FUNGICIDE RESISTANCE MANAGEMENT IN POTATO LATE BLIGHT (June 2025)

June update: EU46_A1 has been found, as part of the Fight Against Blight monitoring project, in Wales.

BACKGROUND TO LATE BLIGHT

Potato late blight, caused by *Phytophthora infestans*, has been the major disease of potatoes since its introduction to the UK in 1845, causing losses by destroying foliage and by infecting tubers. It reproduces asexually by producing sporangia and zoospores or sexually when two mating types (A1 and A2) exchange DNA, resulting in oospores. Asexual reproduction is very efficient, and its rapid cycles are responsible for devastating epidemics. This can lead to populations containing predominately clonal lineages (genotypes). Oospores, unlike sporangia and zoospores, can survive in the soil for several years in the absence of potatoes and if they germinate, give rise to new genotypes in the population. In the mid-1970s, both A1 and A2 mating types were introduced into Europe in a quarantine-breaking shipment of tubers from Mexico. Further migrations through international trade impacted on the population dynamics of the pathogen in Continental Europe, the UK and also in the Americas and Asia. The new A1 and A2 strains have now replaced the original clonal A1 population throughout Europe and in most parts of the world.

INTEGRATED CONTROL AND EFFECTIVE RESISTANCE MANAGEMENT GUIDELINES

Resistance occurs when a pathogen becomes so insensitive to a fungicide that the fungicide's field performance is impaired. Resistance can arise rapidly and completely or develop gradually so that the pathogen becomes progressively less sensitive. Recent strains of *P. infestans* have generally exhibited rapid and complete resistance to a mode of action. Resistance has sometimes been accompanied by a fitness penalty, resulting in the decline of the resistant genotype on removal of the selector (the fungicide active ingredient) from the environment.

Fungicides continue to be an important component of late blight control. In the 1980s, resistance to phenylamide chemistry was identified, with no further reports of resistance in other fungicide mode of action groups for nearly 30 years. In the last 10 years, resistance has been reported for four of the mode of action groups (associated genotypes) in Europe including phenylamide (genotype EU13_A2), uncouplers of oxidative phosphorylation (genotypes EU33_A2 and EU37_A2), Carboxylic Acid Amide or CAA (some isolates of genotype EU43_A1) and OxySterol Binding Protein homologue Inhibition or OSBPI (some isolates of genotypes EU43_A1, EU46_A1 and EU36_A2) modes of action. This demonstrates a quickening pace towards fungicide insensitivity; therefore action is required to maintain effective control.

Genotypes with insensitivity to phenylamide (e.g. metalaxyl) and uncouplers of oxidative phosphorylation (fluazinam) have been confirmed in GB and NI. The Fungicide Resistance Action Committee (FRAC) OSBPI Working Group indicated that a single OSBPI resistant sample was found in the UK in 2023, with no report of reduced product performance. In 2024, EU46_A1 was found in two late season samples in GB (Wales and Scotland) as part of the Fight Against Blight monitoring project. Intensive monitoring of the area local to the outbreak in Wales, which is remote from main commercial potato production areas, identified EU46_A1 was present on a sample sent in to FAB on 3 June 2025. The location and unique identification of the Welsh sample serves to highlight the importance of adhering to anti-resistance stewardship principles in developing a late blight programme. All EU46_A1 strains found in GB so far are insensitive to OSBPI (oxathiapiprolin) but sensitive to CAA chemistry (dimethomorph, benthiavalicarb, mandipropamid, valifenalate). Continued vigilance is required, as EU43_A1 and EU46_A1 have been widely reported in areas bordering the UK. Previously, fungicide insensitivity has been linked to genotype, but for CAA and OSBPI modes of action, there appears to be variation in fungicide insensitivity for individual strains within the genotype. Therefore, the presence of a particular genotype cannot be used to confirm that fungicide insensitivity is definitely present and further testing will be required to confirm whether or not this trait is present. See **A HISTORY OF *PHYTOPHTHORA INFESTANS* GENOTYPES on page 4.**

A good resistance management strategy should provide effective disease control whilst slowing the selection for resistant strains. This requires careful choice of fungicide programmes and implementation of cultural control measures. Adopting an integrated approach to disease and crop management will avoid over-reliance on fungicides and decrease the risk of selecting for resistant pathogen strains. Key cultural control options include:

Cultivar choice: grow cultivars with as high a disease resistance rating as possible. Disease resistance ratings are available: [Variety Database - Home (agricrops.org)](). Avoid growing large areas of highly susceptible cultivars, particularly in locations prone to late blight. Very susceptible cultivars not only risk becoming infected early in the season, but they may also infect neighbouring crops.

