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Phytotoxicity of Pendimethalin on the Emergence of Seedlings and Microbial Count in Direct-seeded Rice Across Different Concentrations

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Abstract

A field trial was conducted to investigate the 'Phytotoxicity of pendimethalin on the emergence of seedlings in direct seeded rice (DSR) across different concentrations' during the *Kharif* season of 2022 at the experimental farm of the School of Agriculture, Lovely Professional University, Phagwara, Punjab. The experiment was conducted using a randomized block design with five treatments using different doses of pendimethalin (1600, 1800, 2000, and 2200 gram active ingredient per hectare (g ai per ha), and control (untreated)). Application of pendimethalin at 1600 g ai per ha resulted in a significantly higher number of seedlings than other treatment groups. The lowest number of seedlings was observed in the 2200 g ai per ha treatment group. The number of microbes present was optimal during the treatment with 1600 g ai per ha pendimethalin. With an increase in the dosage of pendimethalin, a decrease in the count of soil microbes was observed, with the lowest microbial count observed with the highest dose of pendimethalin, i.e., 2200 g ai per ha. No phytotoxic effect was observed in the DSR treated with pendimethalin at 1600 g ai per ha. Therefore the present study has to be obtain the appropriate use of dosage to inhibit the toxicity of herbicide as well as maintain the soil fertility and microbial growth.

Keywords: Phytotoxicity, Microbes, Seedlings, Pendimethalin

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INTRODUCTION

Direct-seeded rice (DSR) is an alternative method of rice cultivation that conserves both labor and water. Considering the shortages of labor and irrigation water, farmers in several Asian nations are showing interest in adopting DSR systems. This approach to rice cultivation is mechanization-friendly as it does not require puddling (land preparation in standing water) and transplanting that is necessary for typical cultivation systems. DSR increases the physical and chemical properties of the soil, which facilitates crop growth and increases the production of non-rice crops cultivated in rotation with rice. One of the major challenges in sustaining the cultivation of DSR is the adaptability of weeds to alternative weed management techniques.[1] Herbicides are commonly applied for weed control.[2] Weed infestation can lead to yield loss, requiring extensive use of herbicides such as pendimethalin. The results revealed a reduction in soil microbial biomass.[3] However, the widespread use of these chemicals causes environmental damage.

Herbicides have been used for weed management in croplands since the Green Revolution. Herbicide use has expanded drastically owing to its effectiveness in weed control and cheaper labor costs. However, the use of excessive herbicides harms plants and negatively impacts the ecosystem by contaminating the soil, water, and air.

The herbicide pendimethalin prevents the synthesis of microtubulin, which is essential for the development of cell walls and the movement of chromosomes during mitosis. Plant roots absorbs a lower concentration of these herbicides, with a greater portion being absorbed by the organs of the young shoots, such as the hypocotyl or coleoptiles. Grass and broad-leaf weeds are selectively controlled using pendimethalin. Pendimethalin at concentrations of 500 and 750 g ai per ha was most effective in controlling barnyard grass and bulrush.[4] Although, pendimethalin significantly reduces weed growth when applied at higher concentrations, it can cause rice seedling phytotoxicity, resulting in decreased yields. Microorganisms are pivotal for maintaining soil fertility and are the principal indicators of soil quality and crop productivity. Environmental factors and agronomic practices can directly or indirectly influence soil microbial communities.[5] Pre-emergence herbicide rates must be appropriately selected to minimize herbicide toxicity in rice ecosystems, preserve the microbial population, promote DSR productivity, and sustain effective weed management.[4] Weed control in rice using herbicides has become a common practice owing to its efficiency and cost-effectiveness. The use of chemical herbicides for weed control raises concern regarding their negative impact on soil health given that they could upset the balance of soil microflora, thereby potentially affecting future crop growth and development. Hence, the application of herbicides for the control of weeds in agricultural ecosystems poses a significant threat to naturally occurring beneficial microbes. The toxicological effects of herbicides have recently gained considerable attention, particularly their impact on cyanobacteria survival.[6] Moreover, pendimethalin causes phytotoxicity in crops by causing injury without phytotoxic effects in subsequent crops.[7]

