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Major Crop-Protection Chemicals in Rice and Wheat: An Agronomic Guide to Classification, Formulations, Target Organisms and Modes of Action

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Rice and wheat are important food crops that are affected by insect pests, diseases, and weeds, resulting in significant yield losses. This article provides an agronomic overview of major crop-protection chemicals used in rice and wheat, focusing on their classification, formulations, target organisms, and modes of action. Important insecticides, fungicides, and herbicides used for managing major pests, diseases, and weeds are discussed, including stem borers, leaf folders, aphids, blast, sheath blight, *Phalaris minor*, and broad-leaved weeds. The article also emphasizes the importance of correct formulation, dose, application timing, and mode-of-action rotation to improve control efficacy and reduce resistance development. Integrating chemical methods with cultural practices, field monitoring, resistant varieties, and other integrated pest, disease, and weed management approaches is essential for effective and sustainable rice and wheat production.

Keywords: Rice, wheat, crop protection, insecticides, fungicides, herbicides, pesticide formulations, target organisms, mode of action, weed management, insect-pest management, disease management, herbicide resistance, integrated pest management.

Rice crop

1. Chlorantraniliprole - Stem Borer and Leaf Folder

Chlorantraniliprole is a modern insecticide belonging to the anthranilic diamide group and is widely used for managing important lepidopteran pests of rice. It is particularly effective against the yellow stem borer (*Scirpophaga incertulas*) and rice leaf folder (*Cnaphalocrocis medinalis*). The insecticide acts mainly on ryanodine receptors (RyR) in insect muscle cells. It causes uncontrolled release of calcium ions within the muscles, resulting in muscle contraction, paralysis, cessation of feeding, and eventually death of the insect. Chlorantraniliprole has both contact and ingestion activity and provides relatively long-lasting protection when used appropriately. A commonly encountered formulation is 18.5% SC (Suspension Concentrate), although the exact registered formulation and use pattern should be checked against the current product label. In rice, its use is particularly important when stem borer or leaf folder populations reach economically damaging levels (Mahato *et al.,* 2023).

2. Fipronil - Stem Borer and Soil-Inhabiting Insects

Fipronil is a broad-spectrum insecticide belonging to the phenylpyrazole group. It is used in rice for the management of several insect pests, including stem borers and certain soil-inhabiting insects. Fipronil primarily affects the insect nervous system by interfering with GABA-gated chloride channels, causing excessive nervous stimulation, paralysis, and death of susceptible insects. It can have contact, ingestion, and systemic-like activity depending on

the formulation and application method. Formulations used in agriculture include granules and suspension concentrates, with examples such as 0.3% GR and 5% SC, subject to local registration and label approval. Fipronil can be useful where rice pests occur near the soil or plant base, but its application should follow the recommended dose, method, and safety precautions because it is a broad-spectrum insecticide (Buckingham *et al.,* 2005).

3. Tricyclazole - Rice Blast

Tricyclazole is a systemic fungicide belonging to the melanin biosynthesis inhibitor group and is particularly associated with the management of rice blast disease caused by *Magnaporthe oryzae*. Rice blast may occur on leaves, nodes, necks, and panicles and can cause considerable yield loss when infection is severe, particularly at the neck and panicle stages. Tricyclazole interferes with the pathogen's melanin biosynthesis, which is important for the development and functioning of the fungal infection structure called the appressorium. By interfering with this process, the fungicide reduces successful penetration and infection of rice tissues. A commonly known formulation is 75% WP (Wettable Powder). Timely application based on disease risk and the recommended label schedule is important for effective blast management (Cruz-Magalhães *et al.,* 2012).

4. Hexaconazole - Sheath Blight

Hexaconazole is a systemic fungicide belonging to the triazole or demethylation inhibitor (DMI) group. It is used against several fungal diseases and is particularly important in rice for managing sheath blight, caused by *Rhizoctonia solani*. Sheath blight generally develops on the leaf sheaths near the waterline and can spread upward under favourable conditions, especially in dense and highly fertilized rice crops. Hexaconazole inhibits sterol biosynthesis, particularly the formation of ergosterol required for normal fungal cell-membrane development. This disrupts fungal growth and development. A commonly used agricultural formulation is 5% SC (Suspension Concentrate). Proper crop monitoring and timely fungicide application are important because sheath blight can spread rapidly under warm, humid, and dense crop conditions (Gowdar *et al.,* 2026).

5. Bispyribac-sodium - Grasses, Sedges and Broad-leaved Weeds

Bispyribac-sodium is a selective post-emergence herbicide belonging to the pyrimidinyloxybenzoic acid group. It is widely used for weed management in rice and is particularly useful because it can control weeds belonging to different groups, including grasses, sedges, and broad-leaved weeds. It inhibits the acetolactate synthase (ALS/AHAS) enzyme, which is required for the synthesis of branched-chain amino acids such as valine, leucine, and isoleucine. Inhibition of this enzyme stops the growth of susceptible weeds, followed by gradual chlorosis and death. A common formulation is 10% SC. Bispyribac-sodium is generally applied after weed emergence, and its effectiveness depends strongly on weed species, weed growth stage, dose, water management, and correct application timing. It is therefore an important component of post-emergence weed management in rice (Sekhar *et al.,* 2024).

