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Role of Zinc Fertilizer on Grain Yield and Some Qualities Parameters in Iranian Rice Genotypes

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ABSTRACT

This experiment was carried out at Sari, Mazandaran, Iran in 2012. This experiment was done as split plot in randomized complete blocks design based three replications. Zinc fertilizer application was chosen as main plots (0, 20 and 40 kg/ha) and genotypes as sub plots (Tall cultivars: Sang Tarom and Mahalli Tarom; Short cultivars: Neda and Shiroodi). The results showed that the most panicle number per m^2 and harvest index had observed in 40 kg Zn ha and the least of those was obtained in control treatment. Mahalli Tarom cultivar had the maximum panicle length and plant height, but the maximum panicle number per m^2, grain yield and harvest index were produced for var. Neda and Shiroodi. The highest Zinc content in grain, zinc uptake in grain and straw, and nitrogen uptake in grain were observed in 40 kg Zn ha, as the most zinc content in straw, nitrogen content in grain and straw, and nitrogen uptake in straw were observed with application of 40 and 20 kg Zn ha. The maximum zinc content in grain and straw and zinc uptake in straw was obtained for var. Sang Tarom, but the most zinc uptake in grain and nitrogen uptake in straw had produced for var. Neda and Shiroodi. The highest nitrogen content in grain and straw and nitrogen uptake in grain was obtained for var. Shiroodi. The most zinc content in grain and straw were produced at interaction of 40 kg Zn ha and var. Sang Tarom and the highest nitrogen content in straw and nitrogen uptake in straw had produced under interaction of 20 kg Zn ha and var. Shiroodi. So according to the results 20 and 40 kg Zn ha was the best treatment.

Keywords: Genotype, Grain yield, HI, Rice, Zn.

INTRODUCTION

Rice (*Oryza sativa* L.) is the main staple food of around half of the world's population. On a global basis, rice provides 21 and 15% per capita of dietary energy and protein, respectively [1]. Rice is one of highly sensitive crops to zinc deficiency [2, 3], and zinc is the most important micronutrient limiting rice growth and yield [4]. Zinc is one of the necessary micro-nutrients both for the growth of plants and for human beings. Reports showed that 30% soils in the world exhibit Zinc deficiency to different extents [5], and more than two billion people cannot be supplied with sufficient Zinc. Zinc is one of the most important micronutrient essential for plant growth especially for rice grown under submerged condition. Zinc fertilizer can be applied as ground fertilizer, root dipping, seed socking, seed dressing and top dressing. The critical index of effective Zn in the soil suitable for rice growth is 1.5 mg kg^{-1} (DTPA solution lixiviated), [6]. Zinc deficiency is prevalent worldwide in temperate and tropical climates [7, 8]. Zinc deficiency continues to be one of the key factors in determining rice production in several parts of the country [9]. Combining Zinc fertilizer with NO_3^- and SO_4^{2-} can improve the effect of Zn fertilization, reduce adverse impacts of a single-form Zinc fertilizer on crude protein and starch accumulation in rice seeds, and strengthen rice against disease or adversity, thereby improve quality of irrigated rice and increase yield [10]. Zinc deficiency in rice has been reported in lowland rice of India [11], and Brazil [12]. Zinc deficiency in plant is noticed when the supply of zinc to the rice plant is inadequate. Among the many factors which influence zinc supply to the plants, pH, concentration of zinc, iron, manganese and phosphorus in soil solution are very important. Zinc deficiency is usually corrected by application of zinc sulphate. Zinc deficiency and response of rice to zinc under flooded condition have been studied by many workers [12, 13, 14, 15]. Zinc is essential for several biochemical processes in the rice plant, such as cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll production, enzyme activation, and membrane integrity [16]. Soil application of Zn about 4 mg kg^{-1} and 6 kg ha^{-1} in pot culture and field study gave maximum yield in calcareous soil [17]. It has been reported that rice yield was 427 and 983 kg higher in 75 % NPKSZn and 100% NPKSZn treatment over control and also increased the growth parameters in field trials [18]. Complete doze of NPKSZn fertilizer with and without organic amendments increased the grain yield of rice and increased or maintained the sustainability of ricewheat cropping system [19]. Soil or foliar applications of Zn may also increase grain zinc concentration and thus contribute to grain nutritional quality for human beings. In rice, soil zinc application has been reported to increase grain yield whereas foliar Zn application increased grain concentration of Zn [20]. Zinc deficiency is a well-documented nutritional and health problem in human populations in most of Asian countries where rice is the dominating staple food crop [21]. Higher grain Zn concentration is also important for better seedling vigor and field establishment, particularly on Zn deficient soils [22]. Zinc deficiency in crops is widespread, largely reflecting the regions of low Zn availability in soils and crops [3]. As a result, the introduction of aerobic rice on low Zn soils places the problem of Zn deficiency in rice in a new perspective [23]. Zinc deficiency in common in rice soils. The availability of Zn in the soil varies widely depending on the soil properties. Zinc contents in soil and leaves of rice were directly related to the increased application of these elements. Zinc deficiency is usually more prevalent in rice soils with a high pH and high content of organic matter or when organic manures are applied [24]. According to the importance of zinc fertilizer for rice genotypes, also extreme role of zinc fertilizer on qualities parameters, an experiment was conducted for study role of zinc fertilizer application on agronomical traits and some quantities and qualities parameters of Iranian rice genotypes.

