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Evaluation of related to lodging characteristics and grain yield in Iranian rice genotypes under modified agronomical systems

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ABSTRACT

This experiment was carried out at Neka, Mazandaran, Iran in 2011. This experiment was done as split plot in randomized complete blocks design based four replications. Planting systems were chosen as main plots (Conventional, Improved and SRI or System of Rice Intensification) and genotypes as sub plots (Tall cultivars: Sang Tarom and Hashemi Tarom; Semi dwarf cultivars: Neda and Shiroodi). The results showed that maximum panicle length, plant height and grain yield was obtained by improved system. Maximum 4th inter-nodes length, 3rd and 4th inter-node bending moment, 3rd and 4th inter-nodes lodging index and straw yield was presented by conventional system, but breaking resistance by SRI had maximum tolerance. Hashemi Tarom cultivar had maximum panicle length, plant height, 3rd and 4th inter-nodes length and 3rd inter-node bending moment. Maximum 4th inter-node length, 3rd and 4th inter-nodes lodging index and straw yield was determined for Sang Tarom and Hashemi Tarom cultivars. But highest grain yield was noted for Neda and Shiroodi cultivars. Maximum plant height and 4th inter-nodes lodging index was found by interaction conventional system × Hashemi Tarom cultivar. So according to the results improved system was the best one because of decrease in lodging and increase in grain yield.

Keywords: Bending moment, Breaking resistance, Lodging index, Planting system, Rice.

INTRODUCTION

Customary and conventional rice cultivation is faced with many problems because the lack of proper understanding of rice requirements. Inappropriate use of the water, fertilizers and chemical pesticides increased production costs, reduced yield and destroyed resources and environment in the long term. The System of Rice Intensification (SRI) is a method of increasing the yield of rice produced and decrease of water using in farming. It was developed in 1983 by the French Jesuit Father Henri de Laulanie in Madagascar. Assembly of the practices that culminated in SRI began in the 1960s based on Fr. de Laulanie's observation of 'positive-deviant' farmer practices, starting with planting single seedlings instead of multiple seedlings in a clump, and not keeping irrigated paddy fields flooded during the rice plants' vegetative growth stage. Planting with wider spacing in a square pattern, rather than randomly or in rows, followed, as did controlling weed growth by use of a soil-aerating push-weeder [1, 2]. Drainage of the season and periodic irrigation caused to remove of harmful gases, increase of rhizosphere oxidative activity, stimulation of root growth and increase of fertile tiller per hill. Alagesan and Budhar (2009) reported that use of weed rotary in SRI caused to increase in soil aerobic conditions, composition of soil with organic matter, tiller number and panicle number [3]. Grain yield decreased with SRI in salinity soil compare to conventional system because of periodic irrigation method [4]. Styger (2009) stated plants in SRI were ripped two weeks sooner than control and the net investment return was 108 % more than conventional system [5]. Diseases damage (sheath blight, leaf blight, cicala and brown grig) in SRI was less than conventional system (63, 76.5, 49.5 and 83 % respectively). Net income and grain yield increased at Bangladesh (59 and 27 %), Cambodia (74 and 41 %), China (64 and 29 %), India (67 and 32 %), Indonesia (100 and 78 %), Nepal (163 and 82 %) and Sri Lanka (117 and 49 %) in SRI [6].

Plants grown in SRI method have more root activity in flowering time and have more resistance to drought and lodging [7]. Research showed grain yield was 2 to 3 tone less in aerobic system compare to flooding irrigation and efficiency in water use was 64 to 88 % more in aerobic system compare to flooding irrigation. Release of oxygen is less than 10000 times in water compare to air and permanent flooding cause to lack of oxygen in rhizosphere and need more energy for formation of aeranchyma system consequently it decreased grain yield. Uptake of soil minerals decreased by permanent flooding and 78 % of rice roots in flowering time are dead in flooding conditions [8]. SRI system increased grain yield because of additive effects, periodic irrigation management, use of 3 to 3.5 leaves seedling, use of one seedling per hill with more space, square planting pattern and fertilization with the use of organic sources [1, 9]. The ability to provide nutrients and their absorption in the SRI system is more common methods of planting. The use of compost and organic fertilizers for gradual and steady share of nutrients, especially during the grain filling period associated with the increased volume of roots and soil to absorb more nutrients due to periodic irrigation increased grain yield. The use of compost and periodic irrigation under SRI system increased 3 tons per hectare yield compared to the conventional system of planting and this was for increase of panicle number per m^2 and filled spikelet per panicle [8]. Lodging is more effective elements in grain yield [10]. Photosynthetic capacity and dry matter production were decreased by change of planting densities and normal canopy condition [11]. Lodging prevents the transfer of water, food and assimilation (through phloem and xylem) and reduces the number of filled spikelet [12]. Increase of moisture in the lodging of a plant canopy provides for fungal growth and spread of diseases and makes disorder formation and grain quality [13]. Grains may grow on panicle in lie down plants, so it caused to decrease quality and quantity of grain, therefore lodging caused to increase cost of production by disorder in harvesting time and increase of grain drying [14]. Essential of agricultural sector are sustainable development of rice cultivation for yield increasing and optimal use of production inputs, protect the environment and production resources. Sustainable product depends on decrease of product cost and increase of production efficiency. Comprehensive system and holistic in planting method and rice field management are necessary and unavoidable for increase of yield and protect use of product inputs.

