National Strategy for Weed Management: The Policy Blueprint for Food and Feed Security by 2047

By 2047, India must feed over 1.6 billion people with limited farmland. Weeds cause major crop losses and economic damage but receive little attention. Adopting modern weed control methods is vital to boost yields, cut costs, and ensure food and feed security. This paper highlights weed management as essential.

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Part-1-Why Weed Management Matters

1) Weed Management and India's Food and Feed Security by 2047

As India approaches 2047—marking 100 years of independence—the country must urgently address the challenge of ensuring long-term food and feed security for its growing population, expected to exceed 1.6 billion. With cultivable land area largely fixed, the pathway to meeting future demand lies in significantly boosting agricultural productivity from existing farmland.

Weeds are among the most serious biological constraints in Indian agriculture, causing an estimated loss of 25-26% in kharif crops and 18-25% in rabi crops due to inadequate weed management practices as per a recent report by ICAR-Directorate of Weed Research, Jabalpur. It is valued at 92,000 crore ($11 billion) worth loss in crop productivity each year, according to a study commissioned by the Federation of Seed Industry of India (FSII), carried out by experts N.T. Yaduraju, M.R. Hegde and A.R. Sadananda. These losses are not just numbers—they represent food that could feed millions and fodder critical for India's livestock sector.

Despite these alarming figures, weed management continues to receive insufficient attention compared to other crop protection measures. NITI Aayog projects that India could potentially exceed food demand by 2047. However, this projection hinges on the adoption

of modern agricultural practices—including **efficient and timely weed control**. Without focused intervention, uncontrolled weeds will continue to lower yields, inflate production costs, reduce farm profitability, and increase dependence on imports of oilseeds, pulses, and livestock feed—undermining national food and nutritional security.

A renewed focus on weed management, supported by **herbicide innovations, precision technologies, and integrated practices**, offers a transformative opportunity to unlock higher productivity and ensure sustainable food and feed systems. This white paper explores the critical role that weed management can play in securing India's agricultural future.

2) Why Weeds Are a Bigger Problem Than Pests

Weeds pose a greater challenge to crop productivity than pests, yet they receive far less attention in research and policy. Unlike pests, which can be controlled through targeted interventions, weeds **directly compete with crops** for nutrients, water, and sunlight, leading to significant **yield losses and economic damage.**

In India, **annual economic losses from weeds exceed $11 billion**, yet herbicide adoption remains low at **15.8% of total pesticide use**. Limited domestic research and regulatory bottlenecks hinder innovation, making India reliant on multinational companies for new herbicide chemistries. Rising labour costs and minimal institutional support further strain farmers. Without **urgent investments in domestic herbicide research and integrated weed management strategies**, weeds will continue to threaten food security and agricultural resilience.

Crop	*Potential Yield Loss Due to Weeds (%)*	*Economic Loss ($ Billion)*	*Source*
Rice	10-100	4.42	ICAR-Directorate of Weed Research (2024)
Wheat	10-60	2.50	Rao et al. (2014)
Maize	18-65	1.00	Gharde et al. (2018)
Pulses	30-50	0.80	ICAR-Directorate of Weed Research (2024)

3) Why Indian Farmers Struggle to Control Weeds Effectively

Weed management remains a persistent challenge for Indian farmers due to knowledge gaps, limited resources, and financial constraints. Over **50% of farmers do not follow recommended herbicide guidelines or adopt integrated weed management practices** (ICAR, 2023). Access to quality herbicides and modern spraying tools is particularly limited in remote areas, resulting in ineffective control. Many small-scale farmers also find herbicides costly, opting for labor-intensive manual weeding despite its inefficiency. According to the **FSII Report (2023)**, weed infestations lead to an annual crop productivity loss of **92,000 crore**, yet policy support to promote sustainable weed control remains inadequate. Bridging these gaps through farmer education, better access to inputs, and financial assistance is essential for effective and scalable weed management in India.

