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Crop Establishment Methods, Varieties and Levels of Zinc on Growth and Yield of Rice in Chitwan, Nepal

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ABSTRACT

With the aim of identifying the appropriate doses of Zinc in rice for different varieties under various establishment methods, an experiment was carried out in a strip-split plot design with three replications at Agriculture and Forestry University, Rampur, Chitwan during 2015-16. The treatment consists of two crop establishment methods (Transplanted rice (TPR) and Direct Seeded Rice (DSR)) in the vertical strip and two varieties (Hybrid Gorakhnath-509 and Sabitri) in the horizontal strip and four levels of $ZnSO_4$ (0, 15, 30 and 45 kg ha^{-1}) in sub-sub plot. The observations were recorded on growth, yield attributes, grain yield and economics. The research results revealed that the application of $ZnSO_4$ @ 15 Kg ha^{-1} significantly increased the grain yield of DSR as compared to the non-application of $ZnSO_4$. The higher grain yield of rice was because of increased yield attributes like effective tillers, thousand-grain weight and the number of filled grains per panicle. Crop establishment methods and varieties did not have a significant influence on the grain yield of rice. DSR had a lower cost of cultivation, higher net return and higher benefit-cost ratio as compared to TPR. The variety Sabitri had lower cost of cultivation, higher net return and higher benefit-cost ratio as compared to Gorakhnath-509. Similarly, the application of $ZnSO_4$ @ of 15 Kg ha^{-1} produced the highest net return and the highest benefit-cost ratio. Therefore, $ZnSO_4$ @ 15 kg ha^{-1} could be an option for increased yield and net return for DSR in Chitwan.

Keywords: Direct seeded rice, grain yield, transplanted rice, zinc

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INTRODUCTION

Rice (*Oryza sativa* L.) is the main staple food crop of Nepal and ranks first in terms of areas and production and contributes approximately 23% to agriculture gross domestic production (AGDP) (MOAD, 2016/17). Rice is mainly grown by transplanting seedlings in puddled fields which is very burdensome and labor intensive (Prasad, 2004). Direct Seeded Rice (DSR) is an alternative method of rice cultivation, where seeds are directly sown in un-puddled fields (Farooq et al 2011). In DSR, the dynamics of several nutrients including N, P, S and micronutrients such as Zn and Fe change (Ponnamperuma, 1972).

Widespread Zinc deficiency in rice-growing areas is one of the major causes of the low yield of rice (Nawaz et al 2015). Zinc sulfate ($ZnSO_4$) and NPK application had a significant influence on the number of tillers, plant height, thousand-grain weight, panicle length and grain yield (Nawaz et al 2015). Application of $ZnSO_4$ along with different fertilizers improves crop yield.

Information on levels of Zn application in rice under DSR is meager in Nepal. Therefore, the research was carried out to determine the economics of zinc application in hybrid and high-yielding rice varieties under different crop establishment methods.

MATERIALS AND METHODS

The field experiment was conducted at Agronomy farm of Agriculture and Forestry University, Rampur from June to November 2016. The field was geographically situated at $27^0$30' North latitude and $84^0$25' east longitude and has an elevation of 256 m above mean sea level (Thapa and Dangol, 1988). The site is situated 9.8 km South-West of Bharatpur, headquarter of Chitwan district. Physiochemical properties of the soil of experimental soil were sandy-loam. The experiment was laid out in a strip-split plot design with the combinations of 16 treatments consisting of two crop establishment methods as a horizontal factor, two varieties as a vertical factor and four levels of zinc sulphate applications with three replications. The size of each plot was 6 m X 4 m (24 m^2). Phosphorus (P_2O_5) @ 60 kg ha^{-1} and potassium (K_2O) @ 40 kg ha^{-1} applied. Nitrogen (N) applied @ 120 kg ha^{-1}. Nitrogen was applied in split doses. Half of the nitrogen was applied in basal dose. The remaining one-fourth of nitrogen was applied in tillering stage and one-fourth in the pre-flowering stage. Sources of fertilizers were Urea, Diammonium Phosphate and Muriate of Potash. And 4 levels of $ZnSO_4$ were applied at the rate of 0, 15, 30 and 45 kg ha^{-1}. Phenological observations, economic analysis, yield, and yield attributing characteristics of rice were observed during the experiment. All the collected data were analyzed by using GENSTAT software.