MATERIALS AND METHODS

In order to evaluation of role of Zn fertilizer application on grain yield and some qualities parameters in Iranian rice genotypes, an experiment was carried out at Sari, Mazandaran, Iran in 2012. The experimental farm is geographically situated at 36°, 4' N latitude and 53°, 5' E longitude at an altitude of 13.2 m above mean sea level. The soil was analysed and the soil of field was clay-loam (Table 1), weather conditions were also measured in vegetation period (Table 2).

Table 1. Selected soil properties for composite samples at experimental site in 2012.

Soil texture	K (ppm)	P (ppm)	N (%)	OM (%)	Mn (ppm)	Zn (ppm)	pH	EC (µmohs/cm)	Depth (cm)
Clay-loam	182	8.8	0.18	1.2	16	22	7.2	0.22	0-30

Table 2. Weather condition in experiment site in rice growth stages at Sari in 2012.

Variable	Jan.	Feb.	March	April	May	June	July	August
Minimum tem. (°C)	2	4	9.3	7.5	14	18.8	23.1	23.7
Maximum tem. (°C)	12	14	15.2	16.4	24	27.8	32.6	33.2
Evaporation (mm)	40	50	43	58.1	75.8	135.1	128.2	152.6
Precipitation (mm)	62	85	78	124.9	26.9	29.4	8.1	11.9

This experiment was conducted as split plot in randomized complete blocks design based three replications. Zinc fertilizer application was chosen as main plots (0, 20 and 40 kg/ha applied as zinc sulphate ($ZnSO_4$) at tillering stage) and genotypes as sub plots (Tall cultivars: Sang Tarom and Mahalli Tarom; Short cultivars: Neda and Shiroodi).

Seeds were soaked for 12 to 24 h and emergence date was considered to be five days after sowing, when 90% of the seedlings showed coleoptiles. Seeds spread with hands into an area of 10 m^2 (2 × 5). Sowing arrangement was 20 × 20 cm^2. The water depth was controlled at 3 to 5 cm. Nitrogen, phosphorous and potassium fertilizers were used at the rates of N 150 kg ha^{-1} urea, P_2O_5 100 kg ha^{-1} triple superphosphate and K_2O 100 kg ha^{-1} potassium sulphate. Basal fertilizers were applied in all plots 1 day before transplanting. Nitrogen was applied by designing map arrangement. Nitrogen was applied three times (first at planting time, second at tillering time and third panicle imitation, using 33.3%, 33.3% and 33.3% in each stage in plot. Phosphate and potassium fertilizers weren't used during of growth stages. Zinc levels used were 0, 20 and 40 kg/ha applied as zinc sulphate. Weeding was made 22 days after sowing by hand. 10 hills were randomly collected at harvesting time from each plot to measure grain yield and agronomical traits. Grain yield and straw yield was harvested from 4 m² from the middle of the sub plots with

12 % humidity (Yoshida, 1981). Zinc concentration in the digested material was estimated in atomic absorption spectrophotometer (AAS) ICP-OES (Inductively Coupled Plasma-Optical Emission Spectroscopy), as their uptake was computed by multiplying zinc content (mg/kg) with DMP. Nitrogen concentration in grain and straw was determined by Kjeldahl method. All the data were subjected to statistical analysis (one-way ANOVA) using SAS software [25]. Differences between the treatments were performed by Duncan's Multiple Range Test (DMRT) at 5% confidence interval.

RESULTS AND DISCUSION

Panicle length

Results in table 3 showed that panicle length had significant effect under genotype treatment in 1 % probability level (Table 3). Maximum panicle length (28.78 cm) was observed for 100 var. Mahalli Tarom and minimum panicle length (23.89 cm) was obtained for var. Neda, these traits for Sang Tarom and Shiroodi was 26.33 and 24.56 cm, respectively (Table 4). The most panicle length (29.67 cm) was observed at interaction of 40 kg/ha Zn application and var. Mahalli Tarom and the least panicle length (23.33 cm) were obtained at interaction of control treatment and var. Neda and Shiroodi (Table 5). Panicle length affects in grain yield by more transport of photosynthesis material [26]. The low size of panicle length was observed in without Zn application [27]. The present study is in partial agreement with the results reported by [28, 29].

Table 3. Mean square of zinc fertilizer application on agronomical traits and quantities yield in rice genotypes.

