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EFFECT OF DIFFERENT METHODS OF ZINC APPLICATION ON THE PERFORMANCE OF SPRING RICE (HARDINATH-1) IN BANKE, NEPAL

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ABSTRACT
The study was conducted to evaluate the effect of different methods of zinc application on yield and yield-attributing characters of rice at the Agriculture Knowledge Center, Banke, under the supervision of AFU and PMAMP from March to July using the Hardinath-1 variety of rice. Different amounts and application methods of Zinc were used as treatments, namely control using only the recommended dose of NPK (T1), soil application of 15 kg/ha ZnSO4 after transplanting (T2), seedling dipping with 7.5 kg/ha ZnSO4 by making solution (T3), foliar spray of 7.5 kg/ha ZnsO4 (T4), and soil application followed by foliar spray of 15 kg/ha (T5) using a RCBD design with four replications each. T5 produced the greatest plant height (98.43 cm), which was statistically significant to the treatment with zinc application to soil (95.90 cm). At 60 DAT, a significantly higher number of tillers were observed from T5, which is significantly different (17.30) from all other treatments except the second treatment at the 1% level of significance. Similarly, T5 had the longest panicle length (25.57 cm), while the control had the shortest panicle length (21.94 cm). The highest number of filled grains per panicle was obtained from the T5 (89%). From field experiments with different treatments, the highest TGW was obtained from T5 (22.89 g), which is a statistically significant attribute with an F value of 0.001. Thus, it can be concluded that soil application of zinc during transplanting followed by foliar spray at the flowering stage is the most appropriate method of zinc application for efficient production and economy.

KEY WORDS
Effective tillers, Foliar spray, Panicle length, Rice transplanting, ZnSO4.

The genus *Oryza* L. belongs to the tribe *Oryza*, subfamily Oryzoideae, in the family Poaceae. Rice is a ubiquitously cultivated crop, occupying the third position in terms of total production after maize and wheat, with total production and acreage of 509.87 million metric tons and 164.19 million hectares, respectively, among total global grain production of 2284 million metric tons (Shahbandeh, 2022). Because rice is a daily staple food in Asian countries, Asia accounts for approximately 90.5% of total rice production, with China being the leading producer with a total production of 194,442,014.07 tons (FAOSTAT, 2020). The total rice cultivated area of Nepal is approximately 1.5 million ha, with an average productivity of 3.33 t/ha (FAOSTAT, 2020; Tripathi & Bhandari, 2019). Rice is one of the accentuated cereal crops of Nepal, with a production of 5.55 million metric tons and an annual growth rate of 2.72% (Nepal Rice and Paddy Production, 2021).

Though there are numerous ways to increase rice yield through improved breeding and biotechnological activities, soil nutrient deficiencies limit rice yield potential (Regmi et al., 2002). Increased land exploitation, combined with poor nutrient availability, has been identified as a major cause of rice yield decline (Ladha et al., 2003). Declining soil fertility due to poor mineral application in rice fields is another cause of the decline in rice yield (Timsina et al., 2010; Timsina et al., 2013). Soil fertility is found to be declining due to inadequate application of mineral fertilizers as well as organic manures (Becker et al., 2007; Devkota et al., 2016). Because of intensive cropping and the use of nutrient-demanding varieties, there is a greater scarcity of essential micronutrients for growth and yield (B, Cu, Fe, Mn, Mo, and Zn) in the soil (Fageria et al., 2002). Though their trace nutrients form only 1% of the dry weight of the plant, they are very important for the proper growth and development of rice plants (Das, 2014). Zn deficiency is the most common major micronutrient deficiency in Asian lowland rice and is found to be positively correlated with high pH, high organic matter, and poor drainage facilities (Yoshida & Forno, 1973). Along with one third of the human population, millions of hectares of croplands suffer from zinc deficiency (Alloway, 2009). Zinc deficiency is more noticeable in cereal crops than legumes, as well as other crops (Quijano-Guerta et al., 2002).