MATERIALS AND METHODS

In order to evaluation of related to lodging morphological characteristics and grain yield in Iranian rice genotypes under modified agronomical systems, an experiment was carried out at Neka, Mazandaran, Iran in 2011. The experimental farm is geographically situated at 43°, 36' N latitude and 13°, 53' E longitude at an altitude of 15 m above mean sea level. The soil was analyzed 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 2011.

Soil texture	K (ppm)	P (ppm)	N (%)	OM (%)	pH	EC (µmohs/cm)	Depth (cm)
Clay-loam	180	15.8	0.18	2.4	7.7	0.22	0-30

Table 2. Weather condition in experiment site in rice growth stages at Sari in 2011.

Variable	Jan.	Feb.	March	April	May	June	July	August
Minimum tem.	2.5	4.2	9.3	7.5	14	18.8	23.1	23.7
Maximum tem.	10.2	12.1	15.2	16.4	24	27.8	32.6	33.2
Evaporation (mm)	52	52	43	58.1	75.8	135.1	128.2	152.6
Precipitation (mm)	65	136	38	124.9	26.9	29.4	8.1	11.9

This experiment was conducted as split plot in randomized complete blocks design based four replications. Planting system were chosen as main plots (Conventional system, Improved system, and SRI or System of Rice

Intensification) and genotypes as sub plots (Tall cultivars: Sang Tarom and Hashemi Tarom; Semi dwarf cultivars: Neda and Shiroodi).

Conventional system: conventional planting (rill and stack), mature seedling (35 days after sowing), more than three seedlings per hill, random planting arrangement, permanent flooding and keep water in all vegetation period in field, without drainage, use of chemical fertilizers (200 kg h^{-1} N, 100 kg h^{-1} P and 100 kg h^{-1} K) which P and K fertilizers were applied before transplanting and 75 % N was used before transplanting and the rest of that was used 30 days after transplanting as top dressing fertilizer. Weeds control had done 28 and 40 days after transplanting by hand.

Improved system: planting (rill and stack), semi-mature seedling (25 days after sowing), two seedlings per hill with 20 × 20 cm^2 planting arrangement, permanent flooding and keep water in all vegetation period in field except one time drainage in tillering time, use of chemical fertilizers (200 kg h^{-1} N, 100 kg h^{-1} P and 100 kg h^{-1} K) which P fertilizer was applied before transplanting and 25 % N and 50 % K were used before transplanting and 25 % N and 50 % K were used 30 days after transplanting as top dressing fertilizers and the rest of N fertilizer was applied in heading time. Weeds control had done one time by herbicide and three times (28, 40 and 50 days) after transplanting by hand.

System of Rice Intensification (SRI): young seedling (20 days after sowing), one seedling per hill with 10 × 30 cm^2 planting arrangement, two weeks use flooding system then periodic irrigation system, use of 10 ton h^{-1} compost (cow and sheep manures) before transplanting and nitrogen fertilizer application (46 kg h^{-1}) was applied 50 % before transplanting and the rest of that was in heading time. Weeds control had done by rotary weeder (two to four times) and be used within two to seven days. During the growth time, following characteristics was measured randomly from each plot.

1. 20 panicles from each plot were collected for earmarking of morphological characteristic related to lodging [15].
2. Inter-nodes lengths of 1, 2, 3 and 4 (cm) were measured from top to bottom respectively.
3. Diameters of 3rd and 4th inter-nodes (mm) were measured by Caliper.
4. Bending moment of 3rd and 4th inter-nodes was calculated by below formula [15].

Bending moment of 3rd inter-node (g cm) = length of the plant from the lowest node of 3rd inter-node up to the panicle × the wet weight of the same part.
Bending movement of 4th inter-node (g cm) = length of the plant from the lowest node of 4th inter-node up to the panicle × the wet weight of the same part.

