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INTEGRATED EFFECTS OF WATER MANAGEMENT PRACTICES AND NANO FERTILIZERS APPLICATION ON WEED DENSITY AND WEED CONTROL EFFICIENCY IN RICE (*ORYZA SATIVA* L.)

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ABSTRACT

Rice (*Oryza sativa* L.) is a crucial global crop facing productivity challenges due to water scarcity, high weed density, and excessive use of inorganic fertilizers. This study evaluated the integrated effects of water management practices and nano-fertilizer applications on weed density, dry matter production, and weed control efficiency in rice cultivation. This study, conducted at the Student's Instructional Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, over two consecutive Kharif seasons (2022 and 2023), aimed to evaluate the effects of water management practices and nano fertilizers on different rice varieties. A split-plot design was used, with water management systems (I_1- Flooding throughout crop growth (3+/-2cm), I_2- Saturation maintenance up to PI and (3+/-2cm) after PI, and I_3- Alternate wetting and drying) in main plot, three varieties (V_1- NDR 2064, V_2- Pusa Basmati 1509 and V_3- Arize 6444 Gold) in sub plot and five nano fertilizers treatments (F_1- 100% RD- $N_{120kg/h}$ $P_{60kg/h}$ $K_{40kg/h}$ + $Zn_{25kg/h}$, F_2- 100% RD- $N_{120kg/h}$ $P_{60kg/h}$ $K_{40kg/h}$ + $Zn_{25kg/h}$ + Nano fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$, F_3- 75% RD- $N_{90kg/ha}$ $P_{45kg/ha}$ $K_{30kg/ha}$ + $Zn_{18.75kg/ha}$ + Nano fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$), F_4- 50% RD- $N_{60kg/ha}$ $P_{30kg/ha}$ $K_{20kg/ha}$ + $Zn_{12.5kg/ha}$ + Nano fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$) and F_5- Nano fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$)) in sub- sub plots with three replications. Results indicated that flooding throughout the crop growth cycle resulted in the lowest weed density (13.28, 15.01, and 14.11 weeds m^{-2} at 30, 60, and 90 DAT, respectively) and highest weed control efficiency (14.70%). Among varieties, hybrid Arize 6444 Gold exhibited the highest weed control efficiency (11.87%). Nano-fertilizers significantly enhanced weed suppression, with the combination of 50% recommended dose of fertilizers (RDF) and nano-fertilizers achieving a weed control efficiency of 26.37%. These findings suggest that integrating nano-fertilizers with optimal water management practices effectively reduces weed density and enhances weed control efficiency in rice cultivation, ensuring sustainable crop production.

***Keywords*: ** Weed, rice, nano fertilizers, water management and weed control efficiency.

Introduction

Rice (*Oryza sativa* L.), one of the oldest and most crucial cereal crops, feeds over half of the world's population and holds immense importance for food security, especially in the Asia-Pacific, where 90% of global rice is produced and consumed (Fukagawa *et al.,* 2019). With 165 million hectares under cultivation and an annual output of 787 million tons, rice is widely grown on all continents except Antarctica (Anonymous, 2018). In 2022-23, China led global production with 146 million metric tons of milled rice, while India, as the second-largest producer, contributed approximately 42% of its total food grain production, amounting to 135 million tons from an area of 46 million hectares (Shahbandeh, 2024). However, India's rice productivity, at 28.05 q ha^{-1}, is lower than China's, reflecting challenges such as high-water consumption (3,000–5,000 litters per kg) and environmental impacts from traditional flooding methods (Kumar *et al.,* 2022). Water scarcity, exacerbated by climate change and competition with industry, has led to methods like saturation irrigation, which conserves water while maintaining soil saturation to support growth, reduce weed competition, and cut methane emissions (Fujihara *et al.,* 2013; Matsue *et al.,* 2021). Alternate Wetting and Drying Irrigation (AWDI) has also gained popularity for its efficiency in conserving water and maintaining rice yields by alternating wet and dry cycles (Carrijo *et al.,* 2017). While high-yielding varieties introduced during the Green Revolution bolstered productivity, heavy reliance on inorganic fertilizers like urea has led to reduced soil health and nutrient efficiency, promoting research on nano-fertilizers (Rai *et al.,* 2012). Innovations like nano-urea, developed by the Nano Biotechnology Research Center and IFFCO, enhance nitrogen uptake through nanoparticles that enter plant cells directly, improving crop yield and sustainability (Liu and Lal, 2015 and Dheer *et al.,* 2024). Effective weed management is also crucial, as weeds can reduce rice yields by up to 76%, draining essential nutrients and affecting crop quality. High labour costs and limited herbicide access remain challenges for small farmers in managing these impacts (Sureshkumar *et al.,* 2016).