Outgrade piles: these are an important source of early inoculum. Avoid having them or destroy all outgrade piles, killing any growth before crop emergence. Sheeting with heavy gauge black polythene can prevent haulm growth or young haulm can be killed by applying an approved herbicide. Check outgrade piles throughout the season for re-growth.

Control volunteers/groundkeepers: these can be an inoculum source to infect crops early and late in the growing season. Use appropriate herbicides or cultural control across the rotation.

Seed: source good quality certified seed and don't risk planting home-saved seed after years when there has been a high risk of tuber blight. Discard and destroy blighted seed tubers appropriately (see advice above for outgrade piles).

Minimise the risk of additional fungicide–resistant *P. infestans* genotypes being produced in the UK and contributing to epidemics: the risk of further genotypes that combine aggressiveness and reduced fungicide sensitivity becoming established in the UK is higher if crops are infected by soil-borne oospores. Longer crop rotations of at least 1 in 5 can substantially reduce this risk, provided groundkeepers are effectively controlled.

Below is a summary of recommendations, which reflect recent research findings, and recommended guidelines from crop protection product manufacturers. This guidance is specific to GB and NI and may vary to that suggested for other countries. Using fungicides responsibly will maintain control and decrease the risk of selection for fungicide insensitivity, ensuring products remain effective and available for longer. There are twelve modes of action currently available for late blight control (Page 3). Recommendations include:

Implement cultural controls: this will reduce the risk from severe outbreaks.

Monitor and report outbreaks in your area: use and contribute to in-season pathogen monitoring results and know what strains are present to inform decision making: Fight Against Blight | The James Hutton Institute.

Start spray programmes promptly: start when there is a warning of risk (1. weather-based, 2. local outbreak or 3. transmission from infected seed). The growth stage at which the fungicide programme should start will be dictated by the risk, e.g. crop emergence for 3. In the absence of risk, the timing of the first fungicide application should take account of crop-specific and local factors and the guidance on specific product labels. It's well established that plants are most susceptible between crop emergence and when they have *c*. 10 leaves. Weather-based risk can be assessed using e.g. Hutton criteria (see blightspy (huttonltd.com)).

Optimise applications: Aim to maximise coverage of the canopy through selection of suitable nozzles and use of water volumes appropriate for crop growth stage. For example, focus on getting effective fungicide application to what will later be the lower inaccessible part of the canopy.

Make full use of fungicides with different modes of action: know the FRAC mode of action group(s) in your products. This is necessary as the sequential and repeated application of products with a single site mode of action will select for resistance. Never exceed the label or manufacturer's recommendation for number of applications or the total dose that can be applied.

Use mixtures and alternation throughout the fungicide programme: both strategies have been demonstrated experimentally to be effective for resistance management. It is important to avoid using the same mode of action sequentially throughout the fungicide programme.

Select an effective mixture partner: when selecting a mixture partner, ensure the product is used at an effective dose to control late blight and has good persistence. This could be a multisite (if available) or another product to improve disease and resistance management. It is recommended, for as many applications as possible, that a mixture contains at least one active ingredient that is effective against all late blight strains currently confirmed to be in GB or NI.

Alternation for resistance management: it is recommended to use a strict alternation strategy throughout the fungicide programme (strict alternation = switch to different modes of action at every application). If resistant strains are reported in GB or NI, then mixtures containing the affected modes of action should be applied in strict alternation, and any additional guidance from manufacturers followed (see links below).

Include multi-site fungicides: multisite modes of action are low risk for resistance development e.g. mancozeb or potassium phosphonates) and will protect currently available fungicides when used in mixtures (see Table 1 for options).

Avoid eradicant treatments: apply fungicides preventatively and not when late blight is well established in the crop. Do not 'chase' the epidemic with fungicides and consider burning off. This will help protect the crop from tuber infection and reduce late blight inoculum for neighbouring crops.

Use appropriate spray intervals: do not over-extend intervals and consider the persistence of mixture partners to protect the individual components of any fungicide mixture.

Protect until the end of the season: maintain protection of the foliage with fungicides until the foliage is dead. Where there is a risk of tuber infection, complete the spray programme with fungicides with tuber blight activity and make full use of all modes of action available. Apply a fungicide with the desiccant (check product labels for approved tank-mixes) and make further fungicide applications until the haulm is dead.

ACTIVE INGREDIENT AND PRODUCT SPECIFIC GUIDANCE (as of October 2024)

Information will be provided by manufacturers that should be considered in addition to label recommendations and this guidance document if their products are or may be affected by resistance. Links to the relevant information are given below.