4) Labor-Intensive Weeding and the Myth of Cheap Rural Labor

The belief that rural labour is cheap and readily available is outdated. **Urban migration and rising wages under MGNREGA have led to severe labour shortages**, making manual weeding increasingly impractical. Even when family labour is available, manual weeding remains physically exhausting and time-consuming, especially for large farms.

In crops like **wheat and rice, manual weeding costs 7,500 per hectare**, whereas herbicide use costs only **4,000 per hectare**. Additionally, **manual weeding requires at least 20 labour days per hectare, while herbicide application takes just a few hours.**

Impact Metric	*Manual Weeding*	*Herbicide Usage*	*Improve-ment*	*Source*
Labor Requirement (days/ha)	20	8	-60%	ICAR-DWR (2024)
Yield Loss (%)	40	10	+30%	ICAR, Punjab Case Study
Cost of Weed Management (₹/ha)	7,500	4,000	-47%	FICCI Report (2015)

Countries like **Brazil, the U.S., and Argentina** have successfully reduced weed management costs by **40-50%** through herbicide adoption. Strengthening herbicide use provides a big opportunity in India as part of an **integrated solution with new innovations** in herbicides including services and market intelligence.

PART II: Strategic Gaps in India's Weed Management Approach

1) Lack of Indigenous R&D and Public-Private Collaboration

India remains heavily dependent on **imported herbicides**, with **over 39,000 metric tons imported in 2021**, primarily from **China and Germany**. Unlike fertilizers, which were prioritized alongside the Green Revolution, **herbicides were overlooked**, despite their critical role in reducing yield losses.

While some domestic efforts have led to the production of certain herbicides, **no major indigenous herbicide innovations have emerged in the last 50 years**. In contrast, countries like **China and Brazil** have strong **public-private partnerships (PPPs)** to drive herbicide R&D, whereas **India's ecosystem remains fragmented, underfunded** and full of uncertainties.

Key barriers include:

- **High costs of new active ingredients innovation and research.**
- **Regulatory uncertainty delaying private-sector investments**
- **Reliance on multinational patents instead of India-specific solutions**

Without **policy reforms to encourage local innovation and ease regulatory approvals**, India will continue to **depend on costly foreign herbicides**, increasing **costs for farmers** and limiting **agricultural resilience.**

2) Lack of an integrated approach to sustain herbicide use

Rising **contract labour costs** make weed management increasingly expensive, emphasizing the need for **Integrated Weed Management (IWM)**—a strategy combining **cultural, mechanical, biological, and chemical methods** to keep weed populations below economic damage thresholds.

Key IWM cultural practices include:

- **Crop rotation** (e.g., replacing wheat with maize or sugarcane to break weed cycles)
- **Early sowing** (e.g., wheat sown in late October outcompetes P. minor)
- **Biological control** (e.g., weevils for water hyacinth, beetles for parthenium)

While some biological solutions have shown partial success, a **sustainable weed management strategy** requires **continuous adaptation and economic viability**. Without an integrated approach, dependence on herbicides alone may **lead to resistance issues and long-term inefficiencies.**

3) Why India is Failing at Herbicide Innovation?

India's lack of herbicide innovation threatens agricultural productivity and food security. Despite being a global agricultural powerhouse, the country remains dependent on **imported active ingredients (a.i.) and outdated formulations** due to the absence of indigenous herbicide breakthroughs. Unlike nations such as the **U.S., Brazil, and China**, which prioritize **herbicide R&D**, India has seen no major herbicide discovery in the last **50 years.**

The **underfunded research ecosystem**, lack of **public-private collaboration**, and **regulatory bottlenecks** hinder innovation. Agricultural research institutions focus on **crop breeding and pest control**, while weed science receives minimal attention. Moreover, government subsidies **favor fertilizers and pesticides**, sidelining herbicide development. Without proactive investment and policy support, India's dependence on costly foreign herbicides will persist.