5. Breaking resistance was measured by prostrate tester [15].
6. Lodging index of 3rd and 4th inter-nodes was calculated by below formula [15].

$$\text{Lodging index of 3rd inter-node} = \frac{\text{Bending moment of 3rd inter-node}}{\text{Breaking resistance of 3rd inter-node}}$$

$$\text{Lodging index of 4th inter-node} = \frac{\text{Bending moment of 4th inter-node}}{\text{Breaking resistance of 4th inter-node}}$$

7. Grain yield was harvested from 4 m² from the middle of the sub plots with 12 % humidity [16].

Data analyzed by SAS statistical software and Averages comparison were calculated by Duncan's multiple range tests in a 5% probability level.

RESULTS AND DISCUSION

Lengths of 1st, 2nd, 3rd and 4th inter-nodes

Results in table 4 showed that lengths of 1st and 2nd inter-nodes were significant in 1% probability level and 5 % in lengths of 3rd and 4th inter-nodes. Also genotype effect was significant in 1% probability level on lengths of 1st, 2nd, 3rd and 4th inter-nodes. Interaction of planting system × genotype had significant effect on lengths of 1st and 3rd inter-nodes in 1 % probability level (Table 4). Maximum lengths of 1st and 3rd inter-nodes (43.25 and 17.06 cm) were obtained for conventional system and for 2nd inter-node was seen for improved system (31.13 cm) and conventional system (30.44 cm). But minimum lengths of 1st, 2nd and 3rd inter-nodes (39.31, 29.13 and 14.75 cm) were found for SRI. Maximum lengths of 1st and 2nd inter-nodes (51 and 26.5 cm) were observed for interaction of conventional system × Tarom Hashemi cultivar. Minimum length of 1st inter-node was seen in interaction of improved system × Neda cultivar (34.75 cm) and interaction of SRI × Neda cultivar (33.75 cm), but minimum length of 3rd inter-node was showed for SRI × Neda cultivar (19.25 cm) and interaction of conventional system × Neda cultivar (19.25 cm). The results shown that characteristics are under effect of genotype (Tbale 8). Islam *et al*. (2007) reported the maximum height difference was 30 % in 16 genotypes that were from 100 cm till 136 cm. There was no correlation between plant height and grain yield. Plant height, lengths of 1st, 2nd, 3rd, 4th inter-nodes, bending moments of 3rd and 4th inter-nodes had positive correlation [15].

Diameters of 3rd and 4th inter-nodes

This character was significant under effect of planting system and genotype in 1 % probability level. But interaction planting system × genotype was significant for diameter of 4th inter-node in 1 % probability level (Table 4). Minimum diameters of 3rd and 4th inter-nodes (2.38 and 3.28 mm) were observed for improved system and maximum of those (2.73 and 3.89 mm) for SRI and for conventional system (2.68 and 3.94 mm). Maximum diameters of 3rd and 4th inter-nodes (2.98 and 3.95 mm) were obtained for Shiroodi cultivar and minimum of those (2.28 and 3.15 mm) were for Sang Tarom cultivar (Table 5). Utmost diameter 4th inter-node under interaction SRI with Neda and Shiroodi cultivars was obtained (4.18 and 4.33 mm) and Shiroodi cultivar (4.33 mm) and lowest of that under interaction improved system and conventional system at Sang Tarom cultivar (3.05 or 3.03 mm) (Table 8). Morphological characteristics related to lodging were different in rice genotypes [15]. Wet weight of diameters of 3rd and 4th inter-nodes are important to the lodging because stem lodging were happened in lower inter-nodes [14, 17], so lower inter-nodes are important for breaking resistance and lodging index [15].

Wet weights of 3rd and 4th inter-nodes

Wet weight of 3rd inter-node was significant in 5 % probability level and in 1 % probability level was for wet weight of 3rd inter-node under planting system. Interaction planting system × genotype in 5 % probability level was considerable for wet weight of 3rd inter-node (Table 4). Smallest wet weights of 3rd and 4th inter-nodes (9.77 and 11.71 g) were shown for SRI and maximum wet weights of 3rd and 4th inter-nodes (2.68 and 14.81 g) were for conventional system. Maximum wet weights of 3rd and 4th inter-nodes (13.50 and 16.29 g) were demonstrated for Tarom Hashemi cultivar and minimum of those (8.75 and 11.01 g) were for Neda cultivar (Table 5). Maximum wet weight of 3rd inter-node (14.5 g) was observed under interaction conventional system × Tarom Hashemi cultivar and minimum of that was for interaction SRI × Shiroodi cultivar (Table 8). Diameters and wet weights of 3rd and 4th inter-nodes are important for rice lodging because stem lodging were happened in lower inter-nodes [14, 17], so lower inter-nodes are important for breaking resistance and lodging index [15].

