

Effect of Density on Morphological Characteristics Related-Lodging on Yield and Yield Components in Varieties Rice (*Oryza sativa* L.) In Iran

¹H.R. Mobasser, ²R. Yadi, ²M. Azizi, ³A.M.Ghanbari and ⁴M. Samdaliri

¹Department of Agronomy, College Agriculture, Ghaemshar Branch, Islamic Azad University, Iran

²Department of Agronomy, College Agriculture, Bojnord Branch, Islamic Azad University, Bojnord, Iran

³Department of Agronomy, Faculty member, Jouybar Branch, Islamic Azad University, Jouybar, Iran

⁴Department of Agronomy, College Agriculture, Chalous Branch, Islamic Azad University, Chalous, Iran

Abstract: In order to investigate effects of planting density on agronomical traits and morphological characteristics that related to lodging an experiment was carried out at split plot in randomized completely block design with four replications in Mazandaran province in 2008. Main factor was cultivar in five levels including Mahalli Tarom, Hashemi Tarom, Deylamani Tarom, Langrodi Tarom and Sang Tarom and subfactor was density in three levels including 40, 80, 120 plant / m². Results showed that the least spikeletes number and sterile spikeletes number in spike were obtained in Langrodi Tarom and the least tiller number per hill and panicle number in m² was produced in Mahalli Tarom and Sang Tarom, respectively. The shortest length of first, second and third internode and the biggest third internode diameter and also the least plant height were obtained in Langrodi Tarom. As a result the most resistance to lodging and the least lodging index for third and fourth internode were produced in Langrodi Tarom. Tiller numbers in hill was decrease with increasing of planting density, but panicles number in m² was significantly increased. Internodes number and first, second, third and fourth internodes length and fourth internode diameter and also third, fourth internode bending moment were decreased with increase of planting density. The Minimum of lodging index in third and fourth intrnodes were produced in density 80 plant / m². Interaction effect of cultivar × density had significant effect an all of agronomical traits and morphological characteristics that related to lodging (except panicle / m²).

Key words: Rice % Density % Bending moment % Lodging index

INTRODUCTION

Farmer grow the cultivars had high quality also, they had long height and sensitive to lodging and including 50% plant density area in Iran. Weather condition especially wind and rain in during full heading to ripening stages result in yield loss because increasing lodging and disease as a result decrease in grain yield. Lodging has long been a problem with many of the local varieties of rice in Iran. The aging of farmers and falling or constant rice prices have created serious problems for rice farmers and have led, recently, to demands for reductions in the costs and labor required for rice production. Decreasing lodging, which does not require farmer to be harvested rice, is regarded as the most effective method for reducing costs and labor. Lodging is problematic for rice production because it makes machine harvesting difficult.

In lowland rice, lodging is characterized by stem bending, stem breakage and root lodging [1]. Stem bending type is the main type of lodging in lowland rice. It is caused by the increase in panicle weight during maturation and by environmental effects (i.e., rain and wind). Stem breaking occurs at lower internodes (below the third internode from the top) in response to bending higher up the stem [2,3]. Lodging is a major problem in the production of cereal crops, because it causes decreases in yield and quality by reducing photosynthesis in the canopy, damages vascular bundles by bending or breaking stem and causes problem associated with mechanical harvesting [1,4,5]. Furthermore, the lodging of rice plants during the ripening period results not only in a reduction in yield, owing to decreased canopy photosynthesis as a result of self-shading, but also in a decrease in the grain quality, due to increased coloring of brown rice and/or decreased flavor [5].

