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Studies of agronomic and eco-physiological indices of nutrient elements stress on Iranian rice genotypes

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ABSTRACT

*In general, most plants grow by absorbing nutrients from the soil. Their ability to do this depends on the nature of the soil. Depending on its location, a soil contains some combination of sand, silt, clay, and organic matter. The makeup of a soil (soil texture) and its acidity (pH) determine the extent to which nutrients are available to plants. This experiment was carried out at in two location with rich soil farm at Rice Research Institute of Tonekabon and poor soil farm at Ramsar, Mazandaran, Iran in 2012, as split split plot in randomized complete blocks design based three replications. Macro element in five levels {M_1: NPK, M_2: PK, M_3: NK, M_4: NP and M_5: 1/3 NPK} was chosen as main plots, Micro elements in two levels as sub plots {N_1: Mn-Zn-Si and N_2: non application} and cultivars as sub sub plots including line 843 and cv. Shiroodi. The results showed that the most panicle length and number of filled spikelet per panicle were as noted for M_1. Number of filled spikelet per panicle in Line 843 more than cv. Shiroodi. At double interaction of L*C the most number of filled spikelet per panicle was observed at interaction of L_1C_1 and L_2C_2. As, at double interaction of N*C the highest number of filled spikelet per panicle had obtained at N_1C_2. Grain width in Line 843 more than cv. Shiroodi. At triple interaction of L*M*N the maximum grain width had shown at $L_1M_3N_2$. The maximum grain yield equivalent to 6499.2 and 6433.8 kg/ha was produced in M_1 and M_2. Grain yield in Line 843 because of increase number of filled spikeler per panicle, grain length and grain width more than cv. Shiroodi. At double interaction of L*M the most grain yield was produced at interaction of L_2M_1 and L_2M_3. As, at double interaction of N*C the highest grain yield was obtained in N_2C_2. At triple interaction of L*N*C the most grain yield had produced in $L_2N_1C_2$ and $L_2N_2C_2$, as the least grain yield in this interaction had observed at $L_1N_1C_2$ and $L_1N_2C_1$. At double interaction of M*C the most harvest index was observed at M_4C_1, M_4C_2 and M_5C_2, respectively.*

Keywords: Cultivar, Grain yield, HI, Nutrient stress, Rice.

INTRODUCTION

Rice is one the most important crops in developing countries and a main food stuff for about 35% of the whole world population [1]. Rice production in much of the world increasingly focuses on optimizing grain yield, reducing production costs, and minimizing pollution risks to the environment [2]. Rice plants require large amounts of mineral nutrients including N for their growth, development and grain production [3]. Nitrogen nutrition is critical in yield realization of irrigated rice ecosystems. Nitrogen is clearly the most limiting element; we proposed a set of basic guidelines for improved nutrient management, which after further efforts of all stakeholders involved, could contribute to increased system productivity [4]. Nitrogen fertilization increased the number of stems and panicles per square meter and the total number of spikelets, reflecting on grain productivity. Excessive tillering caused by inadequate nitrogen fertilization reduced the percentage of fertile tiller, filled spikelet percentage and grain mass [5]. Nitrogen application significantly increased grain yield largely through an increased biomass and grain number [6].

Phosphorus (P) is one of the major essential mineral nutrients, and is involved in many key metabolic pathways in plants [7]. Rice removes about 2 to 3 kg P for 1 Mg of grain produced [8, 9]. the rice requirement for P is much less than that for N, the continuous removal of P exploits the soil P reserve if the soil is not replenished through fertilizer or manure application. Chemical P fertilizer is a costly agricultural input for rice farmers of the developing world, and sometimes the material is not available in the local village market. Cattle manure may be considered as an alternative to chemical P fertilizer. Many studies have shown that cattle manure can be a potential source of P [10]. Eghball and Power, (1999) reported that manure application of 92 Mg ha^{-1} in four year increased soil available P at the 0 to 15 cm depth from 49 to 116 mg kg^{-1} [11]. The greater accumulation of P due to manure application may increase the potential of P loss through run-off water [12], but mixing the manure with soil may potentially decrease the problem of P loss [13, 14].