Additionally, it is crucial to use an optimal herbicide rate to effectively manage weeds and minimize toxicity to crop plants.[8] The size of the weed seed bank, the presence or lack of residue, and soil characteristics are some of the variables that affect herbicide rates.[9,10] Under different environmental circumstances discovered significant variances in the efficacy of weed control with various herbicide concentrations.[11] Smith[12] applied pendimethalin to Basella alba at rates ranging from 990 to 1980 g ai per ha. This application inhibited the growth of weeds, while the crop demonstrated dark-green leaves, stunted growth, swollen stems, and depressed mottled leaves. While the crop's growth and biomass output were unaffected, lower pendimethalin dosages of 330-660 g ai per ha were found to be less effective against weeds.

Several factors, such as rainfall upon application, soil moisture, temperature, soil type, and weed species affect the effectiveness of PPI (pre-plant incorporated) and pre-emergence herbicides in controlling weeds. Herbicides, when applied to the soil, typically disrupt seed emergence or the growth of weed seedlings. Additionally, they must persist in the soil to ensure long-term effectiveness. Pre-emergence controls are typically less risky, and systemically sprayed herbicides rarely cause problems unless used excessively.

Herbicides used in crop fields for weed control can affect the soil microorganisms residing in the soil as well as the rhizosphere of crops and weeds. While herbicide treatment can temporarily reduce the microbial population, the microorganisms were observed to adapt to the new substrate 25 days later, and were able to proliferate normally. The application of herbicides affects the population of soil heterotrophs, although these negative effects gradually diminish with time. Following the application of pre-emergence herbicides, there was a decrease in the population of bacteria, fungi, and actinomycetes for up to 20 days; however, after 30 days, the microbes returned to their original level. The biological equilibrium in the soil is typically disturbed and altered when herbicides are used in agricultural systems.[13] According to Sandor,[14] herbicides reduce the total number of viable bacteria and small fungi. Both cellulose-degrading and nitrifying bacterial populations increased considerably. The response of soil microbes to herbicide application cannot be predicted in all situations; however, field dosages of herbicides are frequently safe for soil bacteria. This can be attributed to the fact that the interaction between a herbicide and a microbe depends on various soil and climatic conditions, including temperature, soil moisture, and soil acidity, in addition to the molecular structure of the herbicide itself. However, higher dosages have been observed to significantly affect soil microorganisms.

According to a previous study,[4] pendimethalin exposure may decrease the rate and effectiveness of carboxylation during photosynthetic respiration in rice plants. Achieving sustainable barnyard grass management and optimizing DSR productivity requires the application of pendimethalin at an appropriate rate to minimize the harmful effects of herbicides or oxidative damage to rice. Several pendimethalin concentrations and other pre-emergence herbicides for weed control have been studied in many DSR experiments, with different outcomes observed under various environmental conditions.

Objectives

1. The primary objective of the experiment was to evaluate the phytotoxic effects of different concentrations of pendimethalin on seedling emergence and the soil microbial count.
2. This experimental design allowed for a systematic investigation of the effect of herbicide concentration on both the plant (seedling emergence) and soil health (microbial count).
3. The inclusion of a control treatment helped establish a baseline for comparison. The use of a randomized block design enhanced the statistical validity of the results by accounting for the variability within blocks.
4. Overall, this study aimed to provide valuable insights into the effects of herbicide on the early growth stages of DSR and the associated soil microbial communities.

MATERIALS AND METHODS

The study was conducted at Lovely Professional University, Agronomy Farm in Jalandhar, Punjab, to assess the impact of herbicide phytotoxicity on seedling emergence and soil microbial count for DSR during the *Kharif* season of 2022.

Details about the experimental setup are listed below:

Location

Lovely Professional University, Agronomy Farm, Jalandhar, Punjab.

