**THE IMPACT OF ZINC NUTRITION ON WEED COMPETITIVENESS IN RICE**

**ABSTRACT**

The experiment was conducted at the Integrated Farming System Research Station, Karamana, Thiruvananthapuram, Kerala Agricultural University, Kerala, India, during the *Kharif* Season 2022-2023 to study the influence of different zinc nutrition treatments on weed competitiveness in rice. The treatments were T1- Soil application of ZnSO4 at 20 kg ha-1 T2- Nutri priming with Nano Zn at 0.05% T3- Nutri priming with Nano Zn at 0.05% + Foliar spray with Nano Zn at 0.05% at maximum tillering stage T4-Nutri priming with ZnSO4 at 0.5% T5- Nutri priming with ZnSO4 at 0.5% + Foliar spray with Nano Zn at 0.05% at maximum tillering stage T6- Foliar spray with Nano Zn at 0.05% at maximum tillering stage and panicle initiation stage T7- Foliar spray withZnSO4 at 0.5% at maximum tillering stage and panicle initiation stage T8- Control (Recommended dose of nutrients without application of P and Zn). The experiment was laid out in a randomized block design with three replications. The predominant weed flora was grasses. The highest weed smothering efficiency was recorded in T3 and T2 at 20 days after transplanting (DAT) and 40 DAT. The lowest weed persistence index was recorded in T3. It can be concluded that Nutri priming with Nano Zn at 0.05%, followed by foliar spray with Nano Zn at 0.05% at the maximum tillering stage, enhanced the weed competitiveness in rice.

**Keywords:** Nutri priming, Foliar spray, Maximum tillering, Panicle initiation, Nano Zn.

**INTRODUCTION**

Rice is predominantly grown and consumed in Asian continent accounting for more than 90 per cent of the world’s production. India isthe second major producer of rice after China, with the contribution of 26 percent to the worldrice production (USDA, 2024). In India, rice is grown on 47.83 Mha, with a Production of 137.82 Mt and productivity of 2.88 t ha⁻¹ (INDIASTAT, 2024)

Proper plant nutrition is essential not only for improving the quality and quantity of produce but also for supporting the overall growth and development of the plant. Micronutrients are the essential nutrient component which plays a vital role in plant physiology,even if they are taken up in comparatively lesser amounts by the plants (Sharma et al., 2013).Zinc is one such micronutrient which is associated withbiotic and abiotic stress management.Apart from playing a major role inbiochemical processes, integral factors of different enzymes, a cofactor for enzymes required for specific protein biosynthesis, and prominent in chlorophyll formation (Alloway, 2001; Das et al., 2018).

Despite the crucial roles associated with the zinc micronutirent, its deficiency is particularly widespread and more problematic than other micronutrient deficiencies, significantly affecting photosynthesis in cereal crops (Barman et al., 2018). The main issue lies in the low solubility of Zn in soil, despite the adequate total Zn content. The application and availability of phosphorus in the soil play a vital role in regulating zinc uptake, as these two nutrients interact antagonistically in plant nutrition (Sánchez-Rodríguez et al., 2017;Watts-Williams et al., 2014; Zhang et al., 2012).Nanotechnology is revolutionizing agriculture by enhancing the efficiency of nutrient absorption in plants through the use of nanofertilizers. These fertilizers utilize nanoparticles, which are typically sized between 1 and 100 nanometers, to improve nutrient delivery and uptake (Nongbet et al., 2022;Yadav et al., 2023).

Weeds pose a significant biotic constraint in rice cultivation and are expected to become more challenging. Weed interference causes considerable yield losses, ranging from 11 to 90 percent, and, in severe cases, can lead to complete crop failure (Rao et al., 2015). Puddled-transplanted rice provides an anaerobic environment by maintaining a water layer on the surface, which reduces oxygen and light availability. This environment limits weed establishment, improve crop establishment and increasing the crop's competitiveness against weeds (Chauhan and Johnson, 2011). However, weed control in rice cultivation remains a persistent challenge for achieving optimal yield and quality, as weeds can significantly reduce both (Ashraf et al., 2018).

