Threshing force of paddy as affected by loading manner and grain position on the panicle

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Abstract

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Threshing force, which is the force that separates a grain from the panicle, has a great importance in evaluating losses over design and application of harvesting and threshing machines. In addition, it is important to know the shattering habit of rice varieties in rice breeding program. In this study, the threshing force of two improved rice cultivars Dorfac and Kadous (long-grain), and three local cultivars of Hashemi, Alikazemi (long-grain), and Binam (medium-grain) was determined. The threshing force was measured at three portions of upper, middle, and lower of the panicle and three loading manners as tension, bending perpendicular to the front of the grain (type 1) and bending perpendicular to the side of the grain (type 2). The results revealed that cultivars, loading manners and the grain position on the panicle significantly ($P < 0.01$) affected the threshing force. The highest threshing force of 0.887 N was obtained from the lower portion of the panicle under tension loading; while the least threshing force of 0.267 N was determined for grains from the upper portions of the panicle under bending force of type 2. In the case of tension loading, the highest threshing force value pertained to long-grain cultivars.

Keywords: rice; harvesting machines; shattering habit; threshing force

Grain shattering is an adaptive trait for seed dispersal in wild species of cereals. However, easy shattering causes considerable yield loss in domesticated grain crops. Through the domestication process, humans selected crop plants with low shattering thresholds. Today, the degree of shattering that is considered favorable in a cultivar depends on the way the rice crop is harvested. Varieties with moderate shattering are favored where rice is harvested by large combine harvester-threshers, while harvesting using a small head-feeding combine is the most efficient when hard-shattering to non-shattering varieties are used (Kobayashi 1990). Easy shattering varieties are not acceptable to any of the farmers because they cause severe yield loss no matter what type of harvesting is practiced (Ji et al. 2006).

Threshing force (the required force to detach a grain from the panicle) which describes the grain-shattering habit, assumes to be one of the effective loss-evaluating parameters during harvesting by means of reapers, combines, and threshers. It is an effective parameter for evaluating different rice varieties in breeding programs. Therefore, it is necessary to recognize and classify varieties with the view of shattering habit for optimum application of harvesting machine and reducing losses (Ichikawa, Sujiyama 1986). Likewise, design and optimization of rice harvesters can accomplish by using these sorts of data.

Some researchers did investigations with respect to measuring the threshing force. Lee and Huh (1984) examined the threshing force of different rice varieties. Their results state that the threshing force value in tension is significantly higher than the one applied in bending to detach the grain from the panicle.

Ichikawa et al. (1990) used two testing devices to identify the threshing force and the shattering habit. One of them had a threshing drum with 365 mm diameter and 440 mm width in size, equipped with 32 threshing teeth of 66 mm height. To run the test, they used stalks bearing panicles with a length of 500 mm from the top and weight of 450 g. The velocity at the top of the threshing teeth maintained at 12 m/s. The second method, measurement of straight tension, was taken with TR-11 to quantify separating forces. The values of straight tension showed a wide range, in which there seemed to be a tendency that higher values of the tension were corresponding to the degree of stiffness of the grains in the threshing operation.

Ichikawa and Sujiyama (1986) examined the relationship between the threshing force and losses during harvesting with rice combine. They found that there was a high correlation among combine loss, the threshing rate, and the threshing force. Szot et al. (1998) investigated threshing force of some Italian rice varieties and observed that a tendency of detaching force to take higher values for the lower locations of the kernel on the branch. Tsuneo et al. (2002) investigated the effect of tensile speed on detaching single grain of 20 kinds of rice varieties. Results of their experiments indicated that the behavior of detaching was not affected by the tensile speed but it was dependent on the water content of stem and the kind of rice. Inoue et al. (2003) evaluated strength distribution on detachment force of paddy grain. Experiments were carried out for 49 days during the harvest season, and the grain detachment force was measured based on parallel and perpendicular force. Results showed that the mean value of the parallel force slightly increased through the experiments.

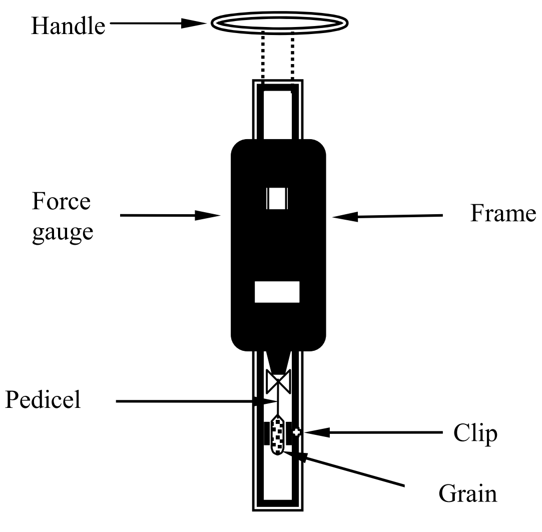

Fig. 1. Schematic representation device for measuring threshing force

Hosoi et al. (2008) studied the seed threshability and shattering habit of weedy rice accessions collected from paddy fields. They reported that some seeds were threshed about 2 weeks after heading, and almost all within 1 month. The number of threshed seeds per day was the highest about 3 to 4 weeks after heading.