Elliot et al., (2010) showed that potassium fertilization increased grain yield by 8 to 11% above rice receiving no K [15]. Slaton *et al.*, (2009) founded that rice having whole-plant K concentrations of 23.1 g kg^{-1} at panicle differentiation and 13.0 g kg^{-1} at early heading were predicted to produce 95% relative yield [16]. The predicted K-fertilizer rates required to optimize rice grain yield depended on the model and ranged from 51 to 90, 41 to 70, 30 to 55, and 20 to 35 kg K ha^{-1} for soil having Mehlich soil K concentrations of 60, 70, 80, and 90 mg K kg^{-1}, respectively. K uptake by plants is similar to that of N, however, and is usually an order of magnitude greater than that for P [17]. Potassium and stover management are critical to the uplands of Sitiung, Indonesia, where the predominant cropping system is upland rice followed by soybean or peanuts [18]. Dierolf and Yost, (2000) showed that soil and crop management factors also contribute to the occurrence of K deficiency [19].

Silicon is necessary for grain yield stability in rice [6]. Silicon uptake is different in varieties and parts of plants [20]. Silicon caused to be vertical in leaves, increase to resistance in fungal diseases [21], and caused to increase filled spikelets percentage and grain yield [22]. Optimal silicon application increase tolerance of plants to salinity and drought [23].

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), [24]. Zinc deficiency is prevalent worldwide in temperate and tropical climates [25, 26]. Zinc deficiency continues to be one of the key factors in determining rice production in several parts of the country [27]. 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 [28]. 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 [29, 30, 31]. 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 [32].

According to the importance of macro and micro element for rice cultivars, also extreme role of these element on growth parameters, an experiment was conducted for study studies of agronomic parameters and grain yield of rice Cultivars on nutrient elements stress.

MATERIALS AND METHODS

This experiment was carried out in two location with rich soil farm at Rice Research Institute of Tonekabon and poor soil farm at Ramsar, Mazandaran, Iran in 2012. The experimental rich soil farm is geographically situated at 36°, 54' N latitude and 40°, 50' E longitude at an altitude of -21 m above mean sea level and poor soil farm is geographically situated at 36°, 54' N latitude and 40°, 50' E longitude at an altitude of -20 m above mean sea level. The soil was analysed in two location (Table 1, 2).

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

Soil texture	K (ppm)	P (ppm)	N (%)	OM (%)	Mn (ppm)	Zn (ppm)	pH	EC (µmohs/cm)	Depth (cm)
Silt-clay	112	10.5	0.26	6.69	25	7.52	7.35	1.42	0-30

Table 2. Selected soil properties for composite samples at poor experimental site

Soil texture	K (ppm)	P (ppm)	N (%)	OM (%)	Mn (ppm)	Zn (ppm)	pH	EC (µmohs/cm)	Depth (cm)
Loam	116	8.7	0.23	6.02	17.12	1.32	7.08	0.53	0-30

This experiment was conducted as split split plot in randomized complete blocks design based three replications in two location with rich and poor soil. Macro element in five levels {M_1: NPK, M_2: PK, M_3: NK, M_4: NP and M_5: 1/3 NPK} was chosen as main plots, Micro elements in two levels as sub plots {N_1: Mn-Zn-Si and N_2: non application} and cultivars as sub sub plots including line 843 and cv. 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. 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. All the data were subjected to statistical analysis (one-way ANOVA) using SAS software. Differences between the treatments were performed by Duncan's Multiple Range Test (DMRT) at 5% confidence interval.

