

Effective Herbicide Molecules for Major Indian Crops: Enhancing Yield Through Superior Weed Management

ARTICLE ID: 0198

Abhay Kumar¹, Sushmita², Prafulla Kumar^{3*}

¹PG Department of Botany, M.S. College, Motihari, BRA Bihar University Muzaffarpur, Bihar

²Department of Agronomy, College of Agriculture, SVPUAT, Meerut

³Department of Biotechnology, University institute of Engineering and Technology, Guru Nanak University

India, with its diverse agro-climatic conditions, cultivates a variety of crops including cereals, pulses, oilseeds, and cash crops. However, a major challenge affecting agricultural productivity is weed infestation, which competes with crops for essential nutrients, water, sunlight, and space, ultimately leading to significant yield losses. Weeds can also harbor pests and diseases, further deteriorating crop health and productivity. Efficient weed

management is crucial to sustaining agricultural output, and herbicides play a vital role in this regard. By effectively controlling weeds, herbicides not only improve crop yield but also reduce labor costs, minimize competition for resources, and enhance overall farm efficiency. The development and adoption of advanced herbicide formulations have

revolutionized modern agriculture by providing farmers with reliable solutions for weed control, reducing the dependency on manual weeding, and ensuring better economic returns.

Understanding Herbicides and Their Importance

Herbicides are chemical compounds specifically designed to control or eliminate unwanted plants (weeds) in agricultural fields. Their application is crucial in preventing crop loss due to weed competition, which can

lead to drastic reductions in yield and profitability. Herbicides can be classified based on their mode of action, selectivity, and application timing:

1. Classification Based on Selectivity

Selective Herbicides: These herbicides target specific weed species while sparing the crop, making them ideal for use in crop fields. They help in controlling



weeds without causing harm to the cultivated plants, ensuring better crop establishment and growth.

Non-Selective Herbicides: These herbicides destroy all vegetation they come into contact with and are primarily used in land preparation before planting. They are also utilized in non-crop areas, such as roadsides and industrial sites, to prevent weed proliferation.

2. Classification Based on Application Timing

Pre-emergence Herbicides: These herbicides are applied before weed seeds germinate to prevent weed growth in the early stages of crop development. They create a protective chemical barrier in the soil that inhibits the emergence of unwanted plants.

Post-emergence Herbicides: These are applied after weeds have emerged and are actively growing. They provide effective control of existing weed populations, helping farmers maintain a clean and healthy crop stand.

Major Herbicide Molecules Used in Indian Agriculture
The choice of herbicide varies depending on the type of crop, the prevalent weed species, and the stage of crop growth. Below are some widely used herbicide molecules in India, along with their roles in ensuring effective weed management:

1. Glyphosate

- Type: Non-selective, systemic herbicide
- Crops: Used for pre-planting weed control in soybean, cotton, maize, and horticultural crops.
- Effectiveness: Effective against a broad spectrum of weeds, including grasses and broadleaf weeds. It is widely used in zero-tillage farming systems.

- Mode of Action: Inhibits the enzyme EPSP synthase, which is essential for plant growth, leading to plant death over time.

2. Atrazine

- Type: Selective pre-emergence and post-emergence herbicide
- Crops: Commonly used in maize and sugarcane fields.
- Effectiveness: Controls annual broadleaf weeds and grasses, ensuring the young crop receives adequate nutrients and moisture.
- Mode of Action: Inhibits photosynthesis by blocking electron transport in plants, leading to gradual weed suppression.

3. 2,4-D (2,4-Dichlorophenoxyacetic acid)

- Type: Selective post-emergence herbicide
- Crops: Used in wheat, rice, maize, and sugarcane fields.
- Effectiveness: Targets broadleaf weeds while sparing cereal crops, reducing manual weeding efforts.
- Mode of Action: Mimics natural plant hormones, causing abnormal growth and eventually killing the weeds.