The present study was conducted to evaluate the effectiveness of Zn in managing biotic stress like weed competition, with a focus on zinc application and their impact on weed competitiveness in rice cultivation.

**MATERIAL AND METHODS**

The field experiment was conducted in the *Kharif* season 2022-2023 (April to August) at integrated farming system research station, Karamana, Thiruvananthapuram. The site is located at 8 ̊28′ 26 N latitude and 76 ̊ 57′ 38 E longitude at an altitude of 10 m above mean sea level.The soil of the experimental site is sandy clay loam with pH being acidic, EC being normal, high organic carbon, low in available nitrogen, high in available phosphorus, and low in available potassium.

The field was previously under rice cultivation through transplanting . The weather condition during the growing season of the crop experienced many rainy days. The duration of the crop was 140 days. The total rainfall received during the season was 540.01mm.The variety used was Uma (MO-16) which is a medium duration variety released from Rice Research Station, Moncompu, Alapuzha, Kerala Agricultural University.

The experiment was laid out in a randomized block design with three replications and eight treatments. The treatments of the experiment include T1- Soil application of ZnSO4 at 20 kg ha-1 T2- Nutri priming with Nano Zn at 0.05% T3- Nutri priming with Nano Zn at 0.05% + Foliar spray with Nano Zn at 0.05% at Maximum tillering stage T4-Nutri priming with ZnSO4 at 0.5% T5- Nutri priming with ZnSO4 at 0.5% + Foliar spray with Nano Zn at 0.05% at Maximum tillering stage T6- Foliar spray with Nano Zn at 0.05% at Maximum tillering stage and Panicle initiation stage T7- Foliar spray withZnSO4 at 0.5%at Maximum tillering stage and Panicle initiation stage T8- Control (Recommended dose of nutrients without application of P and Zn).

Seedlings were raised using the wet nursery method, and they were transplanted to the main field at the age of 21 days.

Lime application @ 600 kg ha-1 was applied in two splits, one as basal and the rest as top dressing at 30 days after transplanting. Seed rate used was 75 kg ha-1, in case of the nutri priming treatments; the seeds were soaked in the mentioned concentration of the nutrients for 16 hours. 63.9 kg ha-1 N, 21.6 kg ha-1 P and 87.75 kg ha-1 K was applied to the crop according to the soil test based nutrient application based on the package of practices, Kerala Agricultural University.

Weed density was observed usinga quadrant of 50 cm × 50 cm which was placed in the plot at random, and the component plants were expressed as the number of plants per square meter at 20 DAT and 40 DAT, respectively. The weeds were again classified into grasses, sedges and broad leaved weeds.

To assess weed dry matter, a quadrant of 50 cm × 50 cm was placed in the plot at random in two different sites. The weeds present in the quadrant were pulled along with roots, washed, and dried under shade, and oven died at 60 ± 5 ̊C to a constant weight. The dry weights of the weeds were expressed as g m-2.

Weed smothering efficiency (WSE) was computed using the formula and was expressed in percentage at 20 DAT and 40 DAT (Mani *et al*., 1981).

WC- WT

WSE = × 100

WC

Where, WC- Dry weight of weeds in the control plot

WT- Dry weight of weeds in the treated plot

Weed persistence index (WPI) was computed using the formula at 20 DAT and 40 DAT(Mishra et al., 2016)

Weed dry matter in treated plot Weed density in control plot

WPI= **×**

Weed dry matter in control plot Weed density in treated plot

**3.Results and discussion**

**3.1 Weed Composition**

The experimental site was previously under rice cultivation, andthe predominant weed species at the experimental site was grasses.The weed floras of the different treatments were grouped into grasses, sedges, broad-leaf weeds and are listed in the Table 1.

