THE POTENTIALS OF HULLING HIGH-MOISTURE PADDY

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ABSTRACT

Field hulling of high-moisture paddy followed by brown rice drying offers many advantages over the present paddy harvesting and drying system. We did a preliminary study of the parameters for efficient hulling of high-moisture paddy using the IRRI Centrifugal Huller and two Indica rice varieties.

Hulling capacity, hulling efficiency, brown rice recovery and percent whole bown rice were generally best at the impeller peripheral speed of 44 m/s. A second pass through the huller increased hulling capacity, brown rice recovery and hulling efficiency, but reduced percent whole brown rice. To solve this, we recommend separation of paddy after hulling and aspiration such that only unhulled and partially-hulled grains will be fed back to the huller. Paddy at even 23% m.c. could be effectively hulled by the impeller-type huller, but the results were generally better at 14 to17% m. c.. Only in percent whole brown rice did the 17 to 23% m.c. range performed better than that of 14% m.c. Difference in varietal response to hulling was observed.

Keywords: High-moisture hulling, brown rice, centrifugal huller, Indica rice, Japonica rice

INTRODUCTION

Paddy or rough rice is hulled conventionally at low moisture, about 14 to15% m.c. [1] to minimize breakage due to shear and friction. This practice requires drying high-moisture paddy down to this moisture level. The presence of covering hull, however, prevents rapid moisture loss resulting in high drying energy requirement.

Brown rice dries about twice as fast as paddy in a given drying environment (Henderson, 1973). If high-moisture paddy could be economically and efficiently hulled, followed by brown rice drying, then drying energy could be significantly reduced. The volume reduction due to the removal of hulls will further result in more brown rice which could be dried for a given dryer capacity. Moreover, as in the case of in-field hulling, hulls

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[1] All reference to moisture content is in wet basis.

will be left in the field as soil conditioner and need not be transported to the milling or storage site. Thus, transport, drying, and storage costs will be reduced and hull disposal problems will be eliminated (Pasikatan et. al., 1995).

The tradeoff is, in the absence of the protective hulls, brown rice may readily fissure during drying and transit (Henderson, 1973; Ito, 1992). The extent of checking, as well as the energy savings due to brown rice drying need to be quantified to arrive at an informed decision.

Ito (1987, 1992) reported that paddy with up to 26% moisture content could be hulled by an impeller-type huller with proper speed adjustment. He claimed that combine harvesters equipped with impeller-type huller is a promising technology which could save 20-30% of the total costs compared to the existing system. Yamashita (1993), using Japonica rice varieties showed the feasibility of hulling high-moisture paddy, and even the superiority of impeller-type huller over the rubber-roll type. To our knowledge, very little work was done in evaluating the perfomance of impeller-type huller with high-moisture, Indica-type paddy.

Henderson (1973) reported that some varieties hull more effectively than others, and that rice with higher moisture content does not hull as well as that with lower moisture content. Hak et. al. (1991) compared the mechanical behavior under impact loading of Japonica and Indica-type rice with high (21%), medium (17%), and low (13%) m.c.. They observed that for a given impact load, the damage in terms of cracks and brokens was higher in Indica than in Japonica rice, and highest at medium m.c. than at low and high m.c. They reported that rupture force and rupture energy appeared to be least at 17% m.c., and that rupture force and energy of Japonica rice were higher than that of Indica at the same moisture content. Barredo et.al., (1992) reported that two models of centrifugal huller gave significantly higher brown rice yield, for single-pass hulling, than the rubber roll-type, for IR 44 and IR 72 (both Indica rice varieties).

This study aimed to explore further the potentials of high-moisture paddy hulling using the IRRI centrifugal (or impeller-type) huller and two Indica rice varieties. The specific objectives were: to determine the machine (impeller speed and number of passes) and paddy parameters (variety and moisture content) for effective and efficient high-moisture hulling.