RESULTS

Yield attributes

The level of zinc sulphate application significantly influenced the number of effective tillers in rice. The plot receiving zinc sulphate had significantly more effective tillers m^{-2} as compared to the non-application of zinc sulphate. Similarly, the levels of zinc sulphate application significantly influenced the sterility % in rice. The plot receiving zinc sulphate had a significantly lower percentage of sterility as compared to the non-application of zinc sulphate. The levels of Zinc sulphate application significantly influenced the thousand-grain weight. The plots receiving zinc sulphate had significantly higher thousand-grain weight (TGW) as compared to the non-application of zinc sulphate. The panicle length of the rice was the lowest (24.01 cm) in the control plot (non-application of zinc sulphate) and it was smaller than the panicle length obtained due to the application of zinc sulphate application (Table 1).

Table 1. Yield attributes of rice as influenced by various crop establishment methods, varieties and zinc level of zinc sulphate application at AFU, Rampur, Chitwan, Nepal, 2015-16

Treatment	Yield attributing characters					
	Effective tillers m^{-2}	**Sterility %**	**Thousand-grain weight (g)**	**Panicle Length (cm)**	**Panicle weight(g)**	**Grains per panicle**
Crop establishment methods						
DSR	313.8	8.08	16.71	24.45^{b}	3.73	220.0
TPR	273.9	8.20	16.68	24.61^{a}	3.83	217.8
LSD (<0.05)	ns	ns	ns	0.16	ns	ns
CV (%)	14.8	7.75	3.49	0.52	11.65	1.7
SEM (±)	8.80	0.53	0.12	0.03	0.09	0.75
Varieties						
Sabitri	309.7^{a}	7.48	19.95^{a}	24.40	3.71	210.0^{b}
Gorakhnath 509	278.1^{b}	8.80	13.44^{b}	24.66	3.84	227.8^{a}
LSD (<0.05)	20.9	ns	0.66	ns	ns	8.3
CV (%)	5.7	22.69	3.19	1.15	6.74	3.0
SEM (±)	3.4	0.64	0.11	0.06	0.05	1.4
Levels of zinc sulphate (kg ha^{-1})						
0	267.6^{b}	9.73^{a}	16.47^{b}	24.01^{b}	3.55^{b}	201.9^{b}
15	294.1^{ab}	7.67^{b}	16.64^{ab}	24.94^{a}	3.89^{a}	229.4^{a}
30	311.0^{a}	7.74^{b}	16.79^{a}	24.80^{a}	3.83^{a}	223.4^{a}
45	302.8^{a}	7.42^{b}	16.88^{a}	24.38^{ab}	3.83^{a}	221.0^{a}
LSD (<0.05)	31.36	1.22	0.30	0.64	0.23	18.8^{a}
CV (%)	12.70	17.70	2.10	3.10	7.20	10.2
SEM (±)	10.74	0.825	0.10	0.22	0.08	6.45
Grand mean	**293.9**	**8.14**	**16.69**	**24.53**	**3.78**	**218.9**

The panicle weight of the rice was the lowest (3.55 g) in the control plot and it was lower than the panicle weight obtained due to the application of 15, 30 and 45 kg ha^{-1} $ZnSO_4$ (Table 1). Further, the number of grains per panicle was the lowest (201.9) in the control plots (0 kg $ZnSO_4$ ha^{-1}) and it was lower than the number of grains per panicle obtained due to the application of zinc sulphate. The number of grains per panicle at 15, 30 and 45 kg ha^{-1} $ZnSO_4$ application was statistically similar.

Grain and straw yields as influenced by varieties and zinc management practices

The level of zinc sulphate application significantly influenced the grain yield in rice. The grain yield of rice was the lowest (4334 kg ha^{-1}) in the control plots (0 kg $ZnSO_4$ ha^{-1}) and it was lower than the grain yield of rice obtained due to the application of 15 and 30 kg ha^{-1} zinc sulphate but statistically similar to 45 kg ha^{-1} zinc sulphate application (Table 2). The grain yield of rice at 15, 30 and 45 kg ha^{-1} zinc sulphate application was also statistically at par (Table 2).

The level of zinc sulphate application significantly influenced the straw yield in rice. The straw yield of rice was the lowest (5633 kg ha^{-1}) in the control plots ($ZnSO_4$- 0 kg ha^{-1}) and it was lower than 15 and 45 kg ha^{-1} $ZnSO_4$ but statistically similar to 30 kg ha^{-1} $ZnSO_4$. The straw yields at 15 and 30 kg ha^{-1} $ZnSO_4$ were also statistically similar. Similarly, HI did not vary due to various levels of $ZnSO_4$ (Table 2).