**Table 1. Major weed species observed during the crop season.**

|  |  |  |
| --- | --- | --- |
| **Common name** | **Scientific name** | **Family** |
| **Grasses** | | |
| Jungle rice | *Echinochloa colona* | Poaceae |
| Barnyard grass | *Echinochloa crus-galli* | Poaceae |
| Blood grass | *Isachne miliacea* | Poaceae |
| Chinese sprangletop | *Leptochloa chinensis* | Poaceae |
| Weedy rice | *Oryza sativa* f. *spontanea* | Poaceae |
| **Sedges** | | |
| Rice sedge | *Cyperus difformis* | Cyperaceae |
| Yellow nut sedge | *Cyperus iria* | Cyperaceae |
| Globe finger rush | *Fimbristylis miliacea* | Cyperaceae |
| **Broad-leaf weeds** | | |
| False daisy | *Eclipta prostrata* | Asteraceae |
| Goose weed | *Sphenoclea zeylanica* | Sphenocleaceae |
| Hermits water lily | *Limno charisflava* | Limnocharitaceae |
| Blue moneywort | *Lindernia grandiflora* | Linderniaceae |
| Oval leaf pond weed | *Monochoria vaginalis* | Pontederiaceae |

**3.2. Weed Density**

The analyzed data revealed that at 20 DAT, the population of grasses and sedges were influenced by the treatments. The lowest weed density of grasses was recorded in T2, which was followed by T3,T4 and T5.The sedge population was the lowest in T3 and was on par with T2, T4, T5, and T6. The results clearly indicated that nutri priming with Zn enhanced the vigour of rice seedlings for early establishment and competitiveness.The highest weed density of grasses and sedges has been recorded in the control treatment (T8) which was on par with T1 and T7. Weed density at 40 DAT did not show any significant difference between treatments.

Weed density was reported higher in the control treatment, which applied the recommended dose of fertilizers excluding P and Zn, making the rice plants less established and less competitive compared to the treatments that are sufficiently supplied with nutrients.The absence of phosphorousnutrition, which plays an important role in early root growth and root proliferation,in the control treatment might have affected the proper establishment of the plants to compete with weeds in the control treatment (Malhotra et al., 2018).

**3.3 Weed Dry Matter**

Weed dry matter at 20 and 40 DAT differed significantly among the zinc application treatments. The treatment T8 recorded the highest weed dry matter and was found on par with T1. The treatment T3 has recorded the lowest weed dry matter at 20 and 40 DAT.

Plant growth and development require Zn to undergo biological processes like the synthesis of proteins and nucleic acids (Han et al., 2004; Broadley et al., 2012).Weed growth was also associated with nutrient supply when considered as plant species, and weed biomass was higher in Zn soil application treatments (El-Metwalley et al., 2020; Saudy et al., 2021), which is in justification with treatment T1.The absence of both the P and Zn nutrients would make the plant species weak, resulting in more weed-dry matter in the control treatment.

**Table 2. Effect of zinc nutrition on weed density (No. m-2)in rice at 20 and 40 DAT**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **20 DAT** | | | | **40 DAT** | | | |
|  | **Grasses** | **Sedges** | **Broad- leaf**  **weeds** | **Total weeds** | **Grasses** | **Sedges** | **Broad- leaf**  **weeds** | **Total weeds** |
| T1- Soil application of ZnSO4 at 20 kg ha-1 | 33.00ab | 9.07ab | 4.73 | 46.80ab | 17.40 | 4.47 | 3.13 | 25.00 |
| T2- Nutri priming with Nano Zn at 0.05% | 18.53d | 6.13d | 3.47 | 28.13e | 17.60 | 4.27 | 2.67 | 24.53 |
| T3- Nutri priming with Nano Zn at 0.05% + Foliar spray with Nano Zn at 0.05% at Maximum tillering stage | 23.60c | 6.00d | 4.00 | 33.60d | 17.53 | 4.00 | 2.27 | 23.60 |
| T4- Nutri priming with ZnSO4 at 0.5% | 25.33c | 7.33cd | 4.47 | 37.13d | 17.33 | 4.40 | 2.93 | 24.87 |
| T5- Nutri priming with ZnSO4 at 0.5%+ Foliar spray with Nano Zn at 0.05% at Maximum tillering stage | 25.53c | 6.87cd | 4.67 | 37.07d | 17.33 | 4.33 | 2.67 | 24.33 |
| T6- Foliar spray with Nano Zn at 0.05% at Maximum tillering stage and Panicle initiation stage | 29.67b | 7.60bcd | 4.60 | 41.87c | 17.27 | 4.07 | 2.33 | 23.67 |
| T7- Foliar spray with ZnSO4 at 0.5% at Maximum tillering stage and Panicle initiation stage | 31.00ab | 8.47abc | 4.60 | 44.07bc | 17.67 | 4.40 | 2.93 | 25.00 |
| T8- Control (Recommended dose of nutrients without application of P and Zn). | 34.67a | 9.80a | 4.93 | 49.40a | 17.80 | 4.67 | 3.13 | 25.60 |
| **SEm (±)** | 1.26 | 0.55 | 0.43 | 1.53 | 0.92 | 0.22 | 0.42 | 1.40 |
| **CD (0.05)** | 3.807 | 1.659 | **NS** | 4.631 | **NS** | **NS** | **NS** | **NS** |

