

Effect of Plant Density on Morphologic Characteristics Related to Lodging and Yield Components in Different Rice Varieties (*Oriza Sativa* L.)

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Abstract

In order to study the effects of plant density on agronomical and morphologic characteristics which are related to the lodging in rice varieties, an experiment was carried out in 2008 in split plot in randomized complete block design based on 4 replications in Iran. In this experiment, five rice varieties of Tarom (Local, Hashemi, Dilamani, Langhrodi and Sangh) were chosen as main factors and three plant density levels (40, 80, and 120 bushes per m²) as sub-factors. The results showed that Langhrodi Tarom had minimum total number of spikelets and number of hollow spikelets per panicle and minimum tiller per bush and number of panicles per m² had seen sequentially in Local Tarom and Sangh Tarom. The shortest length of first, second, and third inter-nodes, longest diagonal of the third inter-node and minimum plant height obtained for Langhrodi Tarom. Number of node and length of first, second and third inter-node and diagonal of the forth inter-node and Stem tension to lodging in third and forth inter-node decreased as plant density increased. Minimum lodging index of the third and forth inter-node came out at 80 bushes per m². Interaction effects in plant density had significant effects on all parameters except panicle number per m².

Keywords: Rice, Plant-density, Bending movement, Lodging index

1. Introduction

Lodging is one of the important environmental factors for limiting of having the maximum grain yield in cereal such as rice (Setter *et al.*, 1997). In plant density with destruction of normal structure of canopy, the photosynthesis capability and dry-material production is decreased (Hitaka and Kobayashi, 1961). Lodging prevents the water transition, nutrition and assimilation through xylem and phloem and consequently, reduces the fill of the seeds (Kashikawa *et al.*, 2005). Increasing of the lodging humidity in a canopy, prepares the conditions of illness expanding and growth of fungus, which is the limiting factor for constructing and qualification of the seeds (Kono, 1995).

In those plants which have faced lodging, it is possible that some kinds of seeds, that have a weak dormancy, can germinate on the panicle of main bush. But lodging decreases the qualitative and quantitative of the seeds. Therefore, lodging brings problems in harvest, increases the time of seed-dryness and finally increases the expenses of the production (Hoshikawa *et al.*, 1990). Expanding of short-height rice varieties and wheat in 1960s by Sd-1 gene brought a lot of success for improvement of insistency against the lodging and increasing of grain yield potential (Chandler, 1969). The reduction of plant height with Sd-1 gene reduced the effects of up parts of the plant on lower parts and also it improved the insistency against the lodging. The recent studies revealed that

grain yield does not change because short-height of the rice limits the canopy photosynthesis and biomass production (Kuroda *et al.*, 1989).

Flintham *et al.* (1997) indicated that plant height for maximum photosynthesis capacity in canopy should be suitable and grain yield can reduce with reduction of plant height under less than proper level, But Ookawa *et al.* (1992) reported that the plant height is not a significant and necessary factor for identifying of resistance rate against the lodging and the lodging ability is diverse among varieties with same plant height (Ookawa and Ishihara, 1992). Among of morphological characteristics, there is a connection between the weight and diagonal of the stem with the resistance against the lodging and stem stability with brokenness (Yoshinaga, 2005). The husk of leaf and length of below inter-node of the stem are main characters for recognizing of the stem consistency (Chang and Vergara, 1972). The husk of the leaf helps 30-60% the resistance of above ground parts brokenness (Chang, 1964). Lodging resistance in below inter-nodes is twice more than the leaf-husk and thrice more than the middle inter-node (Ookawa and Ishihara, 1992).

The resistance-pressure is a lodging index which has a positive correspondence with the thickness of the stem and the weight of the roots under the deep soil (Terashima *et al.*, 1994). Maximum use of necessary factors for the growth of the plant occurs when the canopy enters maximum pressure to the all production factors; consequently, because of canopy competition among the bushes of this canopy goes under extreme stress (Dunald and Dilly, 1982). Hence, when the fertility of the soil is abundant we should have consideration to the number of bush per square-unit in comparison with the weakness of the soil (tang and Oingfa, 2000). Whereas the economic yield includes only the grain yield, then we have to choose an proper planting distance and beyond that because of high planting-density, photosynthesis material is consumed for the growth and respiration of the plant rather than growth of the grain (Hadji, 2002).