Table 2. Grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index (HI) of rice as influenced by various crop establishment methods, varieties and levels of zinc sulphate application at AFU, Rampur, Chitwan, 2015-16

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (HI)
Crop establishment methods			
DSR	4770	5983	0.44
TPR	4626	5756	0.44
LSD (<0.05)	ns	ns	ns
CV(%)	16.90	3.52	8.79
SEM (±)	162.10	42.30	0.00798
Varieties			
Sabitri	4615	6295^{a}	0.42
Gorakhnath 509	4781	5444^{b}	0.46
LSD (<0.05)	ns	802.90	ns
CV (%)	11.73	11.01	12.06
SEM (±)	112.6	131.9	0.01096
Levels of zinc sulphate (kg ha^{-1})			
0	4334^{b}	5633^{b}	0.43
15	4903^{a}	6210^{a}	0.44
30	4940^{a}	5913^{ab}	0.45
45	4615^{ab}	5723^{b}	0.44
LSD (<0.05)	390.6	425.8	ns
CV (%)	9.90	8.60	6.2
SEM (±)	133.8	145.9	0.00793
Grand mean	**4698**	**5870**	**0.44**

Benefit-cost ratio (BCR)

The average BCR of 1.83 was obtained in this experiment (Table 3). It was influenced by varieties and levels of $ZnSO_4$, but not by crop establishment methods. BCR obtained in both DSR and TPR were statistically similar. Sabitri produced a statistically higher BCR of 1.94 as compared to Gorakhnath-509 with 1.73.

The level of zinc sulphate application significantly influenced the BCR in rice. The highest of it was recorded in 15 kg $ZnSO_4$ ha^{-1} (1.94) and was statistically similar to the application of 30 kg $ZnSO_4$ ha^{-1}. The lowest BCR was obtained in the zero level of $ZnSO_4$ (1.74) which was statistically similar to the application of 45 kg $ZnSO_4$ ha^{-1} (Table 3).

Table 3. Economics of rice as influenced by various crop establishment methods, varieties and levels of zinc sulphate application at AFU, Rampur, Chitwan, 2015-16

Treatment	Economic analysis			
	Production cost (NRs. '000' ha^{-1})	**Gross return (NRs. '000' ha^{-1})**	**Net return (NRs. '000' ha^{-1})**	**BCR**
Crop establishment methods				
DSR	69.43	138.8	69.4	2.00^{a}
TPR	81.39	134.4	53.0	1.66^{b}
LSD (<0.05)		ns	ns	0.28
CV (%)		11.18	33.70	12.32
SEM (±)		4.21	4.21	0.04
Varieties				
Sabitri	68.21	131.2	63.0	1.94^{a}
Gorakhnath 509	82.61	142.0	59.4	1.73^{b}
LSD (<0.05)		ns	ns	0.16
CV (%)		27.31	21.37	7.16
SEM (±)		2.68	2.68	0.02
Levels of zinc sulphate (kg ha^{-1})				
0	73.16	126.7^{b}	53.6^{c}	1.74^{b}
15	74.66	142.8^{a}	68.2^{a}	1.94^{a}
30	76.16	142.8^{a}	66.6^{ab}	1.90^{a}
45	77.66	134.1^{ab}	56.4^{bc}	1.74^{b}
LSD (<0.05)		10.30	10.30	0.13
CV (%)		8.9	20.0	8.9
SEM (±)		3.53	3.53	0.04
Grand mean	**85.83**	**136.6**	**61.2**	**1.83**

Note: Means followed by the same letter(s) in the same column are not significantly different at 5% probability level of Duncan Multiple Range Test.

Interaction

The interaction between crop establishment methods and levels of $ZnSO_4$ on BCR was significant (Table 4). For DSR, the application of $ZnSO_4$ on either dose produced a significantly higher BCR as compared to no application of $ZnSO_4$. But in the case of TPR, no significant difference on BCR was observed due to various levels of $ZnSO_4$.