**Table 3. Effect of zinc nutrition on weed dry matter (g m-2) in rice at 20 and 40 DAT**

|  |  |  |
| --- | --- | --- |
| **Treatments** | **20 DAT** | **40 DAT** |
| T1- Soil application of ZnSO4 at 20 kg ha-1 | 17.10a | 11.40ab |
| T2- Nutri priming with Nano Zn at 0.05% | 9.27d | 9.73cd |
| T3- Nutri priming with Nano Zn at 0.05% + Foliar spray with Nano Zn at 0.05% at Maximum tillering stage | 9.10d | 8.63d |
| T4- Nutri priming with ZnSO4 at 0.5% | 12.57c | 10.87bc |
| T5- Nutri priming with ZnSO4 at 0.5%+ Foliar spray with Nano Zn at 0.05% at Maximum tillering stage | 13.30c | 10.57bc |
| T6- Foliar spray with Nano Zn at 0.05% at Maximum tillering stage and Panicle initiation stage | 15.57b | 8.73d |
| T7- Foliar spray with ZnSO4 at 0.5% at Maximum tillering stage and Panicle initiation stage | 15.23b | 10.50bc |
| T8- Control (Recommended dose of nutrients without application of P and Zn). | 17.90a | 12.67a |
| **SEm (±)** | 0.42 | 0.52 |
| **CD (0.05)** | 1.266 | 1.59 |

**3.4. Weed Smothering Efficiency (WSE)**

Weed smothering efficiency at 20 DAT was found to be significant, and the highest values in the treatment T3and T2were on par and were superior to other treatments. The lowest WSE was recorded in treatmentsT1,T6 and T7.At 40 DAT,the highest WSE was recorded inT3, T6 and T2. The lowest WSE was recorded in T1.

Weeds undergo nutritional stress and herbicidal stress in the course of their growth period. Activation of ribulose 1,5- bisphosphate carboxylase / oxygenase in the process of photosynthesis was correlated with the Zn, and decreased photosynthetic activity was seen in weeds which were insufficiently supplied with Zn micronutrient (Storey, 2007; Sasaki et al., 1998). Moreover the treatments which were supplied with the Zn, as Nano application and foliar application, the plants have absorbed the nutrients and become more competitive with the weeds. Similar results were also reported by (Hasanain et al., 2019).