Baloch *et al.* (2002) found that the reason of rice grain yield enhancement under high plant density was due to the increase of the panicles in M^2 . But at the same time the number of tillers and effective tiller in bush showed significant reduction (Baloch *et al.*, 2002). Therefore, with increasing of planting-density, in spite of the reduction of total number of tiller and effective tiller per bush, because of the increasing of the stem per square meter; consequently, number of panicle in M^2 and grain yield were increased. Also plant height in various genotypes of rice decreased by the increasing plant density (Mobasser *et al.*, 2007). According to the importance of plant density on yield and yield components and also extreme role of lodging on agronomical characteristics of the rice an experiment was conducted for study effects of plant density on the morphological and yield components characteristics of lodging in 5 varieties of rice.

2. Materials and Methods

In order to consider effect of plant density on agronomical characteristics, indices of lodging resistance and rice varieties yield an experiment was done during the year 2009 in Babol, Iran. This place has 36° , $33'$ N and 53° E and 14 meters above the sea level. Rainfall and evaporation was 79.9 cm. Maximum rains were 42 mm in (Aug-Sep) and minimum rain in (May-Jun) was about 0.3 mm. The soil of field was clay-loam. The results of soil analysis were as follows:

Depth=0-30 cm

pH = 7.94

Electric conductivity = 0.8 mille-mousse

OM = 3.38

Available P= 23 ppm

Available K = 100 ppm

Total Nitrogen = 22%

This experiment was done as split plot in randomized complete blocks design based 4 replications. Rice variety was arranged as main factor in five varieties which are famous in Iran (Local Tarom, Hashemi Tarom, Deylami Tarom, Langhrodi Tarom, and Sangh Tarom) and plant density was as sub-factor in three levels (40, 80, and 120 bushes in M^2 respectively). Rice was also the previous cultivated product. For planting of the rice at the end of February the field was plowed and at the middle of May was done the complete plow operation, which includes vernal plow, trowel and levelling. Before transplanting, the field divided into four replications and in any repetition it divided into 15 plots, $2 \times 5 m^2$.

150 kg/ha Urea was supplemented as a source of urea to the main plant in three times (in time of transplantation, in time of initiative panicle, and in time of complete panicle). Also Phosphoric fertilizer in form of triple super-phosphate and potassium fertilizer in form of Sulphate-potassium was used about 110 and 100 kg/ha respectively. When the seedlings have gotten 25 cm of height, seedlings were uprooted then were transplanted in main field according to plant-density treatment with various plant-dressing. All operations like irrigation, weeds control, plant illnesses controlling, pests controlling were done during the growth process with chemical

components.

During the growth time, following characteristics was measured randomly from each plot.

- 1) Plant height was measured from 12 bushes in middle of each plot.
- 2) Number of panicle per M² was numerated in the middle of each plot.
- 3) Total number of tiller was numerated per bush in each plot from 12 bushes.
- 4) Total number of spikelet per panicle and number of hollow spikelet per panicle were counted from 15 panicles in each plot.
- 5) Grain yield and biomass were harvested from 4 M² from the middle of the plot with 12% humidity.
- 6) Also harvest index has come from grain yield / biologic yield.
- 7) Weight of 1000-seed by choosing and numerating of 10 panicles in hundred numbers (in 12% humidity).

For measuring characteristics morphological (30 days after panicle initiation) from each plot 4 bushes and from per bush 3 stems were chosen and then these characteristics were measuring:

- 1) Length of inter-node 1, 2, 3 and 4 (numeration of inter-node is from up to down of the stem) were measured in cm.
- 2) Diagonal of 3rd and 4th inter-node was measured by calliper in millimetre.
- 3) Stem tension to lodging in 3rd and 4th inter-node of any stem was measured as below:
Stem tension to lodging of the 3rd inter-node = length of the plant from the lowest node of 3rd inter-node up to the panicle × the wet weight of same part.
Stem tension to lodging of 4th inter-node = length of the plant from the lowest node of 4th inter-node up to the panicle × the wet weight of the same part.
- 4) Lodging resistance was calculated by Prost rate and according to the necessary power for breaking of 3rd and 4th inter-nodes of the stem.