Oduori et al. (2008) determined tensile force required to detach a single grain from the ear of a Japonica rice variety that was ready for harvesting to measure shattered rice grain loss attributable to the combine harvester. Azouma et al. (2009) measured the grain-shattered force during the design and development of throw-in type rice thresher for small-scale farmers. Effect of harvesting time on the separation force of grain from panicle was studied by Fangping et al. (2004). Results showed that moisture content of the grain at harvest significantly affected on the separation force. This study aimed to investigate the effect of cultivar, loading manner, and the grain position across the panicle on the threshing force.

MATERIALS AND METHODS

Hashemi, Binam, Alikazemi, Dorfac, and Kadous were rice cultivars used to identify the threshing force. At the end of the crop maturity, ten rice plants were randomly selected and cut carefully. Then, they were sent to the lab of the Department of Agricultural Engineering, Rice Research Institute, Rasht, Iran. Drying three samples of 15 g from each cultivar in a ventilated oven at 103°C for 72 h determined the initial moisture content of paddy (Tado et al. 1999).

To measure the threshing force value, five panicles out of all were randomly selected. In each panicle from the three portions of upper, middle, and lower, the grain with spikelet attachment was carefully detached from the panicle by a pair of scissors. An electronic force gauge (FG-5000, Taiwan) with the resolution of ± 0.01 N was used for measurement of the threshing force. The force gauge was placed on a special pedestal made for this purposes. Adjustable jaw of the pedestal firmly holds the grain and in the mean time, a special clip made for the force gauge gripes the spikelet attachment (Fig. 1). Turning the handle manually, the force gauge is vertically

Table 1. Some agronomic characteristics of cultivars used in tests

Cultivar	Yield (t/ha)	Plant height (cm)	1,000 grain weight (g)	Panicle length (cm)	Length of grain* (mm)
Hashemi	3.5	139.3	25.0	30.7	7.2
Binam	3.5	135	28.0	28.1	6.6
Alikazemi	3.8	125.6	30.0	32.2	7.2
Dorfac	5.5	110	25.5	28	7.7
Kadous	5.7	105.3	27.0	30.25	7.6

*length of milled rice

moveable. The measurement of the maximum force would be readable on the gauge screen when the applied force separates the grain from the pedicel. The bending force applied on the spikelet attachment occurred when the grain fixed horizontally between the jaws of the pedestal. At the same time, the spikelet attachment was connected to the holding clip of the force gauge in two bending positions: perpendicular to the front of the grain (bending type 1) and perpendicular to the side of the grain (bending type 2). The separating force value was recorded at the detaching moment of the grain from the pedicel. The force gauge movement was so that the loading could be considered as a quasi-static manner.

Experiments were carried out in split-split plots. The main factor was cultivar at five levels (Hashemi, Binam, Alikazemi, Dorfac, and Kadous). The grain position on the panicle was considered as the first subordinate factor at three levels (upper, middle, and lower portions of the panicle) and loading manner or direction of the applied force was established as the second subordinate factor at three levels (tension, bending type 1, and bending type 2) in a randomized complete block design with five replications.

RESULTS AND DISCUSSION

Some agronomic characteristics of cultivars used in the threshing force tests are shown in Table 1. Hashemi, Alikazemi, and Binam are categorized as local cultivars, but Dorfac and Kadous (long grain and good quality) are improved and high yielding. Table 2 shows the analysis of variance of the examined variables. The effect of cultivar, the grain position on the panicle and the loading manner on the threshing force was significant at 1% level. However, the interactions between the main variables were not-significant at 5% level.

Comparison between means of the threshing force under different loadings and for all cultivars

Table 2. Analysis of variance for variables used in tests

Source of variation	Degree of freedom	Means of squares
Replication	4	0.0290^{ns}
Cultivar	4	0.0735**
Error (a)	16	0.0101
Grain position on panicle	2	0.2231**
Cultivar × Grain position on panicle	8	0.0117^{ns}
Error (b)	40	0.0198
Loading manner	2	5.5385**
Cultivar × Loading manner	8	0.0285^{ns}
Grain position on panicle × Loading manner	4	0.0313^{ns}
Loading manner × Grain position on panicle × Cultivar	16	0.0042^{ns}
Error (c)	120	0.0186
Total	224	–

**significant at the level of 1%; *significant at the level of 5%; ^{ns}non-significant

Table 3. Means comparison of threshing force (N) in three loading manners

Cultivar	Loading manner		
	Tension	Bending type 1	Bending type 2
Hashemi	0.816[ab]	0.417[a]	0.343[a]
Binam	0.699[c]	0.381[ab]	0.301[ab]
Alikazemi	0.856[a]	0.345[ab]	0.313[ab]
Dorfac	0.857[a]	0.359[ab]	0.280[ab]
Kadous	0.741[bc]	0.300[b]	0.230[b]

In each column, means with similar letters are not-statistically significant at 5% level

is illustrated in Table 3. It is clear that the threshing force value in tension is significantly higher than the two other loadings. The highest threshing force in tension pertained to Dorfac (with the mean of 0.857 N), and the lowest was for Binam (with the mean of 0.699 N). In the bending loadings of type 1 and type 2, the highest threshing force value was concerned to Hashemi with 0.417 and 0.343 N, respectively, while Kadous possessed the lowest values of 0.300 and 0.230 N, respectively. In Fig. 2, the comparison between the values of the threshing force in three loading manners (mean of five cultivars) was plotted. The highest and lowest threshing force were in tension and bending type 2 with the values of 0.794 and 0.293 N, respectively. The direction of the forces applied to the grain is very important in determining the magnitude of the threshing force and in selecting the method of handling the bundles of rice plants for the maximum harvesting efficiency (Lee Huh 1984).