REVUS guidance from Syngenta UK (mandipropamid): Syngenta advice to protect blight fungicide efficacy | Syngenta

ZORVEC guidance from Corteva Agriscience UK (oxathiapiprolin): Zorvec application advice

FRAC Mode of Action Group (FRAC Code)	Active ingredient(s)/ (mobility)	Resistance Reported in GB/NI	Availability as solo and/or co-formulated products
Benzamides (pyridinylmethyl-benzamides) (43)	fluopicolide (translaminar/protectant activity)	None	co-formulated with propamocarb hydrochloride. Good activity on zoospores.
Benzamides (toluamides) (22)	Zoxamide (non-systemic/protectant)	None	co-formulated with mancozeb, cymoxanil or dimethomorph. Good activity against zoospore development.
Carboxilic acid amides (CAA) (40)	dimethomorph, benthiavalicarb-isopropyl, mandipropamid, valifenalate (translaminar/locally systemic)	None (mainland Europe: some strains of 43_A1)	dimethomorph (solo product, or co-formulated with propamocarb-hydrochloride, mancozeb, ametocradin, fluazinam or zoxamide), mandipropamid (solo product, or co-formulated with cymoxanil or amisulbrom), benthiavalicarb (oxathiapiprolin). valifenalate (fluazinam).
Carbamates (28)	propamocarb hydrochloride (systemic)	None	co-formulated with cymoxanil, dimethomorph or fluopicolide.
Cyanoacetamide-oxime (27)	cymoxanil (translaminar/locally systemic)	None	co-formulated with mandipropamid, mancozeb, propamocarb-hydrochloride or fluazinam, or as a solo product. Short persistence: always use with a suitable partner.
Dithiocarbamates (M3)	mancozeb (protectant)	None	co-formulated with metalaxyl-M, cymoxanil, zoxamide or dimethomorph, or a solo product.
Phenylamides (4)	metalaxyl-M (systemic)	Yes 13_A2 and 41_A2 (mainland Europe: 43_A1)	co-formulated with mancozeb.
QiI fungicides (21)	cyazofamid (contact) amisulbrom (contact)	None	cyazofamid is available as a solo product. Amisulbrom is available as a co-formulation with mandipropamid or as a solo product.
QoSI fungicides (45)	ametoctradin (protectant)	None	co-formulated with mancozeb, dimethomorph or potassium phosphonates, or available as a solo product.
Uncouplers of oxidative phosphorylation (29)	fluazinam (protectant)	Yes 33_A2 and 37_A2	co-formulated with cymoxanil, dimethomorph or valifenalate, or available as a solo product.
OSBPI oxysterol binding protein homologue inhibition (49)	oxathiapiprolin (systemic)	Yes 46_A1 (mainland Europe: some strains of 43_A1 and 36_A2)	co-formulated with benthiavalicarb or amisulbrom.
Phosphonates (P07)	potassium phosphonates (systemic)	None	co-formulated with ametoctradin. Host plant induced defence.

A HISTORY OF *PHYTOPHTHORA INFESTANS* GENOTYPES

A genotype of *P. infestans* is a sub-variety of the pathogen that is genetically distinguishable from others. This is done by using defined genetic markers (protocols on EuroBlight webpage, see links on p5). The *P. infestans* population consists of a number of (mainly) clonally propagated genotypes which vary in prevalence within the population depending on local conditions and selection pressures. In 2005, genotype EU13_A2 was reported in GB for the first time and likely originated in Continental Europe. It spread rapidly and was found in 82% of GB outbreaks in 2007. The strain expressed phenylamide resistance, and also overcame a large number of varietal 'R' genes, which decreased the effectiveness of host resistance in several varieties considered to have good resistance. Its dominance of UK and NI *P. infestans* populations resulted in a dramatic decline in the use of phenylamide chemistry, in particular metalaxyl-M (FRAC Group 4 – phenylamide fungicides). Over time, its frequency has declined and genotype EU6_A1 became the dominant strain from 2011 to 2016. In Northern Ireland EU6_A1 and the older A1 genotypes used to be common, however, in 2023 the population was 100% 36_A2. One genotype, EU33_A2, was found at very low levels in 2011 and 2012 only and was confirmed to be fluazinam insensitive. It did not persist in the population. In recent years, although most UK *P. infestans* isolates collected belong to clonal genotypes, the occurrence of miscellaneous types, particularly in Scotland, suggests the possibility that the pathogen is sexually reproducing and that oospores are acting as inoculum. There are two reasons why this is a concern: 1) sexual reproduction can generate novel pathogen genotypes, and 2) the resulting oospores may remain viable in the soil between crops and lead to early outbreaks of the disease.