Table 4. Benefit-cost ratio of rice as influenced by the interaction between various crop establishment methods and levels of zinc sulphate application at AFU, Rampur, Chitwan, 2015-16

Levels of $ZnSO_4$ (kg ha^{-1})	Benefit-cost ratio	
	Direct seeded rice	**Puddled transplanted rice**
0	1.79^{bc}	1.69^{cd}
15	2.15^{a}	1.73^{cd}
30	2.15^{a}	1.66^{cd}
45	1.93^{b}	1.56^{d}
LSD (<0.05)	0.2305	
CV (%)	8.9	
SEM (±)	0.07	

Means followed by the same letter(s) in the same column are not significantly different at 5% probability level of Duncan Multiple Range Test.

DISCUSSION

Effect of zinc sulphate on productivity of rice

Application of $ZnSO_4$ had increased the yield of rice (Table 2). Zinc is an essential micronutrient. Zinc involves in physiology of plant growth and metabolism like enzyme activation, protein synthesis, metabolism of carbohydrates, lipids, auxins and nucleic acids, gene expression and regulation and reproductive development (pollen formation) (Cakmak 2000; Marscher 1995). Zinc is a constituent of carbonic anhydrase which is required for the activity of Rubisco (Storey 2007), the photosynthetic enzymes catalyzing the diffusion of CO_2 through the cell to the chloroplasts (Hatch and Slack, 1970). Zn-deficient plants usually have reduced leaf chlorophyll (Chl) concentration and lower Chlorophyll a:b ratio, which indicates damage to intrinsic quantum efficiency of the photosystem-II (PSII) units (Chen et al 2008). It can be attributed to reduced antioxidant enzyme activities and high oxidative stress damage in chloroplasts due to a blockage of energy spillover from PS-II to photosystem-I (PS-I) (Chen et al 2009). Such damage to photosynthetic centers, decreased leaf photosynthetic capacity due to a decreased number of PS-II units per unit leaf area, making them susceptible to photo damage (Chen et al 2008). In Zn-deficient plants, a decrease in CO_2 assimilation is primarily due to ROS-induced damage to the photosynthetic apparatus (Sasaki et al 1998) and a decrease in Rubisco activity (Marschner 1995). Nonetheless, accumulation of saccharides in leaves (Marschner 1995) due to a decline in CO_2 concentration and stomatal conductance may be a possible reason for decreased photosynthetic rate under Zn deficiency (Marschner 1995).

Mustafa et al (2011) reported the highest paddy yield was attained due to basal application of $ZnSO_4$ @ 25 kg ha^{-1}. They also observed that application of $ZnSO_4$ produced statistically higher yield than no application of $ZnSO_4$. Nawaz et al (2015) reported that the maximum paddy yield (6.72 Mt ha^{-1}) was obtained when ZnSO4 +NPK was added in soil at the time of puddling and it was followed by 6.27 Mt ha^{-1} of paddy harvested when ZnSO4 + NPK was applied at 20-25 days after transplanting. The minimum paddy yield was recorded in case of no application of Zn. Shehu et al (2011) reported that yield of rice due to application of Zn was significantly higher than no application zinc. But, Yakan et al (2001) reported that Zn application and no application of zinc produced statistically similar grain yield.

The yield of rice due to application of $ZnSO_4$ was significantly higher than no application of $ZnSO_4$ because yield attributing characters were higher due to application of $ZnSO_4$. Application of $ZnSO_4$ had increased the ET m^{-2}, thousand grain weight, panicle length, panicle weight, grain per panicle and reduced sterility percentage (Table 18). TGW was influenced by application of $ZnSO_4$. Khan et al (2007) reported that TGW was significantly higher in zinc fertilizer application. Zinc take part in carbonic activity. Carbonic activity and more carbohydrate accumulation increase test weight (Saha et al 2013). Ghasemi et al (2013) reported application of zinc fertilizer in rice increased TGW over no application of zinc. Sarwar (2011) also reported that application of zinc fertilizer over no application of zinc significantly increased TGW.

Similarly, panicle length, harvest index and filled grains were significantly influenced by application of $ZnSO_4$. Metwally (2011) stated that application of zinc on rice produced significantly longer panicle length over no application of zinc. Panicle length of rice genotype significantly influenced by application of zinc fertilizer (Sudha and Stalin 2015). Mustafa et al (2011) reported that application of zinc significantly increased panicle length over no application of zinc. Application of zinc fertilizer significantly increased HI of rice over no application of zinc. Mahmudi et al (2015) revealed that application of zinc increased HI of rice.

Saha et al (2013) also stated that application of zinc increased HI over no application of zinc. Zinc application significantly increased kernel per panicle over no application of zinc (Mustafa 2011). Sudha and Stalin (2015) observed that zinc application significantly increased the filled grains per panicle over no application of zinc.