In a lodged plant community, the normal canopy structure is destroyed, resulting in reduced photosynthetic ability and dry matter production [6]. Severe lodging prevents the transport of water, nutrients and assimilates through the xylem and phloem, resulting in a reduction in assimilates for grain filling [7]. High moisture levels in a lodged plant community may be favorable for fungal growth and for the development of diseases, which have detrimental effects on grain quality and appearance [1]. The grains of lodged plants may also germinate on the panicle, especially in cultivars with weak seed dormancy. As a result, lodging causes great losses in both grain quantity and quality. Furthermore, it also causes difficulties in harvest operations, increases demand for grain drying and consequently results in increased production cost [7]. The development of semi-dwarf rice and wheat varieties by introducing the *sd-1* gene in the early 1960s represented the greatest success in improving lodging resistance and yield potential of cereal crops [8]. Reducing plant height with the *sd-1* gene has decreased the effects of the upper part of the plant on the lower part, thereby improving resistance to lodging. Recent studies, however, suggest that the height of semi-dwarf rice and wheat may limit canopy photosynthesis and biomass production and therefore, stagnate grain yield [9,10]. Flintham *et al.* [11] observed an optimum plant height for maximum photosynthetic capacity within a vegetative canopy and that reducing plant height below this level could reduce crop yield. Ookawa and Ishihara [12] reported that plant height was not necessarily the most important factor in determining lodging resistance. They found that susceptibility to lodging differs among cultivars with similar plant heights. Among morphological traits, stem diameter and weight have been directly correlated with lodging resistance and the breaking strength of the stem [13]. Leaf sheath wrapping, basal internode length and the cross-sectional area of the culm are the major plant traits that determine straw strength [14]. The leaf sheaths contribute to the breaking strength of the shoot by 30–60% [15]. Ookawa and Ishihara [12] reported that the breaking strength of the basal internode was doubled due to leaf sheath covering and was tripled due to the large area of the basal internode cross-section. Several methods have been used to assess lodging resistance [1]. Pushing resistance has been used primarily as an index of resistance to stem bending or root lodging in several crops [16,17]. Terashima *et al.* [16] demonstrated a high positive correlation between pushing resistance and lodging in paddy fields (correlation coefficient was 0.79). Berry *et al.*, [18] showed that measuring wheat shoot lodging resistance by rotational

displacement, which accounted for a little more than half of the stem and root lodging. Pushing resistance in rice is determined by root morphology, stem bending strength and other characters. There is a positive correlation between pushing resistance and culm or root thickness and root weight in deeper soil layers [17,19]. Stem weight and diameter are strongly related to physical strength [13]. Stem strength is also the product of its chemical and biochemical components. Generally, lignin or cellulose determine physical strength, as lower lignin or cellulose contents cause the culm to be brittle [20-22]. In the rice mutant *brittle culm1 (bc1)*, the altered biosynthesis of cellulose, hemicellulose and lignin in culms reduced secondary cell wall thickness and mechanical strength [23]. In addition, the accumulated carbohydrate contents of rice stems are related to lodging resistance [24] and a greater accumulation of starch increases the bending strength and stiffness of culms [25]. Likewise, higher silicon contents are also related to physical strength [26,27]. It has been shown that the locus for pushing resistance in the lowest part of the rice plant (*pr15*) increases the weight of the lowest stem due to higher carbohydrate contents at maturity and consequently improved lodging resistance [28]. Analysis of quantitative trait loci (QTLs) can reveal the genetic basis of relationships among traits and allows a comprehensive investigation of the genetic relationships among morphological and physiological traits [29-32]. Combining QTL and physiological analyzes with near isogenic lines (NILs) selection can help clarify the function of a particular locus [33]. Comparisons between QTLs for lodging and other traits have been made in several cereals. In barley, one QTL has been associated with grain yield and plant height and reduces lodging severity [34]. Seven wheat and spelt lodging resistance QTLs correspond with the QTLs for plant height, culm stiffness, leaf width, leaf-growth, days to ear emergence and culm thickness [35]. Lodging resistance, which is assessed by the physical strength of aerial plant parts and the load they must bear, is clearly determined by various factors, but thus far suitable targets for genetic improvement of lodging resistance are not clear. Therefore, this paper aims to evaluate the effect of plant density on morphological characteristics related-lodging, yield, yield components of cultivars rice.

MATERIALS AND METHODS

Plant materials for determining varietal differences among five rice cultivars was analyzed to evaluate the potential factors that determine lodging resistance. Field experiments were

conducted in the growth season of 2007 at the farm of the Research Institute, BaBol (36 33 N, 53 12 E, 21 m altitude), Iran. The precipitation and evaporation were 79 and 888, respectively that maximum rain in Sep. with 42 mm and minimum was in Jun with 0.3 mm. The soil of the fields is clay loam with pH 7.94, 3.38% organic matter, 0.22 % total N, 23 ppM P, 100 ppM extractable K and 0.8 mose EC. The soil tests were based on samples taken from the upper 20 cm of the soil. The previous crop was rice. The experiment was laid out in split-plot design that arranged in a randomized complete block design with four replications, with five rice genotypes as main factor, including Mahali Tarom (MT), Hashemi Tarom (HT), Deylamani Tarom (DT), Langrodi Tarom (LT) and Sang Tarom (ST) developed from Iran Rice Research Institute. Rice genotypes were used of their tall plant height (has over 140 cm height) and three levels of density including 40, 80 and 120 Plant / m² as sub factor with plant pattern 15×16.6, 10×12.5 and 10×8.3, respectively. Clean seeds of each genotype with a minimum of 95% germination rate were soaked in water for 24 h and incubated for another 24 h. Then, the pre-germinated seeds were sown in seedling trays filled with soil to produce uniform seedlings. Seeds were sown on 1 May 2007. Seedlings 30 days old were transplanted in each hill and with a single plant per hill on 30 may 2007. The total number of unit plots was 60, the size of each plot being 5 m × 2 m. After transplanting, 5 cm water depth was maintained in the experimental plots. Ten days before harvest, the plots were drained to facilitate harvesting. Insects, diseases and weeds were intensively controlled to avoid any yield loss.

