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Breeding for biotic stresses resistance in tomato: A review

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Abstract

Pests and diseases that affect tomato production have a major impact. Although fungicides and pesticides have helped to manage plant diseases and insects/pests, indiscriminate use of hazardous chemicals pollutes the environment, causes chemical residues in tomatoes to exceed threshold values, and leads to the establishment of novel races/biotypes. Breeding for the production of biotic resistant cultivars is thus a primary goal of vegetable breeders at this point. Basic research into the genetic origins of pest and disease resistance in tomato crops, as well as host-pathogen interactions, has resulted in the production of high-yielding genetically resistant cultivars. Sources of resistance, as well as genetic information, are required for the production of resistant cultivars and pre-breeding ling.

Keywords: Inheritance of resistance, Resistance sources, Biotechnological approaches, Grafting, Molecular Marker

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the leading vegetable crops of Solanaceae [1]. It has become an important commercial crop when we talk about the human nutrition. Tomatoes were originated in Peru (South America) and primary domesticated in Mexico on the basis of availability of numerous cultivated and wild Species of the tomato initiate in this area [2]. It provides nutrients like beta-carotene, lycopene, vitamin C and flavonoids. Moreover tomato has achieved high popularity especially in latest years because of lycopene's anti-oxidative activities and anti-cancer functions [3]. conventional cultivated tomato lack genetic diversity. Hence it has been suggested to transmit the desired resistance traits from their wild type Species [4]. Upon stress observation, transcription factors (TFs) attach to their target genes to regulate their expression and orchestrate biochemical and physiological modifications critical for stress tolerance and the alteration of plant growth [5]. The significant incidences of diseases and pests in tomato production are the main issue. Pesticides used indiscriminately to manage diseases, insect pests, and nematodes are detrimental to human health and the environment. On the contrary the progress in the development of insect resistance is very limited. Host plant resistance is the economical method but such resistance against insect pest is not at all stable due to population pressure of insects on the host, therefore there is evolution of novel biotypes and breakdown of resistance [6].

Varieties released till date are having one or more undesirable characters associated with them and hence have not gained the popularity. Insect-pests are accountable for falling about 40% yield in vegetables [7] Tomato (*Solanum lycopersicum* L.) possesses unique properties, as it is both an economically important crop, the first vegetable in production in the world (FAOSTAT 2011), and a model plant species, due to its diploid, relatively compact, and recently sequenced genome and its large genetic and genomic resources [8]. The biotrophic ascomycete *Oidium neolycopersici* (causing PM) is one of the economically most important foliar pathogens of tomato, both in the greenhouse and in open field conditions [9].

Table 1: Major Diseases and Insect-Pests Attacking Tomato Crop

Crop	Major Diseases	Major Insect-Pests
Tomato	ToL CV, CMV, late blight, early blight, bacterial wilt, root-knot, nematodes, septoria leaf spot, tomato spotted wilt virus	Fruit borer, white fly, aphid

Source: Dhall R.K (2015) [4]

The tomato leaf curl New Delhi virus (ToLCNDV) is a bipartite begomovirus species (genus *Begomovirus*, family *Geminiviridae*) whose isolates are transmitted in nature by the whitefly *Bemisia tabaci* (family *Aleyrodidae*, order *Hemiptera*) in a circulative and constant manner [10]. ToLCNDV is an economically significant begomovirus identified to cause overwhelming damage to tomato (*Solanum lycopersicum*) production, and it is more prevalent in northern India [11, 12, 13, 14]. Wilt diseases of tomatoes can be caused by fungal, bacterial, viral, and nematode pathogens, and a biotic factor. There are over 100 different special forms of Fusarium oxysporum, each usually with a specific host on which they can cause disease by Fusarium oxysporum. The fungus is the soil borne hyphomycete and is one of more than 100 F. oxysporum that causes vascular wilts of flowering plants [15]. Tomatoes are attacked by a variety of insects, including mites, whiteflies, aphids, Lepidoptera (such as tomato fruitworm, beet armyworm, cotton bollworm, southern armyworm, soybean podworm, and Egyptian cottonworm), Coleoptera (such as Colorado potato beetle and tobacco flea beetle), Diptera (such as leafminers and fruit fly), thrips, sinkbugs, and cutworms).

Table 2: Biotic Stresses and their Source of Resistance in Tomato

Resistant gene	Resistance against	Resistance Source	References
Asc-1	Alternaria alternata f. sp. lycopersici	S. Lycopersicum	[16]
Am	Alfalfa mosaic virus	S. Habrochaites	[17]
Bs4	Xanthomonas campestris	S. Lycopersicum	[18]
Cmv	Cucumber mosaic virus	S. Chilense	[19]
Cf-1	Cladosporium fulvum	S. Lycopersicum Var Cerasiforme	[20]
Cf-2	Cladosporium fulvum	S. Pimpinellifolium	[21]
Cf-3	Cladosporium fulvum	S. Pimpinellifolium	[22]
Frl	Fusarium oxysporum f.sp. radicis-lycopersici		[23]
Hero	Globodera rostochiensis	S. Pimpinellifolium	[24]
I	Fusarium oxysporum formae speciales lycopersici	S. Pimpinellifolium	[25]
Mi-1.2	Meloidogyne spp	S. Peruvianum	[26]
Ph-1	Phytophthora infestans	S. Pimpinellifolium	[27]
Sw-5	Tomato spotted wilt virus, tomato chlorotic spot virus	S. Peruvianum	[28
Sw-7	Tomato spotted wilt virus	S. Chilense	[29]
Ve1	Verticillium dahliae	S. Lycopersicum	[30]
Ty-1	Tomato yellow leaf curl virus	S. Chilense	[31]
Ty-2	Tomato yellow leaf curl virus	S. Habrochaites	[32]
Ty-3	Tomato yellow leaf curl virus, Tomato mosaic virus	S. Chilense	[33]
Ty-4	Tomato yellow leaf curl virus	S. Chilense	[34]
	Tomato yellow leaf curl virus	S. Peruvianum	[35]
ol-1	Oidium neolycopersici	S. Habrochaites	[36]
ol-2	Oidium neolycopersici	S. Lycopersicum Var Cerasiforme	[37]
ol-3	Oidium neolycopersici	S. Habrochaites	[38]