S.O.V.	DF	Panicle length	Plant height	Panicle number per m^2	Filled spikelet percentage per panicle	Grain yield	Straw yield	Harvest index
Replication	2	0.028	226.58*	11418.69**	71.03	624185.33	2762272.69	7.75*
Zinc (A)	2	20.06	186.33*	7076.69**	452.69*	22307.25	4251808.53	46.58**
Error	4	24.44	14.79	90.53	47.49	994290.08	1210351.53	1.46
Genotype (B)	3	128.89**	2553.51**	19382.40**	5.58	33351055.81**	5129436.63*	525.41**
A×B	6	3.94	29.37*	669.51	10.92	88984.81	672969.71	3.21
Error	18	8.17	8.39	899.58	12.22	280583.94	1272885.21	11.89
C.V. (%)	-	12.60	12.37	9.04	3.96	10.42	14.15	9.07

*** and * respectively significant in 1% and 5% level.*

Plant height

This character was significant under effect of zinc fertilizer and interaction of zinc and genotype in 5 % probability level and genotype treatment in 1 % probability level (Table 3). Minimum plant height (118.3 cm) was noted for 20 kg/ha zincs application and maximum of that (126.1 cm) was obtained for control treatment. The highest plant height (140.4 cm) was observed fir var. Mahalli Tarom and the lowest plant height (105.9 cm) was obtained for var. Neda (Table 4). The most plant height (147 cm) had observed at interaction of control treatment and var. Mahalli Tarom and the least plant height (102.3 cm) was obtained at interaction of 20 kg/ha Zn application and var. Neda (Table 5). Plant height response to Zn application was more pronounced, significantly higher growing efficiency was recorded with Zn and the lowest without Zn application [27]. Significant effect of Zn on plant height of rice has been observed by many others in the past [28, 30, 31, 32].

Panicle number per m^2

Panicle per m^2 was significant in 1 % probability level under zinc fertilizer and genotype (Table 3). The most panicle number per m^2 (357.8 panicle) was shown with 40 kg/ha zinc application and the least panicle number per m^2 was obtained in control treatment. The maximum panicle number per m^2 was demonstrated for var. Neda abd Shiroodi (369 and 374 panicle, respectively) and the minimum of those (294.7 and 288.6 panicle g) were produced for var. Sang Tarom and Mahalli Tarom (Table 4). The most panicle number per m^2 was observed at interaction of 40 kg/ha zinc application and var. Neda and Shiroodi (379.3 and 359.7 panicle) and application of 20 kg/ha zinc and var. Neda and Shiroodi (380.3 and 370.7 panicle) and the least panicle number per m^2 was obtained at interaction of 20 kg/ha zinc application for var. Sang Tarom and Mahalli Tarom (275.7 and 283 panicle) and interaction of control treatment with var. Sang Tarom and Mahalli Tarom (265 and 269.7 panicle) (Table 5). Panicle number per unit area was the most important component of yield [33, 34]. Overall, panicle number increased with the application of Zn in the growth medium. With the application of Zn, about 5% increase was observed in panicle number as compared with the control treatment [33].

Filled spikelet percentage per panicle

This trait showed significant difference in 5 % probability level under Zn fertilizer (Table 3). The maximum filled spikelet percentage per panicle had obtained with application of 40 and 20 kg/ha Zn fertilizer (90.67 and 90.92 %), and the least filled spikelet percentage (81.33 %) was observed in control treatment (Table 4). The highest filled spikelet percentage per panicle had shown under interaction of 40 kg Zn ha^{-1} for Mahalli Tarom, Neda and Shiroodi genotypes (92.33, 91.67 and 90.33 %, respectively), as interaction of 20 kg Zn ha^{-1} for Sang Tarom, Mahalli Tarom, Neda and Shiroodi genotypes (91.33, 94.33, 91.67 and 94.33 %, respectively). The least filled spikelet percentage had obtained at interaction of control treatment for var. Mahalli Tarom (80.33 %) and control treatment for var. Shiroodi (79.33 %) (Table 5). Results showed, application of Zn fertilizer was effective in improving rice growth and subsequently main yield components such as filled spikelet per panicle [35].

Grain yield

Grain yield demonstrated significant difference in 1 % probability level under genotype treatment (Table 3). The maximum grain yield because of increase panicle number per m^2 was produced for var. Neda and Shiroodi (6680 and 6810 kg/ha, respectively), and the minimum grain yield had produced in var. Sang Tarom and Mahalli Tarom (3288 and 3546 kg/ha), that the cause of this result was decrease panicle number per m^2 for these cultivars (Table 4). The most grain yield was obtained under interaction of 40, 20 and 0 kg Zn ha^{-1} for var. Neda and Shiroodi (6601, 6679, 6789, 6906, 6650 and 6846 kg/ha, respectively) and the least grain yield was observed at interaction of 40, 20 and 0 kg Zn ha^{-1} for var. Sang Tarom and Mahalli Tarom equal to 3477, 3767, 3186, 3338, 3202 and 3533 kg/ha, respectively (Table 5). The superiority of Zn application for grain yield may be due to improvement in soil properties to support the roots of treated plants due to Zn supply. Grain yield of field crops is estimated by various yield components. The important yield components in cereals are panicle number per unit area, number of spikelet's per panicle, and spikelet weight [36]. It has been reported that rice yield was 427 and 983 kg higher in 75 % NPKSZn and 100% NPKSZn treatment over control and also increased the growth parameters in field trials [18]. The yield of rice was increased significantly by Zinc treatments compared to control without fertilizer application. With the increase in dose level from 20 kg to 30 kg Zn ha^{-1}, there was corresponding increase in grain yield regardless of the two varieties [27]. The grain yield per plant in rice is associated with heterosis due to panicle length, number of productive tillers per plant, number of grains per panicle and testweight [37].

