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Weed Flora Dynamics in Rice-Based Cropping Systems: A Comprehensive Review

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Abstract

Rice-based cropping systems (RBCS) are critical for food security in many regions, particularly in Asia. The dynamics of weed flora in these systems significantly impact crop yield and sustainability. This review synthesizes current knowledge on weed dynamics in RBCS, emphasizing the influence of cropping practices, environmental factors, and management strategies. Key weeds identified include *Echinochloa* spp., *Cyperus* spp., and *Phalaris minor*, which exhibit varying dominance based on the cropping system employed. Factors such as tillage practices, crop rotation, and herbicide application play pivotal roles in shaping weed populations. Effective management strategies, including integrated weed management (IWM) approaches, are essential to mitigate weed competition and enhance crop productivity. The review also highlights the need for further research into the ecological impacts of weed dynamics and the development of sustainable practices tailored to local conditions. Weed flora dynamics in rice-based cropping systems influence both agricultural productivity and ecosystem health. This review explores patterns in weed population dynamics, the effectiveness of various management strategies, and their implications for sustainable rice cultivation.

Keywords: Rice-Based Cropping Systems; Weed Dynamics; Integrated Weed Management; Crop Rotation; Herbicide Resistance

Abbreviations

RBCS: Rice-Based Cropping Systems; CA: Conservation Agriculture.

Introduction

Agriculture is the major source of livelihood for half of the Indian population. However, the productivity of crops is much lower than many countries and needs enhancement to produce~ 400 million tons of food grains for meeting food demands of a population of 1.7 billion by 2050 Rao AN, et al. [1]. Weeds are a major constraint in agricultural systems, particularly in rice-based cropping systems (RBCS). Ramanjaneyulu, et al. [2] reported that of the total loss caused by pests, weeds have a major share (30%).The dynamics of weed flora are influenced

by several factors, including cropping practices, soil type, and climatic conditions. Understanding these dynamics is essential for developing effective weed management strategies. The rice-wheat cropping system is one of the most widely practiced in India, occupying significant agricultural land. However, the intensification of cropping systems has led to shifts in weed populations, requiring a comprehensive review of current knowledge on weed dynamics in RBCS. According to Ramanjaneyulu, et al. [2], the introduction of new crop varieties and management practices has resulted in significant shifts in weed flora, impacting overall system productivity. Weeds are dynamic in nature and weed shift is influenced by crop, cropping system, variety, type of soil, tillage, method of sowing, water, nutrient and weed management methods.

Weeds are unwanted and undesirable plants that interfere with cultivated crops for utilization of natural resources such as nutrients, water, and light, space, causing harbour of insect pests and disease adverse allelopathic effects and increasing cost of production indirectly, reducing crop yield. Rice based cropping systems face significant challenges due to weed infestations, leading to yield losses ranging from 13% to 97%. Weeds like grass, sedge and broad-leaf weed varieties pose a large terror to these crops, particularly in direct-seeded conditions [3].

Weed flora dynamics in rice-based cropping systems are shaped by agronomic practices, environmental conditions, and the biology of weed species. Effective weed management is essential for maintaining crop productivity and achieving sustainable agriculture [4]. This review provides a comprehensive overview of weed dynamics in rice cultivation, emphasizing the impact of various management practices and environmental factors on weed populations.

Overview of Weed Flora in Rice-Based Systems

The composition and abundance of weed species in rice-based systems are influenced by soil conditions, water management, and crop rotation [5]. For instance, fields with inconsistent water levels often see a proliferation of aquatic and semi-aquatic weed species [6]. This section reviews key weed species in rice systems, their competitive interactions with rice, and the factors affecting their prevalence [7].

Weed Management Practices

Weed management in rice-based cropping systems typically involves a mix of cultural, mechanical, and chemical strategies [8]. Cultural practices, such as crop rotation and the use of competitive rice varieties, play a crucial role in suppressing weed growth [9]. Mechanical methods, including manual weeding and the use of machinery, are essential for controlling weed populations, although their effectiveness can be limited by labour and cost constraints [10]. Herbicides are widely used but must be managed carefully to avoid resistance issues and environmental impact [11].

Impact of Environmental Factors

Environmental factors such as temperature, rainfall, and soil type significantly influence weed dynamics in rice systems [12]. For example, variations in rainfall can affect weed germination and growth, while soil type can determine the competitive advantage of different weed species [13]. This section examines how these factors interact with weed populations and influence management practices [14].

Factors Influencing Weed Dynamics

Weed dynamics refer to the changes in weed populations over time, influenced by biological, environmental, and management factors. Effective weed management is essential for sustainable agricultural practices, particularly as reliance on herbicides decreases in favour of integrated approaches. Cropping practices, including crop rotation and nutrient management, significantly affect weed dynamics by altering the competitive environment for weeds and crops alike.

Cropping Practices and Weed Dynamics

Crop Rotation-Crop rotation is a fundamental practice that can disrupt weed life cycles and reduce weed seed banks in the soil. Diverse crop rotations can lead to varying weed dynamics due to differences in crop growth patterns, canopy cover, and allelopathic effects. Wickramasinghe, et al. [15] reported that crop rotation and integrated nutrient management approach were effective in suppressing weeds, both densities, and biomass, with several effective mechanisms within the system itself. Having an interseason green manure crop in the rotation was effective in suppressing the weeds, particularly in the conventional system. Favourably, the weed compositional changes with the presence of Sunn hemp in organic nutrient management systems effectively reduced the grass biomass.