MATERIALS AND METHODS

Materials

Wagwag (medium-grain, traditional) and RC12 (long-grain) rice varieties were used. Newly harvested paddy (about 26% m.c.) was threshed, cleaned, and dried separately to correspond to 14, 17, 20 and 23% m.c. For Wagwag which was hulled in a farmer's field, paddy was sun- and air- dried down to the desired m.c., tempered and then hulled. The hulled samples were packed in an ice box for transport to IRRI, then transferred to a freezer. In the case of RC12 which was hulled in the laboratory, paddy was dried to the desired m.c., then placed inside a freezer at 0 °C. The samples were thawed and allowed to equilibrate with room temperature for 30 minutes before the hulling tests.

Equipment

The IRRI Centrifugal Huller (ICH) with integral aspirator was used. The impact surface was lined with rubber. Engine speed was measured by a tachometer and set through the throttle adjustment. A Bates Laboratory Aspirator was used to further separate the hulls from brown rice and paddy. All samples were weighed through a Sartorius digital balance.

Experimental Procedure

The ICH speed and grain intake opening were set. The air intake of the aspirator was fixed to a slight opening to avoid unnecessarily separating the broken brown rice. The pre-weighed, one-kg samples were fed to the ICH hopper. Time to finish one sample was recorded. The paddy samples were subjected to single and double pass according to the experimental design. The samples from ICH were further aspirated using a laboratory aspirator to remove the remaining hulls, then weighed. Paddy was then separated from brown rice, brokens from whole brown rice, by indented trays and through manual picking. Paddy, brown rice (whole and brokens) were weighed, bagged, and returned to the freezer.

Definition of Terms and Equations Used

Four hulling parameters were used: hulling capacity, hulling efficiency, brown rice recovery (or yield), and percent whole brown rice. They are defined by the following equations:

a) hulling capacity (kg/h)

$$\text{hulling capacity (kg/h)} = \frac{\text{weight of brown (hulled) rice}}{\text{time}}$$

b) hulling efficiency (%)

$$\text{hulling efficiency (\%)} = \frac{\text{weight of whole brown rice}}{\text{weight of paddy sample}} \times 100$$

c) brown rice recovery (%) $= \dfrac{\text{total weight of brown rice}}{\text{weight of paddy sample}} \times 100$

d) whole brown rice (%) $= \dfrac{\text{weight of whole brown rice}}{\text{total weight of brown rice}} \times 100$

Experimental Design

The hulling tests with Wagwag were done in a farmer's field, hence it was not possible to maintain the paddy moisture content for a few hours or days. A completely randomized design (CRD) with three replications made it possible to do the tests as soon as the paddy reached the desired moisture content. The variables were impeller speed (2800, 3000, 3200, 3400 rpm or corresponding to peripheral speeds of 36, 39, 42, 44 m/s) and paddy moisture content (14, 17, 20, and 23%). Hulling tests with RC12 were done at the IRRI AED. The paddy samples were sun-and air-dried and placed inside a freezer as soon as the desired m.c. was reached. A randomized complete block design (RCB) with four replications using the same variables as the preceding tests was used. This enabled comparison of results across m.c. which could not be done with a CRD.

RESULTS AND DISCUSSION

Hulling Capacity

The hulling capacity of the IRRI Centrifugal Huller (ICH) increased with impeller speed, but decreased with second pass and moisture content, for both Wagwag and RC12 (Fig. 1; Tables 1 and 2). Impeller speed and second pass significantly influenced hulling capacity for the tests with Wagwag. In the tests with RC12, impeller speed, second pass and moisture content significantly influenced hulling capacity.

Higher impeller speed imparts higher centrifugal force to the grains, thus greater impact force is exerted against the lining. Consequently, more paddy are expected to be hulled. A second pass allows unhulled or partially-hulled grains to be further hulled by the additional impact and grain-to-grain and grain-to-lining friction. However, the added time required for the second pass decreased the hulling capacity. The mean decrease in hulling capacity due to the second pass was 16.7% for Wagwag and 12.9% for RC12. Therefore, for higher hulling capacity, it is advisable to separate the paddy first such that only paddy will be returned to the huller.