Materials and Methods

The present investigation was conducted at the Student's Instructional Farm of the Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) over two consecutive years during *Kharif* 2022 and 2023 as presented in Fig. 1. Kanpur is located in the sub-tropics, which has a semi-arid climate, positioned between latitudes 25.26° to 28.58° North and longitudes 79.31° to 80.34° East, at an elevation of approximately 125.9 meters above sea level. The experimental plot was adequately levelled, properly drained, and equipped with reliable irrigation via a tube well. It is located in the alluvial Gangetic region of central Uttar Pradesh.

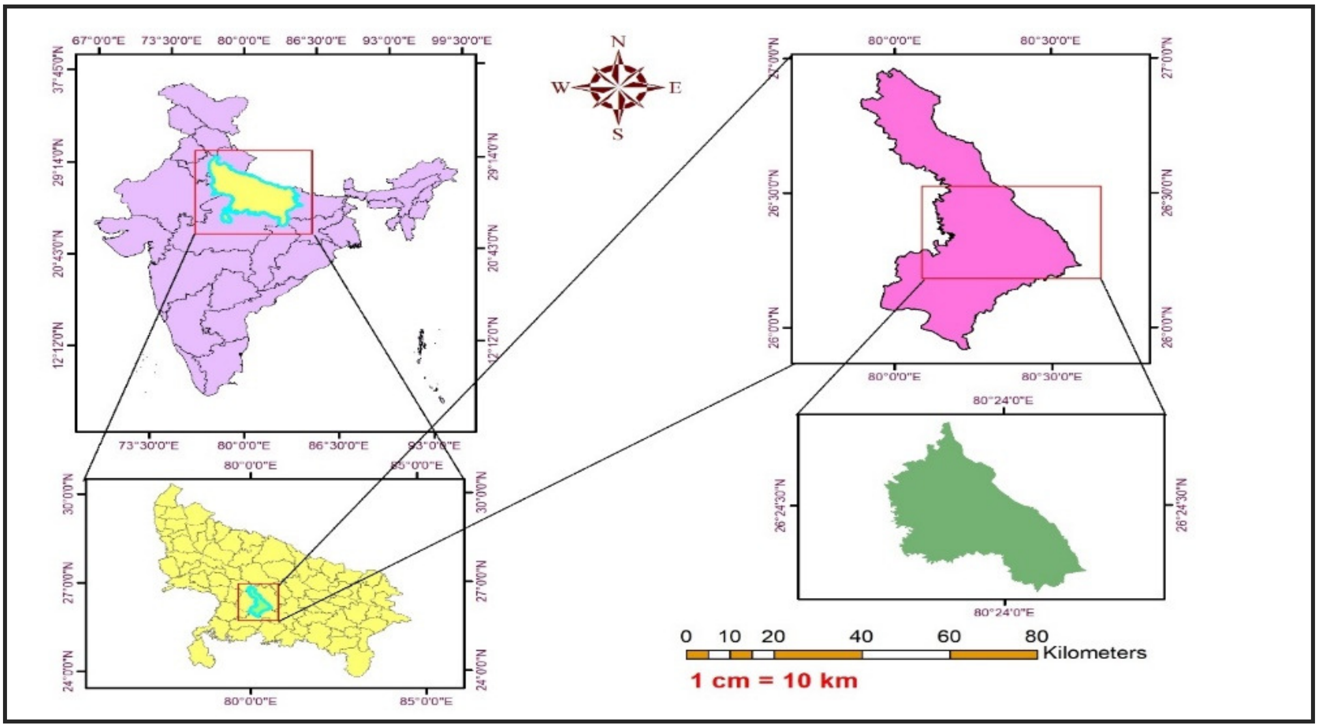

Fig. 1: Study area map.