Zinc is found as one of the major limiting nutrients for rice production, so Zn application in soil is very crucial for achieving potential rice yield (Rehman et al., 2012). As a crucial micronutrient for rice, zinc plays a prime role in the growth and metabolism of plants, including protein synthesis, enzyme activation, and the metabolism of carbohydrates, lipids, auxins, and nucleic acids (Chang et al., 2005). Because of its major role in auxin synthesis, zinc deficiency leads to discernible symptoms like leaf distortion and shortening of internodes (Irshad et al., 2004). In many parts of Asia, zinc deficiency has led to adverse effects on rice production (Rehman et al., 2012). The use of zinc-containing fertilizer has a significant impact on rice grain yield and zinc content. Therefore, the proper application method at the proper time in a befitting way is crucial for the efficient use of zinc by plants (Guo et al., 2016). Khaira disease is the most common zinc deficiency symptom in rice (Dubey et al., 2016). Deficiency symptoms of zinc appear after 2–3 weeks of transplanting, showing brownish blotches and streaks on leaves, and the plant remains stunted and, in severe cases, dies (Wissuwa et al., 2006). According to many studies, its importance and growth-limiting effects on wetland rice are increasing in Asian agriculture. To mitigate this limiting effect, zinc may be applied by different methods, such as soil application, foliar application, dipping seedling roots in solution, etc. If enough zinc is taken up by rice seedlings before transplanting, it may not be necessary to apply additional zinc, and for this reason, the roots of rice seedlings may be treated with zinc solution before transplanting (Katyal & Ponnamperuma, 1974). Yoshida et al. (1970) studied several methods for correcting zinc deficiency in rice and concluded that soil or foliar application of $ZnSO_4$ was as effective as dipping seedling roots in a 1% ZnO suspension, but the cost of the later method was cheaper. Besides, dipping seedling roots in ZnO solution before transplanting reduced the incidence of Kresek (Mew et al., 1979). Thus, it is very important to find the keys to zinc management in rice. The best technique to apply zinc in terms of use and economic efficiency must be identified because it is well recognized that applying zinc is the only way to solve these issues. The major objective of this study was to determine the best and most cost-effective method of applying zinc to rice.

MATERIALS AND METHODS OF RESEARCH

Banke district was purposefully selected for the experimental study as it is one of the major rice-growing regions in the Lumbini Province and operates under the supervision of the Agriculture Knowledge Center, Banke. The experiment was laid out in one factorial Randomized Complete Block Design (RCBD) comprising five treatments with four replications each.

To analyze the physicochemical properties of the soil, a composite soil sample was prepared using samples collected randomly from five spots in the 15 cm soil layer (each four corners and a center experimental plot). The samples were mixed followed by sieving through a 2 mm sieve. The samples were then sent to NARC, Khajura for the test. From the analysis, the soil texture of the research plot was found to be loam. The pH of the soil was neutral (6.84) in nature. The total nitrogen content of the soil was medium (0.08%), while available phosphorus (20.06 $kgha^{-1}$) and available potassium (121.2 $kgha^{-1}$) were low respectively.

The variety of spring rice used in the experiment is Hardinath-1. This variety has a maturity period of 120 days and is recommended for terai and inner terai.

Details of experiment:

- Number of Treatment: 5;
- Number of Replication: 4;
- Number of Plots: 20;
- Dimension of each plot: 2m * 2m;
- Error df: (t-1) (r-1)= (5-1) (4-1) =12;
- Spacing: 20cm*20cm;
- No. of seedlings per hill = 3 seedlings per hill;
- Area of total field=136.5m^2.

Table 1 – Methods used to determine the chemical and physical properties of soil at Khajura, Banke, 2022

Properties	Values	Rating	Methods
Soil pH	6.84	Neutral	Beckman Glass Electrode (Estefan et al., 2013)
Organic matter (%)	1.68	Low	Walkey and Black (Estefan et al., 2013)
Total Nitrogen (%)	0.08	low	Micro-Kjeldahl distillation (Estfan et al., 2013)
Available P_2O_5 (kg ha^{-1})	20.06	Low	Modified Olsen's method using a spectrophotometer (Estefan et al., 2013)
Available K_2O (kg ha^{-1})	121.2	Medium	Ammonium acetate method (Estean et al., 2013)
Soil texture	Sandy loam		Hydrometer (Estefan et al., 2013)

Table 2 – Treatments used in the experiment

Treatments	Symbol
Control(no application of zinc)	T1
Soil application of zinc (15 kg/ha)	T2
Seedling dipping of zinc (7.5 kg/ha)	T3
Foliar spraying zinc (7.5 kg/ha)	T4
Soil application + foliar spray (15 kg/ha)	T5

