Established Insecticide Target Site Mutations

Development of insecticide resistance can result from various mechanisms: increased ability for insecticide detoxification, decreased penetration/transport, or modification of the insecticide's target site. Selection pressure may lead to resistance from a single mechanism or combination of resistance mechanisms (ie. target-based and metabolic). Mutation of an amino acid residue (or multiple residues) at the target site can dramatically reduce sensitivity to an entire class of insecticides. This table provides a comprehensive list of established target site mutations associated with published cases of insecticide resistance.

IRAC MoA Group	Target Site	Mutation	Subunit	Mutation Common Name	Affected Organisms	Field Relevance	Literature References
1A	Acetylcholinesterase (Carbamates)	S431F, A302S		MACE (S431F)	*Aphis gossypii, Myzus persicae*	Yes	Nabeshima et al. (2003) Biochem Biophys Res Comm, 307; 15; Nauen et al. (2004) Pest Manag Sci, 60;1051; Andrews et al, (2004) Insect Mol Biol, 13;555; Toda et al. (2004) Insect Mol Biol, 13:549;
		G119S, A201S, T280A, F331C/Y/W, G328A			*Tetranychus urticae, Tetranychus evansi*	Yes	Khajehali et al. (2010) Pest Manag Sci, 66:220; Carvalho et al. (2012) Pest Biochem Physiol, 104:143
1B	Acetylcholinesterase (Organophosphates)	S431F, A302S		MACE (S431F)	*Aphis gossypii, Myzus persicae*	Yes	Nauen et al. (2004) Pest Manag Sci, 60:1051; Andrews et al. (2004) Insect Mol Biol, 13:555; Toda et al. (2004) Insect Mol Biol, 13:549;
		Δ3Q			*Bactrocera oleae*	Yes	Kakani et al. (2008) Insect Biochem Mol Biol, 38:781
		G119S, A201S, T280A, F331C/Y/W, G328A			*Tetranychus urticae, Tetranychus evansi*	Yes	Khajehali et al. (2010) Pest Manag Sci, 66:220; Carvalho et al. (2012) Pest Biochem Physiol, 104:143
2	GABA-gated chloride channel	A302S/N	α	rdl	*Bemisia tabaci, Sogatella furcifera, Laodelphax striatellus*	Yes	Anthony et al. (1995) Pest Biochem Physiol, 51:220; Nakao et al. (2010) Pest Biochem Phys, 97:262; Nakao et al. (2011) J Econ Entom, 104:646
		A302S (A301G), T350M	α	rdl	*Drosophila melanogaster, Drosophila simulans,*	No	ffrench-Constant et al. (1993) Nature, 363:44; Le Goff et al. (2005) J Neurochemistry, 92:1295
		V410A/G		IS6	*Helicoverpa zea*	Yes	Hokins et al. (2010) Insect Biochem Mol Biol 40:385
		V410L		IS6	*Cimex lectularius*	Yes	Yoon et al. (2008) J Med Entomol 45, 1092-1101.
		V410M		IS6	*Heliothis virescens Helicoverpa zea*	Yes	Park et al. (1997) Biochem Biophys Res Comm 239:688; Hokins et al. (2010) Insect Biochem Mol Biol 40:385
		M918I		IIS4-S6	*Plutella xylostella*	Yes	Sonoda et al. (2012) Pest Biochem Physiol 102:142.
		M918L		IIS4-S5	*Aphis gossypii, Myzus persicae*	Yes	Fontaine et al. (2011) Pest Manag Sci 67:881.
		M918T		IIS4-S6	*Tetranychus evansi, Myzus persicae, Haematobia irritans, Liriomyza huidobrensis, Musca domestica, Myzus persicae, Thrips tabaci, Tuta absoluta*	Yes	Williamson et al. (1996) Mol Gen Genet 252, 51-60. Nyoni et al. (2011) Pest Manag Sci 239:688. Eleftherianos et al. (2008) Bull Entom Res 98:183. Toda and Morishita (2009) J Econ Entomol 102:2296. Haddi et al. (2012) Insect Biochem Mol 42:506
		M918V		IIS4-S6	*Bemisa tabaci*	Yes	Morin et al. (2002) Insect Biochem Mol 32:1781.
		L925I		IIS5	*Bemisa tabaci, Cimex lectularius, Rhipicephalus microplus*	Yes	Morin et al. (2002) Insect Biochem Mol 32:1781. Yoon et al. (2008) J Med Entomol 45, 1092-1101. Roditakis et al. (2006) Pest Biochem Phys 85:166. Morgan et al. (2009) Int J Parasit 39:775.
		T929C/I/V		IIS5	*Frankliniella occidentalis*	Yes	Forcioli et al. (2002) J Econ Entomol 95, 838-848.
		T929I		IIS5	*Thrips tabaci, Tuta absoluta*	Yes	Haddi et al. (2012) Insect Biochem Mol 42:506. Toda and Morishita (2009) J Econ Entomol 102:2296.
		T929V		IIS5	*Bemisa tabaci, Ctenocephalides felis, Pediculosis captis, Plutella xylostella*	Yes	Roditakis et al. (2006) Pest Biochem Phys 85:166. Bass et al. (2004) Insect Biochem Mol 34, 1305-1313. Schuler et al. (1998) Pest Biochem Phys 59:169. Lee et al. (2000) Pest Biochem Phys 66, 130-143.
		L932F		IIS5	*Myzus persicae, Pediculosis capitis*	Yes	Fontaine et al. (2011) Pest Manag Sci 67:881. Lee et al. (2000) Pest Biochem Phys 66:130.
		I1011M		IIS6	*Aedes aegypti*	Yes	Brengues et al. (2003) Med Vet Entomol 17:87.