PART III: Leveraging Herbicide Innovations for Scalable Weed Control

1) Laying the Groundwork for Scalable Herbicide Adoption

Despite their proven effectiveness, herbicides remain **vastly underutilized** in Indian agriculture. Overdependence on manual weeding, limited innovation, and policy inertia have held back their adoption—jeopardizing crop productivity and national food and feed security. A focused shift is now essential to mainstream herbicides as a cornerstone of India's agricultural strategy.

Strategic Priorities for Scaling Herbicide Use:

- **Recognize** weeds as a major threat to food and feed security, and prioritize herbicide-based weed control in national agricultural policy.
- **Promote** research and knowledge-sharing on effective, crop-specific herbicide use across India's diverse agro-ecological zones.
- **Strengthen** the policy and regulatory ecosystem to fast-track safe, innovative, and affordable herbicide technologies.
- **Facilitate** the adoption of bioengineered herbicide-tolerant crops to enhance efficiency and reduce weeding costs.

- **Implement** farmer-centric incentives, such as subsidies, credit support, and training programs, to drive large-scale, responsible herbicide adoption.

2) Unlocking the Potential of Herbicide-Tolerant Crops

Herbicide-tolerant crops (HTCs) have transformed weed control globally since their introduction in the mid-1990s. By allowing targeted herbicide application without crop damage, they reduce labor needs, improve efficiency, and support sustainable weed management. In India, however, regulatory uncertainty around genetically modified (GM) crops has stalled investment and limited farmer access to these innovations.

One notable opportunity lies in **imidazolinone-tolerant rice**, which is well-suited for direct-seeded rice (DSR) systems—a method gaining traction due to water and labor savings. Integrating herbicide tolerance traits into Indian rice varieties could significantly reduce weed-related losses and enhance farmer livelihoods. Still, concerns over gene flow to wild or weedy relatives—as seen in the U.S., Europe, and China—underscore the need for strong biosafety protocols and risk monitoring. With the right safeguards, HTCs can be a game-changer in India's weed management strategy.

3) Decades of Herbicide Evolution: Trends, Benefits, and Resistance Risks

Herbicide use in India accelerated after the Green Revolution, as intensive farming practices led to a surge in weed pressure. By the late 1970s, herbicide demand soared to such an extent that distribution had to be monitored by authorities. The 1980s and 1990s marked the widespread adoption of herbicides in wheat and rice, with compounds like isoproturon and Clodinafop effectively controlling major weeds such as *Phalaris minor* and *Echinochloa spp.*

However, by the early 2000s, overreliance on the same herbicides triggered widespread resistance—beginning with isoproturon in wheat and followed by cross-resistance to other molecules. In response, farmers increasingly turned to herbicide mixtures and repeated applications, raising costs and reducing efficiency.

Yet, India's approach remains largely reactive—focused on managing resistance rather than preventing it. With limited domestic innovation and a heavy dependence on imported chemistries, there is an urgent need to invest in research and promote **Integrated Weed Management (IWM)**. A forward-looking strategy that blends chemical, agronomic, and mechanical solutions is essential for sustainable weed control and long-term productivity.