The highest hulling capacity for Wagwag, 264.08 kg/h, was obtained at 3400 rpm

(44 m/s) with paddy at 14% m.c.. Likewise, the highest hulling capacity for RC12, 273.74 kg/h was obtained at the same impeller speed and moisture content. The results with peripheral speed was consistent with results reported by Yamashita (1993) that peripheral impeller speed should be more than 43 m/s. The ICH performance with paddy of higher moisture content, i.e. above 14%, seemed to indicate higher moisture (Indica) paddy may be less hard for effective impact separation of hulls. This may further indicate that Indica varieties may have different hulling properties compared to Japonica. Henderson (1973) observed this varietal differences in response to hulling.

Brown Rice Recovery

Brown rice recovery (BRR) increased with impeller speed and with second pass but decreased with moisture content (Tables 1 and 2). Impeller speed and second pass significantly influenced BRR for Wagwag (Table 1). Impeller speed, second pass and moisture content significantly influenced BRR for RC12 (Table 2). As in the trend with hulling capacity, higher impeller speed means higher acceleration of the grains and higher impact force against the lining, thus higher probability of hulling. A second pass further increases hulling because of additional pressure and friction. Yamashita (1993) explained that 20 to 50% of the paddy is hulled in the impeller part, and the rest is hulled by sliding after impact against the lining.

The mean increase in BRR due to second pass, was 62% for Wagwag and 69.86% for RC12. This decrease in BRR was linear with increasing moisture content. The highest BRR for Wagwag was 72.07%, whereas for RC12 it was 74.35%. Both were obtained with paddy at 14% m.c. and 3400 rpm (44 m/s). Similar results, 72.25% BRR, were observed with parboiled, glutinous rice (A. Tec Jr., AED, IRRI, personal communication). As with hulling capacity, this result may further indicate an optimum hardness of paddy for effective rupture and separation of hull.

Hulling Efficiency

Hulling efficiency (HE) increased significantly with impeller speed and with second pass (Fig. 2, Tables 1 and 2) but decreased with moisture content. The mean increase in HE due to the second pass was 71.2% for Wagwag and 63.1% for RC12. For Wagwag, HE was highest at 14% m.c. (83.05%) and at 17% m.c. (83.81%). For RC12, HE was highest at 17% paddy m.c. and second pass (73.24%), but this did not differ significantly from HE of paddy at 14% and 20% m.c.. At 3000 to 3400 rpm, the HE results for paddy at 14 to 17% m.c. were not significantly different. This seemed to suggest that the moisture range of 14 to 17% as optimum for high hulling efficiency of Indica rice.

The highest HE for Wagwag was 83.81%, obtained at 17% m.c. and 44 m/s impeller speed, whereas, the highest HE for RC12 was 73.24% at the same m.c. and impeller speed. This indicated hulling properties may be rice variety-dependent. Length-width ratio could be one factor, since Wagwag is shorter but wider than RC12. However, Barredo et.al., (1993) have observed significant differences in hulling efficiency even between two long-grain rice varieties. Other factors such as amylose content and grain strength may also have an effect on HE. For example, gelatinization of starch and sealing of fissures due to parboiling makes grain hard and resistant to breakage. Thus, higher HE, as much as 96.18%, was obtained with parboiled, glutinous rice using the same ICH (A. Tec Jr., personal communication).

Percent Whole Brown Rice

Percent whole brown rice (WBR) decreased with impeller speed and second pass (Tables 1 and 2). WBR was significantly influenced by impeller speed, number of passes (Table 1) and moisture content (Table 2). Faster impeller speed produced higher centrifugal and impact force, hence, resulting in more breakage of the grain. In the same manner, grains previously strained due to the impact and friction of the first pass, break during the second pass. Table 2 shows breakage generally occurred after the second pass. There was an average 4% reduction in WBR due to the second pass - a further indication of the desirability of separating the paddy first such that only paddy will be returned to the huller. It is generally the speed of 3400 rpm (44 m/s) which gave significantly lower WBR.