Lodging index of 3rd and 4th inter-nodes brought out by these formulas:

$$(\text{Lodging index of 3}^{\text{rd}} \text{ inter-node}) LIN3 = \frac{\text{Stem tension to lodging of 3}^{\text{rd}} \text{ inter-node}}{\text{Lodging resistance of 3}^{\text{rd}} \text{ inter-node}}$$

$$(\text{Lodging index of 4}^{\text{th}} \text{ inter-node}) LIN4 = \frac{\text{Stem tension to lodging of 4}^{\text{th}} \text{ inter-node}}{\text{Lodging resistance of 4}^{\text{th}} \text{ inter-node}}$$

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

3. Results and Discussion

3.1 The effect of variety and interaction effect of variety × plant density over morphological treats and yield components

As it is seen in the diagram 1, plant height was significant under the effect of variety and interaction effect of variety × plant density in 1% probability level. The max and min plant height came out, sequentially, local Tarom and langhrodi Tarom. Also in table 2 it is seen that with increasing of plant density from 40 to 120 bushes in any m² plant height had decrease 1/42% but it was nonsignificantly. Max plant height was (168/5 cm) under the interaction effect of variety × planting-density, for local Tarom with 40 bushes in M² and min plant height was (132/5 cm) for Langhrodi Tarom with 120 bushes in M² (Diagram1). Number of tiller per bush was significant under effect of variety, plant density and their interaction effects in 1% probability level (table 1). In table 2 we can see that the minimum number of tiller per bush is for local Tarom, maximum of that is for Hashemi Tarom and Dilamani Tarom. Maximum total number of tiller per bush was under the various plant density for 40 bushes per M² and by increasing of plant density up to 80 and 120 bushes in M² this number was reduced. Maximum total number of tiller per bush under the interaction effects of variety × plant density was for Dilamani Tarom with 40 bushes per M² and minimum of that was for Langhrodi Tarom with 120 bushes per M² (Table 3).

Total number of spikelet and hollow spikelet per panicle had not a significantly difference under the effect of variety and interaction variety effects × plant density in 1% probability level (Table 1). Minimum total number of spikelet and hollow spikelet per panicle came to Langhrodi Tarom. Maximum hollow spikelet was seen in Sangh Tarom (Table 2). Sangh Tarom had maximum number of hollow spikelet per panicle, minimum number of panicle per M² and consequently it had minimum grain yield. It is clear from the table 1 that the number of panicle per M² was significant under the effect of variety and plant density in a 1% probability level, as the maximum number of the panicle was for Dilamani Tarom, Langhrodi Tarom and minimum of that was for Sangh Tarom and also minimum number of panicle per M² was under the effect of various plant density in 40 bushes per M². By increasing of the plant density up to 80 and 120 bushes per M² it increases into 9/2 and 18/5%

(table 2). Number of the panicle per M^2 by increasing of the density from 40 into 120 bushes per M^2 under the interaction effect of variety $\times$ plant density were increasing, local Tarom, Hashemi Tarom, Dilamani Tarom, Langhrodi Tarom and Sangh Tarom (table 3). Variety and interaction effects of variety $\times$ plant density were significant on the weight of 1000-grain in a 1% probability level (table 1). Minimum weight of 1000-grain was for Hashemi Tarom and it was not significant for other varieties. Also, there was not any difference under various plant density (table 2). As it is clear from table 1, grain yield was significant under effect by variety, plant density, and their interaction effects in 1% probability level. Maximum grain yield was for Langhrodi Tarom, for local Tarom and minimum of it was for Hashemi Tarom. It also under the various plant density (40, 80, and 120 bushes per m^2) has shown for Langhrodi Tarom, local Tarom and Hashemi Tarom (table 2). Maximum grain yield under the interaction effect of variety $\times$ plant density was for local Tarom (40 bushes per m^2) and minimum of it was for Hashemi Tarom under the density of 40, 120 bushes per m^2 (table 3).

Mobasser *et al.* (2007) concluded that length of growth period, length of panicle, percent of full spikelet and weight of 1000-grain was not affected by planting-density. By increasing of plant density in various genotypes of rice, in spite of the deduction of total number of tiller and effective tiller per bush, because of increasing of stem number and number of panicle increased per M^2 (Mobasser *et al.*, 2007).

Usually in rice plant, plant height deduced when it has a limitations on assimilation of food materials, by increasing of plant density (Vojdani, 2006; Mobasser *et al.*, 2007).

3.2 The effect of variety, plant density and their interaction on inter-nodes

As it is seen in table 4, the length of 1st and 2nd inter-nodes was experimented from statistical point of view under the effect of variety, plant density and their interaction effects in 1% probability level and the variety in 1% probability level had significantly effect on the length of 3rd and 4th inter-nodes, but plant density had only significantly effect on the length of 3rd inter-node. Interaction effects of the variety $\times$ plant density had significantly effect on 3rd inter-node in 5% probability level and on 4th inter-node in 1% probability level. Maximum length of 1st and 2nd is seen in Hashemi Tarom and shortest length of 4th inter-node also is seen in Hashemi Tarom. Minimum length of 2nd and 3rd inter-node had seen in Langhrodi Tarom.