RESULTS AND DISCUSION

Panicle length

This character was significant under effect of locaction and macro element application in 1% probability level and double interaction of L*M and L*C, as triple interaction of L*M*N in 5 % probability level (Table 3). The most panicle length (30.84 cm) was noted for M_1 and the minimum panicle length (29.68 and 29.39 cm) was obtained for M_4 and M_5 (Table 4). At double interaction of L*M showed the highest panicle length was observed L_1M_1 (31.03 cm), L_1M_3 (30.97 cm), L_1M_4 (30.37 cm), L_1M_5 (30.33 cm), L_2M_1 (30.65 cm), L_2M_3 (30.28 cm) and L_2M_4 (30.28 cm) and the lowest panicle length was obtained for L_1M_2 (29.9 cm), L_2M_2 (28.88 cm) and L_2M_2 29.03 cm (Table 5). At triple interaction of L*M*N panicle length was noted, as the most panicle length was obtained at $L_1M_1N_2$ 31.33 cm and $L_1M_3N_1$ 31.27 cm and the lowest panicle length was observed at $L_2M_2N_1$ 28.77 cm, $L_2M_2N_2$ 29 cm and $L_2M_5N_2$ 28.87 cm (Table 6). At double interaction of L*C had observed the most panicle length was produced at L_1C_1 and L_1C_2 (30.56 cm) and the lowest panicle length was obtained at L_2C_2 29.56 cm (Table 7). Panicle length affects in grain yield by more transport of photosynthesis material [33]. stated panicle length had significant effect in tillering time by nitrogen contributing treatments in 1 % probability level [34].

Most panicle length was obtained for interaction of 50 kg N ha^{-1} × 225 kg P ha^{-1}, and least of that was observed at interaction of 100 kg N ha^{-1} and 150 and 225 kg P ha^{-1} [35]. Panicle length response to Zn application was more pronounced, significantly higher growing efficiency was recorded with Zn and the lowest without Zn application [Sarwar, 2011]. Significant effect of Zn on plant height of rice has been observed by many others in the past [36].

Table 3. Mean square of nutrient element stress on agronomical traits and yield yield in rice cultivars

S.O.V.	DF	Panicle length	Number of filled spikelet per panicle	Grain length	Grain width	Grain yield	Harvest index
Location	1	14.42**	747.00*	0.0032*	0.00005	46104443.01**	1616.41**
R (L)	2	2.09	536.00	0.0003	0.0010	857051.76	12.58
Macro (M)	4	9.15**	522.46**	0.0029*	0.0004	14106962.24**	16.43
L * M	4	1.41*	150.35	0.0013	0.0005	4345081.97**	6.90
Error	16	1.38	175.72	0.0009	0.0007	734614.77	9.25
Micro (N)	1	0.65	13.47	0.0000	0.0005	37559.41	14.53
L * N	1	0.26	0.0003	0.0000	0.0001	215307.41	25.06
M * N	4	0.77	43.10	0.0013	0.0002	690423.74	5.79
L * M * N	4	1.30*	85.14	0.0006	0.0014**	29247.70	7.10
Error	21	1.15	134.76	0.0010	0.0006	129823.58	5.84
Cultivar (C)	1	1.59	763.05*	0.0790**	0.015**	288610.21	2.09
L * C	1	2.88*	878.04**	0.0041*	0.0006	108781.41	20.85
M * C	4	0.73	107.48	0.0011	0.00003	135302.62	34.92*
L * M * C	4	0.49	88.20	0.0008	0.0003	161492.74	24.47*
N * C	1	1.41	340.71*	0.0077*	0.00008	1237285.21*	0.018
L * N * C	1	0.10	51.48	0.0002	0.00008	1382238.68*	1.43
M * N * C	4	0.21	53.67	0.0004	0.0002	139982.92	18.89
L * M * N *C	4	0.48	65.69	0.0018	0.0007	310072.59	13.51
Error	40	22.42	109.48	0.0011	0.0003	343791.8	9.22
C.V. (%)	-	2.48	10.17	3.05	8.43	10.15	5.79