Soil type

The soil in the experimental field was classified as clayey loam in texture.

Experimental design

The experiment was organized using a Randomized Block Design (RBD), a commonly employed experimental design in agricultural research, to minimize variability within blocks. Three replications were used to enhance the reliability of the results.

Herbicide treatments

Different concentrations of the herbicide pendimethalin were used for the study, which

Table 1. Effect of herbicide phytotoxicity on seedling emergence in direct seeded rice

Control	76
1600 g ai per ha	72
1800 g ai per ha	66
2000 g ai per ha	55
2200 g ai per ha	35
C.D.	2.57

is expressed in grams of active ingredient per hectare (g ai per ha). Specifically, the herbicide concentrations were set at 1600, 1800, 2000, and 2200 g ai per ha. A control treatment without herbicide application was also included.

Crop sowing

The DSR crop was sown on May 22, 2022, in accordance with the *Kharif* season.

RESULTS AND DISCUSSION

Seedling emergence is an important criterion for assessing the potential yield during DSR cultivation, and it indicates the onset of photosynthetic activity in the seedling. Seedling emergence is crucial for a successful crop, and its occurrence in rice can be influenced by different concentrations of pendimethalin.

Data were recorded and presented in the Table 1, after the preemergence application of pendimethalin in rice fields, and seedling emergence was significantly affected by the application of various dosages of pendimethalin. The highest seedling emergence was observed in the control treatment (no pendimethalin application). The concentration of 1600 g ai per ha pendimathalin recorded significantly higher seedling emergence compared to the use of 1800, 2000, and 2200 g ai per ha. Consequently, the dosage of 1600 g ai per ha pendamethalin application was considered to be the recommended dosage of pendimethalin for DSR. In contrast, considerably lower seedling emergence was observed at higher dose of pendimethalin (2200 g ai per ha) than at all other concentrations of pendimethalin. Significant differences in seedling emergence were observed among different concentrations of pendimethalin. However, higher pendimethalin dosages had adverse effects on the emergence of seedlings as well as the productivity of DSR in the fields, consistent with previous findings.[15]

Table 2. Effect of herbicide phytotoxicity on microbial count in direct seeded rice

Treatment	AHB	Fungi
Control	6.23×10^6	13.35×10^4
1600 g ai per ha	5.02×10^6	9.54×10^4
1800 g ai per ha	4.85×10^6	6.85×10^4
2000 g ai per ha	4.23×10^6	5.9×10^4
2200 g ai per ha	3.85×10^6	4.8×10^4

Microbial count data were recorded and presented in the Table 2, after the application of pendimethalin to rice fields, and the bacterial count was significantly influenced by the different concentrations of pendimethalin. However, the counts of microbes, AHB, and fungi were significantly higher in the control treatment than in all other treatments. An optimum number of microbes was present with the treatment of 1600 g ai per ha pendimethalin. With an increase in the dosage of pendimethalin, there was a decrease in the soil microbial counts. The lowest microbial count was observed in the treatment with the highest dose of pendimethalin i.e., 2200 g ai per ha. A decrease in the growth of microorganisms was observed with an increase in the herbicide dosage, consistent with the findings of previous studies.[6,15]

CONCLUSION

From the experimental data, it was concluded that in the DSR, seedling emergence was highest with the treatment with 1600 g ai per ha, while the lowest seedling emergence was recorded with the treatment of 2200 g ai per ha of pendimethalin. Additionally, increasing the dosage of pendimethalin, decreased the number of microbes in the soil owing to its toxicity. Therefore, the application of pendimethalin at a dosage of 1600 g ai per ha is considered beneficial to farmers in DSR. Nutrient cycling and other processes maintained by soil microbes are essential for soil health and fertility.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORS' CONTRIBUTION

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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None.

DATA AVAILABILITY

All datasets generated or analyzed during this study are included in the manuscript.

ETHICS STATEMENT

This article does not contain any studies on human participants or animals performed by any of the authors.

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