Experimental Details

The experiment was conducted in the split plot design, with three replications during both the years. The water management system was implemented in the main plot (I_1- Flooding throughout crop growth (3+/-2cm), I_2- Saturation Maintenance up to PI and (3+/-2cm) after PI and I_3- Alternate wetting and drying), while numerous varieties were allotted to the sub-plot (V_1- NDR- 2064, V_2- PB-1509 and V_3- Arize-6444 Gold) and nano fertilizers were assigned to the sub

sub-plot (F_1- 100% RD- N 120 kg/h P 60 kg/h K 40 kg/h + Zn 25 kg/h, F_2- 100% RD- N 120 kg/h P 60 kg/h K 40 kg/h + Zn 25 kg/h + Nano Fertilizers (Urea 4 ml/l + DAP 4 ml/lit + Zn 0.5 ml/l), F_3- 75% RD- N 90 kg/ha P 45 kg/ha K 30 kg/ha + Zn 18.75 kg/ha + Nano Fertilizers (Urea 4 ml/l + DAP 4 ml/lit + Zn 0.5 ml/l), F_4- 50% RD- N 60 kg/ha P30 kg/ha K 20 kg/ha + Zn 12.5 kg/ha + Nano Fertilizers (Urea 4 ml/l + DAP 4 ml/lit + Zn 0.5 ml/l) and F_5- Nano Fertilizers (Urea 4 ml/l + DAP 4 ml/lit + Zn 0.5 ml/l). The following observations were recorded under study.

Weed studies

Weed density (No. m^{-2})

The weed population of various weed species in each plot was examined at 30, 60, 90 days after transplanting (DAT), and throughout the harvest stage. Two rectangular iron frames, each measuring 25 × 25 cm, were randomly put at two locations in the boundary rows on either side of each plot. The number of weeds within the quadrate was tallied. Subsequently, they were categorized into three distinct groups, namely grasses, broadleaves, and sedges. The aforementioned observation was calculated to determine the weed density (number per square meter) prior to doing statistical analysis (Mishra *et. al.,* 2019).

Dry matter production of weeds (g m^{-2})

The weed samples collected for recording observations on weed density at 30, 60, 90 days after transplanting, and at the harvest stage were first dried in the sun to eliminate any extra moisture on the surface of the weeds. They were then further dried in an oven at a temperature of 60 °C ± 5 °C. Following the process of fully drying the oven, the weight of the dried substance was measured using an electronic balance and then converted into grams per square meter. The dry matter of weeds underwent a square root transformation (i.e., √x + 0.5) before being analyzed statistically for significance testing (Verma *et. al.,* 2021).

Weed Control Efficiency

Weed Control Efficiency is a percentage that measures how much a weed control treatment reduces the number of weeds. It's calculated by comparing the number of weeds in a treated plot to the amount in an untreated plot.

$$WCE = \frac{Wu - Wt}{Wu} \times 100$$

Where,

Wu: is the weed dry weight in the untreated plot,

Wt: is the weed dry weight in the treated plot

The collected data on various aspects of weeds during two years of experimentation Data obtained for statistical analysis of variance difference among mean of different treatments. The treatments means were compared using the Least Significant Differences test at 5% level of probability by using the Split-split Plot Design procedure as given by Fisher and Yates (1949). The data on population of individual weed species and their dry matter and spike deformities were analysed after square root transformation (X= √x+0.5). The treatment comparisons were made at 5 % level of significance (Choudhary and dixit, 2018).

Results and Discussion

Effect of treatments on density of total weeds (m^{-2})

It is clearly depicted that water management practices influenced the density of broadleaf significantly at 30, 60, 90 DAT. The minimum number of total weed density was recorded under Flooding throughout crop growth (3+/-2cm) (13.28, 15.01 and 14.11 at 30, 60 and 90 DAT, respectively) followed by Saturation Maintenance up to PI and (3+/-2cm) after PI (15.28, 17.26 and 16.22 m^{-2} at 30, 60 and 90 DAT, respectively). The maximum number of density (17.56, 19.83 and 18.65 at 30, 60 and 90 DAT, respectively) was recorded under alternate wetting and drying practice. There was significant variation on density of total weeds under the present study. Aromatic rice variety PB 1509 was found to cause the comparatively higher weed density of total weeds (16.01, 18.08 and 17.00 at 30, 60 and 90 DAT, respectively) as compared to open pollinated variety NDR 2064 (15.38, 17.37 and 16.34 at 30, 60 and 90 DAT, respectively) and hybrid Arize 6444 Gold (14.74, 16.67 and 15.66 at 30, 60 and 90 DAT, respectively). The Nano fertilizers treatments either alone or in combinations with 100% RD- $N_{120kg/h}$ $P_{60kg/h}$ $K_{40kg/h}$ + $Zn_{25kg/h}$ significantly influenced the density of total weeds. A perusal of data presented in Table 1. clearly revealed that the absolute doses of Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$) caused the lower density (14.15, 15.98 and 15.03 at 30, 60 and 90 DAT, respectively) of total weeds even in comparison to 100% RD- $N_{120kg/h}$ $P_{60kg/h}$ $K_{40kg/h}$ + $Zn_{25kg/h}$. However, the treatment combination consisted 100% RD- $N_{120kg/h}$ $P_{60kg/h}$ $K_{40kg/h}$ + $Zn_{25kg/h}$ + Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$) showed the maximum density (16.31, 18.44 and 17.33 at 30, 60 and 90 DAT, respectively) of total weeds.