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

Number of filled spikelet per panicle

Number of filled spikelet per panicle was significant in 5 % probability level under location, cultivar and double interaction of N*C, as this traits had significant in 1 % on macro element factor and double interaction of L*C (Table 3). The most number of filled spikelet per panicle (105.85 numbers) was shown in M_1 and the least number of filled spikelet per panicle was obtained in M_5. The maximum number of filled spikelet per panicle (105.43 numbers) was demonstrated for Line 843 and minimum of that (100.39 numbers) was produced for cv. Shiroodi (Table 4). At double interaction of L*C the most number of filled spikelet per panicle was observed at interaction of L_1C_1 (100.60 numbers) and L_2C_2 (110.63 numbers) and the least number of filled spikelet per panicle was obtained at interaction of L_1C_2 100.23 numbers and L_2C_1 100.18 numbers (Table 7). As, at double interaction of N*C the highest number of filled spikelet per panicle 104.75 numbers had obtained at N_1C_2 and the lowest of that 99.04 numbers was observed at N_1C_1 (Table 8). The study of Sahrawat *et al.*, (1995) was based on varied levels of P using the same level of N, it was not possible to detect the significant interactions between the two nutrients when levels of both nutrients were varied [37]. Results showed, application of Zn fertilizer was effective in improving rice growth and subsequently main yield components such as filled spikelet per panicle [38].

Grain length and grain width

This trait showed significant difference in 5 % probability level location, macro element and double interaction of L*C and N*C, as had dofference significant in 1 % probability level in cultivar (Table 3). The maximum grain length had obtained in M_1, M_2 and M_3 in order 1.11, 1.10 and 1.10 mm, respectively. As the least grain length 1.08 mm was observed M_5. Grain length in Line 843 1.12 mm was more than cv. Shiroodi 1.07 mm (Table 4). At double interaction of L*C had shown the most grain length had shown in L_1C_2 and the least grain length had obtained in L_1C_1 1.07 mm and L_2C_1 1.07 mm (Table 7). At double interaction of N*C shown the maximum grain length 1.13 mm had obtained in N_1C_2 and the minimum of that 1.06 mm was observed in N_1C_1 (Table 8). Grain wigth demonstrated significant difference in 1 % probability level under cultivar and triple interaction of L*M*N (Table 3). Grain width in Line 843 (0.23 mm) more than cv. Shiroodi 0.21 mm (Table 4). At triple interaction of L*M*N the maximum grain width 0.25 mm had shown at $L_1M_3N_2$ and in other interaction factor was least (Table 5).

Grain yield

Grain yield showed significant difference in 1 % in probability under location, macro element and double interaction of L*M, as significant difference in 5 % in probability in double interaction of N*C and triple interaction of L*N*C (Table 3). The maximum grain yield equivalent to 6499.2 and 6433.8 kg/ha was produced in M_1 and M_2 and the minimum grain yield equal to 5121 and 4819.1 kg/ha was obtained in M_4 and M_5, respectively. Grain yield in Line 843 5824.4 kg/ha because of increase number of filled spikeler per panicle, grain length and grain width more than cv. Shiroodi 5726.3 kg/ha (Table 4). At double interaction of L*M, the most grain yield was produced at interaction of L_2M_1 7517.75 kg/ha and L_2M_3 7383.75 kg/ha and the least grain yield was produced at interaction of L_1M_5 5062.58 and L_2M_4 6791.25 kg/ha (Table 5). As, at double interaction of N*C, the highest grain yield 5908.2 kg/ha was obtained in N_2C_2 and the least grain yield 5607.03 kg/ha was observed in N_2C_1 (Table 8). At triple interaction of L*N*C, the most grain yield had produced in $L_2N_1C_2$ 6540.13 kg/ha and $L_2N_2C_2$ 6408.47 kg/ha, as the least grain yield in this interaction had observed at $L_1N_1C_2$ 4940.87 kg/ha and $L_1N_2C_1$ 4952.33 kg/ha (Figure 1).

