CM. New construct approaches for efficient gene silencing in plants. Plant physiology. 2006 Aug 1; 141(4): 1508-18.

Zitnak A, Johnston GR. Glycoalkaloid content of B5141-6 potatoes. American Potato Journal. 1970 Jul 1; 47(7):2 56-60.

How to cite this article:

Mainak Barman, Saipayan Ghosh, Kingsuk Das and Sabir Ahmed Mondol. 2020. Intragenesis as a Sustainable Crop Improvement Method: A Review. *Int.J.Curr.Microbiol.App.Sci.* 9(04): 773-782. doi: https://doi.org/10.20546/ijcmas.2020.904.092