Effect of treatments on dry matter accumulation of total weeds (g m^{-2})

It is clearly depicted that water management practices influenced the dry weight of broad leafy weeds significantly at 30, 60, 90 DAT. The highest dry weight of total weeds was recorded under alternate wetting and drying practice (13.91, 17.56 and 16.50 g

m^{-2} at 30, 60 and 90 DAT, respectively) followed by Saturation Maintenance up to PI and (3+/-2cm) after PI (12.09, 15.28 and 14.36 g m^{-2} at 30, 60 and 90 DAT, respectively). The minimum dry weight of total weeds 11.25, 14.20 and 13.35 g m^{-2} at 30, 60 and 90 DAT, respectively, was recorded under Flooding throughout crop growth (3+/-2cm). There was significant variation for dry weight of total weeds under the present study. Aromatic rice variety PB 1509 was found to cause the maximum weed dry weight of broadleaf weeds (13.29, 16.78 and 15.76 g m^{-2} at 30, 60 and 90 DAT, respectively) as compared to open pollinated variety NDR 2064 (12.34, 15.58 and 14.64 g m^{-2} at 30, 60 and 90 DAT, respectively) and hybrid Arize 6444 Gold (11.63, 14.68 and 13.81 g m^{-2} at 30, 60 and 90 DAT, respectively). The Nano fertilizers treatments of either alone or in combinations with RDF+Zn or alone significantly influenced the dry weight of total weeds. A perusal of data presented in Table 2. clearly revealed that the absolute doses of Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$) caused the low dry weight of total weeds (11.42, 14.43 and 13.56 at 30, 60 and 90 DAT, respectively) even in comparison to 100% RD- $N_{120kg/h}$ $P_{60kg/h}$ $K_{40kg/h}$ + $Zn_{25kg/h}$. However, the treatment combination consisted 100% RD- $N_{120kg/h}$ $P_{60kg/h}$ $K_{40kg/h}$ + $Zn_{25kg/h}$ + Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$) showed the maximum 13.18, 16.63 and 15.64 g m^{-2} at 30, 60 and 90 DAT, respectively dry weight of total weeds.

Effect of treatments on weed control efficiency (WCE):

It is revealed from the data presented in Fig 2. that water management practices significantly influenced the weed control efficiency (%) in same trend during both years. The treatment consisted Flooding throughout crop growth (3+/-2cm) showed the maximum pooled weed control efficiency (14.70 %) followed by Saturation Maintenance up to PI and (3+/-2cm) after PI (11.14%). The alternate wetting and drying practice showed the minimum (7.80 %) weed control efficiency. The varieties were found to be significantly varied to each other for their weed control efficiency under study (Fig. 2). The trend of weed control efficiency variation of varieties was same during both the years. The data of both years were therefore pooled and elaborated. The hybrid variety Arize 6444 Gold caused the maximum pooled weed control efficiency (11.87 %) followed by NDR 2064 was recorded (10.11 %). The variety PB 1509 was recorded with minimum (9.53 %) weed control efficiency. The treatments pertaining to nano fertilizers either alone or in combinations to different fraction of RDF influenced the weed control efficiency significantly. The trend of weed control efficiency variation of treatment was in same trend during both the years. The data of both years were therefore pooled and elaborated. The maximum weed control efficiency (26.37 %) was observed by the treatment combination of Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$) followed by the treatment combination of 50% RD- $N_{60kg/ha}$ $P_{30kg/ha}$ $K_{20kg/ha}$ + $Zn_{12.5kg/ha}$ + Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$). The absolute doses of 100% RD- $N_{120kg/h}$ $P_{60kg/h}$ $K_{40kg/h}$ + $Zn_{25kg/h}$ depicted the minimum 4.41 % weed control efficiency.