Nitrogen from urea was used at the rates of 150 kg N/ha. Phosphorous and potassium fertilizers were used 110 kg P₂O₅ haG¹ as triple superphosphate, 100 kg K₂O haG¹ as potassium sulfate as basal fertilizers were applied, respectively. Basal fertilizers were applied and incorporated in all plots 1 day before transplanting. Nitrogen in the form of urea was split-applied: 50 kg N haG¹ at basal, 50 kg N haG¹ at panicle initiation, 50 kg N haG¹ at full heading by hand broadcast method [36]. Twelve hills (0.48 m²) were sampled diagonally from a 5 m² harvest area from each plot at maturity to determine aboveground biomass production, harvest index and plant height. Plants were separated into straw and panicles. Straw dry weight was determined after oven drying at 70°C to constant weight. Panicles were hand-threshed and the filled spikelets were separated from unfilled spikelets by submerging them in tap water. Dry weight of rachis and filled and unfilled spikelets was determined after oven drying at 70 °C to constant weight.

Aboveground biomass was the total dry matter of straw, rachis and filled and unfilled spikelets. Grain, straw and biological yields were determined from the 5m² area in each plot and adjusted to the standard moisture content of 140 g H₂O kg⁻¹. Harvest index was calculated as the ratio of filled spikelet weight to aboveground biomass. Plant height was measured from the plant base to the tip of the highest leaf (or panicle, whichever was longer) for all 12 hills in each plot. Lodging characteristic was observed when the flowering of the plant just started. Culm characters related to lodging were determined at 30 days after flowering for each genotype. Three representative hills were sampled from each plot and the 12 largest tillers, 4 from each hill, were used to measure characters related to lodging. Culm height (length between plant base and panicle neck node) and the lengths of the first (N₁), second (N₂), third (N₃) and fourth (N₄) internodes from the top were measured. The breaking resistances of the middle point of N₃ or N₄ with leaf sheath were measured using a Prostrate Tester (DIK 7400, Japan). The distance between fulcra of the tester was set at 5 cm. The center of the internode, where breaking resistance was measured, was aligned horizontally with the middle point between the two fulcra. After measuring the breaking resistances of N₃ and N₄, the stem was cut at the lowest nodes of N₃ and N₄. Fresh weight of the upper portion of the plant, including panicle and N₁ and N₂ with leaf and leaf sheath (W₁), was measured. The fresh weights of the third (W₂) and fourth (W₃) internodes with leaf sheath were also measured. Bending moment (BM) at N₃ or N₄ internode was calculated using the following formula [3]:

BMN₃= Length from the lowest node of N₃ to the top of panicle × (W₁ + W₂),

BMN₄= Length from the lower node of N₄ to the top of panicle × (W₁ + W₂ + W₃)

Then, lodging index (bending moment/breaking resistance×100) was calculated for both N₃ (LIN₃) and N₄ (LIN₄) according to Amano *et al.* [37] and bending moment as (culm length × plant fresh weight). The breaking weight is the force required to break the 3th and 4th internode and was measured with a spring balance. Since stem lodging usually occurs at the lowest internodes [2], only the diameter of N₄ was measured near the lowest node of N₄ after removing the leaf sheath. Length (mg cmG¹) was calculated for both N₃ and N₄. Prior to harvest, the plants from 5 hills were obtained from each replication to measure yield components. Plant stems diameter was measured with a slide caliper

according to the method described previously [28]. Measurement of pushing resistance whole plant pushing resistance was measured with a prostrate tester (Daiki Rika Kogyo Co., Tokyo, Japan) at the full-ripe stage, according to a method reported previously [28]. The prostrate tester was set perpendicularly to the whole plant at 20 cm height and pushing resistance was measured when plants inclined to 45E. Measurement of lodging resistance in Pushing resistances and culm stiffness were analyzed at the full-ripe stage as lodging resistance. Likewise, pushing resistance of the lowest part of the plant was measured in 2007 after the stem was cut at 40 cm height and the upper parts were removed. Six or more plants in each line were used to measure pushing resistance. Statistical analysis data of morphological traits were analyzed following analysis of variance (SAS) and means of genotypes were compared based on Duncan multiple range test (DMRT) at the 0.05 probability level.