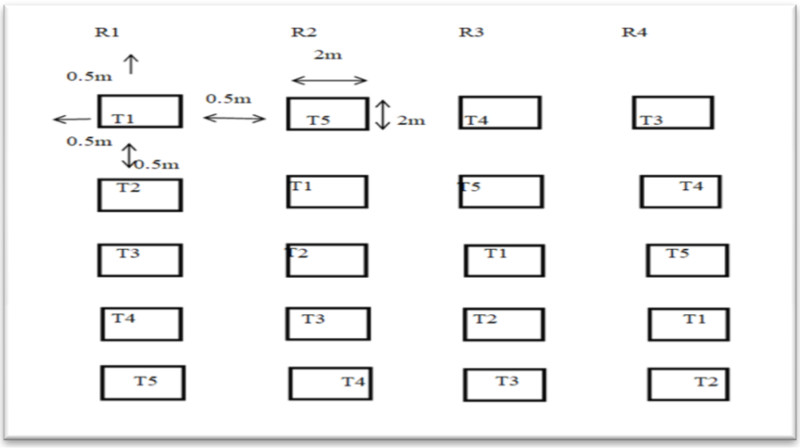

Figure 1 – Layout of the experimental plots

After priming, seedlings were planted in a dry bed measuring 2 m by 1 m in the third week of February 2021. After 25 days of sowing, transplantation was done in twenty plots of 2 m by 2 m at a distance of 20 cm by 20 cm by puddling with a tractor. Manure and fertilizer in nursery beds were kept as per requirement, while in the main field, chemical fertilizers—urea (46% N), DAP (18% N, 46% P_2O_5), and MOP (60% K_2O) —were applied in the field at 150:40:40 kg NPK/ha. Half the dose of nitrogen and the full dose of phosphorus and potash were applied as the basal dose during transplanting, while the remaining half of the dose of nitrogen was applied as the top dressing. In every replication of T2, 6 g of zinc was applied after transplanting. For T3, 3 g of $ZnSO_4$ was solubilized in 2 liters of water, and seedlings from all four replications were dipped for one hour before transplanting. For T4, a suspension of 3 g of $ZnSO_4$ was made in 2 liters of water and sprayed uniformly on all seedlings. For T5, 4 g of $ZnSO_4$ in each plot was applied after transplanting, and the remaining 2 g dissolved in 2 liters of water was sprayed on each replication at the panicle initiation stage to make 15

$kgha^{-1}$. Harvesting was done manually with the help of a sickle over an area of 1 m^2 at the center. After one day of sun drying, threshing was also done manually. Then the weight of each treatment was taken using an electrical balance at 13% seed moisture content.

RESULTS AND DISCUSSION

The data were collected at 30 DAT, 60 DAT and 90 DAT. The effect of different zinc application methods on the height of rice is illustrated below.

Table 3 – Effect of different Zinc application methods on plant height of rice at Banke, Nepal, 2022

Treatment	30 DAT	60 DAT	90 DAT
Control	39.57^{c}	53.03^{bc}	87.0^{d}
Soil application of Zn	43.95^{a}	54.55^{b}	95.90^{ab}
Seedling dipping	41.38^{bc}	52.43^{c}	92.50^{c}
Foliar spray	41.18^{bc}	51.30^{c}	92.99^{bc}
Soil application + foliar spray	43.26^{ab}	57.67^{a}	98.43^{a}
LSD	2.40	1.85	3.28
SEm(+/-)	0.34	0.26	0.47
F-probability	0.05	0.001	0.001
CV (%)	3.72	2.24	2.28
Grand Mean	41.87	53.79	93.36

Note: Treatment means separated by DMRT and columns represented with same letter (s) are non-significant at respective level of significance, DAS: days after sowing, NS= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance.

The plant height was observed at different periods, and a significant difference was observed among all treatments. The difference in plant height at different growth stages depicted that there was a significant difference between different zinc application methods in paddy. At 30 DAT, the highest plant height (43.95 cm) was obtained from soil application of zinc, followed by soil application and foliar spray of zinc (43.26 cm), followed by seedling dipping, foliar spray, and control, respectively. Similarly, at 60 DAT, maximum plant height was obtained from the T5, followed by the T2, T1, T3, and T4, respectively. At 90 DAT, plant height was found to be highly significant among all treatments at the 0.1% significance level. Maximum plant height was obtained from zinc soil application and foliar spray (98.43 cm), which was statistically significant from that of zinc soil application (95.90 cm), and this was comparable to zinc foliar spray (92.99 cm). The plant height was then measured in decreasing order following foliar spray, seedling deepening, and control treatment. This result is very similar to Ghoneim (2016) and Yakan et al. (2000).