Biotechnological Interventions

Marker-assisted breeding can also be used to introduce certain desired genes from wild relatives into domesticated species, known as introgression. Because the desired gene is only found in one or a few places in the genome, markers indicating other parts of the wild type chromosomes can be selected against, resulting in the elimination of those (usually undesired) genes from the progeny. Genetic engineering has been attempted for developing plants resistant to various biotic stresses such as viruses, bacteria, fungus and insect pests. Significant resistance to tobacco mosic virus (TMV) infection termed "Coat protein mediated protection" has been achieved by expressing only the coat produced similar results in transgenic tomato plants against a broad spectrum of plant viruses including alfalfa mosaic virus, cucumber mosaic virus, (39) Progress in engineering insect resistance in transgenic tomato has been achieved [40, 41].

Table 3: Molecular markers used for tomato crop

Marker type	Crop	Reference
SNP	tomato	[42, 43, 44, 45, 46, 47, 48]
CAPS	tomato	[49]
SSR	tomato	[50, 51, 52, 53, 54, 55]
AFLP	tomato	[56]
RFLP	tomato	[57]
SRAP	tomato	[58, 59]
SCAR	tomato	[60]

Table 4: Transgenes Resistant to Viral Diseases in tomato Crop

Crop/Class of Transgene	Origin of Transgene	Resistant to
Cp gene	ToMV	Tomato mosaic virus
Cp gene	TYLCV	Tomato yellow leaf curl virus
Antisense RNA	ToMV	Tomato mosaic virus
Satellite RNA	CMV	Cucumber mosaic virus
N gene	TSWV	Tomato spotted wilt virus
Truncated C1gene	CMV	Cucumber mosaic virus
Two Cp genes	CMV	Cucumber mosaic virus

***Source*:** Dhall R.K (2015) [4]

Grafting

To minimize main crop loss caused by infection of soil born disease exacerbated by successive cropping, grafted seedling vegetable production was developed in Japan and Korea. The vigorous roots of selected rootstock can show excellent tolerance to serious soil-borne diseases, such as those caused by Fusarium, Verticillium, Pseudomonas, Phytophthora. Didymella bryoniae, Monosporascus cannonballus, and nematodes [61, 62] yet though the degree of tolerance varies considerably with the rootstocks. Even the scion infection of certain virus diseases (TMV races) could be markedly influenced by virus resistant rootstocks depending upon the level of resistance in scion and rootstocks. The disease tolerance in grafted seedlings may be entirely due to the tolerance of rootstock roots to such diseases. It is generally accepted, on the other hand, that the disease vulnerable characteristics of the scion are not transported to the rootstock [63, 64].

Table 5: Rootstocks for Controlled Diseases and Pests of tomato crop by Grafting

Crop	Rootstock	Disease Resistance
Tomato	S. habrochaites	CR
	Brinjal (EG-203 and EG-195) S. Melongena, S. Lycopersicum L. × S. Habrochaites	BW, NMR MDR

Source: Dhall R.K (2015) [4]

Solanum Pennelli: Resistance to Alternaria alternata f. sp. Lycopersici [65]

S. Habrochaites: Resistance to Pseudomonas syringe pv. tomato race 1 [66]

S. Chilense: Resistance to diseases (CMV, TYLCV) Zamir *et al.* [67]

S. Neorickii: Resistant to Botrytis cinerea [68]

S. Pimpinellifolium: Colour, quality, resistance to bacterial wilt (69), late blight [69]

S. Lycopersicum: Resistance to fungi and root rot [70]

Cerasiforme S. Peruvianum: Resistance to tomato spotted wilt virus and RKN [71, 72, 73]

Future Strategies

One of the best strategies for minimizing losses due to disease/insect occurrence is to develop resistant or tolerant cultivars. Although there are effective chemical control strategies for a variety of insect pests and diseases, the expense of such pesticides is quite high, and many chemicals have long-term impacts. There is a need to conduct an active research programme to make the most use of the country's existing germplasm, particularly wild relatives, for the establishment of pre-bred lines that may be used successfully against certain biotic stresses as and when resistance sources are required. When methods of artificial inoculation on plantlets are devised, breeding for disease and pest resistance becomes considerably more successful. In addition, through gene pyramiding, major efforts should be made to generate varieties or hybrids with various disease resistance. Breeding should be prioritised for integrated disease and insect pest management, such as leaf curl and TMV in tomatoes. An effective collaboration of breeders and plant pathologists/ entomologists will be of high proposition to tackle this problem.

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