4. Pendimethalin

- Type: Pre-emergence selective herbicide
- Crops: Rice, wheat, soybean, cotton, and vegetables.
- Effectiveness: Prevents weed seed germination and early growth, providing long-lasting weed control.
- Mode of Action: Inhibits microtubule formation in dividing cells, preventing seedling emergence and establishment.

5. Paraquat

- Type: Non-selective contact herbicide
- Crops: Used in plantation crops like tea, rubber, and orchards.
- Effectiveness: Quickly burns down green tissue but does not translocate within plants, making it a fast-acting herbicide.
- Mode of Action: Produces reactive oxygen species that damage cell membranes, causing rapid desiccation and plant death.

6. Metsulfuron-methyl

- Type: Selective post-emergence herbicide
- Crops: Wheat, rice, and sugarcane.
- Effectiveness: Controls broadleaf weeds and some grasses, ensuring better crop health.
- Mode of Action: Inhibits acetolactate synthase (ALS), which is crucial for amino acid synthesis in plants, ultimately leading to weed suppression.

7. Butachlor

- Type: Selective pre-emergence herbicide
- Crops: Widely used in paddy fields (rice).
- Effectiveness: Controls annual grasses and some broadleaf weeds, improving crop establishment.
- Mode of Action: Inhibits cell division and elongation in germinating weeds, preventing their growth.

Best Practices for Herbicide Application in Indian Agriculture

To maximize the efficiency of herbicides and reduce the risk of resistance development, it is essential to follow best practices in herbicide application:

Proper Selection: Choose the right herbicide based on the crop type, weed species, and field conditions.

Application Timing: Apply herbicides at the appropriate crop and weed growth stages for maximum effectiveness.

Correct Dosage: Overuse can lead to crop toxicity and environmental hazards, while underuse may not effectively control weeds.

Tank Mixing: Combining different herbicides with complementary modes of action can enhance weed control and prevent resistance.

Integrated Weed Management (IWM): Combining herbicide use with mechanical, cultural, and biological control methods helps in sustainable weed management.

Environmental Safety: Use eco-friendly herbicides and adhere to guidelines for safe handling and application to minimize soil and water contamination.

Challenges and Future Prospects in Herbicide Use

Despite their benefits, herbicide use in India faces several challenges:

- **Herbicide Resistance:** Continuous and improper use of herbicides has led to the development of herbicide-resistant weed species, reducing the efficacy of existing chemicals.
- **Environmental Concerns:** Excessive herbicide use can lead to soil degradation, water pollution, and harm to non-target organisms.
- **Regulatory Restrictions:** Stricter regulations on certain herbicides require farmers to seek alternative weed control strategies.
- **High Costs:** Some herbicides can be expensive, making them less accessible for small-scale farmers.

To address these challenges, research is being directed towards developing bio-herbicides, herbicide-tolerant crop varieties, and precision agriculture techniques that optimize herbicide application.

Conclusion

Effective weed management through herbicide application is a key factor in enhancing agricultural productivity in India. By selecting the right herbicide molecules and adopting best practices, farmers can

significantly reduce weed infestations, leading to healthier crops and increased yields. However, sustainable and integrated approaches must be implemented to minimize environmental impacts and prevent herbicide resistance. With advancements in agricultural technology and weed management strategies, the future of herbicide use in India looks promising, ensuring a balance between productivity and sustainability.

References

1. Chhokar, R. S., Sharma, R. K., Jat, G. R., Pundir, A. K., & Gathala, M. K. (2007). Herbicide efficacy on weeds in wheat under zero-till systems. *Weed Research*, 47(1), 52–61.
2. Government of India, Ministry of Agriculture & Farmers Welfare. (2022). *Handbook on Weed Control in Indian Agriculture*. Directorate of Weed Research, Jabalpur.
3. Yadav, D. B., Malik, R. K., & Garg, R. (2015). Herbicide resistance management in Indian agriculture. *Indian Journal of Weed Science*, 47(3), 265–275.