In 2013, genotype EU37_A2, now known to be insensitive to fluazinam (FRAC Group 29 – uncouplers of oxidative phosphorylation), emerged in the Netherlands and was detected in GB crops and blighted tubers in 2016. It was detected in 24% of outbreaks in 2017 in England, and it was reported in Northern Ireland in 2018 and 2019. While EU37_A2 has subsequently declined in the UK population it is still present, as indicated by samples tested annually under Fight Against Blight (FAB) at the James Hutton Institute (Figure 1). Genotype EU36_A2 was reported in Continental Europe in 2013 and was first reported in GB in 2017 and Northern Ireland in 2019. It remains the dominant strain in GB and NI populations and, although not associated with resistance to any fungicide mode of action, its ability to multiply rapidly in a wider range of environmental conditions has meant it has increased in UK and NI populations across all regions in recent seasons. In 2018, a novel strain EU43_A1 emerged in Denmark and spread south-east into northern Continental Europe from Scandinavia. Isolated cases have been reported in Portugal and France, with one isolate detected in Ireland in 2023. The EU43_A1 strain was confirmed to exhibit resistance to mandipropamid (FRAG group 40 – Carboxylic acid amide) in 2022 and this mode of action group also contains other active ingredients commonly used against late blight, including dimethomorph, benthiavalicarb and valifenalate. In 2023, it was confirmed that some isolates of EU43_A1, tested from specific geographies in Continental Europe were insensitive to CAA fungicides (mandipropamid) and OSBPI fungicides (oxathiapiprolin). It is not currently clear whether resistance to both modes of action are present in all EU43_A1 strains, or if there are strains that are resistant to only one of those modes of action. Further work is underway to understand the nature of these mutations, how they should be defined and their distribution.

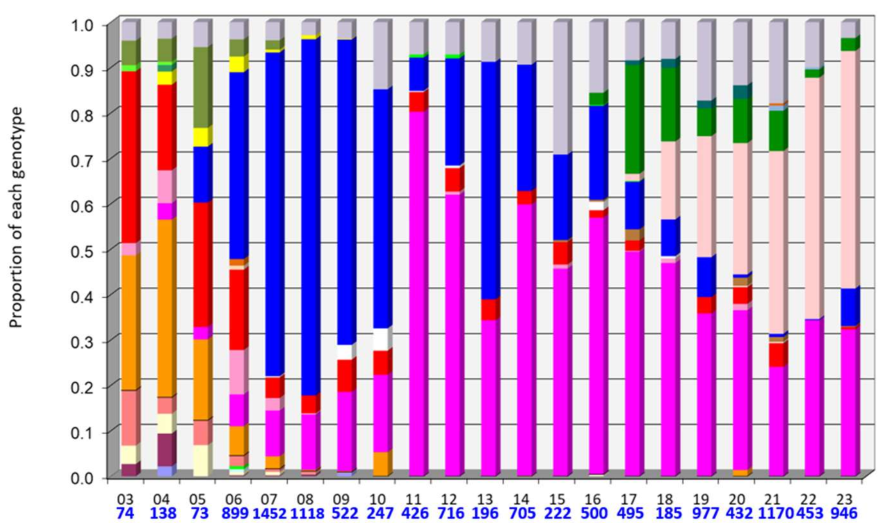

Figure 1. Proportion of *Phytophthora infestans* genotypes collected as part of the Fight Against Blight initiative. Key genotypes: beige = 36_A2, light green (2011 and 2012) = 33_A2, green (2016 onwards) = 37_A2, pink = 6_A1, dark blue = 13_A2, red = 8_A1, grey = 'other' strains.

FURTHER READING

Genotypes: About Pathogen Monitoring (au.dk)
AHDB fungicide resistance project 2022: 11120032_Final report 2019-2022.pdf (windows.net)
Managing late blight document: Managing the risk of late blight in potatoes | AHDB
AHDB potato variety database: https://ahdb.org.uk/potato-variety-database.
Euroblight fungicide efficacy table: Late blight fungicide table (au.dk)
Fungicide Resistance Action Committee (FRAC): FRAC | Home
Fungicide Resistance Action Group UK (FRAG-UK): The Fungicide Resistance Action Group (FRAG-UK) | AHDB
Fight Against Blight in-season genotyping reporting: Fight Against Blight | The James Hutton Institute
BlightSpy (in-season weather-based risk assessment): blightspy (huttonltd.com)
FRAC Recommendations for using CAA fungicides: FRAC | Recommendations for CAA
FRAC Recommendations for OSBPI fungicides: FRAC | Recommendations for OSBPI

For more information on potato late blight management, access the AHDB Horticulture and Potatoes archive website for previous reports: https://potatoes.ahdb.org.uk/potatoes

Acknowledgements and disclaimer

The Fungicide Resistance Action Group - UK (FRAG-UK) is a forum to look at fungicide resistance issues and to publish information and advice relevant to the UK. The group combines the expertise of industry with the independent sector to produce up-to-date information on the resistance status of important diseases in UK agriculture and to suggest ways of combating resistance before and after it has occurred.

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This leaflet is available at ahdb.org.uk/frag along with information on resistance which is available from the FRAG-UK.

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