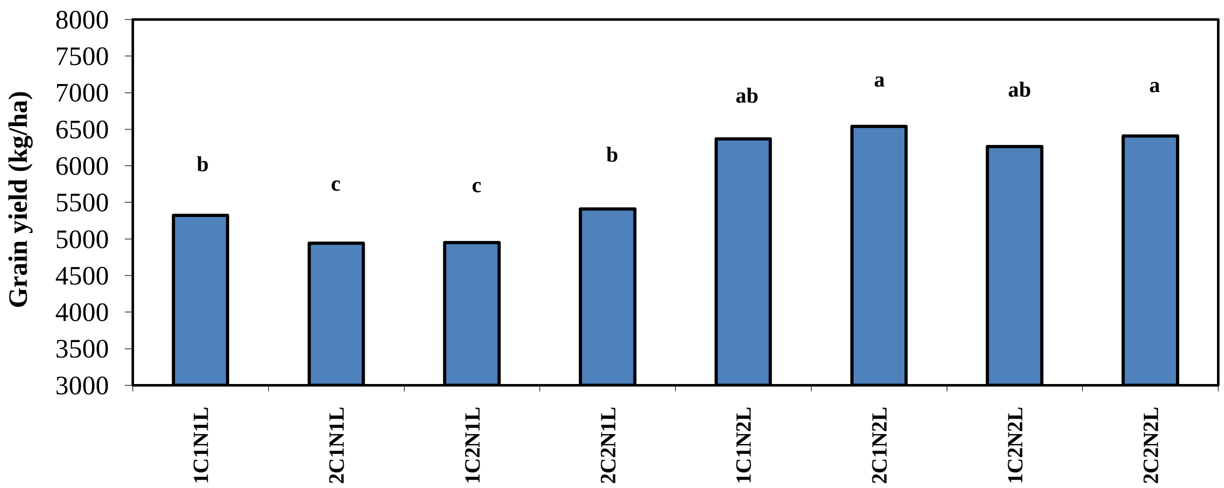

Figure 1. Triple interaction of L*N*C on grain yield

Pantuwan *et al.* (2002) reported that grain yield had positive correlation with flag leaf length. Grain yield increased by 120 kg h^{-1} nitrogen contributing in three times (transplanting time, tillering time and panicle initiation) [39]. Chaoming *et al.* (1999) stated that silicon application increased grain yield by increase of spikelet number, filled spikelet percentage and 1000-seed weight [40]. 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 [41]. 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 [42].

Harvest index

Harvest index showed significant difference in 1 % probability level in location, and significant difference in 5 % probability level at double interaction of M*C and L*M*C (Table 3). The highest harvest index 53.93 % was observed in M_1 and the least of that 51.76 % was observed in M_5 (Table 4). At double interaction of M*C the most harvest index was observed at M_4C_1 54.06 %, M_4C_2 53.81 % and M_5C_2 54.26 %, respectively. As, in this interaction the least harvest index had obtained in M_3C_2 50.76% and M_5C_1 50.4 % (Figure 2).