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3	Sodium channel	I1011M/V		IIS6	*Aedes aegypti*	Yes	Saavedra-Rodrigues et al. (2007) Insect Mol Biol 16:785.
		L1014C		kdr (IIS6)	*Anopheles sinensis Culex pipiens*	Yes	Saavedra-Rodriguez et al. (2007) Insect Mol Biol 16, 785-798. Kim et al. (2007) Pest Biochem Physiol 87:54.
		L1014F		kdr (IIS6)	*Aedes albopictus, Anopheles gambiae, Anopheles sacharovi, Anopheles stephensi, Anopheles subpictus, Blattella germanica, Ctenocephalides felis, Culex pipiens, Culex quinquefasciatus, Cydia pomonella, Frankliniella occidentalis, Haematobia irritans, Leptinotarsa decimlineata, Liriomyza huidobrensis, Liriomyza sativae, Liriomyza trifolii, Meligethes aeneus, Musca domestica, Myzus persicae, Plutella xylostella, Thrips tabaci, Tuta absoluta, Plutella xylostella*	Yes	Williamson et al. (1996) Mol Gen Genet 252, 51-60. Dong (1997) Insect Biochem Mol 27, 93-100. Schuler et al. (1998) Pest Biochem Phys 59:169. Martinez-Torres et al. (1999) Insect Mol Biol 8:339. Martinez-Torres et al. (1999) Pest Sci 55:1012. Haddi et al. (2012) Insect Biochem Mol 42:506. Toda and Morishita (2009) J Econ Entomol 102:2296. Luleyap et al. (2002) J Med Entomol 39:870. Enayati et al. (2003) Med Vet Entomol 17:138. Verhaeghen et al. (2006) Malaria J 5:16. Etang et al. (2006) Am J Trop Med Hyg 74:795. Karunaratne et al. (2007) Pest Biochem Phys 88:108. Sonada et al. (2008) Insect Biochem Mol Biol 38:883; Nauen et al. (2012) Pest Biochem Physiol 103, 173.
		L1014H		kdr (IIS6)	*Heliothis virescens, Liriomyza trifolii, Musca domestica*	Yes	Park et al. (1997) Biochem Biophys Res Comm 239:688 Rinkevich et al. (2006) Insect Mol Biol 15, 157-167.
		L1014S		kdr (IIS6)	*Anopheles arabiensis, Anopheles gambiae, Anopeles sacharovi, Culex pipiens, Culex quinquefasciatus*	Yes	Ranson et al. (2000) Insect Mol Biol 9:491. Ranson et al. (2000) Insect Mol Biol 9:491. Luleyap et al. (2002) J Med Entomol 39:870. Verhaeghen et al. (2006) Malaria J 5:16. Etang et al. (2006) Am J Trop Med Hyg 74:795.
		L1014W		kdr (IIS6)	*Anopheles sinensis*	Yes	Tan et al. (2012) J Med Entomol 49:1012.
		V1016G		IIS6	*Aedes aegypti*	Yes	Saavedra-Rodriguez et al. (2007) Insect Mol Biol 16, 785-798.
		V1016I		IIS6	*Aedes aegypti*	Yes	Karunaratne et al. (2007)Pest Biochem Physiol 88:108.
		F1020S		IIS6	*Plutella xylostella*	Yes	Endersby et al. (2011) Bull Entomol Res 101:393.
		F1534C		IIIS6	*Aedes aegypti*	Yes	Harris et al. (2010) Am J Trop Med Hyg 83, 277-284.
		G1535D		IIIS6	*Sarcoptes scabiei*	Yes	Pasay et al. (2008) Med Vet Entomol 22, 82-88.
		F1538I		IIIS6	*Rhipicephalus microplus*	Yes	He et al. (1999) Biochem Biophys Res Comm 261, 558-561.
		D1549		IIIS6	*Helicoverpa zea Heliothis virescens*	Yes	Head et al. (1998) Insect Mol Biol 7:191.
		E1553G		IIIS6	*Helicoverpa zea Heliothis virescens*	Yes	Head et al. (1998) Insect Mol Biol 7:191.
4	Nicotinic acetylcholine receptor	R81T	β		*Myzus persicae*	Yes	Bass et al. (2011) BMC Neuroscience, 12:51
		Y151S			*Nilaparvata lugens*	No	Liu et al. (2005) PNAS, 102:8420
5	Nicotinic acetylcholine receptor	trunc α6	α		*Drosophila melanogaster*	No	Watson et al. (2010) Insect Biochem Mol Biol, 40:376; Perry et al. (2007) Insect Biochem Mol Biol, 37:184
		trunc α6	α		*Plutella xylostella*	Yes	Baxter et al. (2010) PLoS Genet, 6:e1000802;