These yield attributing parameters increased yield and productivity of rice. Therefore, $ZnSO_4$ application is necessary to increase the yield of rice.

Economics of DSR and TPR

The cost of production of rice in DSR was found to be lower (NRs 69.43 thousand ha^{-1}) as compared to TPR (NRs. 81.39 thousand ha^{-1}) (Table 3). It was because DSR does not require nursery raising, puddling and transplanting of seedlings. Rahman, and Masood (2014) revealed dry direct-seeded rice required lower total cost as compared with puddle transplanted conventional irrigation and puddled transplanted alternative wetting and drying. Rana et al (2014) reported the higher variable cost incurred by the transplanting method compared with direct seeding of dry seed method. The gross return in DSR was also higher than TPR. It was because DSR produced comparatively higher grain and straw yield, which resulted comparatively higher net return in DSR. Rahman and Masood (2014) revealed dry direct seeded rice produced similar total benefit compared with puddle transplanted conventional irrigation and puddled transplanted alternative wetting and drying. Similarly, B:C ratio in DSR was higher than TPR, it was because of lower production cost and higher gross return. Rahman and Masood (2014) found dry direct seeded rice produced higher net benefit compared with puddle transplanted conventional irrigation and puddled transplanted alternative wetting and drying. Rana et al (2014) found higher B:C ratio in direct seeded rice compared to transplanted rice.

Application of $ZnSO_4$ had resulted in statistically higher gross return over no application of $ZnSO_4$ (Table 3). It was because grain yield and straw yield were statistically higher in zinc sulphate application over no application (Table 2). Similarly, net return was influenced by the application of $ZnSO_4$ (Table 3). Application of $ZnSO_4$ @ 15 and 30 kg ha^{-1} $ZnSO_4$ provided a higher net return because grain and straw yield at that condition was statistically higher. Application of 45 kg $ZnSO_4$ ha^{-1} and no application of $ZnSO_4$ provided a lower and similar net return. It was because the application of $ZnSO_4$ and no application of $ZnSO_4$ produced statistically lower and similar grain and straw yield. Furthermore, the application of $ZnSO_4$ @ 45 kg ha^{-1} increased production cost which ultimately decreased net return.

Similarly, application of $ZnSO_4$ @ 15 and 30 kg ha^{-1} obtained higher BCR over no application of $ZnSO_4$ and 45 kg ha^{-1} $ZnSO_4$ application (Table 4). It was simply due to no application of $ZnSO_4$ and 45 kg ha^{-1} that produced statistically lower grain and straw yield. Furthermore, the application of $ZnSO_4$ @ 45 kg ha^{-1} increased the production cost which reduced the BCR.

CONCLUSIONS

Direct seeded rice was found to be economically profitable than transplanted rice. The variety Sabitri had lower cost of cultivation, higher net return and higher benefit-cost ratio as compared to Gorakhnath-509. Similarly, the application of Zinc Sulphate @ of 15 kg ha^{-1} produced the highest net return and benefit-cost ratio in Chitwan.

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AUTHORS' CONTRIBUTION

R Pariyar in consultation with SK Sah, S Marhatta and TB Karki formulated the research proposal, carried out the experiment, collected the data, and prepared ANOVA and manuscript. SK Sah, S Marahatta and TB Karki guided him in all aspects but particularly in the ANOVA and write-up of the manuscript.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

REFERENCES

Cakmak I. 2000. Role of zinc in protecting plant cells from reactive oxygen species. New Phytologist. **146**:185–205.

Chen WR, Y Feng and YE Chao. 2008. Genomic analysis and expression pattern of OsZIP1, OsZIP3, and OsZIP4 in two rice (Oryza sativa L.) genotypes with different zinc efficiency. Russian Journal of Plant Physiology. **55**(3):400-409.

Chen WR, ZL He, XE Yang and Y Feng. 2009. Zinc efficiency is correlated with root morphology, ultrastructure, and antioxidative enzymes in rice. Journal of Plant Nutrition, **32**(2):287-305.

Farooq M, KHM Siddique, H Rehman, T Aziz, DJ Lee and A Wahid. 2011. Rice direct seeding: experiences, challenges and opportunities.Soil Tillage Research. **111**:87–98. doi.org/10.1016/ j.still.2010.10.008.