**Table 4. Effect of zinc nutrition on weed smothering efficiency (%) in rice at 20 and 40 DAT**

|  |  |  |
| --- | --- | --- |
| **Treatments** | **20 DAT** | **40 DAT** |
| T1- Soil application of ZnSO4 at 20 kg ha-1 | 7.73c | 9.76cd |
| T2- Nutri priming with Nano Zn at 0.05% | 48.13a | 23.10ab |
| T3- Nutri priming with Nano Zn at 0.05% + Foliar spray with Nano Zn at 0.05% at Maximum tillering stage | 49.10a | 31.90a |
| T4- Nutri priming with ZnSO4 at 0.5% | 29.86b | 14.15bc |
| T5- Nutri priming with ZnSO4 at 0.5%+ Foliar spray with Nano Zn at 0.05% at Maximum tillering stage | 25.76b | 16.35bc |
| T6- Foliar spray with Nano Zn at 0.05% at Maximum tillering stage and Panicle initiation stage | 13.06c | 31.03a |
| T7- Foliar spray with ZnSO4 at 0.5% at Maximum tillering stage and Panicle initiation stage | 14.91c | 16.93bc |
| T8- Control (Recommended dose of nutrients without application of P and Zn). | 0.00d | 0.00d |
| **SEm (±)** | 2.44 | 4.18 |
| **CD (0.05)** | 7.388 | 12.682 |

**3.5. Weed Persistence Index**

Weed persistence index as affected by zinc nutrition is shown in Table 5. The results revealed that significant difference were observed at 20 DAT, where the highest value has been recorded in T6 all other treatments except T3were on par,and the lowest weed persistence index was recorded in the treatment T3. This may be attributed to the effect of nutri primedand foliar nutrition of Nano Zn. This proved the effectiveness of nano zinc through seed and foliar nutrition, which enhanced the competitiveness of rice in the early stages. However, soil application of nutrients makes the weeds more available with nutrients, and its population increases (Mahajan and Timsina 2011).

**Table 5. Effect of zinc nutrition on weed persistence index in rice at 20 and 40 DAT.**

|  |  |  |
| --- | --- | --- |
| **Treatments** | **20 DAT** | **40 DAT** |
| T1- Soil application of ZnSO4 at 20 kg ha-1 | 1.01 | 0.97 |
| T2- Nutri priming with Nano Zn at 0.05% | 0.91 | 0.81 |
| T3- Nutri priming with Nano Zn at 0.05% + Foliar spray with Nano Zn at 0.05% at Maximum tillering stage | 0.76 | 0.75 |
| T4- Nutri priming with ZnSO4 at 0.5% | 0.93 | 0.89 |
| T5- Nutri priming with ZnSO4 at 0.5%+ Foliar spray with Nano Zn at 0.05% at Maximum tillering stage | 1.00 | 0.88 |
| T6- Foliar spray with Nano Zn at 0.05% at Maximum tillering stage and Panicle initiation stage | 1.02 | 0.75 |
| T7- Foliar spray with ZnSO4 at 0.5% at Maximum tillering stage and Panicle initiation stage | 0.95 | 0.85 |
| T8- Control (Recommended dose of nutrients without application of P and Zn). | 1.00 | 1.00 |
| **SEm (±)** | 0.04 | 0.07 |
| **CD (0.05)** | 0.131 | NS |