Inter-nodes number

Inter-nodes number showed significant difference in 1 % probability level under genotype effect (Table 4). Maximum inter-nodes were obtained for Sang tarom (4.72) and Tarom Hashemi (4.83), minimum of that were for Neda (4.13) and Shiroodi (4.18) (Table 5). Isalam *et al.* (2007) found that there is a significant difference among rice difference genotypes and inter-nodes number have shown positive correlation between morphological characteristics related to the lodging and breaking resistance in two years [15].

Length and angle of flag leaf

Flag leaf length demonstrated significant difference in 1 % in probability and 5 % in probability level for flag leaf angle under planting system (Table 4). Maximum flag leaf length (31.75 cm) and flag leaf angle (85.86°) were seen under improved system, minimum flag leaf length (27.81 cm) and flag leaf angle (76.69°) were obtained for conventional system and SRI respectively (Table 5).

Length and weight of panicle

Panicle length showed significant difference in 5 % in probability and 1 % in probability level for panicle weight under planting system (Table 4). Maximum panicle length (27.38 cm) and panicle weight (4.23 g) were seen under improved system, minimum panicle length (25.31 cm) and panicle weight (3.75 g) were obtained for conventional system (Table 5). Longest panicle length (29.50 cm) was found for Tarom Hashemi and shortest of that (23.58 cm) was for Neda cultivar. Maximum panicle weight (5.17 g) was for Shiroodi cultivar and minimum of that (3.22 g) was for Tarom Hashemi cultivar (Table 5). Yadi *et al.*, (2011) stated that maximum panicle length has seen for Tall plant and minimum of that was for Short plant [18].

Plant height and stem length
Plant height showed significant difference under effect of planting system and interaction planting system × modified system in 1 and 5 % probability level respectively. Plant height and stem length both had significant difference under effect of genotype in 1 % probability level (Table 4). Highest plant height (123.6 cm) was observed in improved system because of panicle length, also shortest of that (117.7 cm) was for SRI. Stem length Sang Tarom (107.3 cm) and Tarom Hashemi (112.5 cm) were bigger than Neda cultivar (77.85 cm) and Shiroodi (81 cm). Tarom Hashemi (141.2 cm) was highest rice among of other cultivars because of genetically, increase lengths of 1st, 2nd, 3rd and 4th inter-nodes, increase stem length and panicle, and minimum of that (106 cm) was for Neda cultivar because of genetically, decrease lengths of 1st, 2nd, 3rd and 4th inter-nodes, decrease stem length and panicle (Table 5). Maximum plant height (149 cm) was obtained for interaction conventional system × Tarom Hashemi cultivar and minimum of that (102.5 cm) was for interaction SRI × Neda cultivar (Table 8). Islam *et al.,* (2007) reported there is no relation between plant height and grain yield but there are positive correlation between inter-nodes and bending moment [15]. Yadi *et al.,* (2001) stated that maximum breaking resistance and minimum lodging index was for short plant (Langroodi cultivar) which had shorter inter-node, plant height and decrease of inter-nodes number [18]. Increase of stem length and leaf area index in hybrid rice might involve increasing bending moment and lodging index [19].

Bending moment of 3rd and 4th inter-nodes
Bending moment of 3rd and 4th inter-nodes was significant in 1 % probability level under effect of planting system and genotype. Bending moment of 3rd inter-node showed significant in 5 % probability level under interaction planting system × genotype (Table 6). Maximum bending moment of 3rd and 4th inter-nodes (2008 and 2758 g cm) depicted for conventional system because of increase lengths of 1st, 2nd and 3rd inter-nodes, also increase of diameter and wet weight 3rd and 4th inter-nodes, minimum bending moment of 3rd and 4th inter-nodes was (1702 and 2369 g cm) for SRI. Maximum bending moment of 3rd inter-node (2074 g cm) had seen in Tarom Hashemi cultivar because of increase lengths of 1st, 2nd, 3rd and 4th inter-nodes, wet weight of 3rd and 4th inter-nodes, length of stem and panicle, therefore Neda cultivar (1631 g cm) showed minimum on bending moment of 3rd inter-node. For 4th inter-node Sang Tarom and Tarom Hashemi (3002 and 3125 g cm) demonstrated maximum bending moment, hence Neda and Shiroodi cultivar (1985 and 2068 g cm) were observed as minimum bending moment (Table 7). According to table 8 minimum bending moment of 3rd inter-node (1559 g cm) was found for interaction SRI × Neda cultivar and maximum of that (2301 g cm) was for interaction conventional system × Tarom hashemi cultivar.