Conclusion

Keeping above findings in view, it is concluded that the among all the treatments, Flooding throughout crop growth (3+/-2cm) of water management practice with combination treatment of Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$) was found most appropriate irrespective of promising varieties and hybrid to optimize growth and development in rice.

Table 1: Effect of water management practices, varieties and nano-fertilizers on weed density of Total weed (m^{-2}) in rice during kharif 2022 and 2023.

Treatment	Total weed (m^{-2})								
	30 DAT			**60 DAT**			**90 DAT**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
A. Water Management Practices									
I_1- Flooding throughout crop growth (3+/-2cm)	13.72 (61.56)	12.86 (54.00)	13.28 (57.64)	15.50 (79.02)	14.52 (69.25)	15.01 (74.04)	14.57 (69.64)	13.66 (61.12)	14.11 (65.27)
I_2- Saturation Maintenance up to PI and (3+/-2cm) after PI	15.76 (81.75)	14.79 (71.91)	15.28 (76.79)	17.82 (104.91)	16.71 (92.21)	17.26 (98.41)	16.75 (92.52)	15.70 (81.18)	16.22 (86.73)
I_3- Alternate wetting and drying	18.12 (108.54)	16.98 (95.27)	17.56 (101.90)	20.48 (139.06)	18.90 (118.84)	19.83 (130.36)	19.24 (122.56)	18.04 (107.72)	18.65 (115.15)
SE ± (d)	**0.02**	**0.02**	**0.02**	**0.03**	**0.02**	**0.03**	**0.02**	**0.02**	**0.02**
CD (*P*= 0.05)	**0.06**	**0.05**	**0.06**	**0.07**	**0.06**	**0.07**	**0.06**	**0.06**	**0.07**
B. Varieties									
V_1- NDR- 2064	15.89 (83.09)	14.88 (72.80)	15.38 (77.82)	17.93 (106.23)	16.81 (93.34)	17.37 (99.68)	16.85 (93.66)	15.80 (82.28)	16.34 (88.03)

V_2- PB-1509	16.52 (89.96)	15.49 (79.03)	16.01 (84.46)	18.67 (115.31)	17.50 (101.27)	18.08 (108.12)	17.54 (101.61)	16.44 (89.20)	17.00 (95.41)
V_3- Arize-6444 Gold	15.22 (76.12)	14.26 (66.75)	14.74 (71.37)	17.21 (97.76)	16.12 (85.71)	16.67 (91.68)	16.17 (86.11)	15.15 (75.53)	15.66 (80.74)
SE ± (d)	**0.04**	**0.04**	**0.04**	**0.05**	**0.05**	**0.05**	**0.05**	**0.04**	**0.05**
CD (*P*= 0.05)	**0.10**	**0.09**	**0.09**	**0.11**	**0.10**	**0.11**	**0.10**	**0.10**	**0.10**
C. Nano-fertilizers									
F_1- 100% RD- $N_{120kg/h}$ $P_{60kg/h}$ $K_{40kg/h}$ + $Zn_{25kg/h}$	16.51 (89.84)	15.47 (78.81)	15.98 (84.13)	18.66 (115.19)	17.49 (101.16)	18.07 (107.98)	17.54 (101.61)	16.44 (89.20)	16.99 (95.30)
F_2- 100% RD- $N_{120kg/h}$ $P_{60kg/h}$ $K_{40kg/h}$ + $Zn_{25kg/h}$ + Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$)	16.85 (93.66)	15.79 (82.18)	16.31 (87.70)	19.04 (119.99)	17.79 (104.79)	18.44 (112.53)	17.89 (105.76)	16.77 (92.88)	17.33 (99.21)
F_3- 75% RD- $N_{90kg/ha}$ $P_{45kg/ha}$ $K_{30kg/ha}$ + $Zn_{18.75kg/ha}$ + Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$)	16.01 (84.39)	15.01 (74.10)	15.52 (79.27)	17.85 (105.27)	15.74 (82.54)	17.30 (98.86)	16.78 (92.85)	15.73 (81.55)	16.25 (87.05)
F_4- 50% RD- $N_{60kg/ha}$ $P_{30kg/ha}$ $K_{20kg/ha}$ + $Zn_{12.5kg/ha}$ + Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$)	15.38 (77.77)	14.41 (68.18)	14.89 (72.85)	17.62 (102.55)	16.50 (89.87)	17.06 (96.09)	16.55 (90.29)	15.52 (79.34)	16.04 (84.77)
F_5- Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$)	14.61 (70.03)	13.69 (61.39)	14.15 (65.65)	16.50 (89.73)	15.47 (78.81)	15.98 (84.13)	15.51 (79.12)	14.54 (69.46)	15.03 (74.25)
SE ± (d)	**0.06**	**0.06**	**0.06**	**0.07**	**0.06**	**0.07**	**0.07**	**0.06**	**0.06**
CD (*P*= 0.05)	**0.13**	**0.12**	**0.12**	**0.14**	**0.13**	**0.14**	**0.13**	**0.12**	**0.13**