RESULTS

it is seen from Table 1 that the plant height shows the significant differences by the effect of the cultivar of rice and cultivar plant density so the maximum and the minimum plant height was from MT and LT (161.58 and 137.58 cm, respectively). Table 2 shows that with the increase of plant density from 40 to 120 plant / m² the plant height with the 1.42 proportion have meaning less decrease. The maximum plant height by the interaction effect of cultivar × plant density was for MT with the density of 40 plant / m² (168.5cm) and the minimum of it was for LT with the accumulation of 120 plant / m² (132.5 cm). Number of tillers / plant was effected by the cultivar plant density and their interaction effect (p<0.01) (Table 1). it is seen from Table 2 that the minimum tiller numbers / plant were from MT (4.95 number) and the maximum of it were from HT (7.38 number) and DT (7.12 number) and also the tiller numbers / plant which were effected by plant density was for 40 plant / m² (7.76 number) and with the increase of plant density to 40 and 120 plant / m². These numbers with the 15.5 and 43.2 proportion had the descending process. The maximum total tiller number in plant which are effected by interaction effect of cultivar × plant density was for DT with the density of 40 plant / m² (9.5 number) and the minimum of it was for LT (3.81 number) with the plant density of 120 plant / m² (Table 3). The number of spikelets and blank spikelets / spike with the effect of cultivar and interaction effects cultivar × plant density shows the significant differences (P=0.01) (Table 1). The minimum spikelets and blank spikelets / spike is for

LT which frequently are 93.2 and 6.33 number and the maximum blank spikelet numbers / spike is for ST (29.62 number) and according to the statistically these two parts are not affected by the plant density. It is obvious from Table 1 that the spike numbers per square meter is affected by the cultivar × plant density (P=0.01), so the maximum spike number is for DT and (380.42 number) LT (365.08 number), respectively and the minimum was for ST that was 294.08 number of spike per square meter and the minimum spike number per square meter with the different plant density was for density of 40 plant / m² (301.95 number) and with the increase of plant density to 80 and 120 plant / m², these numbers with the proportion of 9.2 and 18.5% had the descending process (Table 2). The spike numbers per square meter with the increase of plant density from 40 to 120 plant / m² with the interaction effect of cultivar × plant density for MT, HT, DT, LT and ST of 24.5, 22.6, 14.2 and 18.4, respectively, had the ascending process.

The cultivar of rice and interaction effect of cultivar × plant density had the significant effect on the weight of thousands grains (p#0.01) (Table 1), so the lowest weight of thousands grains was for HT (25 g) and there was no significant difference in other cultivars and also there was no different at various plant density (Table 1). Grain yield with the effect of cultivar, plant density and their interaction effect was at 0.01% the probability level. The highest grain yield was for LT (744.58 g/m²) and the lowest was for HT that is 461.5 g/m² and with the plant density of 40, 80 and 120 plant / m² is 627.25, 630.8 and 594.5 g/m, respectively (Table 2). The maximum grain yield at interaction effect cultivar × plant density was for MT with the density of 40 plant / m² (772.5 g/m) and the minimum was for HT with the density of 120 and 40 plant / m² (430.75 and 453.0 g/m, respectively) (Table 3). Table 4 shows that the length of first and second internodes were effected by the cultivar, plant density and their interaction effect (p#0.01), also cultivar (p#0.01) had the significant effect on the length of third and fourth internodes but plant density had the significant effect only on the third internodes and the interaction effect of cultivar × plant density had the significant effect on the length of third internodes (p#0.05) and fourth internodes (p#0.01).

The longest first and second internodes were seen at HT (51.45 and 35.75 cm, respectively) and the shortest fourth internodes also seen at this cultivar which is 17.09 cm. The shortest second and third internodes were for LT (27.75 and 24.48 cm). Table 4 shows that with the increase of plant density, the length of first, second and third internode decreased significantly, so the longest

Table 1: Analysis of variance (mean square) tiller number in hill, blank and filled spikelet number in spike, 1000-grain weight, spike number, grain yield and plant height in plant density levels in cultivars rice