Ghasemi M, H Mobasser, AG Malidarreh and H Asadimanesh. 2013. .Zinc, silicon and potassium application on rice.International Journal of Agriculture and Crop Sciences. **5**(9):936-942. Available online at www.ijagcs.com IJACS/2013/5/9/936-942 ISSN 2227-670X.

Hatch MD and CR Slack. 1970. Photosynthetic CO2 fixation pathways.Annual Review of Plant Physiology. **21**:141–162

Khan, MU, M Qasim and I Khan. 2007. Effect of Zn fertilizer on rice grown in different soils of .Sarhad Journal of Agriculture. **23**(4).

Mahmudi J, S Sharafi, M Tanha and R Hassanzade. 2015. Effect of Zn and K elements on yield and yield components of rice (Oryza sativa L.) cv. Tarom Hashemi. International Journal of Farming and Allied Sciences. **4**(1):1-5.

Marschner H. 1995. Mineral nutrition of higher plants.Academic, San Diego.

Metwally TF, EE Gewaily and SS Naeem. 2011. Nitrogen response curve and nitrogen use efficiency of egyptian hybrid rice. J. Agric. Res. Kafer El-Sheikh Univ. **37**(1):73-84.

MoAD. 2016/17. Statistical information of Nepalese Agriculture 2012/13.Ministry of Agriculture Development, Agribusiness Promotion and Statistics Division, Kathmandu, Nepal.

Mustafa G, EN Akbar, SA Qaisrani, A Iqbal, HZ Khan, KJ Ashfaq, A Chattha, R Trethowan, T Chattha and BM Atta. 2011. Effect of zinc application on growth and yield of rice (Oryza sativa L.). IJAVMS. **5**(6):530-535. doi: 10.5455/ijavms.9383.

Nawaz M, N Ibbal, MU Saleem and MU Ashraf. 2015. Effect of ZnSO4 mixed with different fertilizers on paddy yield of fine grain rice. Applied Sciences and Business Economics. **2**(1):08-12.

Nawaz M, N Ibbal, MU Saleem and MU Ashraf. 2015. Effect of ZnSO4 mixed with different fertilizers on paddy yield of fine grain rice. Applied Sciences and Business Economics. **2**(1):08-12.

Ponnamperuma FN. 1972. The chemistry of submerged soils. Advance in Agronomy. **24**:29–96.

Prasad R. 2004. Recent advances in rice agronomy. Indian Farming. **65**:113-136.

Rahman MM and MM Masood. 2014. Sustaining productivity in boro (winter) season using minimal water through dry direct seeding of rice. Journal of Crop and Weed. **10**(2):24-30.

Rana MM, MA Al Mamun, A Zahan, MN Md, N Ahmed and MAJ Mridha. 2014. Effect of planting methods on the yield and yield attributes of short duration Aman rice. American Journal of Plant Sciences. **5**:251-255.

Saha B, S Saha, PD Roy, GC Hazra and A Das. 2013. Zinc fertilization effects on agro- morphological and quality parameters of commonly grown rice. SAARC Journal of. Agriculture. **11**(1):105-120.

Sarwar M. 2011. Effects of Zinc fertilizer application on the incidence of rice stem borers (Scirpophaga species) (Lepidoptera: Pyralidae) in rice (Oryza sativa L.) crop. Journal of Cereals and Oilseeds. **2**(1):61-65.

Sasaki H, T Hirose, Y Watanabe and R Ohsugi. 1998. Carbonic anhydrase activity and CO2-transfer resistance in Zn-deficient rice leaves. Plant Physiology. **118**(3):929-934.

Shehu HE, GY Jamala and AM Musa. 2011. Response of transplanted irrigated rice (Faro, 44) to applied zinc by nursery enrichment of fadama soil in Adamawa State, Nigeria. World Journal of Agricultural Sciences. **7**(2):143-148.

Storey JB. 2007. Zinc. In: Barker AV, Pilbeam DJ (eds) Handbook of plant nutrition. CRC Press, Taylor & Francis Group, Boca Raton.

Sudha S and P Stalin. 2015. Effect of zinc on yield, quality and grain zinc content of rice genotypes.International Journal of Farm Sciences. **5**(3):17-27.

Thapa RB and DR Dangol. 1988. A preliminary survey of bee flora at IAAS and its vicinity. In: Neupane, F. P (Ed.), IAAS Journal.

Yakan H, MA Gurbuz, F Avşar, H Surek and N Beşer. 2000. The effect of zinc application on rice yield and some agronomic characters. Cahiers Options Mediterraneennes. **58**:1-5.