In table 5 can see that by increasing of plant density the length of 1st, 2nd, and 3rd inter-nodes are decreasing significantly and by increasing of the plant density up to 120 bushes per m^2 , the length of these inter-nodes decreased, but the length of 4th inter-node was not affected by the plant density. Maximum length of 1st and 2nd inter-nodes under the interaction effects of variety $\times$ plant density for Hashemi Tarom with 40 bushes per m^2 and minimum of it was for Langhrodi Tarom with 80 bushes per m^2 (table 6). In table 6 also can see that the maximum length of 3rd inter-node was for local Tarom with 40 bushes per m^2 and minimum of it was for Langhrodi Tarom with 120 bushes per m^2 . In local Tarom, Hashemi Tarom, and Langhrodi Tarom variety, by increasing of plant density the length of 3rd inter-node has had a decreasing rate (table 6). Minimum lengths of 3rd inter-node were for Dilamani Tarom and Sangh Tarom with 80 bushes per m^2 . Maximum length of 4th inter-node was for local Tarom with 40 bushes per m^2 and minimum of it was for Langhrodi Tarom with 120 bushes per m^2 (table 6).

The number of inter-nodes from statistical point of view under the effect of variety and plant density did not show a significantly difference (table 4), as the minimum number of inter-node were for Langhrodi Tarom and Sangh Tarom. Also, the number of inter-nodes by increasing of plant density from 40 bushes per m^2 into 120 bushes per m^2 has had 5/7% deduction (table 5). variety and interaction effect of variety $\times$ plant density had significantly effect on the diagonal of 3rd and 4th inter-nodes in 1% probability level and the effect of plant density had significantly affect on the diagonal of the 3rd and 4th inter-nodes in 5% and 1% probability level (table 4), as it is seen in table 5, maximum and minimum diagonal of 3rd inter-node were for Langhrodi Tarom and local Tarom respectively and also, maximum and minimum diagonal of 4th inter-node were for Sangh Tarom and Dilamani Tarom respectively. Minimum diagonal of 3rd inter-node comes under the plant density of 80 bushes per m^2 , but the diagonal of the 4th inter-node by increasing of plant density from 40 bushes into 120 bushes per m^2 deduced.

As mentioned in the results, shortest length of 1st, 2nd and 3rd inter-nodes was for langhrodi tarom but in 4th inter-node was for Hashemi Tarom and minimum number of inter-nodes was for Langhrodi tarom and maximum diagonal of 3rd inter-node and minimum plant height was belong to Langhrodi Tarom and because of this case, maximum Lodging resistance of 3rd and 4th inter-nodes and minimum lodging index of 3rd and 4th inter-nodes was also belong to this variety and for this reason Langhrodi Tarom had better and easy transition of photosynthesis materials to the seeds, consequently it had minimum number of hollow spikelet, maximum number of panicle, maximum grain yield and harvest index.

Maximum diagonal of 3rd inert-node under the interaction effects of variety $\times$ plant density was for Langhrodi Tarom with 80 bushes per m^2 and minimum of it was for local Tarom with 80 bushes per m^2 and for Dilamani Tarom was with same bushes (table 6). Maximum diagonal of 4th inter-node was for Sangh Tarom with 40 bushes per m^2 and minimum of it were for local Tarom and Dilamani Tarom with 80 bushes per m^2 .

Islam and *et al.* (2007) reported that length or height of stem had a positive coefficient with diagonal of 4th

inter-node, length of inter-nodes 1st, 2nd, 3rd, and 4th and Lodging resistance of 3rd and 4th inter-nodes, but it had not significantly correlation with weight of dry matter, Stem tension to lodging and lodging index of 3rd and 4th inter-nodes.

3.3 Effect of variety and interaction of variety $\times$ plant density on Lodging resistance in 3rd and 4th inter-nodes

Lodging resistance in 3rd and 4th inter-nodes under the effect of variety and interaction effects of variety $\times$ plant density showed an extreme significant difference, as the maximum Lodging resistance of 3rd and 4th inter-nodes was for Langhrodi Tarom, but minimum of it in 3rd inter-node was for Hashemi Tarom and for 4th inter-node was for Hashemi Tarom and Dilamani Tarom. While, plant density had not significantly effect on the Lodging resistance of the 3rd and 4th inter-nodes, but maximum of Lodging resistance was seen in 3rd inter-node with 120 bushes per m² and for 4th inter-node was with 80 bushes per m² (table 5).