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		G275E	α		*Frankliniella occidentalis*	Yes	Puinean et al. (2012) J Neurochem, x:xxx,
6	Chloride channel	G323D			*Tetranychus urticae*	No	Kwon et al. (2010) Insect Mol Biol, 19:583
10	Chitin synthase	I1017F			*Tetranychus urticae*	Yes	VanLeeuwen et al. 2012) PNAS, 109:4407
20	Mitochondrial Complex III electron transport	G126S			*Tetranychus urticae*	Yes	Van Leeuwen et al. (2008) PNAS 105:5980; Van Nieuwenhuyse et al. (2008) Pest Manag Sci, 65:404
		G126S + I136T			*Tetranychus urticae*	Yes	Van Leeuwen et al. (2008) PNAS 105:5980; Van Nieuwenhuyse et al. (2008) Pest Manag Sci, 65:404
		G126S + S141F			*Tetranychus urticae*	Yes	Van Leeuwen et al. (2008) PNAS 105:5980; Van Nieuwenhuyse et al. (2008) Pest Manag Sci, 65:404
		P262T			*Tetranychus urticae*	Yes	Van Leeuwen et al. (2008) PNAS 105:5980; Van Nieuwenhuyse et al. (2008) Pest Manag Sci, 65:404
23	Acetyl-CoA carboxylase	E645K			*Trialeurodes vaporariorum*	No	Karatolos et al. (2012) Insect Mol Biol, 21:327
28	Ryanodine receptor	G4946E			*Plutella xylostella*	Yes	Troczka et al. (2012) Insect Biochem Mol Biol, 42:873

Mutations with "No" listed under "Field Relevance" indicates resistance was observed under laboratory conditions though not currently identified in the field.