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PHYSICAL PROPERTIES OF THE RICE PLANT AND PADDY*

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The Agricultural Engineering Department of The International Rice Research Institute is engaged in the development of harvesting and threshing equipment for use in the tropical countries. Basic information on the physical properties of paddy and the rice plants is needed for the development of such equipment. The lack of information in this area prompted the initiation of a study on the forces required to: (a) separate paddy from the panicle, (b) separate the panicles from the stalk, (c) pull the individual tillers from the ground, and (d) pull the whole plant from the ground.

Eight varieties of rice (IR8, Bluebonnet 50, C4-63, T(N)1, 81B-25, IR5, BPI-76, and ADT-27) were transplanted at staggered dates in June and July, 1968 to mature simultaneously on October 7, 1968. Variety ADT-27 matured much earlier than the others and was not included in the test. Tests were conducted at seven different dates, September 26, 30, October 3, 7, 11, 14 and 19, 1968 to assess the effect of plant maturity and moisture content on the required forces.

Experimental Equipment and Procedures

A. Separation of Paddy from Panicle

Detachment of the paddy from the panicle occurs when the applied force exceeds the restraining force. This detaching force was applied by rapidly accelerating the panicle following a definite radial path.

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An experimental non-impulsive centrifugal threshing device was built to thresh 10 panicles at a time (Fig. 1). The device consisted of a circular metal disc, mounted horizontally on a vertical shaft. The circular disc was fitted with 10 clamps for holding individual panicles. The shaft and the disc was driven by a 1-hp electric motor through a variable speed drive. The rotation of the disc could be varied from 1000 to 3500 rpm. A circular flexible plastic shroud was hung around the disc to catch the paddy which was detached and thrown from the panicle. An inclined sheet metal pan was fitted below the shroud to enable the continuous collection of threshed paddy during the test.

Ten panicles of each variety were clamped to the rotary disc by hand for each test. The panicles extended to an average radii (m) of 0.31785 (IR8), 0.35335 (Bluebonnet 50), 0.31620 (CU-63), 0.31905 (TN1), 0.33150 (81B-25), 0.31810 (IR5), and 0.32690 (BPI-76). The samples were rotated at speeds of 1000, 1500, 2000, 2500, 3000, and 3500 rpm, subjecting the paddy grains to accelerations of 364, 820, 1458, 2278, 3281, and 4466 g, respectively.

The grain threshed at each speed increment was collected and the following data was recorded:

1. Total weight of threshed paddy;
2. Number of individual paddy grain;
3. Moisture content of paddy as determined by oven drying.

The weight of threshed paddy at any speed increment was divided by the total paddy in the sample to determine the percentage of paddy threshed at each speed increment.

The threshing force was determined with the use of the equation,

$$F = 3.99433\ W_g R N_c^2$$

a metric equivalent of the one developed by B. J. Lamp, Jr. and W. F. Buchele[1/] where:

F = threshing force
Wg = grain weight, kg
R = average radius of panicle, m
N_c = revolutions of disc per second.

B. Panicle, Tiller, and Plant Strength

A simple, tripod-mounted crank and pulley device with a spring scale fitted flexible wire (Fig. 2) was used to pull the individual panicles, tillers and whole plants. A piece of string (or rope) with a noose was attached to the scale to firmly hold the panicle, tiller, or the whole plant. The crank was manually turned at a steady rate during the tests.

Normal panicles and corresponding tillers from ten plants and ten additional whole plants from each variety were pulled at the rate of 0.45 m/sec. This rate of pulling was used because it would be the approximate forward speed of a stripper-harvester combine being developed in the Department. Individual values and their corresponding averages were recorded.

Results and Conclusions

A. Separation of Paddy from Panicle

1. Figures 3, 4, 5, 6, 7, 8 and 9 show the relationship of threshing force versus paddy threshed for the different varieties tested at seven different stages of maturity and moisture levels. As expected within a variety, the higher moisture content paddy required a larger threshing force. The upper moisture limits and the force required to thresh 98 percent of paddy for the tested varieties are shown in Table 1.

[1/] Lamp, B. J. and W. F. Buchele. "Centrifugal Threshing of Small Grains." Transactions of the ASAE, Vol. 3, No. 2, 1960.

There is a marked difference in threshability among the many varieties tested in this study, the order being:

81B-25 > Bluebonnet 50 > IR8 > C4-63 > T(N)1 > BPI-76 > IR5.

Even at approximately the same grain moisture levels, the forces required for threshing vary among varieties. There was prevalent breakage of the panicle with the variety T(N)1, indicating a relatively weak straw.

A force of 0.075 kg is sufficient to thresh 98 percent of paddy under all typical harvesting conditions for these varieties.

There is evidence of paddy selection by weight in a centrifugal threshing device. The heavier (apparently more mature) kernels were threshed at the lower speeds, i.e., lesser forces. In a germination test conducted with the IR8 variety, the heavier kernels threshed at lesser forces exhibited higher viability as compared to the lighter kernels which were threshed at higher forces and the hand-threshed control sample. Table 2 and Figure 10 show the relationship between grain weight and germination. This observation indicates that a centrifugal threshing device may be more useful for seed threshing purposes than the conventional machines.

B. Panicle, Tiller, and Plant Strength

Straw with extreme moisture levels were more susceptible to breakage as evident in Tables 3, 4 and 5. There are varietal differences with respect to straw strength. The varieties are in the following order as regards:

<u>Panicle strength</u>

BPI-76 > Bluebonnet 50 > C4-63 > 81B-25 > IR8 > IR5 > T(N)1.