4) Keep a guard against herbicide resistance

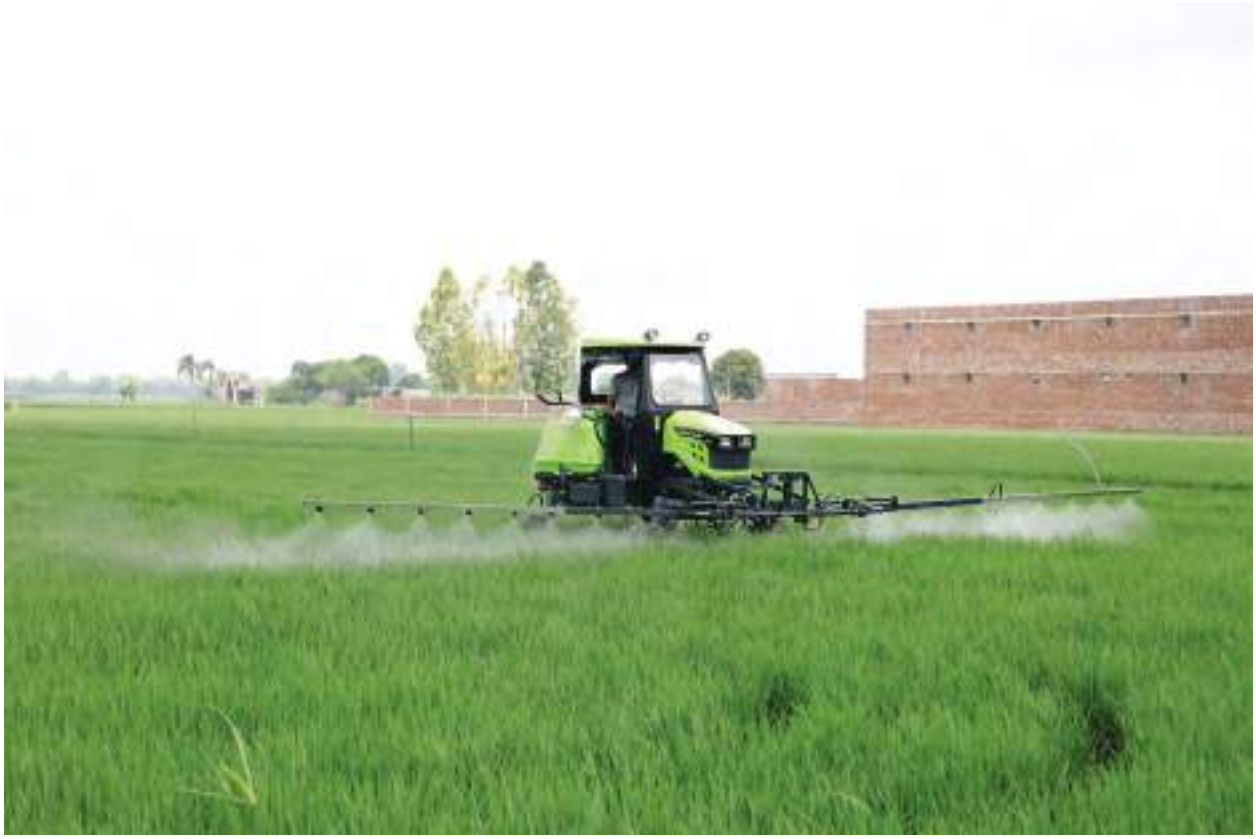
Herbicide **tolerance** is a plant's natural ability to survive treatment, while **resistance** develops when repeated herbicide use selects for resistant biotypes within a weed population. Over time, resistant weeds multiply, reducing herbicide effectiveness.

India has witnessed this trend with **isoproturon (12 years)** and **clodinafop-sulfosulfuron (10 years)**. Without intervention, resistance could spread further, especially through seed movement. To combat this, strategies like **herbicide rotation,herbicide mixtures, crop diversification**, and **farmer-led monitoring** are essential. A policy shift toward monitoring **evaluation and learning** (MEL) will help manage resistance and sustain herbicide efficacy.

5) Herbicide Mixtures to sustain herbicide-based weed management

With limited new herbicide chemistries, **sustaining existing herbicides** is crucial. **Premixed herbicides** can **delay resistance**, expand the weed **control spectrum**, and maintain **affordability**. Since most herbicides struggle against **complex weed flora**, mixtures ensure **season-long control**, especially as **labour costs rise.**

Effective combinations require **careful selection** to avoid negative interactions. For instance, **2,4-D reduces clodinafop's efficacy** on *Phalaris minor*. Understanding **herbicide synergy and optimal ratios** is key to maximizing weed control without compromising performance.