Data subjected to square root transformation $\sqrt{x+0.5}$, Values in parentheses are original,

Table 2: Effect of water management practices, varieties and nano-fertilizers on dry matter accumulation of Total weed (m^{-2}) in rice during kharif 2022 and 2023.

Treatment	Dry matter accumulation of Total weed (m^{-2})								
	30 DAT			**60 DAT**			**90 DAT**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
A. Water Management Practices									
I_1- Flooding throughout crop growth (3+/-2cm)	11.59 (46.75)	10.89 (41.27)	11.25 (44.03)	14.65 (74.33)	13.75 (65.58)	14.20 (69.89)	13.77 (65.51)	12.93 (57.82)	13.35 (61.60)
I_2- Saturation Maintenance up to PI and (3+/-2cm) after PI	12.48 (54.43)	11.72 (48.04)	12.09 (51.11)	15.76 (86.25)	14.79 (76.13)	15.28 (81.16)	14.82 (76.09)	13.90 (67.08)	14.36 (71.51)
I_3- Alternate wetting and drying	14.34 (72.40)	13.46 (63.84)	13.91 (68.13)	18.12 (114.49)	17.00 (101.06)	17.56 (107.66)	17.02 (100.87)	15.98 (89.14)	16.50 (94.90)
SE ± (d)	**0.02**	**0.02**	**0.02**	**0.03**	**0.02**	**0.03**	**0.02**	**0.02**	**0.02**
CD (*P*= 0.05)	**0.06**	**0.05**	**0.06**	**0.07**	**0.06**	**0.07**	**0.06**	**0.06**	**0.07**
B. Varieties									
V_1- NDR- 2064	12.73 (56.72)	11.95 (50.00)	12.34 (53.32)	16.07 (89.73)	15.08 (79.17)	15.58 (84.43)	15.09 (78.96)	14.18 (69.85)	14.64 (74.38)
V_2- PB-1509	13.71 (65.98)	12.77 (57.70)	13.29 (62.07)	17.36 (104.77)	16.23 (91.98)	16.78 (98.17)	16.26 (91.94)	15.27 (81.25)	15.76 (86.45)
V_3- Arize-6444 Gold	12.00 (50.22)	11.26 (44.22)	11.63 (47.17)	15.14 (79.49)	14.23 (70.35)	14.68 (74.81)	14.24 (70.15)	13.36 (61.84)	13.81 (66.02)
SE ± (d)	**0.04**	**0.04**	**0.04**	**0.05**	**0.05**	**0.05**	**0.05**	**0.04**	**0.05**
CD (*P*= 0.05)	**0.10**	**0.09**	**0.09**	**0.11**	**0.10**	**0.11**	**0.10**	**0.10**	**0.10**
C. Nano-fertilizers									
F_1- 100% RD- $N_{120kg/h}$ $P_{60kg/h}$ $K_{40kg/h}$ + $Zn_{25kg/h}$	13.32 (62.23)	12.51 (54.91)	12.92 (58.59)	16.83 (98.55)	15.80 (87.09)	16.31 (92.68)	15.81 (86.81)	14.84 (76.65)	15.33 (81.70)
F_2- 100% RD- $N_{120kg/h}$ $P_{60kg/h}$ $K_{40kg/h}$ + $Zn_{25kg/h}$ + Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$)	13.60 (64.94)	12.77 (57.31)	13.18 (61.01)	17.17 (102.65)	16.12 (90.69)	16.63 (96.43)	16.14 (90.51)	15.14 (79.84)	15.64 (85.13)
F_3- 75% RD- $N_{90kg/ha}$ $P_{45kg/ha}$ $K_{30kg/ha}$ + $Zn_{18.75kg/ha}$ + Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$)	12.93 (58.55)	12.13 (51.55)	12.53 (55.01)	16.32 (92.59)	15.32 (81.79)	15.82 (87.14)	15.34 (81.65)	14.41 (72.19)	14.86 (76.69)