<u>Tiller strength</u>

Bluebonnet 50 > 81B-25 > IR5 > BPI-76 > IR8 > C4-63 > T(N)1.

<u>Whole plant uprooting force</u>

Bluebonnet 50 > 81B-25 > BPI-76 > IR5 > IR8 > C4-63 > T(N)1.

Irrespective of variety, nearly 50 percent of the plants pulled on September 26 were completely uprooted without severing the root from the plant. However, of the plants pulled on October 19, nearly 10 percent were uprooted and the rest were severed at the base leaving the stumps in the ground. The progressive hardening of the soil and the change in the straw strength due to late test seems to have contributed to this difference.

Pulling force was at a maximum for panicle, tiller, and whole plant at the same date, October 7, 1968. Thus, the maximum panicle, tiller, and whole plant pulling force was recorded on the 107th day for Bluebonnet 50; the 112th day for T(N)1; the 116th day for IR8; the 122nd day for BPI-76 and C4-63; and the 129th day for IR5 and 81B-25.

TABLE 1. Maximum permissible paddy moisture levels with corresponding minimum force required to thresh 98 percent of paddy for seven rice varieties.

	Maximum permissible paddy moisture content (% d.b.)	Minimum threshing force (kg)
IR8	32.5	0.058
Bluebonnet 50	34.6	0.052
C4-63	28.4	0.062
T(N)1	31.5	0.069
81B-25	30.1	0.049
IR5	31.8	0.075
BPI-76	29.6	0.073

TABLE 2. Germination of centrifugally-threshed IR8 paddy compared with hand-threshed check samples at seven levels of maturity (10 panicles per test).

Plant age (Days from seedling)		Hand-threshed paddy	Centrifugally-threshed paddy							
			1000 rpm	1500 rpm	2000 rpm	2500 rpm	3000 rpm	3500 rpm	Paddy left on panicle	Total paddy
105	a	.0290	.0310	.0303	.0294	.0288	.0275	.0270	.0268	.0291
	b	86	95	92	87	70	39	21	5	85
109	a	.0287	.0309	.0301	.0294	.0287	.0279	.0269	.0266	.0286
	b	92	96	94	90	70	47	30	8	90
112	a	.0286	.0306	.0298	.0290	.0285	.0277	.0269	.0264	.0285
	b	92	98	95	88	67	46	33	4	91
116	a	.0284	.0301	.0296	.0289	.0282	.0275	.0268	-	.0284
	b	89	97	96	88	66	47	29	-	90
120	a	.0283	.0297	.0292	.0284	.0276	.0273	-	-	.0281
	b	85	96	94	76	59	38	-	-	83
123	a	.0281	.0294	.0286	.0281	.0274	-	-	-	.0280
	b	83	92	86	71	59	-	-	-	82
128	a	.0279	.0290	.0282	.0275	-	-	-	-	.0278
	b	78	82	78	66	-	-	-	-	78

a = Average paddy weight (grams).

b = Germination percentage (%).

TABLE 3. Average panicle pulling force in kilograms at a constant pulling speed of 0.45 meter per second.

Test date	Variety						
	IR8	Bbt.50	C4-63	T(N)1	81B-25	IR5	BPI-76
9-26-68	2.91	3.08	3.20	2.05	3.14	2.57	4.01
9-30-68	2.94	3.42	3.28	2.10	3.18	2.59	4.11
10-03-68	2.99	3.49	3.27	2.07	3.19	2.60	4.10
10-07-68	3.05	3.56	3.30	2.09	3.20	2.61	4.22
10-11-68	3.02	3.48	3.25	2.06	3.20	2.61	4.10
10-14-68	2.97	3.37	3.19	2.05	3.17	2.59	3.95
10-19-68	2.93	3.20	3.18	2.07	3.18	2.53	3.98

TABLE 4. Average tiller pulling force in kilograms at a constant pulling speed of 0.45 meter per second.

Test date	Variety						
	IR8	Bbt. 50	C4-63	T(N)1	81B-25	IR5	BPI-76
9-26-68	6.00	8.41	5.09	3.79	6.95	7.20	6.29
9-30-68	6.12	8.57	5.60	3.92	7.19	7.69	6.38
10-03-68	6.12	8.60	5.60	3.97	7.35	7.67	6.38
10-07-68	6.15	8.66	5.62	3.97	7.37	7.70	6.40
10-11-68	6.13	8.58	5.61	3.95	7.36	6.71	6.34
10-14-68	6.10	8.56	5.56	3.88	7.31	7.60	6.35
10-19-68	6.03	8.37	5.12	3.84	7.08	7.20	6.31

TABLE 5. Average plant pulling force in kilograms at a pulling speed of 0.45 meter per second.

Test date	Variety						
	IR8	Bbt. 50	C4-63	T(N)1	81B-25	IR5	BPI-76
9-26-68	41.6	52.9	43.3	19.8	63.9	56.2	54.2
9-30-68	43.3	61.5	42.6	20.4	65.6	55.3	50.7
10-03-68	45.2	58.1	43.5	22.7	64.9	54.7	56.8
10-07-68	45.6	60.1	44.9	22.8	65.6	55.4	56.6
10-11-68	43.5	57.7	41.7	20.6	63.3	56.3	55.5
10-14-68	44.7	57.3	40.5	18.1	60.4	53.9	52.2
10-19-68	39.3	51.6	38.8	17.5	57.2	51.8	49.3