**Table 6. Species composition of major weeds at 20 DAT**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments**  **20 DAT** | **T1** | **T2** | **T3** | **T4** | **T5** | **T6** | **T7** | **T8** | **SEm (±)** | **CD (0.05)** |
| **Grasses** | | | | | | | | | | |
| *Echinohloa colona* | 5.10  (2.47) | 3.33  (2.08) | 5.07  (2.45) | 6.00  (2.64) | 5.30  (2.51) | 5.87  (2.62) | 5.00  (2.44) | 5.00  (2.44) | 0.085 | 0.258 |
| *Echinochloa crus-galli* | 4.30  (2.29) | 1.63  (1.61) | 2.53  (1.78) | 2.97  (1.98) | 2.53  (1.87) | 3.97  (2.22) | 3.97  (2.22) | 3.43  (2.05) | 0.132 | 0.4 |
| *Isachne miliacea* | 2.30  (1.82) | 1.40  (1.52) | 1.60  (1.61) | 1.30  (1.51) | 1.73  (1.65) | 1.00  (1.38) | 1.53  (1.58) | 2.10  (1.75) | 0.121 | NS |
| *Leptochloa chinensis* | 2.97  (1.95) | 1.07  (1.43) | 1.20  (1.46) | 1.87  (1.68) | 1.87  (1.68) | 2.40  (1.83) | 2.77  (1.93) | 4.43  (2.33) | 0.124 | 0.377 |
| *Oryza sativa* f. *spontanea* | 1.83  (1.68) | 1.83  (1.68) | 1.40  (1.55) | 0.53  (1.22) | 1.33  (1.53) | 1.60  (1.61) | 2.23  (1.80) | 2.37  (1.83) | 0.083 | 0.251 |
| **Sedges** | | | | | | | | | | |
| *Cyperus difformis* | 1.07  (1.42) | 0.53  (1.22) | 0.53  (1.22) | 0.63  (1.27) | 0.83  (1.34) | 0.77  (1.31) | 0.30  (1.13) | 1.43  (1.55) | 0.128 | NS |
| *Cyperus iria* | 1.73  (1.65) | 0.73  (1.31) | 1.07  (1.43) | 1.20  (1.45) | 1.10  (1.45) | 1.20  (1.48) | 1.77  (1.66) | 0.93  (1.38) | 0.104 | NS |
| *Fimbristylis miliacea* | 0.97  (1.37) | 0.73  (1.29) | 0.97  (1.39) | 1.07  (1.43) | 0.63  (1.25) | 0.97  (1.39) | 0.77  (1.31) | 1.53  (1.59) | 0.142 | NS |
| **Broad leaf weeds** | | | | | | | | | | |
| *Ecliptapro strata* | 0.63  (1.27) | 0.60  (1.24) | 0.30  (1.13) | 0.63  (1.25) | 0.73  (1.30) | 0.87  (1.35) | 0.73  (1.30) | 0.77  (1.31) | 0.133 | NS |
| *Sphenoclea zeylanica* | 0.10  (1.04) | 0.30  (1.13) | 0.53  (1.22) | 1.07  (1.40) | 0.53  (1.22) | 0.40  (1.18) | 0.43  (1.17) | 0.53  (1.22) | 0.125 | NS |
| *Limnocharis flava* | 0.77  (1.31) | 0.63  (1.27) | 0.10  (1.04) | 0.20  (1.08) | 0.20  (1.09) | 0.30  (1.13) | 0.73  (1.31) | 0.87  (1.34) | 0.095 | NS |
| *Lindernia grandiflora* | 0.87  (1.34) | 0.20  (1.09) | 1.07  (1.42) | 0.33  (1.13) | 0.87  (1.36) | 0.73  (1.29) | 0.40  (1.18) | 0.30  (1.13) | 0.115 | NS |
| *Monochoria vaginalis* | 0.77  (1.31) | 1.07  (1.42) | 0.43  (1.18) | 0.77  (1.31) | 0.87  (1.35) | 0.87  (1.32) | 1.40  (1.54) | 1.00  (1.41) | 0.138 | NS |