Paddy at 17 and 20% m.c. yielded slightly higher WBR (95.6 to 96.9%) than that of 14% (93.3 to 95.9%). This may indicate that brown rice may break more at lower moisture content, i.e at 14%. Considering the other results, the impact force for effective breaking of hulls may be slightly higher than what brown rice at lower moisture content, i.e 14%, could take to prevent breakage. Hence, for resiliency (or resistance to breakage) during hulling , brown rice should be wetter than at 14%, but the hull must be drier than brown rice. The inference is: a skin-dry paddy (hulls have 14% or less m.c., but brown rice has 17% m.c. or more) will be hulled more effectively with minimum breakage. This needs to be validated by future studies.

For RC12, WBR for paddy at 17 and 20% m.c. were highest, and not significantly different from each other. This was inconsistent with the observation of Hak et. al., (1991) that the rupture force and energy of rough rice was least at 17%m.c. such that the damage to the impact force was highest at this moisture content. This could be due to the difference between impact loading (by pendulum against a hard surface) up to the breaking point of the paddy, and impact loading (by centrifugal force against rubber lining) just to break the hull without breaking the brown rice.

Wagwag yielded higher WBR than the longer RC12. The length-width ratio which could be related to hull-rupture strength, might have influenced WBR. The higher strength against impact of Japonica rice (than Indica rice) is related to its geometric shape

(Hak, et.al., 1991). Barredo et.al. (1993) observed that IR72 consistently yielded higher whole brown rice than IR44 for both centrifugal and rubber-roll type of huller used.

CONCLUSIONS

The four hulling parameters (hulling capacity, hulling efficiency, brown rice recovery and percent whole brown rice) were significantly influenced by impeller speed, number of pass and moisture content. The parameters were generally highest at the impeller peripheral speed of 44 m/s. A second pass increased hulling capacity, brown rice recovery, and hulling efficiency, but reduced percent whole brown rice. It is recommended that paddy be first separated such that only unhulled grains will be fed back to the huller. This will increase hulling capacity and brown rice recovery without reducing hulling efficiency and percent whole brown rice. While paddy at even 23% moisture content could be hulled by the impeller-type huller, the results were generally better at 14 to 17% m.c. Only in percent whole brown rice did the huller performed better at 17 to 23% m.c. range than at 14% m.c.. Differences in varietal response to hulling were observed. Paddy size differences particularly length-width ratio (which could be related to hull-rupture strength) might have an influence on hulling response.

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Table 1. Hulling performance of the IRRI Centrifugal Huller at different impeller speeds, number of passes (N_1 = first pass, N_2 = second pass) and paddy moisture contents using Wagwag (traditional, medium-grain) rice variety.

Impeller speed	**Hulling Capacity (kg/h)**		**Brown Rice Recovery (%)**		**Hulling Efficiency (%)**		**Percent Whole Brown Rice (%)**	
(rpm)	**N_1**	**N_2**	**N_1**	**N_2**	**N_1**	**N_2**	**N_1**	**N_2**
14% m.c.								
2800	127.01d	112.33c	43.36d	66.84c	49.33d	76.68a	95.88a	90.40a
3000	168.64c	137.28b	49.99c	69.51b	58.28c	82.50ab	94.95ab	89.04ab
3200	220.65b	165.03a	54.58b	71.11ab	64.76b	83.53bc	94.76ab	87.59b
3400	264.08a	170.14a	58.13a	72.07a	68.29a	83.05c	93.26b	85.24c
17% m.c.								
2800	83.30d	90.82c	30.40c	62.79ab	33.36c	74.61b	96.92a	93.87a
3000	118.94c	103.91bc	39.52b	62.07b	44.72b	76.11b	96.70a	94.28a
3200	162.19b	122.84b	44.19ab	63.88ab	51.00a	79.26ab	96.80a	93.80a
3400	193.78a	154.90a	47.96a	68.89a	55.74a	83.81a	96.10a	91.33b
20% m.c.								
2800	64.28d	59.12d	24.24d	47.73c	25.51d	55.39c	96.79a	95.16a
3000	86.16c	81.82c	31.27c	57.96b	34.51c	68.49b	96.37ab	93.86b
3200	131.87b	104.56b	37.27b	60.00b	41.82b	71.31b	96.20ab	92.91c
3400	195.63a	134.49a	44.42a	65.52a	48.61a	78.28a	95.60b	91.54d
23% m.c.								
2800	46.82d	49.80d	19.59d	42.47d	20.61d	47.75d	96.35a	95.17a
3000	78.84c	74.26c	27.18c	55.35c	29.73c	64.11c	96.75a	93.74ab
3200	102.84b	91.00b	33.10b	58.44b	36.51b	68.70b	95.94a	92.51bc
3400	126.32a	116.96a	37.78a	61.11a	41.90a	72.69a	95.54a	91.80c