6. Pretilachlor - Early-Season Weed Management

Pretilachlor is a selective chloroacetanilide herbicide used mainly for the control of weeds during the early stages of rice establishment. It is particularly useful against annual grasses and some sedges. The herbicide primarily affects the growth and development of young weed seedlings and is therefore most effective when applied at the appropriate early stage. A commonly encountered formulation is 50% EC (Emulsifiable Concentrate). Pretilachlor is generally used as a pre-emergence or early post-emergence treatment, depending on the formulation and registered recommendation. It helps reduce early weed competition for nutrients, water, light, and space, thereby supporting better crop establishment and early growth. Proper water management following application is also important for achieving effective weed control in rice (Mondal *et al.,* 2019).

7. Butachlor - Early-Season Grass and Sedge Control

Butachlor is a selective chloroacetanilide herbicide widely used for early-season weed management in rice. It is particularly effective against several annual grasses and some

sedges, which are important weeds during the initial stages of rice growth. Butachlor inhibits the growth and development of susceptible weed seedlings and is therefore mainly used as a pre-emergence herbicide. A commonly known formulation is 50% EC (Emulsifiable Concentrate), although formulations and registered uses can vary. Its major agronomic advantage is the reduction of early weed competition before weeds become well established. Effective performance depends on factors such as soil moisture, weed species, application timing, dose, and water management. Because herbicide resistance and repeated use of the same mode of action can reduce long-term effectiveness, butachlor should preferably be integrated with other suitable weed-management practices and herbicide modes of action (Meyyappan *et al.,* 2018).

Table 1. Commonly Used Chemicals for Pest, Disease and Weed Management in Rice with Their Formulations

Chemical	Main target	Category	Common formulation*	Reference
Chlorantraniliprole	Stem borer, leaf folder	Insecticide	18.5% SC, 0.4% GR	PPQS (2022); PPQS (2024)
Fipronil	Stem borer, soil insects	Insecticide	5% SC, 0.3% GR	TNAU (n.d.)
Tricyclazole	Blast	Fungicide	75% WP	TNAU (n.d.)
Hexaconazole	Sheath blight	Fungicide	5% SC	PPQS (2022)
Bispyribac-sodium	Grassy, sedge and broadleaf weeds	Herbicide	10% SC	PPQS (2024); TNAU (n.d.)
Pretilachlor	Early weeds (pre-emergence)	Herbicide	50% EC; 30.7% EC; safener-containing formulations	ICAR (2025); PPQS (2022)
Butachlor	Early weeds (pre-emergence)	Herbicide	50% EC, 5% GR	PPQS (2022); TNAU (n.d.)

Wheat crop

1. Imidacloprid - Sucking Pests

Imidacloprid is a systemic insecticide belonging to the neonicotinoid group and is used for the management of sucking insect pests in wheat. It is particularly effective against pests such as aphids, which suck plant sap and may cause yellowing, curling, weakening of plants, and reduced grain development when populations become high. Imidacloprid acts on nicotinic acetylcholine receptors (nAChRs) in the insect nervous system, causing abnormal nerve stimulation followed by paralysis and death. It has mainly systemic and contact activity and can be absorbed by plant tissues. Common agricultural formulations include 17.8% SL and other registered formulations. Its use should be based on pest monitoring and the locally approved label recommendation (Liu *et al.,* 2023).

2. Propiconazole - Fungal Diseases

Propiconazole is a systemic fungicide belonging to the triazole/DMI group and is used for controlling several fungal diseases of wheat. It inhibits ergosterol biosynthesis in fungi, thereby interfering with fungal cell-membrane formation and growth. It can be used against diseases such as leaf rust, stripe rust, powdery mildew, and other susceptible fungal diseases, depending on the registered label and local disease situation. A commonly known formulation is 25% EC (Emulsifiable Concentrate). Proper disease identification and timely application are important because fungicides are generally more effective when applied before disease becomes severe (Singh *et al.,* 2025).

3. Metsulfuron-methyl - Broad-leaved Weeds

Metsulfuron-methyl is a selective post-emergence sulfonylurea herbicide used mainly for controlling broad-leaved weeds in wheat. It inhibits the acetolactate synthase (ALS/AHAS) enzyme, which is required for the production of branched-chain amino acids. Inhibition of ALS stops the growth of susceptible weeds, followed by gradual yellowing and death. It is effective against several broad-leaved weeds commonly found in wheat fields, although the spectrum depends on weed species and local conditions. A commonly encountered formulation is 20% WP. Correct dose and application timing are important because wheat

selectivity and weed control depend on the registered recommendation (Chhokar *et al.,* 2015).