**Table 7.Species composition of major weeds at 40 DAT**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments**  **40 DAT** | **T1** | **T2** | **T3** | **T4** | **T5** | **T6** | **T7** | **T8** | **SEm (±)** | **CD (0.05)** |
| **Grasses** | | | | | | | | | | |
| *Echinohloa colona* | 1.87  (1.68) | 1.87  (1.61) | 2.53  (1.87) | 2.17  (1.74) | 1.43  (1.54) | 1.43  (1.51) | 1.43  (1.51) | 2.93  (1.96) | 0.243 | NS |
| *Echinochloa crus-galli* | 1.30  (1.47) | 1.83  (1.67) | 2.07  (1.74) | 2.30  (1.80) | 2.30  (1.82) | 2.63  (1.89) | 1.97  (1.69) | 0.43  (1.17) | 0.147 | NS |
| *Isachne miliacea* | 2.40  (1.82) | 1.30  (1.47) | 1.60  (1.61) | 1.83  (1.67) | 1.97  (1.71) | 1.00  (1.38) | 1.60  (1.61) | 2.10  (1.75) | 0.151 | NS |
| *Leptochloa chinensis* | 1.50  (1.58) | 2.07  (1.72) | 1.17  (1.45) | 1.93  (1.70) | 1.77  (1.65) | 1.73  (1.62) | 2.20  (1.77) | 0.77  (1.29) | 0.174 | NS |
| *Oryza sativa* f. *spontanea* | 1.63  (1.61) | 1.73  (1.65) | 1.30  (1.51) | 0.53  (1.22) | 1.20  (1.44) | 1.83  (1.67) | 1.63  (1.60) | 2.67  (1.91) | 0.142 | NS |
| **Sedges** | | | | | | | | | | |
| *Cyperus difformis* | 0.20  (1.09) | 0.30  (1.13) | 0.77  (1.31) | 0.43  (1.18) | 0.20  (1.09) | 0.60  (1.26) | 0.53  (1.22) | 0.83  (1.34) | 0.098 | NS |
| *Cyperus iria* | 0.43  (1.18) | 0.43  (1.18) | 0.53  (1.22) | 0.60  (1.26) | 0.60  (1.26) | 0.50  (1.22) | 0.10  (1.04) | 0.87  (1.36) | 0.084 | NS |
| *Monochoria vaginalis* | 0.97  (1.39) | 0.77  (1.29) | 0.20  (1.09) | 0.30  (1.13) | 0.83  (1.33) | 0.30  (1.13) | 1.17  (1.46) | 0.10  (1.04) | 0.118 | NS |
| *Fimbristylis miliacea* | 0.63  (1.27) | 0.63  (1.27) | 0.50  (1.22) | 0.87  (1.36) | 0.53  (1.22) | 0.63  (1.26) | 0.40  (1.17) | 0.53  (1.22) | 0.100 | NS |
| **Broad leaf weeds** | | | | | | | | | | |
| *Ecliptapro strata* | 0.10  (1.04) | 0.33  (1.13) | 0.20  (1.09) | 0.33  (1.13) | 0.20  (1.08) | 0.77  (1.32) | 0.77  (1.31) | 0.77  (1.32) | 0.100 | NS |
| *Sphenoclea zeylanica* | 0.63  (1.27) | 0.40  (1.18) | 0.40  (1.18) | 0.30  (1.13) | 0.30  (1.13) | 0.10  (1.04) | 0.40  (1.18) | 0.30  (1.13) | 0.052 | NS |
| *Limnocharis flava* | 0.53  (1.22) | 0.40  (1.18) | 0.20  (1.08) | 0.63  (1.27) | 0.10  (1.04) | 0.30  (1.14) | 0.30  (1.13) | 0.20  (1.08) | 0.079 | NS |
| *Lindernia grandiflora* | 0.30  (1.13) | 0.20  (1.08) | 0.33  (1.13) | 0.20  (1.09) | 0.73  (1.29) | 0  (1.00) | 0  (1.00) | 0.30  (1.13) | 0.09 | NS |
| *Monochoria vaginalis* | 0.97  (1.39) | 0.77  (1.29) | 0.20  (1.09) | 0.30  (1.13) | 0.83  (1.33) | 0.30  (1.13) | 1.17  (1.46) | 0.10  (1.04) | 0.118 | NS |

**Conclusion:**

The present study demonstrated that Zn nutrition significantly influences the weed population in transplanted rice. Among the treatments evaluated, nutrient priming with Nano Zn at 0.05%, followed by foliar application of Nano Zn at 0.05% during the maximum tillering stage, was found to be the most effective strategy for enhancing weed competitiveness. Nano fertilizers outperformed traditional ZnSO₄ due to their superior surface-to-volume ratio, which facilitated efficient nutrient absorption by rice plants, thereby improving their ability to compete with weeds. These findings highlight the potential of nano-based fertilizers in integrated nutrient and weed management strategies for rice cultivation.

Disclaimer (Artificial intelligence)

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Details of the AI usage are given below:

1.

2.

3.

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