As it is clear in table 7, maximum Lodging resistance was for the 3rd inter-node under interaction effects for Langhrodi Tarom with 120 bushes per m², and minimum of it was for Dilamani Tarom with 120 bushes per m², Maximum of Lodging resistance in 4th inter-node was for Langhrodi Tarom with 120 bushes per m² and minimum of it was for Hashemi Tarom with 120 bushes per m². Maximum Lodging resistance of 3rd and 4th inter-nodes sequentially were for SL-9H and SL-10H hybrids and minimum lodging index of 3rd and 4th inter-nodes came for IR72. Length of stem and leaf area index in hybrid rice may have effect on the increasing of Stem tension to lodging and consequently it increases the lodging index (Laza *et al.*, 2001). By deduction of panicle number per bush some characteristics like Lodging resistance and lodging index have not got make bigger changes (Vojdani, 2006). Youshinaga (2005) found that by increasing of plant density from 40 into 160 bushes per m² the height of stem was decreased, also lodging index by increasing of plant density increased, but Lodging resistance decreased.

Morphologic characteristics of lodging index was only measured for 3rd and 4th inter-nodes, because lodging of stem took place in low inter-nodes (Hoshikawa and Wang, 1990; Seko, 1962). Morphological characteristics have significantly correspondence between 3rd and 4th inter-nodes; therefore Lodging resistance and lodging index of these inter-nodes are important in lodging matter (Islam *et al.*, 2007).

3.4 Effects of Variety, plant density and their interaction on the Stem tension to lodging of 3rd and 4th inter-nodes

Variety, plant density and their interaction effects has had significantly effect on the Stem tension to lodging of 3rd and 4th inter-nodes (table 4). Maximum Stem tension to lodging was for 3rd inter-node in Hashemi Tarom and Dilamani Tarom. Maximum of Stem tension to lodging in 4th inter-node also was seen in Hashemi Tarom and minimum of it was for Dilamani Tarom. In table 5 can see that Stem tension to lodging of the 3rd inter-node under the various plant density by increasing of it from 40 bushes up to 120 bushes per m² had 20.1% deduction and minimum Stem tension to lodging was for the 4th inter-node with 120 bushes per m². Maximum Stem tension to lodging under the interaction effects of variety $\times$ plant density was for Hashemi Tarom with 40 bushes per m² and minimum of that was for Dilamani Tarom with 80 bushes per m². Minimum Stem tension to lodging of 4th inter-node for various varieties was local Tarom with 120 bushes per m², but minimum of it in 80 bushes per m² was for Dilamani Tarom (table 7).

3.5 The effect of variety and interaction effects of variety $\times$ plant density on Lodging index of 3rd and 4th inter-nodes

Lodging index of 3rd and 4th inter-nodes was experimented from statistical point of view under the variety and interaction effects of variety $\times$ plant density in 1% probability level. Effects of plant density had significantly affect on lodging index of 3rd and 4th inter-node in 5% and 1% probability levels respectively (table 4). Minimum lodging index of 3rd and 4th inter-node in Langhrodi Tarom and maximum of it has seen in Hashemi Tarom.

Minimum lodging index of 3rd and 4th inter-nodes was for 80 bushes per m² (table 5). Maximum lodging index for 3rd and 4th inter-nodes was in Hashemi Tarom with 40 and 120 bushes per m² and minimum lodging index of 3rd and 4th inter-nodes in Langhrodi Tarom was with 120 bushes per m² (table 7).

Islam *et al.* (2007) found that lodging morphological of characteristics are different between hybrids and hybrid-less varieties and it changes from 14 mm to 26 mm among the characteristics of 4th inter-node diagonal among the various genotypes of rice and respectively is IR79172H and SL-11H fro hybrids. Minimum plan height was 93 cm for Indica genotypes IR72 and maximum of it was 129 cm for BRRI Dhan 1H.

4. Conclusions

According to the research results, as the total number of tiller and effective tiller per bush reduces by plant density deduction, but the number of panicle per M² has had a significantly increasing. Also, length of panicle and flag leaf by increasing of plant density had deduction, but the total number of spikelet, hollow spikelet per panicle, weight of 1000-seed and straw yield under the plant density effects have not shown significant differences.

Although, plant density has not had significantly effect on plant height, length of 4th inter-node, Lodging resistance of 3rd and 4th inter-nodes, but by increasing of plant density, Stem tension to lodging of 3rd and 4th inter-nodes was deduced, because minimum number of inter-node and length of 3rd inter-node was reduced in

120 bushes per m². Plant height had not significantly deduction by increasing of bush number per M².