Breaking resistance of 3rd and 4th inter-nodes
As we can see in table 6, breaking resistance of 3rd and 4th inter-nodes are significant under simple effects of planting system and genotype in 1 % probability level but breaking resistance of 4th inter-node had significant difference under interaction planting system × genotype in 1 % probability level (Table 6). Maximum breaking resistance of 3rd and 4th inter-nodes (10.32 and 16.43 g stem^{-1}) was related to SRI and minimum breaking resistance of 3rd inter-node (8.56 g stem^{-1}) was for improved system and for 4th inter-node (14.68 g stem^{-1}) was for conventional system. Minimum breaking resistance of 3rd inter-node (7.38 and 7.68 g stem^{-1}) and 4th inter-node (14.23 and 14.32 g stem^{-1}) were observed for Sang Tarom and Tarom Hashemi, maximum of them (11.18 and 16.75 g stem^{-1}) was for Shiroodi cultivar (Table 7). Maximum breaking resistance of 4th inter-node (17.58 g stem^{-1}) was under interaction SRI × Shiroodi cultivar and minimum of that (13.38 g stem^{-1}) was for interaction conventional system × Sang Tarom cultivar (Table 8). Yadi *et al.,* (2011) found that maximum breaking resistance and minimum lodging index was for short plant (Langroodi cultivar) which had shorter inter-node, plant height and decrease of inter-nodes number [18]. Increase of stem length and leaf area index in hybrid rice might involve increasing bending moment and lodging index [19]. Breaking resistance and lodging index decreased by reduce of seedling number per hill [20]. Diameters and wet weights of 3rd and 4th inter-nodes are important for rice lodging because stem lodging were happened in lower inter-nodes [14, 17], so lower inter-nodes are important for breaking resistance and lodging index [15]. In SRI, plants have more activity in root in flowering time, so they have more resistance to drought and lodging [7].

Lodging index of 3rd and 4th inter-nodes
Statistically, lodging index of 3rd and 4th inter-nodes was significant under effect planting system and genotype in 1 % probability level. Also lodging index of 3rd and 4th inter-nodes have showed significant under interaction planting system × genotype in 1 and 5 % probability level respectively (Table 6). Maximum lodging index of 3rd and 4th inter-nodes (252.8 and 193.1) were observed for conventional system and minimum of those (172.6 and 148.3) were for SRI. Improve of morphological characteristics related to lodging and decrease bending moment of 3rd and 4th

inter-nodes and also increase breaking resistance of 3rd and 4th inter-nodes caused to reduce lodging index in SRI. Maximum lodging index of 3rd and 4th inter-nodes was obtained for Sang Tarom (274 and 213.3) and Tarom Hasehmi (279.3 and 219.7), minimum of those was observed for Neda cultivar (159 and 123.1) and Shiroodi cultivar (156.8 and 126.9) (Table 7). Highest lodging index of 3rd and 4th inter-nodes (335.3 and 251.5) was noted under interaction conventional system × Tarom Hashemi cultivar, the lowest lodging index of 3rd inter-node (131) was seen under interaction SRI × Shiroodi cultivar and for 4th inter-node (107.3) was under interaction SRI × Neda cultivar (Table 8). Yadi *et al.*, (2011) found that maximum breaking resistance and minimum lodging index was for short plant (Langroodi cultivar) which had shorter inter-node, plant height and decrease of inter-nodes number [18]. Increase of stem length and leaf area index in hybrid rice might involve increasing bending moment and lodging index [19]. Breaking resistance and lodging index decreased by reduce of seedling number per hill [20]. Diameters and wet weights of 3rd and 4th inter-nodes are important for rice lodging because stem lodging were happened in lower inter-nodes [14, 17], so lower inter-nodes are important for breaking resistance and lodging index [15]. In SRI, plants have more activity in root in flowering time, so they have more resistance to drought and lodging [7].

Straw yield

Straw yield was significant under effect planting system in 5 % probability level and under effect genotype 1 % probability level (Table 6). Maximum straw yield (7200 kg h^{-1}) was obtained for conventional system and minimum of that (6529 kg h^{-1}) was for improved system. Straw yield increased by conventional system because of increase in tillers, lengths of 1st, 2nd, 3rd and 4th inter-nodes and wet weight of 3rd and 4th inter-nodes. Maximum straw yield (7479 kg h^{-1}) was recorded for Sang Tarom cultivar because of being tall plant, increase length of inter-node and plant height, minimum of that (6077 kg h^{-1}) was for Shiroodi cultivar (Table 7).