ANOVA	df	Tiller N. in hill	Blank spikelet N. spike	Spikelet N. in spike	1000-grain weight	Spike Number	Grain yield	Plant height
Rep	3	*15.3	15.6	88.451	02.1	**4.10058	**9.9060	*5.59
Cultivar	4	**07.12	**79.1012	**23.1388	**2.23	**3.1567	**5.203837	**1.1249
E(a)	12	82.0	72.3	18.245	91.2	5.555	0.1229	7.6
Density	2	**97.57	72.4	77.127	27.2	**4.23822	**5.8009	8.24
A×B	8	**94.4	**94.30	**02.798	**19.6	6.308	**8.9334	**9.133
E(b)	30	02.1	15.9	51.202	29.1	8.160	1.494	2.15
C.V.(%)	—	16.16	57.21	86.12	15.4	7.3	5.3	5.2

* and **: significant at the 5% & 1% levels, respectively.

Table 2: Mean of tiller number in hill, blank and filled spikelet number in spike, 1000-grain weight, spike number, grain yield and plant height in plant density levels in cultivars rice

Treatments		1000-grain weight (g)	Grain yield (g/m ²)	Spikes No. / m ²	Blank spikelet No. / spike	Spikelets No. / spike	Tillers No. / hill	Plant height (cm)
Cultivar	MT	a 2.28	a 5.732	b 0.315	c 6.9	a 9.122	c 9.4	a 5.161
	HT	.0b25	d 5.461	b 3.321	b 4.14	a 3.112	a 3.7	ab5.160
	DT	a 8.26	b 0.647	a 42.380	c 0.10	a 3.112	a 1.7	c3.149
	LT	a 2.28	a 5.744	a 0.365	d 3.6	b 2.93	b 8.5	d5.137
	ST	a 2.28	c 9.501	c 0.294	a 6.29	a 3.112	b 9.5	b 0.159
Density	40	a 6.27	a 2.627	c 9.301	a 5.14	a 1.113	a 7.7	a5.154
	80	a 2.27	a 8.630	b 8.332	a 0.14	a 6.110	b 5.6	a4.154
	120	a 0.27	a 5.594	a 8.370	a 5.13	a 09.108	c 4.6	a3.152

Within each treatment, means followed by different letter in a column are significantly different at the 0.05 probability level.

Table 3: Means of interaction effect tiller number in hill, spike number, grain yield in plant density levels in cultivars rice

Cultivar × Plant density		Tiller numbers / hill	Spike numbers / m ²	Grain yield (g/m ²)
MT	40	75.6 cd	75.273 hi	5.772 a
	80	5.4 fg	5.308 g	2.684 c
	120	62.3 g	.0363 cd	7.740 ab
HT	40	83.8 ab	7.278 hi	0.453 f
	80	99.7 bc	7.324 fg	7.500 e
	120	33.5 def	5.360 d	7.430 f
DT	40	5.9 a	.0351 de	7.658 c
	80	5.6 d	0.381 bc	7.728 b
	120	37.5 de	2.409 a	7.553 d
LT	40	62.5 de	5.338 ef	0.737 b
	80	0.8 bc	5.363 cd	5.754 ab
	120	81.3 g	2.393 ab	2.742 ab
ST	40	12.8 abc	7.267 i	.0515 e
	80	75.5 de	2.286 h	75.485 e
	120	87.3 fg	2.328 f	.0505 e

Within each treatment, means followed by different letter in a column are significantly different at the 0.05 probability level

first, second and third internode was for density of 40 plant / m² (44.92, 32.97 and 29.04, respectively) and with increase of plant density to 120 plant / m², the length of these internodes was decreased with the 2.9, 8.5 and

5.7 % but the length of fourth internode was not effected by plant density. The longest first and second internode with the interaction effects of cultivar × plant density of 40 plants in m² (56.25 and 41 cm) and the lowest length of

Table 4: Analysis of variance (mean square) node length, node diameter and node number in plant density levels in cultivars rice

ANOVA	df	LN1	LN2	LN3	LN4	N.N.	DN3	DN4
Rep	3	8.60	8.30	3.20	43.50	**3.0	**83.1	**35.1
Cultivar	4	**5.306	**2.104	**1.23	**6.93	**1.5	**3.2	**7.3
E(a)	12	0.11	4.20	5.20	2.40	3.0	66.0	81.0
Density	2	**1.35	**2.40	**0.29	7.80	**3.0	**24.0	**94.1
A×B	8	**0.46	**8.19	*6.12	**2.32	0.0	**54.0	**78.0
E(b)	20	7.50	4.40	38.40	0.50	0.0	5.0	19.0
C.V.(%)	-	4.50	6.60	5.70	4.11	1.4	0.4	5.6