On the other hand, maximum Stem tension to lodging of 3rd inter-node came in minimum plant density because maximum number of inter-node and maximum length of 3rd inter-node was seen in 40 bushes per M². In other words, length of 1st, 2nd, and 3rd inter-nodes and number of inter-nodes by increasing of plant density had extreme deduction and the reason of this matter was because of bushes competitions for assimilation of food materials. Also, decrease of lodging index especially Stem tension to lodging of 3rd and 4th inter-nodes in a high plant density was not an exception to the matter.

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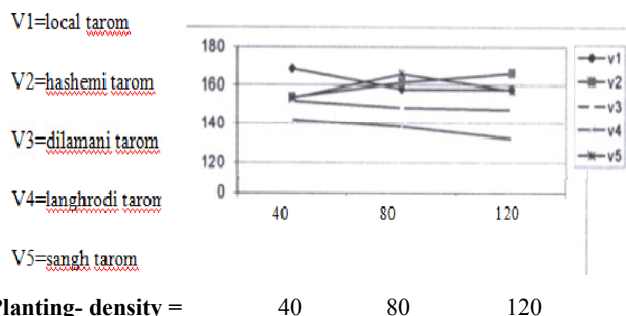


Diagram 1. Interaction effects of variety × plant density on plant height

Table 1. Sum of squares plant height and grain yield and yield components under plant-spacing in five variety

Various source	DF	Plant height (cm)	Number of tiller in bush	Total number of spike-let per panicle	number of hollow spike-let per panicle	number of panicle in m ²	Weight of 1000-grain(gram)	Grain yield (gr/m ²)
Replication	3	59/52*	3/15*	451/88	6/15	10058/44**	1/02	9060/99**
Variety	4	1249/19**	12/07**	1388/23**	1012/79**	1567/30**	23/2**	203837/55**
Error A	12	6/73	0/82	245/18	3/72	555/58	2/91	1229/04
Planting-density	2	24/86	57/97**	127/77	4/72	2382/45**	2/27	8009/51**
Variety×planting-density	8	133/99**	4/94**	798/02**	30/94**	308/67	6/19**	9334/87**
Error	30	15/27	1/02	202/51	9/15	160/85	1/29	494/11
%C.V	-	2/54	16/16	12/86	21/57	3/78	4/15	3/59

*, ** respectively significant in 5 1 probability levels.

Table 2. Simple effects variety and planting-density on average of plant height, yield and its components

Treatments	Plant height(cm)	Number of tiller in bush	Total number of spike-let in panicle	number of hollow spike-let in panicle	number of panicle in m ²	Weight of 1000-grain(gram)	Grain yield(gr/m ²)
Varieties							
Local tarom	161/58 a	4/95 c	122/9 a	9/63 c	315/08 b	28/2 b	732/5 a
Hashemi tarom	160/58 ab	7/38 a	112/3 a	14/47 b	321/33 b	25 b	461/5 d
Dilamani tarom	149/33 c	7/12 a	112/3 a	10/08 c	380/42 a	26/8 a	647/08 b
Langhrodi tarom	137/58 d	5/81 b	93/2 b	6/33 d	365/08 a	28/2 a	744/58 a
Sangh tarom	159/0 b	5/92 b	112/3 a	29/62 a	294/08 c	28/2 a	501/92 c
Planting-density							
40 bushes per m ²	154/5 a	7/76 a	113/1 a	14/52 a	301/95 c	27/6 a	627/25 a
80 bushes per m ²	154/4 a	6/55 b	110/6 a	14/01 a	332/8 b	27/2 a	630/8 a
120 bushes per m ²	152/3 a	6/4 c	108/09 a	13/55 a	370/85 a	27/0 a	594/5 a

Averages with same words in every column according to Duncan test have not significantly difference in a 5 probability level

Table 3. Effects of interaction variety × planting-density on rice grain yield and some of yield components

Variety × planting-density	Total number of tiller per bush	Number of panicle per m ²	Grain yield(gr/ m ²)
40 bushes per m ²	6/75 cd	273/75 hi	772/5 a
80 bushes per m ²	4/5 fg	308/5 g	684/25 c
120 bushes per m ²	3/62 g	363 cd	740/75 ab
40 bushes per m ²	8/83 ab	278/75 hi	453/0 f
80 bushes per m ²	7/99 bc	324/75 fg	500/75 e
120 bushes per m ²	5/33 def	360/5 d	430/75 f
40 bushes per m ²	9/5 a	351 de	658/75 c
80 bushes per m ²	6/5 a	381/0 bc	728/75 b
120 bushes per m ²	5/37 de	409/25 a	553/75 d
40 bushes per m ²	5/62 de	338/5 ef	737/0 b
80 bushes per m ²	8/0 bc	363/5 cd	754/5 ab
120 bushes per m ²	3/81 g	393/25 ab	742/25 ab
40 bushes per m ²	8/12 abc	267/75 i	515 e
80 bushes per m ²	5/75 de	286/25 h	485/75 e
120 bushes per m ²	3/87 fg	328/25 f	505 e