The data were collected at 30 DAT, 60 DAT and 90 DAT. The effect of different zinc application methods on tillering of rice is illustrated below.

Table 4 – Effect of different Zinc application methods on tillering of rice at Banke, Nepal, 2022

Treatment	30 DAT	60 DAT	90 DAT
Control	13.00^{b}	11.72^{c}	10.00^{d}
Soil application of Zn	17.86^{a}	16.50^{ab}	14.85^{ab}
Seedling dipping	14.70^{b}	14.25^{bc}	12.92^{bc}
Foliar spray	12.65^{b}	12.57^{c}	10.80^{cd}
Soil application + foliar spray	18.85^{a}	17.30^{a}	15.35^{a}
LSD	2.30	2.62	2.31
SEm(+/-)	0.34	0.38	0.33
F-probability	0.001	0.01	0.001
CV (%)	9.71	11.78	11.72
Grand Mean	15.41	14.47	12.78

Note: Treatment means separated by DMRT and columns represented with same letter (s) are non-significant at respective level of significance, DAS: days after sowing, NS= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance.

Tillering was also found to be tremendously influenced by the zinc application method. At first record taking (30 DAT), maximum tillering was found for T5 (soil application and foliar spray), followed by soil application, seedling dipping, control, and foliar spray, respectively. The results from soil application and soil application + foliar application showed no significant difference in terms of tillers per plant. Foliar spray and seedling dipping have about the same result in terms of number of tillers at 30 DAT. Similarly, at 60 days after transplanting, the number of tillers from every treatment was slightly less than the previous record; that might be due to the death and decay of tillers, as well as the escaping of the maximum tillering period. At 60 DAT, T5 (soil application and foliar spray) had the most tillers, which was significantly different (17.30) from all other treatments except the second treatment at the 1% level of significance. The number of tillers from the second treatment (16.50) was found to be statistically similar to the T5, which was also statistically at par with seedling dipping treatment (14.25). The number of tillers used for foliar spray and control was found to be non-significant. Similarly, from the record taken at 90 DAT, the number of tillers from every treatment was found to decrease, and maximum tillers were recorded from T5, followed by the T2, T3, T4, and T1, respectively. The result is found in accordance with Ghoneim (2016). Dutta and Rahman (1987) also concluded that zinc plays an important role in increasing the number of tillers and waning the days required for maturity.

Table 5 – Effect of different Zinc application methods on panicle of rice at Banke, Nepal, 2022

Treatment	Panicle length after complete maturity	Days to maturity
Control	21.94[c]	123.25[a]
Soil application of Zn	24.37[ab]	122.25[ab]
Seedling dipping	23.54[b]	122.25[ab]
Foliar spray	23.77[b]	123[ab]
Soil application + foliar spray	25.57[a]	119.75[b]
LSD	1.53	3.16
SEm(+/-)	0.22	0.46
F-probability	0.01	0.05
CV (%)	4.16	1.68
Grand Mean	23.84	122.1

Note: Treatment means separated by DMRT and columns represented with same letter (s) are non-significant at respective level of significance, DAS: days after sowing, NS= non-significant, LSD: Least Significant Difference, SEm: Standartd error of the mean deviation, CV: Coefficient of Variance.

Panicle length is a crucial feature of paddy to increase yield; longer the panicle, greater the numbers of grains per plant. T5 had the longest panicle length among the different zinc application methods, which was found to be significant when compared to the other treatments at the 1% significance level. On average, from all replications, 25.57 cm of panicle length was observed on this treatment, which was found to be statistically similar with T2 (24.37 cm) and non-significant to T3 and T4. A panicle length of 21.94 cm was observed in the control plot, which was significantly lower than all other treatments. This signified that zinc application through soil is more beneficial than others. Only foliar zinc spray was found to be ineffective, but soil zinc application followed by foliar zinc spray was found to be extremely beneficial for increasing paddy panicle length. Sudha and Stalin (2015) also concluded that zinc application significantly enhances panicle length and that application through the soil is very effective, followed by foliar spray. Rahman et al. (2011) concluded from their experiment that zinc application is primarily responsible for the increase in panicle length.

Zinc application was also found to be very significant for reducing the days to maturity; the more efficient the zinc application, the faster the growth of grains and plants. In accordance with the statement, the fastest harvest was done on plots having the fifth (T5) treatment. Maturity of grains was found to be similar across treatments. Results were found in accordance with Yakan et al. (2000) and Arif et al. (2012).