Grain yield

According to table 6, grain yield showed significant difference by planting system in 5 % in probability level and by genotype in 1 % probability level (Table 6). Maximum grain yield (4115 kg h^{-1}) was noted for improved system and minimum of that (3756 kg h^{-1}) was for SRI system. Maximum grain yield was found for Tarom Hashemi and Sang Tarom (3371 and 3449 kg h^{-1}) cultivars and minimum of that was obtained for Shiroodi cultivar (6397 and 6077 kg h^{-1}). Neda and Shiroodi cultivars had more yield because of being short plant, less distance between sink and source and more dry matter transfer to grain consequently increase grain yield, so they have more yield than Sang tarom and Tarom hashemi cultivar (Table 7). Grain yield, a quantitative trait, is itself regulated by various processes of growth, differentiation, including phenology of grain yield formation. It has been customary to consider yield as a single character even though it comprises several components (morphologically differentiated reproductive parts) and each contributing to the final expression of grain yield [21]. SRI decreased grain yield in salinity soil compare to conventional system because of periodic irrigation system. Also grain yield decreased by use of compost and organic combinations in single experiments [4].

Table 3. Mean square of planting system on lodging related characteristics in rice genotypes.

Sours Of Variation	DF	Stem length	Panicle length	Plant height	Panicle fresh weight	Flag leaf length	Flag leaf angle	Internode number	First internode length	Second internode length	Third internode length	Fourth internode length	Third internode diameter	Fourth internode diameter
Replication	3	665.17^{ns}	2.69^{ns}	168.58^{ns}	2.23^{**}	8.63^{ns}	93.92^{ns}	0.06^{ns}	35.33^{**}	14.24^{*}	12.91^{ns}	15.35^{*}	0.31^{*}	0.72^{**}
Planting systems (A)	2	40.65^{ns}	19.31^{*}	267.58^{**}	26.14^{**}	65.27^{**}	336.40^{*}	0.04^{ns}	62.65^{**}	16.52^{**}	9.25^{ns}	21.81^{*}	0.60^{**}	1.70^{**}
E (A)	6	270.65	4.67	10.22	0.04	3.05	66.56	0.16	2.06	1.49	4.89	3.98	1.04	0.03
Genotypes (B)	3	3819.83^{**}	87.92^{**}	3606.58^{**}	16.25^{**}	72.41^{**}	335.25^{**}	1.53^{**}	485.28^{**}	53.58^{**}	75.85^{**}	135.41^{**}	1.08^{**}	1.48^{**}
A×B	6	160.90^{ns}	0.90^{ns}	35.14^{*}	0.02^{ns}	2.24^{ns}	3.40^{ns}	0.02^{ns}	5.51^{**}	1.58^{ns}	2.17^{**}	0.29^{ns}	0.01^{ns}	0.06^{**}
E	27	113.71	2.05	10.30	0.03	1.50	11.11	0.02	0.75	1.10	0.34	0.88	0.03	0.02
C.V. (%)	-	11.27	5.48	2.61	3.98	4.15	4.07	3.33	2.10	3.46	2.61	5.94	6.05	3.55

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

Table 4. Mean comparison of planting system on lodging related characteristics in rice genotypes.

Treatments	Stem length (cm)	Panicle length (cm)	Plant height (cm)	Panicle fresh weight(g)	Flag leaf length(cm)	Flag leaf angle	Internode number	First internode length(cm)	Second internode length(cm)	Third internode length(cm)	Fourth internode length(cm)	Third internode diameter	Fourth internode diameter
Planting systems													
Improved system	96.19 a	27.38 a	123.60 a	4.23 a	31.75 a	85.56 a	4.44 a	40.94 b	31.13 a	22.69 a	15.63 ab	2.38 a	3.28 b
SRI	93.00 a	25.69 ab	118.70 b	3.98 b	29.00 b	76.69 b	4.52 a	39.31 c	29.13 b	21.44 a	14.75 b	2.73 a	3.89 a
Conventional system	94.56 a	25.31 b	119.80 b	3.75 c	27.81 b	83.13 ab	4.44 a	43.25 a	31.44 a	22.81 a	17.06 a	2.68 a	3.94 b
Genotypes													
Sang Tarom	107.30 a	27.08 b	134.30 b	2.78 d	30.08 b	87.33 a	4.72 a	44.00 b	30.42 b	23.25 b	17.75 b	2.28 d	3.15 d
Tarom Hashemi	112.50 a	29.50 a	141.20 a	3.22 c	32.58 a	85.58 a	4.83 a	48.75 a	33.08 a	25.33 a	19.50 a	2.48 c	3.42 c
Neda	77.58 b	23.58 c	106.00 d	4.78 b	26.75 d	76.83 b	4.13 b	35.08 d	28.17 d	19.58 d	12.42 d	2.65 b	3.65 b
Shiroodi	81.00 b	24.33 c	110.60 c	5.17 a	28.67 c	77.42 b	4.18 b	36.83 c	29.25 c	21.08 c	13.58 c	2.98 a	3.95 a

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

Table 5. Interaction effect of planting system × genotypes on lodging related characteristics in rice.