Averages with same words in every column according to Duncan's multiple range test have not significantly difference in a 5% probability level

Table 4. Sum squares morphological characteristics that related to lodging under plant density in different rice varieties

Various source	DF	LN1	LN2	LN3	LN4	nN	DN3	DN4	BR3	BR4	BM3	BM4	LI3	LI4
Replication	3	6/89	3/85	2/37	5/43	0/33**	1/83**	1/35**	1/93**	3/89	165879/83**	196087/08**	3460/37	2269/14
Variety	4	306/53**	104/29**	23/15**	93/69**	5/13**	2/32**	3/72**	117/79**	159/88**	691322/42**	880235/23**	142299/24**	104349/63**
Error A	12	11/007	2/48	2/57	4/24	0/37	0/66	0/81	0/43	3/17	67306/13	133798/44	2788/01	1927/35
Planting-density	2	35/12**	40/28**	29/09**	8/79	0/32**	0/24**	1/94**	0/98	5/1	477552/81**	690550/51**	5495/29*	9895/51**
Variety× plant density	8	46/06**	19/85**	12/68*	32/27**	0/03	0/54**	0/78**	42/81**	37/73**	114834/19**	202057/87**	29190/78**	6041/91**
Error B	20	5/75	4/48	4/38	5/001	0/03	0/05	0/19	0/33	2/06	15475/47	40630/22	1619/36	1092/89
C.V	-	5/49	6/69	7/55	11/04	4/12	4/09	6/58	8/85	14/38	9/06	10/50	15/44	14/85

*, ** sequentially significant in 5, 1 probability levels.

LN1, 2, 3, 4=length of inter-nodes 1, 2, 3, 4(CM)

BM3, 4=Stem tension to lodging of inter-node 3, 4(gr/cm)

n.N=inter-node number

DN3, 4=diagonal of inter-node 3, 4(MM)

BR 3, 4=Lodging resistance of inter-node 3, 4(gram/stalk)

LI 3, 4=lodging index of inter-node

Table 5. Effects of variety and plant density on morphological characteristics that related to lodging in rice

Treatments	Inter-node length				Inter-node Number	Inter-node diagonal lodging resistance				inter-node bending inter-node index (%)			
	1	2	3	4		3	4	3	4	3	4	3	4
Varieties													
Local tarom	39/37c	32/91b	28/62a	23/91a	4/34a	5/25c	6/27bc	5/13c	10/15b	1723/2b	1943/8bc	279/25b	198/42b
Hashemi tarom	51/45a	35/75a	28a	17/09c	4/82a	5/91bc	6/76ab	4/2d	6/32c	1723/4a	2311/9a	417/25a	371/75a
Dilamani tarom	44b	30/92c	28/29a	19/35b	4/62a	5/36bc	5/87c	5/22c	7/51c	1102/7c	1642/1c	233/58b	223/83b
Langhrodi tarom	38/91c	27/75d	24/84b	18/58ba	3/45b	6/21a	6/66abc	12a	15/79a	1200/9bc	1687/3c	112/9c	114/86c
Sangh tarom	44/29b	30/87c	28/81a	22/31a	3/43b	6/1ab	7/36a	6/11b	10/18b	1438/8b	2008/6ab	259/67b	204/08b
Planting-density													
40 bushes in m ²	44/92a	32/97a	29/04a	20/99a	4/23a	5/83a	6/93a	6/54ab	10/05ab	1530/4a	2084/2a	269/55a	224/05a
80 bushes in m ²	42/27b	31/8a	26/69b	20/03a	4/17a	5/64b	6/49b	6/31b	10/46a	1366/4b	1954/25a	241/4b	199/65b
120 bushes in m ²	43/62ab	30/15b	27/41b	19/72a	3/99b	5/83a	6/33b	6/75a	9/46b	1221/55c	1717/7b	270/64a	244/07a

Averages with same words in every column according to Duncan's multiple range test have not significantly difference in a 5% probability level

Table 6. Effects of interaction variety × plant density on morphological characteristics that related to lodging in rice