Straw yield

Straw yield showed significant difference in 5 % in probability under genotype treatment (Table 3). The maximum straw yield equivalent to 8601 kg/ha was produced for var. Neda and the minimum straw yield equal to 7644 and 7209 kg/ha was obtained for var. Sang Tarom and Mahalli Tarom, respectively (Table 4). The most straw yield (10100 kg/ha) was observed under interaction of control and var. Neda and the least straw yield was produced at interaction of 40 kg Zn ha^{-1} for var. Sang Tarom, Mahalli Tarom and Shiroodi equivalent to 7129, 7200 and 7388 kg/ha and interaction of 20 kg Zn ha^{-1} for var. Sang Tarom and Mahalli Tarom (7571 and 6675 kg/ha), as under interaction of control treatment for var. Mahalli Tarom equivalent to 7751 kg/ha ((Table 5). With the application of Zn, Sinha, (1985) observed a progressive increase in the dry matter production of rice at critical growth stages [38]. Researchers reported a significant increase in the straw yield of BR11 rice due to application of Zn [28, 39].

Harvest index

Harvest index showed significant difference under zinc fertilizer and genotype in 1 % probability level respectively (Table 3). Highest harvest index (40.08 %) was observed with 40 kg Zn ha^{-1}, also least of that (36.17 %) was observed for control treatment. The most harvest index was observed for var. Neda and Shiroodi (42.89 and 46 %) and the least harvest index equivalent to 30.11 and 33 % for var. Sang Tarom and Mahalli Tarom (Table 4). The maximum harvest index (47.67 %) was obtained for interaction 40 kg Zn ha^{-1} and var. Shiroodi and the minimum harvest index was observed under interaction of 40 kg Zn ha^{-1} for var. Sang Tarom (32.67 %), as 20 kg Zn ha^{-1} for var. Sang Tarom and Mahalli Tarom equivalent to 29.33 and 33.33 % and control treatment for var. Sang Tarom and Mahalli Tarom equivalent to 28.33 and 31.33 % (Table 5). Sinclair (1998) stated that harvest index has been an important trait associated with a dramatic increase in crop yield that has occurred in the twentieth century [40]. Harvest index reflects the partitioning of photosynthetic between the grain and the vegetative plant, and improvement in the harvest index emphasizes the importance of carbon allocation for grain production. Standpoint, increasing harvest index should be emphasized when the objective is to select for increased grain yield [33].

Table 4. Mean comparison of zinc fertilizer application on agronomical traits and quantities yield in rice genotypes.

Treatment	Panicle length (cm)	Plant height (cm)	Panicle number per m^2	Filled spikelet percentage per panicle	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
Zinc fertilizer							
40 kg Zn ha	26.92 a	122.9 ab	357.8 a	90.67 a	5131 a	7418 a	40.08 a
20 kg Zn ha	25.58 a	118.3 b	327.4 b	92.92 a	5055 a	7896 a	37.75 b
Control	25.17 a	126.1 a	309.8 c	81.33 b	5058 a	8601 a	36.17 c
Genotypes							
Sang Tarom	26.33 b	132.9 b	294.7 b	87.33 a	3288 b	7644 b	30.11 b
Mahalli Tarom	28.78 a	140.4 a	288.6 b	89.00 a	3546 b	7209 b	33.00 b
Neda	23.89 d	105.9 d	369.0 a	88.89 a	6680 a	8978 a	42.89 a
Shiroodi	24.56 c	110.4 c	374.0 a	88.00 a	6810 a	8056 ab	46.00 a

Values within a column followed by same letter are not significantly different at Duncan ($P \leq 0.05$).

Table 5. Interaction effect of zinc fertilizer application on agronomical traits and quantities yield in rice genotypes.

Interaction	Panicle length (cm)	Plant height (cm)	Panicle number per m^2	Filled spikelet percentage per panicle	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
Zn_1V_1	27.67 b	133.7 b	343.3 ab	88.33 ab	3477 b	7129 b	32.67 d
Zn_1V_2	29.67 a	138.3 b	313.0 bc	92.33 a	3767 b	7200 b	34.33 cd
Zn_1V_3	24.67 de	105.7 ef	379.3 a	91.67 a	6601 a	7955 ab	45.67 ab
Zn_1V_4	25.67 cd	114.0 d	395.7 a	90.33 a	6679 a	7388 b	47.67 a
Zn_2V_1	25.33 cd	126.7 c	275.7 c	91.33 a	3186 b	7571 b	29.33 d
Zn_2V_2	28.67 ab	136.0 b	283.0 c	94.33 a	3338 b	6675 b	33.33 d
Zn_2V_3	23.67 ef	102.3 f	380.3 a	91.67 a	6789 a	8883 ab	43.33 ab
Zn_2V_4	24.67 de	108.0 e	370.7 a	94.33 a	6906 a	8455 ab	45.00 ab
Zn_3V_1	26.00 c	138.3 b	265.0 c	82.33 bc	3202 b	8231 ab	28.33 d
Zn_3V_2	28.00 b	147.0 a	269.7 c	80.33 c	3533 b	7751 b	31.33 d
Zn_3V_3	23.33 f	109.7 de	347.3 ab	83.33 bc	6650 a	10100 a	39.67 bc
Zn_3V_4	23.33 f	109.3 de	357.3 ab	79.33 c	6846 a	8325 ab	45.33 ab