Interaction	Stem length (cm)	Panicle length (cm)	Plant height (cm)	Panicle fresh weight(g)	Flag leaf length(cm)	Flag leaf angle	Internode number	First internode length(cm)	Second internode length(cm)	Third internode length(cm)	Fourth internode length(cm)	Third internode diameter	Fourth internode diameter
S_1V_1	107.50 ab	28.25 abc	135.80 b	3.00 g	32.25 b	90.75 a	4.70 a	44.00 d	31.25 b	23.50 d	17.50 cd	2.08 g	3.05 h
S_1V_2	111.00 ab	30.25 a	138.80 b	3.38 f	35.50 a	88.50 a	4.88 a	48.50 b	34.00 a	25.25 b	19.25 b	2.25 fg	3.13 gh
S_1V_3	81.25 c	25.00 def	106.30 ef	5.08 bc	29.50 cde	81.50 bc	4.05 b	34.75 h	29.25 cde	20.25 f	12.25 fg	2.45 def	3.33 efg
S_1V_4	85.00 c	26.00 cde	113.50 d	5.48 a	29.75 cd	81.50 bc	4.13 b	36.50 fg	30.00 bcd	21.75 e	13.50 ef	2.73 cd	3.63 cd
S_2V_1	102.50 b	26.25 cde	128.80 c	2.78 gh	29.50 cde	82.75 b	4.75 a	40.50 e	29.25 cde	21.75 e	16.50 d	2.35 ef	3.74 ef
S_2V_2	106.30 ab	29.50 a	135.80 b	3.28 f	31.75 b	80.50 bc	4.80 a	46.75 c	31.25 b	24.25 cd	18.25 bc	2.60 cde	3.70 bc
S_2V_3	79.50 c	23.00 f	105.50 f	4.70 de	26.25 fg	72.00d	4.25 b	33.75 h	27.00 f	19.25 g	11.50 g	2.8 bc	4.18 a
S_2V_4	83.75 c	24.00 ef	107.80 e	5.15 b	28.50 de	71.50 d	4.28 b	36.25 g	29.00 de	20.50 f	12.75 fg	3.18 a	4.33 a
S_3V_1	111.80 ab	26.75 bcd	138.50 b	2.55 h	28.50 de	88.50 a	4.70 a	47.50 bc	30.75 bc	24.50 bc	19.15 b	2.40 ef	3.03 h
S_3V_2	120.30 a	28.75 bcd	149.30 a	3.00 g	30.50 bc	87.75 a	4.80 a	51.00 a	34.00 a	26.50 a	21.00 a	2.58 cde	3.20 fgh
S_3V_3	72.00 c	22.75 f	109.30 de	4.58 e	24.50 g	77.00 c	4.10 b	36.75 fg	28.25 ef	19.25 g	13.50 ef	2.70 cd	3.45 de
S_3V_4	74.25 c	23.00 f	110.50 de	4.88 cd	27.75 ef	79.25 bc	4.15 b	37.75 f	28.75 de	21.00 ef	14.50 e	3.05 ab	3.90 b

Values within a column followed by same letter are not significantly different at Duncan ($P \le 0.05$).
S_1, S_2 and S_3: Improved planting system, SRI and Conventional planting system, respectively.
V_1, V_2, V_3 and V_4: Sang Tarom, Tarom Hashemi, Neda and Shiroodi genotypes, respectively.

Table 6. Mean square of planting system on lodging related characteristics in rice genotypes.

Sours Of Variation	DF	Third internode fresh weight	Fourth internode fresh weight	Third internode bending moment	Fourth internode bending moment	Third internode breaking resistance	Fourth internode breaking resistance	Third internode lodging index	Fourth internode lodging index	Grain yield	Straw yield
Replication	3	45.32**	37.50**	625793.17**	35727.61ns	21.58**	4.54*	8338.24**	902.50*	1733897.63**	1201424.80*
Planting systems (A)	2	14.73*	39.19**	371652.77*	622851.81**	15.95**	13.58**	26742.27**	8055.25**	603487.58*	2262699.15*
E (A)	6	3.10	2.74	30518.60	23383.42	0.61	0.88	577.66	265.92	75693.11	350625.26
Genotypes (B)	3	56.03**	67.05**	533374.39**	4348032.28**	44.92**	20.51**	56512.85**	33598.61**	3968702.13**	4959737.08**
A×B	6	1.05*	0.43ns	19744.33*	10187.59ns	0.18ns	0.32ns	2232.02**	550.53*	158099.03ns	477610.54ns
E	27	0.43	0.60	5714.29	45158.54	0.40	0.07	252.73	188.83	171365.12	380557.59
C.V. (%)	-	6.11	5.80	4.09	8.35	6.90	1.75	7.32	8.05	10.63	9.12

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

Table 7. Mean comparison of planting system on lodging related characteristics in rice genotypes.