Variety × planting-density		Inter-node length(cm)				inter-node diagonal(mm)			
		1	2	3	4	3	4	3	4
Local tarom	40 bushes per m ²	37/25 gb	32/5 b	31/25 a	27/6 a	5/44 g	7/06 abc		
	80 bushes per m ²	39/37 efg	33/25 b	27/5 cdef	20/6 cdef	4/57 h	5/51 f		
	120 bushes per m ²	41/50 def	33 b	27/12 def	23/5 bc	5/72 fg	6/25 de		
hashemi tarom	40 bushes per m ²	56/25 a	41 a	28/77 a-f	15/9 gh	5/8 ef	7/18 abc		
	80 bushes per m ²	49/75 b	33/37 b	28/12 b-f	18/87 fg	6/1 a-e	7/02 bc		
	120 bushes per m ²	48/37 b	32/87 b	27/12 def	16/5 gh	5/58 def	6/08 ef		
dilamani tarom	40 bushes per m ²	48/75 b	32/37 b	30/62 ab	20/45 cdef	5/41 g	5/95 ef		
	80 bushes per m ²	38/5 fg	28/5 cd	25/12 fg	18/87 efg	4/97 h	5/60 f		
	120 bushes per m ²	44/75 cd	31/87 b	29/12 abcd	18/75 fg	5/69 fg	6/08 ef		
langhrodi tarom	40 bushes per m ²	39/62 efg	27/62 d	25/20 fg	18/75 fg	6/20 abc	6/79 cd		
	80 bushes per m ²	37/25 g	26/87 d	26/07 efg	22 bcde	6/42 a	6/81 cd		
	120 bushes per m ²	39/87 efg	38/75 cd	23/25 g	15 h	6/02 b-f	6/38 de		
sangh tarom	40 bushes per m ²	42/75 de	31/37 bc	29/37 abcd	22/25 bcd	6/28 ab	7/68 a		
	80 bushes per m ²	46/5 bc	28/75 cd	26/62 def	19/8 def	6/14 abcd	7/54 ab		
	120 bushes per m ²	43/62 cd	32/5 b	30/45 abc	24/87 bc	5/88 cdef	6/86 cd		

Averages with same words in every column according to Duncan's multiple range test have not significantly difference in a 5% probability level.

Table 7. Effects of interaction variety × plant density on lodging resistance, Stem tension to lodging and lodging index in rice

Variety × planting-density		Lodging resistance of inter-node		Stem tension to lodging of inter-node (gr/cm)		lodging index of inter-node (%)	
		3	4	3	4	3	4
Local tarom	40 bushes in m ²	6/82 de	11/02 c	1802/7 ab	2486 a	267/2 c	227/2 def
	80 bushes in m ²	4/18 fgh	11/68 bc	1324/7 de	1793/5 cde	326 b	167 ghi
	120 bushes in m ²	4/37 fgh	7/75 de	1067 gh	1551/7 e	244/5 cd	201 efg
hashemi tarom	40 bushes in m ²	3/68 hi	6/81 de	1967 a	2554/7 a	536 a	372/7 b
	80 bushes in m ²	4/78 fg	7/61 de	1745/7 b	2413 ab	364/7 b	317/7 c
	120 bushes in m ²	4/12 gh	4/55 f	1457/5 cd	1968 bc	351 b	324/7 a
dilamani tarom	40 bushes in m ²	7/43 d	8/43 d	1174/2 efgh	1756/2 cde	158 ef	208 efg
	80 bushes in m ²	5/0 f	8/28 d	1016/5 h	1573/7 e	201/7 de	189/7 fgh
	120 bushes in m ²	3/25 i	5/81 ef	1117/2 fgh	1596/2 de	341 b	273/7 cd
langhrodi tarom	40 bushes in m ²	8/44 bc	13/47 b	1172/7 fgh	1644/7 de	139/2 f	122/5 i
	80 bushes in m ²	9/21 b	12/42 bc	1230/5 efg	1825/5 cde	133/7 f	147/7 hi
	120 bushes in m ²	18/37 a	21/47 a	1199/5 efg	1591/5 de	65/7 g	74/3 j
sangh tarom	40 bushes in m ²	6/32 e	10/51 c	1535/25 c	1979/2 bc	247/25 cd	189/7 fgh
	80 bushes in m ²	8/37 bc	12/32 bc	1514/5 c	2165/5 a	180/75 ef	176 gh
	120 bushes in m ²	3/65 hi	7/72 de	1266/5 ef	1881 bcd	351 b	246/5 de

Averages with same words in every column according to Duncan's multiple range test have not significantly difference in a 5% probability level.