Zinc is a very important micronutrient for plant growth. Zinc indirectly enhances rice yield through increased biochemical pathways in plants and also plays a major role in enhancing auxin synthesis and chlorophyll formation. Thus, directly and indirectly, zinc plays a paramount role in enhancing rice yield. From the field research, it was concluded that soil application followed by foliar spraying of zinc increases grain yield per panicle of rice significantly more than other treatments. From the LSD test, there is no significant difference in number of grains per panicle between T2 (149.5) and treatment five (152.25). Similarly, treatments T3 (130.5), T1 (124.75), and T4 (133) were found to be statistically at par which indicated zinc as an important micronutrient influencing number of grains per panicle. More grains per panicle observed in soil application followed by foliar spray may be more efficient due to better and more efficient utilization of zinc. Rahman et al. (2011) also pointed out zinc as an imperative nutrient for grain development in rice. So, maximum grain yield was obtained from the fifth treatment due to efficient zinc utilization.

Table 6 – Effect of different Zinc application methods on filled grain, filled grain per panicle, TGW and average yield of rice at Banke, Nepal, 2022

Treatment	Number of grains per panicle	Number of filled grains per panicle	Thousand grain weight (TGW)	Average yield (tha^{-1})
Control	124.75^{b}	95.75^{c}	21.49^{b}	3.52^{c}
Soil application of Zn	149.5^{a}	127.75^{a}	22.37^{ab}	4.25^{b}
Seedling dipping	130.5^{b}	110^{b}	21.73^{ab}	3.79^{c}
Foliar spray	133^{b}	112.5^{b}	21.36^{b}	3.53^{c}
Soil application + foliar spray	152.25^{a}	134.75^{a}	22.89^{a}	4.74^{a}
LSD	9.82	8.44	1.16	0.16
SEm(+/-)	1.42	1.22	0.16	0.01
F-probability	<0.001	<0.001	<0.001	<0.001
CV (%)	4.62	4.71	3.44	2.98%
Grand Mean	138	116.15	21.96	3.57

Note: Treatment means separated by DMRT and columns represented with same letter (s) are non-significant at respective level of significance, DAS: days after sowing, NS= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance.

All treatments produced highly significant results in terms of filled grain per panicle. The highest number of filled grains per panicle was obtained from the fifth (T5) treatment (89%), which was statistically non-significant compared to treatment T2 (85%) at 0.001 f-value, and the minimum number of filled grains were found in the control treatment.

Thousand grains weight was discovered to be an important factor in total grain yield. From field experiments with different treatments, the highest TGW was obtained from the fifth (T5) treatment (22.89 g), which was a statistically significant attribute with an F-value of 0.001. The results of zinc soil application and seedling dipping are also comparable in accordance with Yakan et al. (2000).

Zinc plays a very crucial role in many internal biochemical activities in plants, including chlorophyll formation, panicle formation, tiller formation, spikelet formation, and ultimately grain formation (Khan & Qasim, 2017). Thus, ultimately, rice yield can be enhanced through zinc application. In addition, it also increases the zinc content of rice grains for human health. From the field experiment on zinc application methods, soil application of zinc followed by foliar spray was found to be a very effective treatment to increase rice yield. And this treatment was found to be more significant (4.74 tons/ha) than other treatments. The yield from the T2 was found to be 4.25 tons/ha, which was also significantly different from other treatments. The yields from the other three treatments were not found to be statistically different. Yield results were in accordance with the findings of Ram (1996); Sudha & Stalin (2015); Yadav et al. (2019); & Yakan et al. (2001). A field experiment by Ghoneim (2016) also concluded that soil application of zinc followed by foliar spray produced the highest yield, which was similar to the findings of this study.

CONCLUSION

Rice production greatly benefits from zinc. Utilizing zinc effectively requires the right technique and dosage. By applying zinc in the appropriate amount and under the appropriate conditions, several growth traits and yield-related parameters can be improved. In terms of plant growth and total yield, a combination of soil application and foliar spray was determined to be the best zinc application method. The doses shouldn't be given all at once if zinc is to be applied in the field. The study's findings emphasize the importance of dividing it into various application techniques at different stages for optimal effectiveness. It is recommended to apply zinc to the soil after transplanting rice seedlings, followed by foliar spraying during the panicle initiation stage, to enhance yield potential. In order to make micronutrients more easily accessible, more research on sources of zinc from organic material needs to be done. For further yield improvement, research work on zinc application amounts and methods under diverse agro-ecological conditions and plant growth stages is imperative.

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