Values within a column followed by same letter are not significantly different at Duncan ($P \leq 0.05$).
Zn_1, Zn_2 and Zn_3: 40, 20 and 0 kg/ha zinc application, respectively.
V_1, V_2, V_3 and V_4: Sang Tarom, Mahalli Tarom, Neda and Shiroodi genotypes, respectively.

Zinc content in grain

This parameter was significant in 1 % probability level under zinc fertilizer and genotype (Table 6). With application of zinc fertilizer zinc content in grain was increase equivalent to 49.32 % that the most zinc content in grain (27.25 mg/kg) was observed with 40 kg Zn ha^{-1} and the least of that had obtained control treatment. The most zinc content in grain equivalent to 27.56 mg/kg was obtained for var. Sang Tarom and the least of that (23.33 mg/kg) had obtained for var. Neda (Table 7). The maximum zinc content in grain (32.67 mg/kg) had obtained under interaction 40 kg Zn ha^{-1} and var. Sang Tarom and the least of that equivalent to 16 mg/kg was observed at interaction of control treatment and var. Neda (Table 8). Soil or foliar applications of Zn may also increase grain zinc content and thus contribute to grain nutritional quality for human beings. In rice, zinc application has been reported to increase grain content of Zn [20]. It appeared that the Zn content in grain varied from 17.35 to 32.51 ppm. The highest value was obtained in the Zn_3 and the lowest value was found in control (Zn_0). All the treatments responded better over control. In case of straw, the Zn content varied from 37.46 to 61.57 ppm. The highest Zn content was observed in Zn_3. It also showed that all the treatments responded better over control [28]. Hossain et al., (1989) found that Zn concentration in grain increased considerably due to application of Zn to soil [41].

Zinc content in straw

As we can see in table 6, zinc content in straw has significant under simple effects of zinc fertilizer in 5 % probability level and genotype in 1 % probability level (Table 6). The most zinc content in straw was observed with application of 40 and 20 kg Zn ha^{-1} equivalent to 9.62 and 8.52 mg/kg and the least zinc content in straw (6.48 mg/kg) had obtained for control. The highest zinc content in straw (9.88 mg/kg) was shown for var. Sang Tarom and the least of that was produced for var. Tarom Mahalli, Neda and Shiroodi equivalent to 8.19, 7.28 and 7.48 mg/kg (Table 7). The maximum zinc content in straw (12.10 mg/kg) had obtained under interaction 40 kg Zn ha^{-1} and var. Sang Tarom and the least of that equivalent to 5.77 mg/kg was observed at interaction of control treatment and var. Neda (Table 8). The highest Zn content was observed in Zn_3. It also showed that all the treatments responded better over control [28]. As well as, Zn content in straw increased considerably due to application of Zn to soil [41].

Zinc uptake in grain

Statistically, zinc uptake in grain was significant under genotype in 1 % probability level (Table 6). The maximum zinc uptake in grain (13.48 kg/ha) was obtained for 40 kg Zn ha^{-1} and least of that (6.48 kg) had produced in control treatment. The most zinc uptake in grain was obtained for var. Neda (13.30 kg/ha) and Mahalli Tarom (14.67 kg/ha), the minimum of those was observed for var. Sang Tarom (9.05 kg/ha) and var. Mahalli Tarom equivalent to 9.26 kg/ha (Table 7). Highest zinc uptake in grain was noted under interaction of 40 kg Zn ha^{-1} for var. Neda and Shiroodi (16 and 16.27 kg/ha) and 20 kg Zn ha^{-1} for var. Shiroodi, as the lowest zinc uptake in grain was noted under interaction of control treatment for var. Sang Tarom (Table 8). There was a significant variation in Zn uptake by grain due to different rate of Zn application. Concerning Zn uptake by the crop, the maximum uptake was due to the application of full dose of recommended Zn and the minimum was due to no use of Zn. Such result was equally true for grain [28]. Salam and Subramanian (1988) reported that Zn application increased Zn uptake by plant [31]. Significant correlation between grain yield and Zn uptake at tillering stage [42]. The main reason attributed for this increase was the pattern of root distribution or the physiological or morphological characteristics of rice roots growing in the moist or flooded soil conditions [44]. Singh, (1995) reported that when Zn accompanied N, significant increase in grain yield was observed up to 150 kg N ha^{-1} [45].