F_4- 50% RD- $N_{60kg/ha}$ $P_{30kg/ha}$ $K_{20kg/ha}$ + $Zn_{12.5kg/ha}$ + Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$)	12.41 (53.83)	11.62 (47.19)	12.03 (50.58)	15.67 (85.25)	14.71 (75.28)	15.19 (80.18)	14.74 (75.21)	13.83 (66.34)	14.28 (70.68)
F_5- Nano Fertilizers ($Urea_{4ml/l}$ + $DAP_{4ml/lit}$ + $Zn_{0.5ml/l}$)	11.79 (48.44)	11.06 (42.59)	11.42 (45.45)	14.93 (77.39)	13.97 (67.76)	14.43 (72.22)	13.99 (67.63)	13.17 (60.10)	13.56 (63.60)
SE ± (d)	**0.06**	**0.06**	**0.06**	**0.07**	**0.06**	**0.07**	**0.07**	**0.06**	**0.06**
CD (*P*= 0.05)	**0.13**	**0.12**	**0.12**	**0.14**	**0.13**	**0.14**	**0.13**	**0.12**	**0.13**

Data subjected to square root transformation $\sqrt{x+0.5}$, Values in parentheses are original

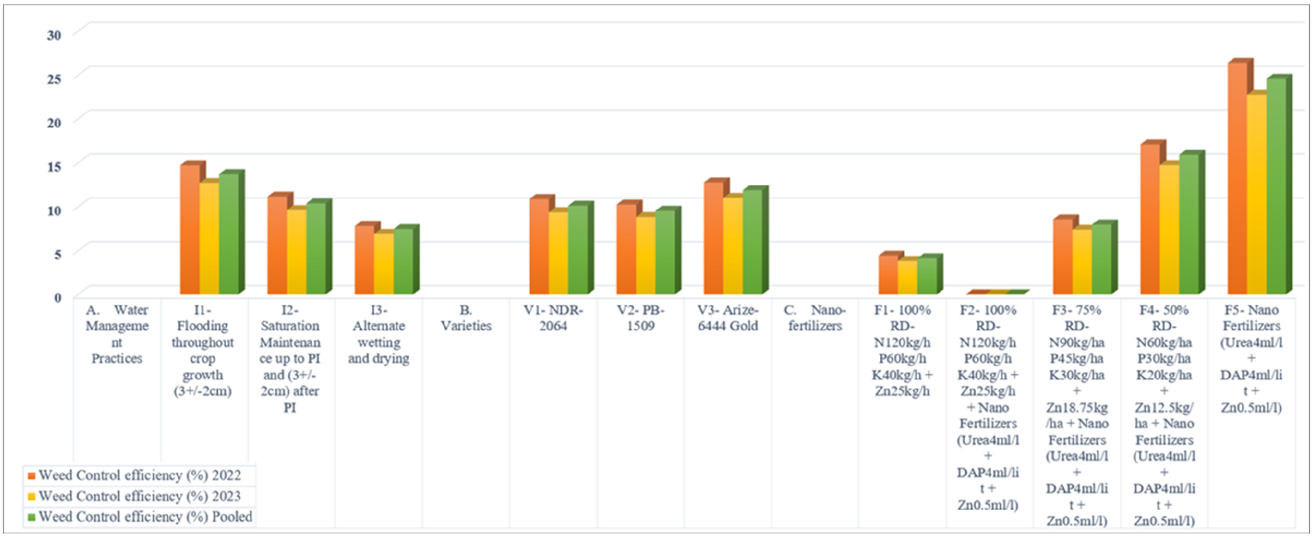

Fig. 2: Effect of different treatment on weed control efficiency in rice during kharif 2022 and 2023.

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Competing Interests

Authors have declared that no competing interests exist.

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