Implementing diverse cropping systems can disrupt the life cycles of weeds and reduce their populations. For example, alternating rice with legumes can suppress certain weed species while enhancing soil fertility [16]. This practice helps in managing the weed seed bank effectively.

Herbicide Application: The judicious use of herbicides, combined with cultural practices, can effectively manage weed populations. However, dependence on herbicides alone can lead to resistance, necessitating a balanced approach [17]. A well-planned herbicide program can significantly reduce weed pressure in rice-based systems.

Nutrient Management- Nutrient management practices also influence weed dynamics. The availability of nutrients can affect weed growth and competitiveness. For example, higher nitrogen levels may favour certain weed species over crops, while balanced nutrient applications can promote crop growth, thereby suppressing weeds. Research indicates that integrated nutrient management strategies, which combine organic and inorganic inputs, can optimize crop performance and minimize weed pressure [15,18].

Tillage Methods: Different tillage practices, such as conventional tillage versus no-till, significantly affect weed populations. No-till systems may favour certain weed species while suppressing others, altering the overall weed community structure. For instance, zero tillage has been shown to reduce the populations of *Phalaris minor* and *Chenopodium album* [2].

Tillage Practices-Armengot, et al. [19] reported that the adoption of non-inversion tillage practices has been widely promoted due to their potential benefits in reducing energy consumption and greenhouse emissions as well as improving soil fertility. However, the lack of soil inversion usually increases weed infestations and changes the composition of the weed community. Weed management is still a main drawback for the wider adoption of reduced tillage practices. Tillage practices affect soil structure and weed seed germination. No-till systems, for instance, can enhance soil health and reduce weed emergence by preserving soil moisture and structure. Conversely, conventional tillage can expose weed seeds to light and create a favourable environment for germination. The choice of tillage system should align with the overall weed management strategy to effectively control weed populations [18,19].

Integrated Weed Management Strategies

The integration of diverse weed management strategies is crucial for sustainable agriculture. These strategies may include cultural practices (such as crop rotation and cover cropping), mechanical methods (like mowing and tillage), and biological controls (utilizing natural predators or competitors). The effectiveness of these strategies is often enhanced when combined with careful nutrient management, leading to reduced reliance on chemical herbicides and improved ecological outcomes [18,20,21].

Cultural Practices: Practices such as mulching, cover cropping, and timely sowing can significantly reduce weed pressure. These methods enhance crop competitiveness and suppress weed growth through physical and biological means. Borges, et al. [22] emphasized the role of cover crops in suppressing weed populations and improving soil health.

Conservation agriculture (CA) is based on minimum soil disturbance, permanent soil cover, and crop rotation; it is promoted as a sustainable alternative to systems involving conventional tillage. Adoption of CA changes weed dynamics and communities and therefore requires adjusting weed control methods [21].

Environmental Conditions: Soil moisture, temperature, and nutrient availability also play critical roles in weed emergence and growth. Flooding conditions typical in rice cultivation can favour specific weed species adapted to such environments. Pradhan, et al. [23] observed that increased irrigation frequency led to higher densities of *Echinochloa colona*, highlighting the importance of moisture management in weed dynamics.

Impact of Zero Tillage on Weed Dynamics**-** Zero tillage has emerged as a popular practice in rice-based cropping systems due to its benefits in soil conservation and moisture retention.

Suppression of Broadleaf Weeds: Zero tillage with residue retention can suppress the growth of certain broadleaf weeds. For instance, a study found that zero tillage significantly reduced the infestation of *Chenopodium album* and other broadleaf weeds compared to conventional tillage [2].

Future Research Directions: Future research should focus on integrated weed management strategies that incorporate the interplay between different weed species, management practices, and environmental conditions [24]. There is also a need for longitudinal studies to assess the long-term effects of various management practices on weed populations and crop productivity [25]. Developing predictive models that account for climatic and agronomic variables could enhance the precision of weed management strategies.

Conclusion

Understanding and managing weed flora in rice-based cropping systems are crucial for sustainable rice production. This review emphasizes the importance of integrating knowledge on weed dynamics with effective management practices to enhance crop yields and sustainability [26]. Continued research into weed population dynamics and management practices will be vital for advancing sustainable rice cultivation.

Cropping practices significantly influence weed dynamics through mechanisms such as crop rotation, nutrient management, and tillage. Understanding these interactions is vital for developing sustainable weed management strategies that minimize herbicide use and enhance crop productivity. Future research should focus on the long-term effects of integrated cropping systems on weed dynamics to inform best practices in diverse agricultural contexts [27,28].

The dynamics of weed flora in rice-based cropping systems are complex and influenced by multiple factors. Effective management requires a holistic approach that integrates various strategies to mitigate weed competition and enhance crop productivity. Future research should focus on the ecological impacts of weed dynamics and the development of sustainable practices tailored to local conditions.

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