In a column under each moisture content, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 2. Hulling performance of the IRRI Centrifugal Huller at different impeller speeds, number of passes (N_1 = first pass, N_2 = second pass) and paddy moisture content using RC12 (long-grain) rice variety.

Moisture Content (%)	Hulling Capacity (kg/h)		Brown Rice Recovery (%)		Hulling Efficiency (%)		Percent Whole Brown Rice (%)	
(rpm)	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2
S = 2800								
14%	130.46 a	109.51 a	40.45 a	68.62 a	40.83 a	71.27 a	88.00 a	81.90 a
17%	77.19 b	82.19 b	27.11 b	56.08 b	27.47 b	61.14 b	90.47 a	84.54 a
20%	71.91 b	72.25 b	24.26 b	51.57 c	23.28 b	52.46 c	89.47 a	84.96 a
23%	40.57 c	65.57 b	14.38 c	45.79 d	13.76 c	44.11 d	87.60 a	80.18 a
S=3000								
14%	188.03 a	149.71 a	49.61 a	72.99 a	51.05 a	70.73 a	85.55 a	75.69 b
17%	120.57 b	115.92 b	34.79 b	63.05 b	36.25 b	65.39 ab	90.47 a	81.44 a
20%	109.35 b	115.88 b	29.98 c	62.60 b	30.54 b	64.51 b	89.72 a	80.91 a
23%	78.89 c	94.00 c	21.43 d	53.28 c	20.38 c	50.06 c	86.36 a	77.71 ab
S=3200								
14%	220.19 a	170.89 a	53.06 a	73.63 a	56.49 a	65.91 ab	86.30 a	69.55 c
17%	171.63 b	146.70 b	42.74 b	67.80 b	44.34 b	70.03 a	87.65 a	79.68 a
20%	144.21 c	143.57 b	35.81 c	66.05 b	36.02 c	63.65 b	89.05 a	76.82 ab
23%	124.22 c	119.03 c	29.75 c	57.07 c	27.95 d	51.56 c	84.01 a	73.28 bc
S=3400								
14%	273.74 a	179.15 a	61.12 a	74.35 a	64.48 a	67.55 a	84.32 a	69.57 b
17%	236.87 b	174.06 a	52.58 b	71.59 ab	56.83 b	73.24 a	87.29 a	78.53 a
20%	200.57 c	165.71 a	44.47 c	68.24 b	45.95 c	67.12 a	88.91 a	75.97 a
23%	157.87 d	139.06 b	35.14 d	60.71 c	33.75 d	54.72 b	83.89 a	69.98 b

In a column under each S, means followed by a common letter are not significantly different at the 5% level by DMRT.