C.V.(%)* and **: significant at the 5% & 1% levels, respectively

Table 5: Analysis of variance (mean square) lodging index, bending moment, breaking resistance internode 3 and 4 in plant density levels in cultivars rice

ANOVA	df	BR ₃	BR ₄	BM ₃	BM ₄	LI ₃	LI ₄
Rep	3	**93.1	89.3	**8.165879	**0.196087	37.3460	1.2269
Cultivar	4	**7.117	**8.159	**4.691322	**2.880235	**2.142299	**6.104349
E(a)	12	43.0	17.3	1.67306	4.133798	0.2788	3.1927
Density	2	98.0	1.5	**8.477552	**5.690550	*2.5495	**5.9895
A×B	8	**81.42	**73.37	**1.114834	**8.202057	**7.29190	**9.6041
E(b)	20	33.0	06.2	4.15475	2.40630	3.1619	8.1092
C.V.(%)	-	85.8	3.14	0.9	5.10	4.15	8.14

* and **: significant at the 5% & 1% levels, respectively

first and second internodes were for LT with the density of 80 plants which were 37.25 and 26.87 cm (Table 4). Table 4 shows that the longest third internode had seen in MT with 40 plant / m² and the minimum of it was for LT with 120 plant / m² which are 31.25 and 23.25 cm and also at MT, HT and LT with the increase of plant density, the length of third internode had descending process (Table 4), But in DT the minimum length or third internode was at density of 80 plant / m² and in ST was at the same density which were 25.12 and 26.62 cm, respectively. The maximum length of fourth internode was for MT with 40 plant / m² and the minimum length has seen in LT at density of 120 plant / m² which are 27.6 and 15 cm (Table 4). The number of internode with effect of cultivar and plant density (p#0.01) didn't show the significant difference (Table 4) so, the lowest number of internode was for LT and ST (3.45 and 3.43 number) and also the number of internode with increase of plant density from 40 plant / m² (4.23 number) to 120 plant / m² have decreased with 5.7% (Table 4). The cultivar and interaction effect of cultivar × plant density with the probability of 0.01% had the significant effect on the diameter of third and fourth internode and the plant density effect at the probability level of 5 and 1 % has the significant effect on the diameter of third and fourth internode (Table 4), so as the table 5 shows the longest and shortest diameter for third internode was for LT (6.21 mm) and MT (5.25 mm) and the maximum and minimum, respectively.

The maximum and minimum diameter of fourth internode was for ST (7.36 mm) and DT (5.87 mm), respectively. The minimum diameter of third internode was at the density of 80 plant density increase from 40 to 120 plant the diameter of fourth internode had the descending process, whereas the diameter changed from 6.93 to 6.33 mm. The longest diameter of third internode with the interaction effect of cultivar plant density of 80 plant / m² (6.42 cm) and the shortest diameter of third internode was for MT and DT at The density of 80 plant / m² which were 4.57 and 4.97 cm (Table 4). Table 4 shows that the longest diameter of fourth internode was for ST with the density of 40 plant / m² (7.68 cm). The minimum diameter of fourth internode was in MT and DT with the density of 80 plant / m² that are 55.51 and 5.60 cm. Resistance breaking showed the significant differences at third and fourth internodes with the effect of cultivar and interaction effect of cultivar × plant density, so the maximum resistance to breaking of 3 and 4 internode had seen in LT (12 and 15.79 gram per stem) but the minimum resistance to breaking of third internode received for HT (4.2 g/stem) and for fourth internode received for HT (6.32 g/stem). Although, the plant density didn't have the significant effect on resistance to breaking of 3 and 4 internodes, but the most resistance to breaking of third internode has seen at density of 120 plant / m² (6.75 g/stem) and for fourth internode received at density of 80 plant / m² (10.46 g/stem) (Table 4).

Table 6: Means of interaction effect for internodes length 1,2,3 and 4 internodes diameter N₃ and N₄ in plant density levels in cultivars rice