Comparison between the means of the threshing force with reference to the grain position on the panicle and under different loadings is shown in Table 4. Apparently, in every grain position on the panicle, the threshing force value was more in tension rather than in bending. In general, there was a significant difference among three loading manners at 1% level.

The mean of the threshing force (the mean of three positions of the grain on the panicle) gave the highest value of 0.794 N in tension, whereas the lowest value (0.293 N) occurred when the bending force applied perpendicular to the side of the grain. There was no-significant difference among the means of the threshing force in tension and bending type 1 for samples taken from the upper, middle, and lower portions, but when the bending force type 2 applied, the threshing force values differed significantly. Fig. 3 represents comparison between the threshing force values (mean of three loading manners). Detaching a grain from the upper portion of the panicle required a force of 0.427 N but for those of the middle and the lower portions, the required forces were as 0.486 and 0.535 N, respectively. This arises from non-uniform grain maturity across the panicle, which affects the required detaching force of a grain from the panicle (Lee Huh 1984; Szot et al. 1998).

The interaction of the grain position on the panicle and cultivar revealed that there was no-significant difference amongst the means of various cultivars at the level of 5% (Table 5). The cultivar affected the threshing force value ($P < 0.01$) so that the maximum and minimum threshing force concerned to Hashemi and Kadous, respectively.

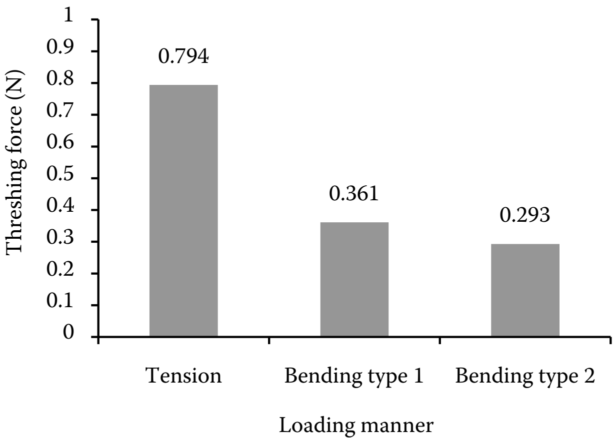

Fig. 2. Means comparison of threshing force for five cultivars

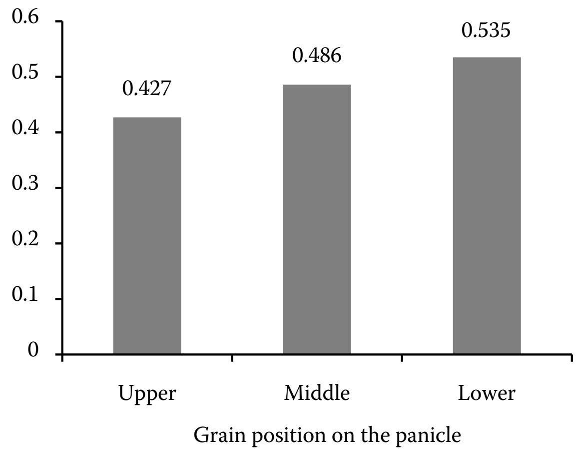

Fig. 3. Comparison between threshing force values at three positions of grain on the panicle

Table 4. Means comparison of the grain position on the panicle and loading manners on the threshing force (N)

Loading manner	Grain position on the panicle			
	upper	middle	lower	mean of loading manner
Tension	0.699[a]	0.796[a]	0.887[a]	0.794[a]
Bending type 1	0.314[b]	0.370[b]	0.398[b]	0.361[b]
Bending type 2	0.267[b]	0.292[c]	0.321[b]	0.293[c]

In each column, means with similar letters are not-statistically significant at 5% level

Table 5. Means comparison of threshing force (N) in three positions of the grain on the panicle

Cultivar	Grain position on panicle			
	lower	middle	upper	mean of cultivar
Hashemi	0.597[a]	0.534[a]	0.445[a]	0.525[a]
Binam	0.549[a]	0.459[a]	0.375[a]	0.460[bc]
Alikazemi	0.547[a]	0.510[a]	0.455[a]	0.505[ab]
Dorfac	0.546[a]	0.493[a]	0.457[a]	0.499[ab]
Kadous	0.437[b]	0.433[a]	0.401[a]	0.424[c]

In each column, means with similar letters are not-statistically significant at 5% level

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