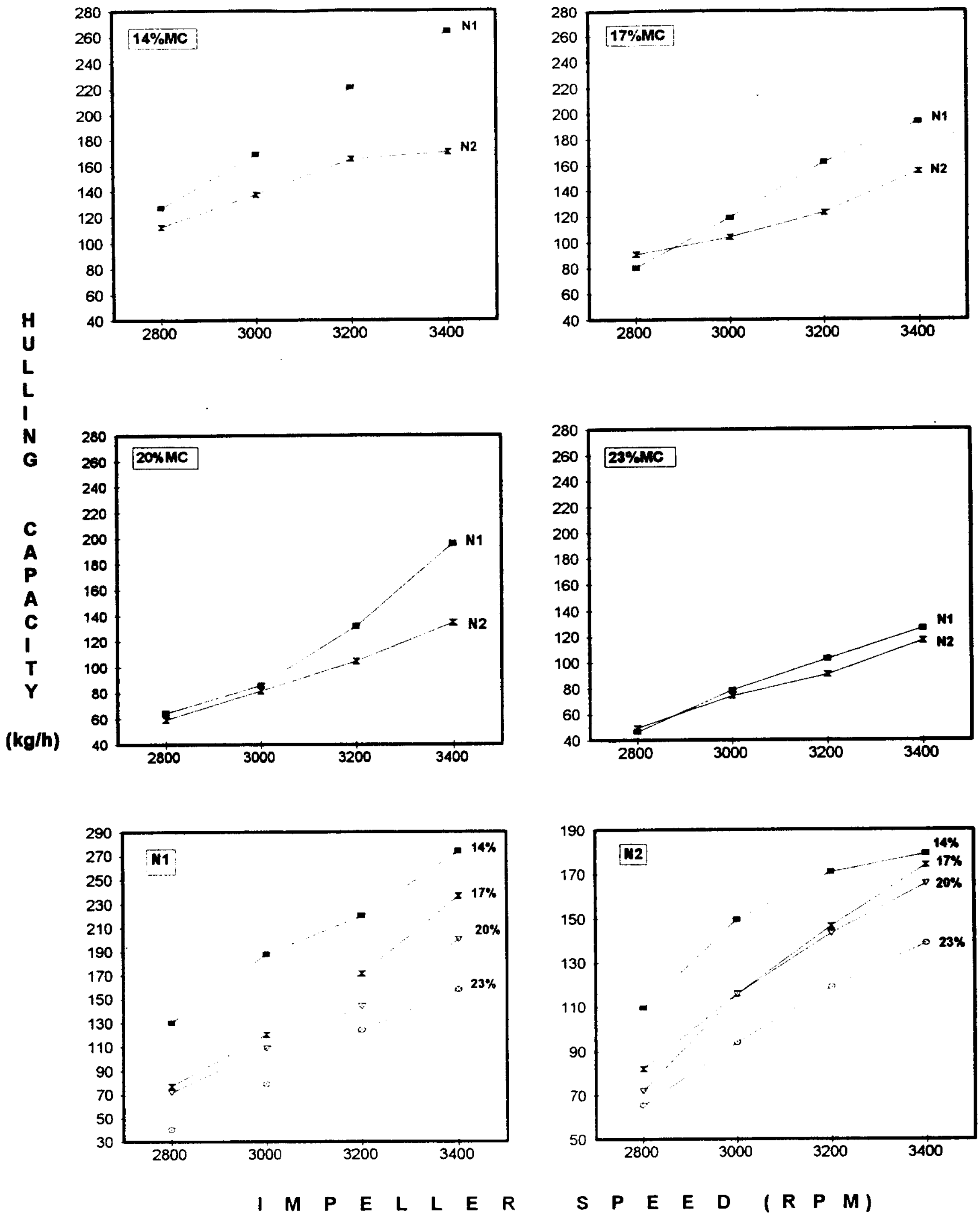

Fig. 1. Hulling capacity of the IRRI Centrifugal Huller at different impeller speeds and moisture contents for Wagwag (medium-grain variety, top four graphs) and RC 12 (long-grain variety, lower two graphs). 1996.