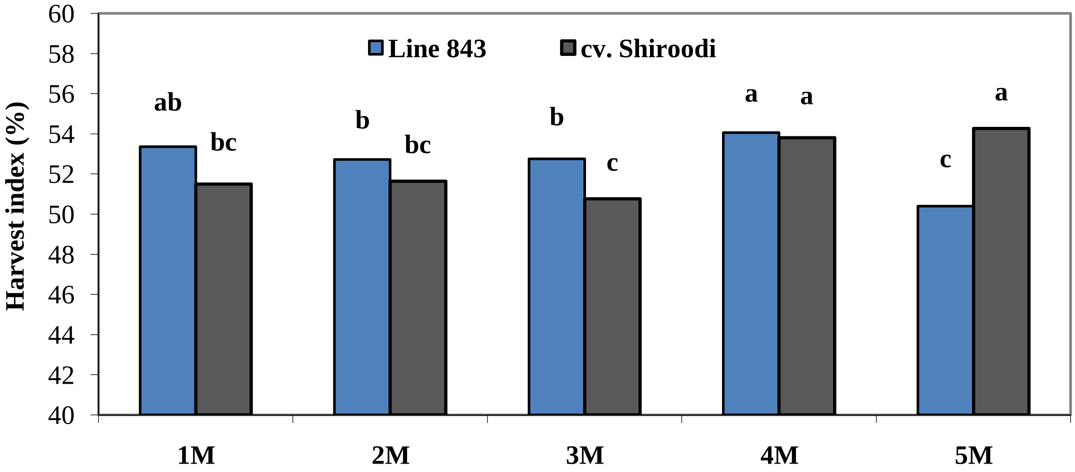

Figure 2. Double interaction of M*C on harvest index

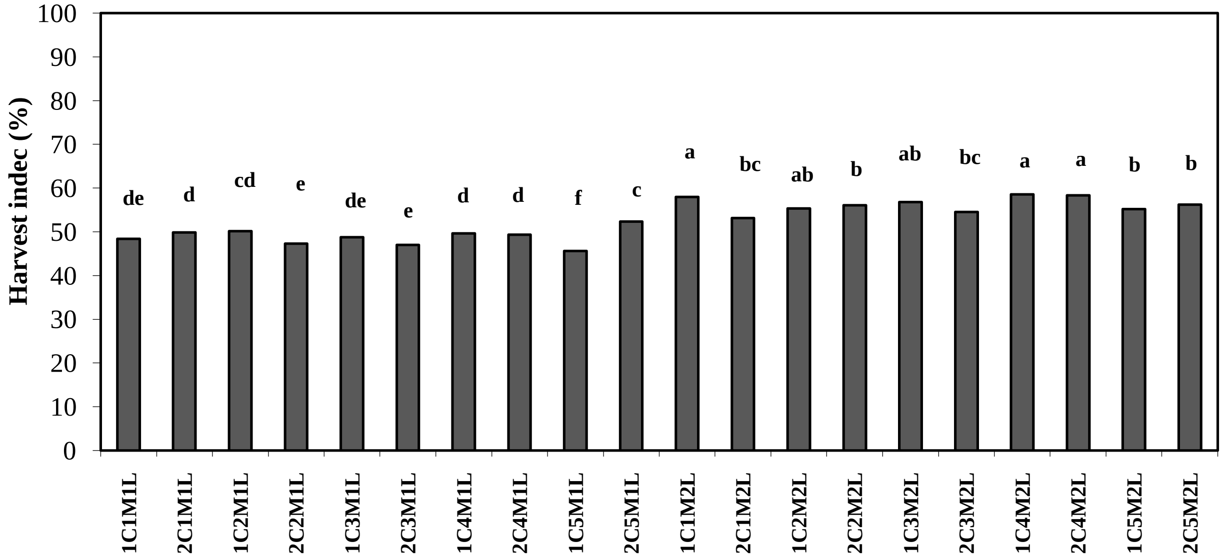

Figure 3. Triple interaction of L*M*C on harvest index

At triple interaction of L*M*C the maximum harvest index was obtained in $L_2M_1C_1$ 57.92 %, $L_2M_4C_1$ 58.52 % and $L_2M_4C_2$ 58.3 %, as the minimum harvest index was observed in $L_1M_5C_1$ 45.61 % (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 [43]. 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 [44].

Table 4. Mean comparison of of nutrient element stress on agronomical traits and yield yield in rice cultivars

Treatment	Panicle length (cm)	Number of filled spikelet per panicle	Grain length (mm)	Grain width (mm)	Grain yield (kg/ha)	Harvest index (%)
Location						
Rich soil	30.2 a	102.3 a	1.12 a	ns	6468 a	52.6 a
Poor soil	28.5 b	96.5 b	1.06 b	ns	5615 b	50.1 b
Macro element						
M_1	30.84 a	108.85 a	1.11 a	ns	6499.20 a	53.93 a
M_2	30.63 ab	105.03 ab	1.10 a	ns	6433.80 a	52.43 ab
M_3	30.33 b	104.08 ab	1.10 a	ns	6004.50 b	52.33 ab
M_4	29.68 c	99.61 bc	1.09 ab	ns	5121.00 c	52.18 ab
M_5	29.39 c	96.99 c	1.08 b	ns	4819.10 c	51.76 b
Micro element						
N_1	ns	ns	ns	ns	ns	ns
N_2	ns	ns	ns	ns	ns	ns
Cultivars						
Line 843	ns	105.43 a	1.12 a	0.23 a	5824.40 a	ns
Shiroodi	ns	100.39 b	1.07 b	0.21 b	5726.30 b	ns

Values within a column followed by same letter are not significantly different at Duncan ($P \leq 0.05$).
Macro element in five levels {M_1: NPK, M_2: PK, M_3: NK, M_4: NP and M_5: 1/3 NPK}
Micro elements in two levels as sub plots {N_1: Mn-Zn-Si and N_2: non application}