Zinc uptake in straw

Zinc uptake in straw was significant under genotype in 5 % probability level (Table 6). With zinc application zinc uptake in straw was increase in ratio 29.93 %, that the maximum zinc uptake in straw (7.12 kg) was obtained for 40 kg Zn ha^{-1} and minimum of that (9.65 kg) was produced for control treatment. Mahalli Tarom, Neda and Shiroodi cultivars had the least zinc uptake in straw equivalent to 5.86, 6.40 and 5.98 kg and Sang Tarom has the least zinc uptake in straw in ratio 7.40 kg (Table 7). The maximum zinc uptake in straw (8.56 kg) was recorded at interaction of 40 kg Zn ha^{-1} and var. Sang Tarom and the minimum of that had produced under interaction of control treatment for var. Mahalli Tarom and Shiroodi equivalent to 4.83 and 4.88 kg (Table 7). Singh, (1995) reported that when Zn accompanied N, significant increase in grain yield was observed up to 150 kg N ha^{-}1. Yields obtained with 150 kg N ha^{-1} alone were statistically at par with those at 100 kg N ha^{-1} with Zn. The addition of Zn at all four N levels (0, 50, 100, 150 kg N ha^{-1}) increased Zn uptake and chlorophyll content significantly over the corresponding N levels without Zn [44].

Zinc harvest index

According to table 6, zinc harvest index showed significant difference by interaction of zinc fertilizer and genotype in 5 % in probability level (Table 6). The maximum zinc harvest index was noted at interaction of 40 kg Zn ha-1 for Sang Tarom, Mahalli Tarom, Neda and Shiroodi (72.99, 73.73, 74.87 and 74.48 %, respectively, as 20 kg Zn ha^{-1} for Sang Tarom, Mahalli Tarom and Shiroodi genotypes equivalent to 74.17, 73.81 and 74.33 %, and control treatment for var. Sang Tarom and Mahalli Tarom (73.95 and 74.59 %), as the minimum of that (71.05 %) was obtained under interaction of 20 kg Zn ha^{-1} for var. Neda (Table 8).

Nitrogen content in grain

This parameter was significant in 5 % probability level under effect of zinc fertilizer and showed significant in 1 % probability level under genotype (Table 6). The most nitrogen content in grain depicted with 40 and 20 kg Zn ha^{-1} in ratio 1.61 and 1.48 % and the least of that (1.12 %) was observed in control treatment, also the minimum nitrogen content in grain 1.33 % was obtained for var. Sang Tarom and the maximum of that 1.49 % had obtained for var. Shiroodi (Table7). According to table 8 minimum nitrogen content in grain was found for interaction of control treatment with Sang Tatom, Mahalli Tarom, Neda and Shiroodi genotypes (1.10, 1.18, 1.03 and 1.17 %, respectively) and maximum of that was obtained for interaction of 40 kg Zn ha^{-1} for Mahalli Tarom, Neda and Shiroodi genotypes (1.60, 1.64 and 1.66 %) and interaction of 20 kg Zn ha^{-1} for var. Neda equivalent to 1.63 % (Table 8). Hasan, (l997) studied the response of rice to Zn application as $ZnS0_4$ and found that application of Zn with recommended NPK resulted in significant increase in grain yield over control [45]. Application of Zn at 9 kg ha^{-1} yielded 5.8 t ha^{-1} compared to 4.6 t ha^{-1} with NPK alone, which was attributed to improved fertilizer NUE from Zn application. Nitrogen content in grain varied due to application of Zn supplied from fertilizer, however this variation was not significant, but the grain N content varied from 1.27 to 1.34% over the treatments. The highest N content (1.34%) in grain was found in the Zn_3. All the treatments showed better effect on N content of rice grain over control [28]. Hoque, (1999) reported that application of Zn showed a decreasing effect on the N concentration of rice grain while an increasing effect was recorded in case of rice straw [46].

Table 6. Mean square of zinc fertilizer application on some qualities parameters in rice genotypes.

S.O.V.	DF	Zinc content in grain	Zinc content in straw	Zinc uptake in grain	Zinc uptake in straw	Zinc harvest index	Nitrogen content in grain	Nitrogen content in straw	Nitrogen uptake in grain	Nitrogen uptake in straw	Nitrogen harvest index
Replication	2	85.36*	7.18	28.35	1.03	7.33	0.23*	0.141*	292.16	726.26	66.13*
Zinc (A)	2	246.36**	30.32*	44.10	8.53	1.39	0.78*	0.203*	2255.19*	791.30*	41.10*
Error	4	11.74	2.55	31.83	5.24	1.93	0.05	0.029	357.15	198.94	18.80
Genotype (B)	3	97.89**	12.56**	72.87**	4.39*	1.84	0.04**	0.011	7307.02**	221.91**	2.83
A×B	6	2.81	1.01	5.25	0.98	4.57*	0.01	0.005	155.33*	82.72*	3.94
Error	18	9.83	1.20	5.01	1.00	2.01	0.01	0.003	77.69	38.85	2.06
C.V. (%)	-	13.60	13.36	19.35	15.60	11.93	6.38	9.17	12.34	14.52	11.99

*** and * respectively significant in 1% and 5% level.*

Table 7. Mean comparison of zinc fertilizer application on some qualities parameters in rice genotypes.

