## Established Insecticide Target Site Mutations (ver 2.4)

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 | Affected Organisms | Mutation | Subunit | Mutation Common Name | Field Relevance | Literature References |
|---|---|---|---|---|---|---|---|
| 1A | Acetylcholinesterase (Carbamates) | *Aphis gossypii* | S431F | | | Yes | Andrews et al, (2004) Insect Mol Biol, 13:555 |
| | | | A302S, S431F | | | | Toda et al, (2004) Insect Mol Biol, 13:549 |
| | | *Tetranychus urticae* | A201S, T280A, F331C/Y/W, G328A | | | | Khajehali et al, (2010) Pest Manag Sci, 66:220 |
| | | | F331Y | | | | Carvalho et al, (2012) Pest Biochem Physiol, 104:143 |
| | | | A201S, T280A, F331C/Y/W, G328A | | | | Ilias et al, (2004) Insect Biochem Mol Biol 48:17 |
| | | *Apolygus lucorum* | A216S | | | | Wu et al, (2015) Insect Biochem Mol Biol, 65:75 |
| | | *Anopheles gambiae* | G119S | | | | Badolo et al, (2015) Malar J 14:477 |
| | | | G119S | | | | Feng et al, (2015) Malar J 14:470 |
| 1B | Acetylcholinesterase (Organophosphates) | *Aphis gossypii* | S431F, A302S | | | Yes | Andrews et al, (2004) Insect Mol Biol, 13:555 |
| | | | | | | | Toda et al, (2004) Insect Mol Biol, 13:549 |
| | | *Bactrocera oleae* | Δ3Q | | | | Kakani et al, (2008) Insect Biochem Mol Biol, 38:781 |
| | | *Tetranychus urticae* | A201S, T280A, F331C/Y/W, G328A | | | | Khajehali et al, (2010) Pest Manag Sci, 66:220 |
| | | | F331Y | | | | Carvalho et al, (2012) Pest Biochem Physiol, 104:143 |
| | | | A201S, T280A, F331C/Y/W, G328A | | | | Ilias et al, (2004) Insect Biochem Mol Biol 48:17 |
| | | *Apolygus lucorum* | A216S | | | | Wu et al, (2015) Insect Biochem Mol Biol, 65:75 |
| 2 | GABA-gated chloride channel | *Nilaparvata lugens* | R300Q | α | rdl | Yes | Zhang et al, (2016) Scientific Reports, doi:10.1038/srep32335 |
| | | *Bemisia tabaci* | A302S/N | | | Yes | Anthony et al, (1995) Pest Biochem Physiol, 51:220 |
| | | *Sogatella furcifera* | | | | | Nakao et al, (2010) Pest Biochem Phys, 97:262 |
| | | *Laodelphax striatellus* | | | | | Nakao et al, (2011) J Econ Entom, 104:646 |
| | | *Plutella xylostella* | | | | | Wang et al, (2016) J Econ Entom, 109:334 |
| | | *Drosophila melanogaster* | A302S | | | No | ffrench-Constant et al, (1993) Nature, 363:44 |
| | | *Drosophila simulans* | A302S (A301G), T350M | | | | Le Goff et al, (2005) J Neurochem, 92:1295 |
| 3 | Sodium channel | *Helicoverpa zea* | V421A/G, L1029H | IS6 | | Yes | Hopkins & Pietrantonio, (2010) Insect Biochem Mol Biol, 40:385 |
| | | *Cimex lectularius* | V419L, L925I | IS6 | | Yes | Yoon et al, (2008) J Med Entomol, 45:1092 |
| | | *Heliothis virescens* | V421M | IS6 | | Yes | Park et al, (1997) Biochem Biophys Res Comm, 239:688 |
| | | *Plutella xylostella* | M918I | IIS4-S6 | | Yes | Sonoda et al, (2012) Pest Biochem Physiol 102:142 |