Cultivar	plant density	Internode length (cm)				Internode diameter	Internode diameter
		1	2	3	4	3 (mm)	4 (mm)
MT	40	2.37 gb	5.32 b	2.31 a	6.27 a	4.5 g	0.7 abc
	80	3.39 efg	2.33 b	5.27 cdef	6.20 cdef	5.4 h	5.5 f
	120	5.41 def	33.0b	1.27 def	5.23 bc	7.5 fg	2.6 de
HT	40	2.56 a	41.0 a	7.28 a-f	9.15 gh	8.5 ef	1.7 abc
	80	7.49 b	3.33 b	1.28 b-f	8.18 fg	1.6 abcd	0.7 bc
	120	3.48 b	8.32 b	1.27 def	5.16 gh	5.5 def	0.6 ef
DT	40	7.48 b	3.32 b	6.30 ab	4.20 cdef	4.5 g	9.5 ef
	80	5.38 fg	5.28 cd	1.25 fg	8.18 efg	9.4 h	6.5 f
	120	7.44cd	8.31 b	1.29 abcd	7.18 fg	6.5 fg	0.6 ef
LT	40	6.39 efg	6.27 d	2.25 fg	7.18 fg	2.6 abc	7.6 cd
	80	2.37 g	8.26 d	0.26 efg	22.0bcde	4.6 a	8.6 cd
	120	8.39 efg	7.38 cd	2.23 g	15.0h	0.6 bc	3.6 de
ST	40	7.42 de	3.31 bc	3.29 abcd	2.22 bcd	2.6 ab	6.7 a
	80	5.46 bc	7.28 cd	6.26 def	8.19 def	1.6 abcd	5.7 ab
	120	6.43 cd	5.32 b	4.30 abc	8.24 bc	8.5 cdef	8.6 cd

Within each treatment, means followed by different letter in a column are significantly different at the 0.05 probability level.

Table 7: Means of interaction effect lodging index, bending moment, breaking resistance for internodes N₃ and N₄ in plant density levels in cultivars rice.

Plant density x Cultiver	Breaking resistance		Bending moment (g/cm)		Lodging index (%)		
	Internode 3	Internode 4	Internode 3	Internode 4	Internode 3	Internode 4	
MT	40	82.6 de	02.11 c	7.1802 ab	2486.0a	2.267 c	2.227 def
	80	18.4 fgh	68.11 bc	7.1324 de	5.1793 cde	326 .0b	167.0 ghi
	120	37.4 fgh	75.7 de	1067.0 gh	7.1551 e	5.244 cd	201.0 efg
HT	40	68.3 hi	81.6 de	1967.0 a	7.2554 a	536.0a	7.372 b
	80	78.4 fg	61.7 de	7.1745 b	2413.0ab	7.364 b	7.317 c
	120	12.4 gh	55.4 f	5.1457 cd	1968.0bc	351.0b	7.424 a
DT	40	43.7 d	43.8 d	2.1174 efg	2.1756 cde	158.0ef	208.0 efg
	80	0.5 f	28.8 d	5.1016 h	7.1573 e	7.201 de	7.189 fgh
	120	25.3 i	81.5 ef	2.1117 fgh	2.1596 de	341.0b	7.273 cd
LT	40	44.8 bc	47.13 b	7.1172 fgh	7.1644 de	2.139 f	5.122 i
	80	21.9 b	42.12 bc	5.1230 efg	5.1825 cde	7.133 f	7.147 hi
	120	37.18 a	47.21 a	5.1199 efg	5.1591 de	7.65 g	3.74 j
ST	40	32.6 e	51.10 c	25.1535 c	2.1979 bc	247.3cd	7.189 fgh
	80	37.8 bc	32.12 bc	5.1514 c	5.2165 a	180 .8ef	176.0 gh
	120	65.3 hi	72.7 de	5.1266 ef	1881.0bcd	351 .0b	5.0246 de

As, Table 5 shown in the most resistance to breaking of third internode with the interaction effects was for LT with the density of 120 plant and the least of it was for DT with the density of 120 plant/m² which was 18.37 and 3.25 g. on stem. Also, the most resistance to breaking of fourth internode resulted for LT with the density of 120 plant / m² (21.47 g/stem) and the least of it was for HT with the same density that was 4.55 g/stem. The cultivar, plant density and their interaction effect had the significant effect on the bending moment on third and

fourth internode (Table 5). So, the most and least bending moment of third internode resulted for HT and DT 1723.4 and 1102.7 g/cm, consequently. The maximum bending moment of fourth internode has seen in HT (2311 g/cm) and it's the minimum was effected by DT (1642.1 g/cm). Bending moment of third internode with the effect of different plant density and increase of density from 40 plant / m² (1530.4 g/cm) to 120 plant / m² had the descending process and also the least bending moment of fourth internode resulted for density of 120 plant / m²