Treatment	Zinc content in grain (mg/kg)	Zinc content in straw (mg/kg)	Zinc uptake in grain (kg/ha)	Zinc uptake in straw (kg/ha)	Zinc harvest index (%)	Nitrogen content in grain (%)	Nitrogen content in straw (%)	Nitrogen uptake in grain (kg/ha)	Nitrogen uptake in straw(kg/ha)	Nitrogen harvest index (%)
Zinc fertilizer										
40 kg/ha	27.25 a	9.62 a	13.48 a	7.12 a	74.02 a	1.61 a	0.62 a	82.78 a	45.78 a	72.40 ab
20 kg/ha	23.67 ab	8.52 a	11.58 ab	6.63 ab	73.34 a	1.48 a	0.63 a	75.37 ab	49.22 a	70.12 b
Control	18.25 b	6.48 b	9.65 b	5.48 b	73.65 a	1.12 b	0.40 b	56.21 b	33.75 b	73.79 a
Genotypes										
Sang Tarom	27.56 a	9.88 a	9.05 b	7.40 a	73.40 a	1.33 c	0.52 b	43.74 c	38.58 b	72.30 a
Mahalli Tarom	23.33 b	8.19 b	9.26 b	5.86 b	74.04 a	1.43 ab	0.55 ab	50.63 c	38.68 b	72.79 a
Neda	20.00 c	7.28 b	13.30 a	6.40 b	73.02 a	1.36 bc	0.53 b	90.43 b	46.71 a	71.51 a
Shiroodi	21.33 bc	7.48 b	14.67 a	5.98 b	73.90 a	1.49 a	0.59 a	101.0 a	47.69 a	71.81 a

Values within a column followed by same letter are not significantly different at Duncan ($P \leq 0.05$).

Table 8. Interaction effect of zinc fertilizer application on some qualities parameters in rice genotypes.

Interaction	Zinc content in grain (mg/kg)	Zinc content in straw (mg/kg)	Zinc uptake in grain (kg/ha)	Zinc uptake in straw (kg/ha)	Zinc harvest index (%)	Nitrogen content in grain (%)	Nitrogen content in straw (%)	Nitrogen uptake in grain (kg/ha)	Nitrogen uptake in straw(kg/ha)	Nitrogen harvest index (%)
Zn_1V_1	32.67 a	12.10 a	11.25 bcd	8.56 a	72.99 a	1.54 ab	0.59 b	53.30 cde	42.32 cde	72.22 b
Zn_1V_2	27.67 ab	9.87 b	10.41 bcd	7.09 ab	73.73 a	1.60 a	0.64 b	60.24 cd	45.92 bcd	71.77 bc
Zn_1V_3	24.33 bc	8.17 bcd	16.00 a	6.51 bc	74.87 a	1.64 a	0.61 b	107.2 a	48.35 bc	72.88 ab
Zn_1V_4	24.33 bc	8.33 bc	16.27 a	6.32 bc	74.48 a	1.66 a	0.63 b	110.4 a	46.54 bcd	72.73 ab
Zn_2V_1	28.00 ab	9.77 b	8.91 cd	7.10 ab	74.17 a	1.36 c	0.55 b	42.84 ef	40.57 c-f	71.41 bc
Zn_2V_2	24.00 bc	8.47 b	8.02 cd	5.65 bc	73.81 a	1.50 abc	0.60 b	49.93 def	40.19 c-f	71.56 bc
Zn_2V_3	19.67 cde	7.90 bcd	13.42 ab	7.02 ab	71.05 b	1.42 bc	0.61 b	96.40 a	54.43 ab	68.31 d
Zn_2V_4	23.00 bc	7.93 bcd	15.96 a	6.74 abc	74.33 a	1.63 a	0.74 a	112.3 a	61.67 a	69.20 cd
Zn_3V_1	22.00 bcd	7.77 b-e	6.99 d	6.53 bc	73.95 a	1.10 d	0.40 c	35.08 f	32.86 ef	73.28 ab
Zn_3V_2	18.33 cde	6.23 cde	9.36 bcd	4.83 c	74.59 a	1.18 d	0.39 c	41.72 ef	29.93 f	75.03 a
Zn_3V_3	16.00 e	5.77 e	10.47 bcd	5.67 bc	73.16 ab	1.03 d	0.37 c	67.72 bc	37.35 c-e	73.56 ab
Zn_3V_4	16.67 de	6.17 de	11.79 bc	4.88 c	72.90 ab	1.17 d	0.42 c	80.33 b	34.87 def	73.49 ab

Values within a column followed by same letter are not significantly different at Duncan ($P \leq 0.05$).
Zn_1, Zn_2 and Zn_3: 40, 20 and 0 kg/ha zinc application, respectively.
V_1, V_2, V_3 and V_4: Sang Tarom, Mahalli Tarom, Neda and Shiroodi genotypes, respectively.