Treatments	Third internode fresh weight(g)	Fourth internode fresh weight(g)	Third internode bending moment(g.cm)	Fourth internode bending moment(g.cm)	Third internode breaking resistance	Fourth internode breaking resistance	Third internode lodging index	Fourth internode lodging index	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Planting systems										
Improved system	10.75 ab	13.59 a	1826 b	2508 b	8.63 b	15.06 b	226.50 b	170.90 b	4115 a	6529 b
SRI	9.77 b	11.71 b	1705 b	2369 c	10.32 a	16.43 a	172.50 c	148.30 c	3756 b	6571 b
Conventional system	11.69 a	14.81 a	2008 a	2758 a	8.56 b	14.68 b	252.80 a	193.10 a	3807 b	7200 a
Genotypes										
Sang Tarom	11.38 b	14.21 b	1972 b	3002 a	7.38 c	14.23 c	274.00 a	213.30 a	3371 b	7479 a
Tarom Hashemi	13.50 a	16.29 a	2074 a	3125 a	7.64 c	14.32 c	279.30 a	219.70 a	3449 b	7114 a
Neda	8.75 d	11.01 d	1631 d	1985 b	10.47 b	16.27 b	159.00 b	123.10 b	4206 a	6397 b
Shiroodi	9.32 c	11.98 c	1707 c	2068 b	11.18 a	16.75 a	156.80 b	126.90 b	4545 a	6077 b

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

Table 8. Interaction of planting system × genotypes on lodging related characteristics in rice.

Interaction	Third internode fresh weight(g)	Fourth internode fresh weight(g)	Third internode bending moment(g.cm)	Fourth internode bending moment(g.cm)	Third internode breaking resistance	Fourth internode breaking resistance	Third internode lodging index	Fourth internode lodging index	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
S_1V_1	11.50 d	14.25 c	1930 c	3002 bc	6.83 e	13.58 h	284.50 b	221.80 bc	3690 de	7341 a
S_1V_2	13.50 b	16.50 b	2065 b	3078 abc	7.10 e	14.18 g	292.30 b	217.30 c	3782 cde	7218 a
S_1V_3	8.75 g	11.25 ef	1609 fg	1922 de	9.80 c	15.97 de	167.80 d	121.00 efg	4416 abc	5962 bcd
S_1V_4	9.25 fg	12.38 de	1699 ef	2029 de	10.77 bc	16.50 c	161.50 d	123.50 efg	4572 ab	5597 d
S_2V_1	9.88 ef	12.38 de	1793 de	2783 c	8.55 d	15.73 e	210.80 c	177.00 d	3245 e	7582 a
S_2V_2	12.50 c	14.38 c	1858 cd	2905 bc	8.85 d	15.25 f	210.50 c	190.30 d	3383 e	6767 abc
S_2V_3	8.50 g	9.65 g	1559 g	1845 e	11.43 b	17.17 b	138.00 e	107.30 g	4120 bcd	6114 bcd
S_2V_4	8.20 g	10.43 fg	1610 fg	1943 de	12.45 a	17.58 a	131.00 e	118.50 fg	4277 a-d	5820 cd
S_3V_1	12.75 bc	16.00 b	2192 a	3222 ab	6.78 e	13.38 h	326.80 a	241.30 ab	3179 e	7514 a
S_3V_2	14.50 a	18.00 a	2301 a	3391 a	6.98 e	13.52 h	335.30 a	251.50 a	3181 e	7357 a
S_3V_3	9.00 fg	12.13 de	1727 e	2188 d	10.18 c	15.65 e	171.30 d	141.00 e	4082 bcd	7116 a
S_3V_4	10.50 e	13.13 d	1812 de	2232 d	1030 c	16.17 cd	177.80 d	138.80 ef	4786 a	6814 ab

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

S_1, S_2 and S_3: Improved planting system, SRI and Conventional planting system, respectively.

V_1, V_2, V_3 and V_4: Sang Tarom, Tarom Hashemi, Neda and Shiroodi genotypes, respectively.

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