(1717.7 g/cm) and for density of 40 and 80 plant / m² they were 2084.2 and 1954.25, respectively. The maximum bending moment by the effect of cultivar interaction effect × plant density is for HT with 40 plant / m² and the minimum of it is for DT with density of 80 plant / m² that are 1967 and 1016.5 g/cm and also the least bending moment of fourth internode resulted in MT, density of 120 plant / m² which were 1551.7, 1978, 1591.5 and 1881 g/cm in turn but the least of that was in DT (1573.7 g/cm) with the density of 80 plant / m² (Table 5). Lodging index of third and fourth internode were effected by cultivar and interaction cultivar × plant density (p#0.01) and the effect of plant density had the significant effect on third internode (p#0.05) and fourth internode lodging index (p#0.01) (Table 5). The least third and fourth internode lodging index had seen in LT (112.9 and 114.86) and the most of them were for HT (417.25 and 371.75). The minimum third and fourth internode lodging index resulted at the plant density of 80 plant / m² (241.4 and 195.65, respectively (Table 5). The most lodging index of third and fourth internode in HT resulted at density of 40 and 120 plant / m² (536 and 424.7 % and the least lodging index of third and fourth internode resulted in LT with the density of 120 plant / m² which were 65.7 and 74.3 %.

DISCUSSION

As, it was mentioned in results, the shortest length of first, second and third internode (Also, fourth internode after HT cultivar and the lowest internode number (After ST) and the longest third internode diameter and because of this the minimum plant height resulted for LT, so for these reasons the most breaking resistance of third and the least lodging index of third and fourth resulted for the same cultivar (LT) so, this case makes the better and easier transfer of photosynthesis materials to grains (sink) and in result and in result the least blank spikelet and the most spike number in area unit and consequent of that, the maximum grain yield and harvest index has seen in LT. also, we saw that the most blank spikelet number in spike and the least spike number in m² and in result the minimum grain yield was for ST. Islam *et al.*, [3] found that morphologic traits related to lodging and in hybrids and non hybrids varieties are different and in diameter traits of fourth internode among the cultivar rice genotypes from 14 mm to 26 mm are different which resulted for SL-11H and IR79172H hybrids and also the least plant high was for IR72 Indica genotypes (93 cm) and the maximum of that was for BRRI Dhan1H hybrid (129 cm), the most breaking resistance of third and fourth internodes resulted

for SL-9H and SL-10H hybrids, respectively and the minimum third and fourth lodging index was for IR72 genotype Indica. The longer stem length and more leaf area index in hybrid rice may have the important role at increase of bending moment and the consequent of that at increase of lodging index. With the decrease of spike number in hill some qualities such as breaking resistance and lodging index are changed significantly. According to the results in this study, with the increase of plant density, the number of tillers / plant decreased but the number of spikes / m² increased significantly. Also, with the increase of density, the length of spike and flag leaf had descending process but qualities like the number of spikelets / spike and the number of blank spikelets / spike and the weight of thousand grain and also the yield of straw with the effect of plant density didn't show the significant difference. Mobasser *et al.*, [38] found that the period of vegetative growth, the length of spike the percent of filled spikelet and the weight of thousand grain were not effected by the plant density, also with the increase of plant density in different genotypes of rice despite the decrease of tiller number in plant, because of the increase of stem number in area unit, the number of spikes / m² increased. In rice plant, because of the limitation of nutrition material absorption, with the increase of plant density became the bending moment of third and fourth internode the least. Although, plant density doesn't have the significant difference on the fourth internode length and breaking resistance in the third and fourth internode length but, decrease bending moment in third and fourth internode was minimum. Because, the minimum number of third internode and the length of third internode resulted in density of 120 plant / m² and also height of plant with the increase of plant number in area unit had not significant. The most third internode bending moment received in low density because the maximum number of third internode and the longest third internode length resulted with the effect of density 40 plant / m². In the other hand, the length of first, second and third internode and also the number of internodes (the height of plant non significant) had the distinctive descending process with the plant density increase that is because of the increase of plant competition in nutrition material absorption (not the light absorption). Then, the decrease of lodging index specially bending moment of third and fourth internode at high density has the same role. Islam *et al.*, [3] reported that the length of stem has the positive correlation coefficient with the diameter of fourth internode, the length of first, second third and fourth internodes and also with the

breaking resistance of third and fourth internodes but doesn't have the significant correlation with the dry weight, bending moment and lodging index of 3 and 4 nodes. Yoshinaga [39] found that with the increase of plant density from 40 to 160 plant / m² the high of stem will decrease and also with the increase of plant density the lodging index had ascending process. Morphologic traits related to lodging measured only for third and fourth internodes because the stem lodging usually happens in lower internodes [7]. Among morphologic traits, third and fourth internodes had the high and significant correlation, so resistance to breaking and lodging index in internodes are important at inflection [1].

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