| | | *Myzus persicae* | M918L, L932F | IIS4-S5 | | Yes | Fontaine et al, (2011) Pest Manag Sci, 67:881 |
| | | *Thrips tabaci* | M918L | IIS4-S5 | | Yes | Wu et al, (2014) Pest Manag Sci, 70:977 |
| | | *Musca domestica* | M918T, L1014F | IIS4-S6 | | No | Williamson et al, (1996) Molec Gen Genet, 252:51 |
| | | *Tetranychus evansi* | M918T | IIS4-S5 | | Yes | Nyoni et al, (2011) Pest Manag Sci, 67:891 |
| | | *Myzus persicae* | M918T | IIS4-S5 | | Yes | Eleftherianos et al, (2008) Bull Entom Res, 98:183 |
| | | *Thrips tabaci* | M918T, T929I, L1014F | IIS4-S6 | super-kdr | Yes | Toda & Morishita, (2009) J Econ Entomol, 102:2296 |
| | | *Tuta absoluta* | M918T, T929I, L1014F | IIS4-S6 | super-kdr | Yes | Haddi et al, (2012) Insect Biochem Mol Biol, 42:506 |
| | | *Bemisa tabaci* | M918V, L925I | IIS4-S5 | | Yes | Morin et al, (2002) Insect Biochem Mol Biol, 32:1781 |
| | | *Bemisia tabaci* | L925I, T929V | IIS5 | | Yes | Roditakis et al, (2006) Pest Biochem Phys, 85:161 |
| | | *Rhipicephalus microplus* | C190A | IIS5 | | Yes | Morgan et al, (2009) Int J Parasit, 39:775 |
| | | *Varroa destructor* | L925V | IIS | | Yes | Gonzalez-Cabrera et al, (2013) PLoS One 8:e82941 |
| | | *Plutella xylostella* | T929V, L1014F | IIS4-S6 | | Yes | Sonada et al, (2008) Insect Biochem Mol Biol, 38:883 |
| | | *Ctenocephalides felis* | T929V, L1014F | IIS4-S6 | | Yes | Bass et al, (2014) Insect Biochem Mol Biol, 34:1305 |
| | | *Pediculosis captis* | T929I, L932F | IIS4-S5 | | Yes | Lee et al, (2000) Pest Biochem Phys, 66:130 |
| | | *Aedes aegypti* | I1011M, V1016G | IIS6 | | Yes | Saavedra-Rodriques et al, (2007) Insect Mol Biol, 16:785 |
| | | *Anopheles sinensis* | L1014F | IIS6 | kdr | Yes | Kim et al, (2007) Pest Biochem Physiol, 87:54 |
| | | *Plutella xylostella* | L1014F | IIS6 | kdr | Yes | Schuler et al, (1998) Pest Biochem Phys, 59:169 |
| | | *Blatella germanica* | L1014F | IIS6 | kdr | No | Dong, (1997) Insect Biochem Mol Biol, 27:93 |
| | | *Myzus persicae* | L1014F | IIS6 | kdr | Yes | Martinez-Torres et al, (1999) Insect Mol Biol 8:339 |
| | | *Culex pipiens* | L1014F | IIS6 | kdr | No | Martinez-Torres et al, (1999) Pest Sci, 55:1012 |
| | | *Tecia solanivora* | L1014F | IIS6 | kdr | Yes | Bacca et al, (2016) Pest Manag Sci,xx:xxx |
| | | *Anopheles gambiae* | L1014F | IIS6 | kdr | Yes | Hanson et al, (2000) Insect Mol Biol, 9:491 |
| | | *Anopholes sacharavi* | L1014F/S | IIS6 | kdr | Yes | Luleyap et al, (2002) J Med Entomol, 39:870 |
| | | *Anopheles stephensi* | L1014F | IIS6 | kdr | Yes | Enayati et al, (2003) Med Vet Entomol, 17:138 |

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|---|---|---|---|---|---|---|---|
| | | *Anopheles gambiae Anopheles arabiensis* | L1014F/S | IIS6 | kdr | Yes | Verhaeghen et al, (2006) Malaria J, 5:16 |
| | | | | IIS6 | kdr | | Etang et al, (2006) Am J Trop Med Hyg, 74:795 |