PART V: Building Future-Ready Weed Management Systems

1) Fill the gaps in capacity building and new innovations

Despite decades of progress, farmers still rely on **dealer-recommended herbicide mixtures** due to gaps in **feedback mechanisms** and **market intelligence**. The usefulness of monitoring tools based on data analytics will increase over time to protect the interest of farmers and stakeholders. Data on the adoption pattern of herbicides may be considered as a lead indicator for which technology is likely to be accepted by the farmers and where there should be relatively more investment by the state departments of agriculture (DOA). The MEL system will strengthen the case for policy underpinning of herbicides research including new innovations.

Without **evidence-based (MEL process), AI-driven insights, and strong domestic R&D**, herbicide innovation will remain stagnant, leaving farmers dependent on outdated formulations.

Extension agencies need **better training, stable funding, and reduced staff turnover** to build **trust and credibility**. Recruiting **technically skilled** field agents/scouts with **local knowledge** and strong **communication skills** is crucial. A **sustainable weed management strategy** requires **public-private partnerships, continuous capacity building, and investment in new technologies.**

2) New science based on common themes

To meet the demands of food and feed security, India must shift to data-driven, technology-enabled weed management. Emerging innovations offer scalable and precise solutions:

1. **Precision Spraying:** AI-based sprayers and drones ensure targeted herbicide application, reducing waste and enhancing efficiency.
2. **Automation in Weeding:** Robots equipped with sensors can distinguish crops from weeds, offering a viable solution for labor-scarce, high-value crops.
3. **AI & Weed Intelligence:** Machine learning models and weed image databases can track weed shifts, guide herbicide strategies, and support resistance monitoring.

PART VI: The Way Forward

Agri-input and chemical companies play a crucial role in shaping weed management practices for maintaining food and feed security in India. With rising labour costs, herbicide resistance, and environmental concerns, these companies must adopt a **Research-centric, sustainable, and result-driven approach**.

1. Agrochemical Companies Must Develop and Promote Herbicides with Lower Resistance Risk

- Introduce multi-mode-of-action herbicides to delay resistance.
- Invest in bio-herbicides and safer chemical formulations (e.g., those with shorter soil half-life).
- Promote pre-emergence herbicides (slower resistance development than post-emergence sprays).
- Prioritize herbicides from underutilized HRAC (Herbicide Resistance Action Committee) groups while avoiding over-reliance on high-risk modes of action.
- Companies must collaborate with seed companies to develop non-GM HT crops (e.g., HT Paddy by IARI).

2. **System of Policy and Regulatory Reforms (SPRR) –** Expectations from Government

   - Scrutinize Herbicide-Tolerant Crop (HTC) policies to facilitate the simultaneous approval of target herbicides by regulatory authorities.
   - Introduce incentivization mechanisms to accelerate herbicide adoption, increasing coverage and efficiency in weed management.
   - Research Subsidies should encourage the development of **non-GM herbicide-tolerant crops** (e.g., HT Paddy by IARI) to provide sustainable alternatives.
   - Support the introduction of bioengineered (BE) crops to reduce dependency on herbicides and enable integrated weed management solutions.
   - Promote or may be incentivised mechanization and precision technology (e.g., boom sprayers,drones) through FPO to enhance herbicide application efficiency, reduce costs, and improve coverage.

3. **Strengthen Farmer Education & Stewardship Programs**

   - Encourage the use of surfactants and adjuvants to lower herbicide application rates while maintaining effectiveness.
   - Prioritize herbicides from underutilized HRAC (Herbicide Resistance Action Committee) groups while avoiding over-reliance on high-risk modes of action.
   - **Train farmers on** correct herbicide dosage, timing, and spray techniques and importance of **rotating herbicides** to prevent resistance.