Table 5. Double interaction of location and macro element on panicle length and grain yield in rice

Interaction	Panicle length (cm)	Grain yield (kg/ha)
L_1M_1	31.03 a	5480.58 c
L_1M_2	29.90 b	4534.67 c
L_1M_3	30.97 a	5481.75 c
L_1M_4	30.37 a	5217.75 cd
L_1M_5	30.33 a	5062.58 d
L_2M_1	30.65 a	7517.75 a
L_2M_2	28.88 b	5103.50 d
L_2M_3	30.28 a	7383.75 a
L_2M_4	30.28 a	6791.25 b
L_2M_5	29.03 b	5179.50 d

Values within a column followed by same letter are not significantly different at Duncan ($P \leq 0.05$).
L_1 and L_2: Rich and poor farm location.
Macro element in five levels {M_1: NPK, M_2: PK, M_3: NK, M_4: NP and M_5: 1/3 NPK}

Table 6. Triple interaction of location with macro and micro element on panicle length and grain width in rice.

Interaction	Panicle length (cm)	Grain width (mm)
$L_1M_1N_1$	30.73 b	0.21 c
$L_1M_1N_2$	31.33 a	0.21 c
$L_1M_2N_1$	30.30 b	0.22 b
$L_1M_2N_2$	29.50 bc	0.21 c
$L_1M_3N_1$	31.27 a	0.21 c
$L_1M_3N_2$	30.67 b	0.25 a
$L_1M_4N_1$	30.30 b	0.22 b
$L_1M_4N_2$	30.43 b	0.21 c
$L_1M_5N_1$	29.87 bc	0.22 b
$L_1M_5N_2$	30.80 b	0.22 b
$L_2M_1N_1$	30.43 b	0.22 b
$L_2M_1N_2$	30.87 b	0.22 b
$L_2M_2N_1$	28.77 c	0.23 b
$L_2M_2N_2$	29.00 c	0.23 b
$L_2M_3N_1$	30.17 b	0.23 b
$L_2M_3N_2$	30.40 b	0.21 c
$L_2M_4N_1$	29.97 bc	0.21 c
$L_2M_4N_2$	30.60 b	0.23 b
$L_2M_5N_1$	29.20 bc	0.21 c
$L_2M_5N_2$	28.87 c	0.22 b

Values within a column followed by same letter are not significantly different at Duncan ($P \leq 0.05$).
**: L_1 and L_2: Rich and poor farm location.*: Macro element in five levels {M_1: NPK, M_2: PK, M_3: NK, M_4: NP and M_5: 1/3 NPK}. *: Micro elements in two levels as sub plots {N_1: Mn-Zn-Si and N_2: non application}*

Table 7. Double interaction of location and cultivar on panicle length, filled spikelet and grain length in rice

Interaction	Panicle length (cm)	Number of filled spikelet per panicle	Grain length (mm)
L_1C_1	30.48 a	100.60 a	1.07 b
L_1C_2	30.56 a	100.23 b	1.13 a
L_2C_1	30.10 ab	100.18 b	1.07 b
L_2C_2	29.56 b	110.63 a	1.11 ab

Values within a column followed by same letter are not significantly different at Duncan ($P \leq 0.05$).
L_1 and L_2: Rich and poor farm location. C_1 and C_2: Line 843 and Shiroodi cultivars.*

Table 8. Double interaction of micro element and cultivar on filled spikelet, grain length and grain yield in rice

Interaction	Number of filled spikelet per panicle	Grain length (mm)	Grain yield (kg/ha)
N_1C_1	99.04 c	1.06 c	5845.50 ab
N_1C_2	107.45 a	1.13 a	5740.50 b
N_2C_1	101.74 bc	1.08 b	5607.03 c
N_2C_2	103.41 ab	1.11 ab	5908.20 a

Values within a column followed by same letter are not significantly different at Duncan ($P \leq 0.05$).
L_1 and L_2: Rich and poor farm location.
Micro elements in two levels as sub plots {N_1: Mn-Zn-Si and N_2: non application}.

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