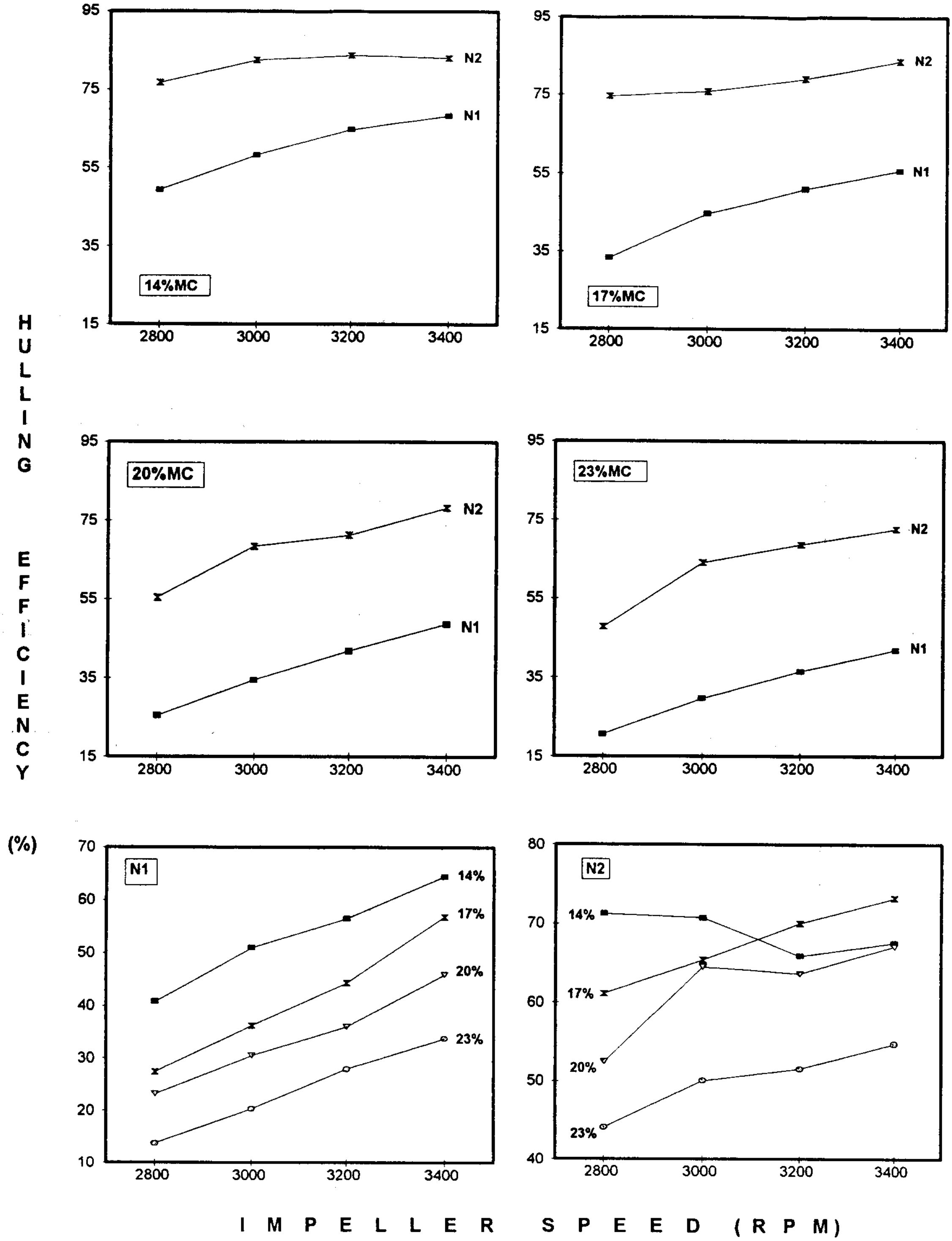

Fig. 2. Hulling efficiency of the IRRI Centrifugal Huller at different impeller speeds and moisture contents for Wagwag (medium-grain variety, top four graphs) and RC 12 (long -grain variety, lower two graphs). 1996.