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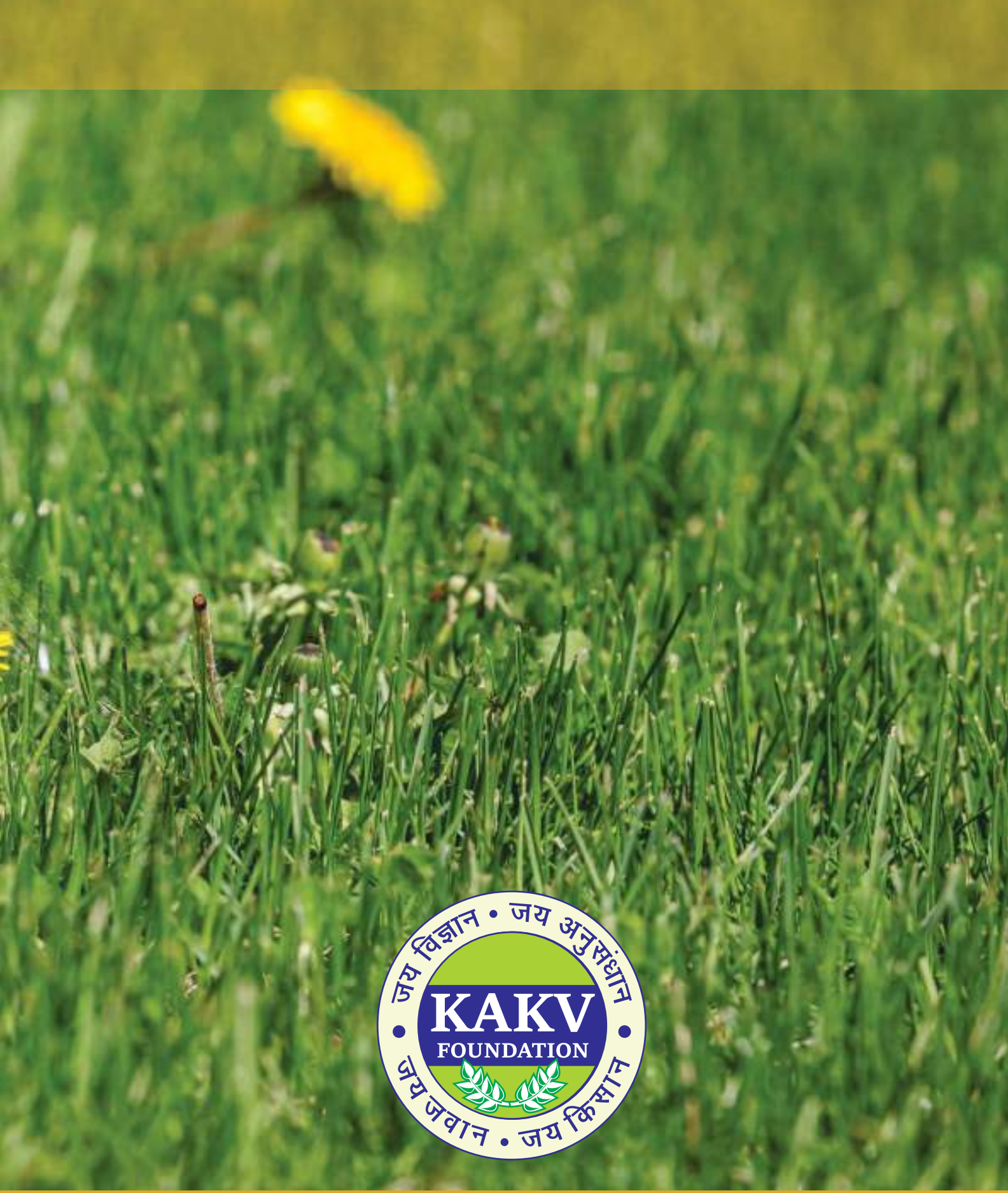

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