Nitrogen content in straw

As we can see in table 6, nitrogen content in straw had shown significant under simple effects of genotype in 5 % probability level (Table 6). The maximum nitrogen content in straw was related to with 40 and 20 kg Zn ha^{-1} (0.62 and 0.63 %) and the least of that (0.40 %) was observed in control treatment, also the minimum nitrogen content in straw 0.52 % was obtained for var. Sang Tarom and the maximum of that 0.59 % had obtained for var. Shiroodi (Table7). The maximum nitrogen content in straw (0.74 %) was produced under interaction of 20 kg Zn ha^{-1} for var. Shiroodi and the least of that had observed under interaction of control treatment for Sang Tarom, Mahalli Tarom, Neda and Shiroodi genotypes equivalent to 0.40, 0.39, 0.37 and 0.42 %, respectively (Table 8). Nitrogen content in straw varied due to application of Zn supplied from fertilizer, however this variation was not significant, but N content in straw ranged from 0.625 to 0.768%, the highest value being in Zn_3 and the lowest in control [28]. Hoque, (1999) reported that application of Zn showed a decreasing effect on the N content of rice grain while an increasing effect was recorded in case of rice straw [46]. Hasan, (l997) studied the response of rice to Zn application to soil as $ZnS0_4$ and found that application of Zn with recommended NPK resulted in significant increase in grain yield over control. Application of Zn at 9 kg ha^{-1} yielded 5.8 t ha^{-1} compared to 4.6 t ha^{-1} with NPK alone [45].

Nitrogen uptake in grain

Statistically, nitrogen uptake in grain was significant under effect zinc fertilizer and interaction of zinc fertilizer and genotype in 5 % probability level, also this parameter have showed significant under genotype in 1 % probability level respectively (Table 6). The most nitrogen uptake in grain (82.78 kg) was observed with 40 kg Zn ha^{-1} and minimum of that (56.21 kg) was obtained for control treatment. The maximum nitrogen uptake in grain was obtained for var. Shiroodi (101 kg) and minimum of that was observed for var. Sang Tarom and Mahalli Tarom in ratio 43.74 and 50.63 kg (Table 7). Highest nitrogen uptake in grain was noted under interaction of 40 kg Zn ha^{-1} for var. Neda and Shiroodi (107.2 and 110.4 kg) and 20 kg Zn ha^{-1} for var. Neda and Shiroodi (96.40 and 112.3 kg), as the lowest nitrogen uptake in grain (35.08 kg) was seen under interaction of control treatment for var. Sang Tarom (Table 8). Hasan, (l997) studied the response of rice to Zn application as $ZnS0_4$ and found that application of Zn with recommended NPK resulted in significant increase in grain yield over control [45]. Application of Zn at 9 kg ha^{-1} yielded 5.8 t ha^{-1} compared to 4.6 t ha^{-1} with NPK alone, which was attributed to improved fertilizer NUE from Zn application. Nitrogen content in grain varied due to application of Zn supplied from fertilizer, however this variation was not significant, but the grain N content varied from 1.27 to 1.34% over the treatments. The highest N content (1.34%) in grain was found in the Zn_3. All the treatments showed better effect on N content of rice grain over control [28].

Nitrogen uptake in straw

Nitrogen uptake in straw was significant under zinc fertilizer and interaction of zinc fertilizer and genotype in 5 % probability level, also this parameter have showed significant under genotype in 1 % probability level respectively (Table 6). The highest nitrogen uptake in straw was observed with 40 and 20 kg Zn ha^{-1} (45.78 and 49.22 kg, respectively), and minimum of that (33.75 kg) was obtained for control treatment. The most nitrogen uptake in straw was obtained for var. Neda and Shiroodi (46.71 and 47.69 kg) and minimum of that was observed for var. Sang Tarom and Mahalli Tarom 38.58 and 38.68 kg (Table 7). The most nitrogen uptake in straw was shown under interaction of 20 kg Zn ha^{-1} for var. Shiroodi (61.67 kg) and the least nitrogen uptake in straw (29.93 kg) was seen under interaction of control treatment for var. Mahalli Tarom (Table 8). Nitrogen content in straw varied due to application of Zn supplied from fertilizer, however this variation was not significant, but N content in straw ranged from 0.625 to 0.768%, the highest value being in Zn_3 and the lowest in control [28]. Hoque, (1999) reported that application of Zn showed a decreasing effect on the N concentration of rice grain while an increasing effect was recorded in case of rice straw [46]. Hasan, (l997) studied the response of rice to Zn application to soil as $ZnS0_4$ and found that application of Zn with recommended NPK resulted in significant increase in grain yield over control. Application of Zn at 9 kg ha^{-1} yielded 5.8 t ha^{-1} compared to 4.6 t ha^{-1} with NPK alone [45].

Nitrogen harvest index

According to table 6, nitrogen harvest index showed significant difference by zinc fertilizer in 5 % in probability level (Table 6). The maximum nitrogen harvest index (73.79 %) was noted for control treatment and minimum of that (70.12 %) was observed for 20 kg Zn ha^{-1} (Table 7). The most nitrogen harvest index (75.03 %) was found at interaction of control treatment for var. Mahalli Tarom and the least of that (68.31 %) was obtained at interaction of 20 kg Zn ha-1 for var. Mahalli Tarom (Table 8).

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