4. Sulfosulfuron - *Phalaris minor*

Sulfosulfuron is a selective sulfonylurea herbicide used in wheat for the management of important grassy weeds, particularly little seed canary grass (*Phalaris minor*). It acts by inhibiting the ALS/AHAS enzyme, which blocks the synthesis of essential branched-chain amino acids and stops weed growth. It is mainly used as a post-emergence herbicide when the target weeds are at a susceptible growth stage. A commonly used formulation is 75% WG (Water-Dispersible Granules). Since repeated use of ALS-inhibiting herbicides can contribute to herbicide resistance, especially in *P. minor*, sulfosulfuron should be used as part of an integrated weed-management programme and not repeatedly relied upon as the only control method (Gherekhloo *et al.,* 2021).

5. Clodinafop-propargyl - *Phalaris minor*

Clodinafop-propargyl is a selective post-emergence herbicide widely used for controlling grassy weeds in wheat, particularly little seed canary grass (*Phalaris minor*). It belongs to the aryloxyphenoxypropionate (FOP) group and inhibits the acetyl-CoA carboxylase (ACCase) enzyme, which is essential for fatty-acid synthesis in susceptible grasses. Inhibition of ACCase causes cessation of growth and eventual death of susceptible grass weeds. A common formulation is 15% WP, although formulation strength and combinations vary among registered products. Because resistance to ACCase-inhibiting herbicides has developed in some *P. minor* populations, herbicide rotation and integrated weed-management practices are important (Raghav *et al.,* 2016).

6. Pinoxaden - Grassy Weeds

Pinoxaden is a selective post-emergence herbicide belonging to the phenylpyrazolin group and is primarily used for the control of important grassy weeds in wheat. It inhibits the ACCase enzyme, thereby interfering with fatty-acid synthesis and preventing normal growth of susceptible grass weeds. It can be effective against weeds such as wild oat (*Avena* spp.) and *Phalaris minor*, depending on the population and registered use. Pinoxaden is particularly useful as a post-emergence option for grassy-weed management in wheat. Because it has an ACCase mode of action, it should be integrated with herbicides having different effective modes of action and non-chemical practices to help manage resistance (Yadav *et al.,* 2009).

7. 2,4-D - Broad-leaved Weeds

2,4-D (2,4-dichlorophenoxyacetic acid) is a selective synthetic auxin herbicide widely used for controlling broad-leaved weeds in wheat. It causes abnormal and uncontrolled growth in susceptible broad-leaved plants, ultimately resulting in their death. It is generally used as a post-emergence herbicide for the management of several broad-leaved weeds in wheat. Different formulations and concentrations are available, including amine and ester formulations, and the exact formulation, dose, and application stage should follow the registered product label. Proper application timing is particularly important because wheat tolerance and weed susceptibility vary with crop and weed growth stages. Care must also be taken to prevent spray drift onto sensitive broad-leaved crops (Chhokar *et al.,* 2015).

Table 2. Commonly Used Chemicals for Pest, Disease and Weed Management in Wheat with Their Formulations

Chemical	Category	Common formulation*	Main target	Reference
Imidacloprid	Insecticide	17.8% SL	Aphids and other sucking pests	PPQS (2022); TNAU (n.d.)
Propiconazole	Fungicide	25% EC	Rusts and other fungal diseases	PPQS (2022); TNAU (n.d.)
Metsulfuron-methyl	Herbicide	20% WP	Broad-leaved weeds	PPQS (2022); TNAU (n.d.)
Sulfosulfuron	Herbicide	75% WG	*Phalaris minor* and other weeds	PPQS (2022); TNAU (n.d.)

Chemical	Category	Common formulation*	Main target	Reference
Clodinafop-propargyl	Herbicide	15% WP	*Phalaris minor* and other grassy weeds	PPQS (2022); TNAU (n.d.)
Pinoxaden	Herbicide	5.1% EC	*Phalaris minor* and other grassy weeds	PPQS (2022); TNAU (n.d.)
2,4-D	Herbicide	38% EC / 80% WP	Broad-leaved weeds	PPQS (2022); TNAU (n.d.)

Conclusion

The judicious use of insecticides, fungicides, and herbicides plays an important role in maintaining crop health, protecting yield, and reducing losses caused by insect pests, diseases, and weeds in rice and wheat. The chemicals discussed in this article represent different groups and modes of action, allowing targeted management of major crop-protection problems such as stem borer, leaf folder, aphids, blast, sheath blight, grassy weeds, sedges, and broad-leaved weeds. However, successful crop protection does not depend only on selecting an effective chemical. Correct identification of the target organism, appropriate formulation, recommended dose, suitable application stage, proper water management, and timely application are equally important.

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