| | | *Anopheles subpictus* | L1014F | IIS6 | kdr | Yes | Karunaratne et al, (2007) Pest Biochem Phys 88:108 |
| | | *Aphis gossypii* | L1014F | IIS6 | kdr | Yes | Marshall et al, (2012) J Pest Sci, 37:169 |
| | | *Meligethes aeneus* | L1014F | IIS6 | kdr | Yes | Nauen et al, (2012) Pest Biochem Phys, 103:173 |
| | | *Sitobian avenae* | L1014F | IIS6 | kdr | Yes | Foster et al, (2013) Pest Manag Sci, 70:1249 |
| | | *Psylliodes chrysocephala* | L1014F | IIS6 | kdr | Yes | Zimmer et al, (2014) Pest Biochem Physiol, 108:1 |
| | | *Musca domestica* | L1014F/H | IIS6 | kdr | No | Rinkevich et al, (2006) Insect Mol Biol, 15:157 |
| | | *Anopheles sinensis* | L1014F/S/W | IIS6 | kdr | Yes | Tan et al, (2012) J Med Entomol, 49:1012 |
| | | *Plutella xylostella* | F1020S | IIS6 | | Yes | Endersby et al, (2011) Bull Entomol Res, 101:393 |
| | | *Tetranychus urticae* | A1215D, F1538I | IIS6-IIIS6 | | Yes | Ilias et al, (2004) Insect Biochem Mol Biol 48:17 |
| | | *Aedes aegypti* | F1534C | IIIS6 | | Yes | Harris et al, (2010) Am J Trop Med Hyg 83:277 |
| | | *Sarcoptes scabiei* | G1535D | IIIS6 | | Yes | Pasay et al, (2008) Med Vet Entomol, 22:82 |
| | | *Rhipicephalus microplus* | F1538I | IIIS6 | | Yes | He et al, (1999) Biochem Biophys Res Comm, 261:558 |
| | | *Panonychus citri* | F1538I | IIIS6 | | Yes | Ding et al, (2015) Pest Manag Sci, 71:266 |
| | | *Helicoverpa zea Heliothis virescens* | D1549, E1553G | IIIS6-IVS1 | | Yes | Head et al, (1998) Insect Mol Biol, 7:191 |
| 4 | **Nicotinic acetylcholine receptor** | *Myzus persicae* | R81T | β | | Yes | Bass et al, (2011) BMC Neuroscience, 12:51 |
| | | | | | | | Beckingham et al, (2013) Pest Biochem Phys, 107:293 |
| | | | | | | | Panini et al, (2014) Pest Manag Sci, 70:931 |
| | | | | | | | Puinean et al, (2013) Pest Manag Sci, 69:195 |
| | | *Aphis gossypii* | R81T | β | | Yes | Koo et al, (2014) Crop Protection, 55:91 |
| | | | | | | | Kim et al, (2015) J Asia-Pacific Entom, 18:291 |
| | | *Nilaparvata lugens* | Y151S | | | No | Liu et al, (2005) PNAS, 102:8420 |
| 5 | **Nicotinic acetylcholine receptor** | *Drosophila melanogaster* | trunc α6 | α6 | | No | Watson et al, (2010) Insect Biochem Mol Biol, 40:376 |
| | | | | | | | Perry et al, (2007) Insect Biochem Mol Biol, 37:184 |
| | | *Plutella xylostella* | trunc α6 | α6 | | Yes | Baxter et al, (2010) PLoS Genet, 6:e1000802 |
| | | | | | | No | Wang et al, (2016) Insect Biochem Mol Biol, 71:29 |
| | | *Frankliniella occidentalis* | G275E | α6 | | Yes | Puinean et al, (2013) J Neurochem, 124:590 |
| | | *Thrips palmi* | | | | Yes | Bao et al, (2014) Pest Biochem Phys, 112:51 |
| | | *Drosophila melanogaster* | P146S | α6 | | No | Somers et al, (2015) Insect Biochem Mol Biol, 64:116 |
| 6 | **Chloride channel** | *Tetranychus urticae* | G323D | | | Yes | Kwon et al, (2010) Insect Mol Biol, 19:583 |
| | | | G314D/G323D, G326E | | | | Ilias et al, (2014) Insect Biochem Mol Biol, 48:17 |
| | | *Plutella xylostella* | A309V | | | Yes | Wang et al, (2015) Insect Mol Biol, 25:116 |
| 10 | **Chitin synthase (CHS1)** | *Tetranychus urticae* | I1017F | | | Yes | VanLeeuwen et al, (2012) PNAS, 109:4407 |
| | | | | | | | Ilias et al, (2014) Insect Biochem Mol Biol, 48:17 |
| | | | | | | | Demaeght et al, (2014) Insect Biochem Mol Biol, 51:52 |
| | | *Plutella xylostella* | I1042M | | | Yes | Douris et al, (2016) PNAS, 113:14692 |
| 11 | **Microbial disruptors of insect midgut membranes** | multiple | multiple | | | Yes | Xiao, Y. and K. Wu (2019) Philos Trans R Soc Lond B Biol Sci 374(1767): 20180316. |
| | | | | | | | Tabashnik, B. E. and Y. Carriere (2020) J Econ Entomol 113(2): 553-561. |
| 15 | **Chitin synthase (CHS1)** | *Culex pipiens* | I1043L/M | | | Yes | Poretta et al (2019) Acta Tropica, 193:106 |
| | | | I1043F | | | Yes | Fotakis et al (2020) PLOS Negl Trop Dis, 14:e0008284 |
| 20 | **Mitochondrial Complex III electron transport** | *Tetranychus urticae* | G126S, G132A, A133T, I136T, S141F, P262T | | | Yes | Van Leeuwen et al, (2008) PNAS, 105:5980 |
| | | | | | | | Van Nieuwenhuyse et al, (2008) Pest Manag Sci, 65:404 |
| | | | | | | | Ilias et al, (2014) Insect Biochem Mol Biol, 48:17 |
| | | | | | | | Fotoukkiaii et al, (2020) Pest Manag Sci |
| 22 | **Voltage-dependent sodium channel blockers** | *Plutella xylostella* | F1845Y, V1848I | | | Yes | Wang et al, (2015) Insect Sci, 23:50 |
| | | | | | | | Samantsidis et al, (2019) Insect Biochem Mol Biol, 104:73 |
| 23 | **Acetyl-CoA carboxylase** | *Trialeurodes vaporariorum* | E645K | | | No | Karatolos et al, (2012) Insect Mol Biol, 21:327 |
| | | *Bemisia tabaci* | A2083V | | | Yes | Lueke et al, (2020) Pest Biochem Mol Biol |
| 28 | **Ryanodine receptor** | *Plutella xylostella* | G4946E | | | Yes | Troczka et al, (2012) Insect Biochem Mol Biol, 42:873 |
| | | | E1338D, Q4549L, I4790M | | | | Guo et al, (2014) Scientific Reports, 4:6924 |
| | | *Tuta absoluta* | G4903E/V, I4746M | | | Yes | Roditakis et al, (2017) Insect Biochem Mol Biol, 80:11 |
| | | *Chilo suppressalis* | G4910E | | | Yes | http://onlinelibrary.wiley.com/doi/10.1002/ps.4439/pdf |
| | | *Spodoptera frugiperda* | I4734M | | | Yes | Boaventura, D., et al. (2020) Pest Management Science 76(1): 47-54. |
| | | *Spodoptera exigua* | I4743M | | | Yes | Zuo, Y. Y., et al. (2019) Insect Sci |
| | | *Chilo suppressalis* | I4758M, Y4667D/C, G4915E, Y4891F | | | Yes | Huang, J.-M., et al. (2020) Insect Biochem Mol Biol, 121:103367 |
| | | *Plutella xylostella, Tuta absoluta, C. suppressalis, Spodoptera frugiperda, Spodoptera exigua* | | | | | Richardson, E. B., et al. (2020) Journal of Pest Science. |

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