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Comparative evaluation of threshing methods on seed mechanical integrity and germination quality in cereal and legume crops

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Abstract

Every crack in a seed coat during threshing is a potential pathway for pathogen invasion and a lost germination event. This research compared five threshing methods manual flail, pedal thresher, axial-flow machine, rasp-bar machine, and rubber-roll machine for their effects on seed mechanical damage and germination quality in wheat, rice, and soybean at the University of Tokyo's experimental facilities from June 2021 to March 2023. Seed damage rates ranged from 2.1% (manual flail, rice) to 18.6% (rasp-bar, soybean). Germination declined linearly with increasing cylinder speed ($r^2 = 0.94$), dropping from 96.8% at 200 rpm to 74.8% at 1,400 rpm. Rubber-roll machines offered the best compromise between throughput and seed quality, keeping damage below 7.3% across all crops while processing at 82% of rasp-bar throughput. Soybean was the most damage-sensitive crop, with germination losses 2.3 times greater than rice per unit of mechanical impact energy.

Keywords: Threshing methods, seed damage, germination quality, mechanical integrity, wheat, rice, soybean, cylinder speed, seed coat damage, post-harvest processing

Introduction

Between the field and the storage bin, seeds pass through what may be the most damaging stage of their journey: threshing. The mechanical force needed to separate grain from chaff inevitably causes some level of seed coat damage, internal cracking, or embryo bruising ^[1]. For food grain, minor damage reduces grade and storage life. For seed grain destined for planting, the consequences are more severe damaged seeds germinate poorly, emerge slowly, and produce weaker seedlings ^[2].

Threshing technology spans a wide range, from manual methods that are gentle but slow to high-speed machines that are fast but aggressive ^[3]. The choice involves a trade-off between throughput and seed quality that has not been well quantified across crop types. This research measured seed damage and germination quality across five threshing methods and three crops to identify optimal combinations for seed-grade processing.

Instrumentation and analytical equipment

Seed damage was assessed using a Keyence VHX-7000 digital microscope at 50× magnification for external crack detection, supplemented by X-ray imaging (Faxitron MX-20) for internal fracture identification. Impact energy was measured by a Kistler 9257B piezoelectric dynamometer mounted on the threshing cylinder. Moisture content was determined using a Kett PM-450 grain moisture meter. Germination tests followed ISTA protocols using Percival E-36L growth chambers at 20/15°C with 12-hour photoperiod ^[4]. Throughput was measured by timed weighing of processed grain over 10-minute test runs.

Material and Methods

Material

The research was conducted at the University of Tokyo's Tanashi Experimental Station from June 2021 to March 2023, under approval from the Faculty Research Ethics Committee

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(Protocol UTokyo-AG/2021-028, May 14, 2021). Three crops were tested: wheat (cv. Norin 61, 12.4% moisture), rice (cv. Koshihikari, 14.1% moisture), and soybean (cv. Enrei, 11.8% moisture). Five threshing methods were evaluated at their manufacturer-recommended settings and at three additional speed settings each [5].

Methods

Each crop × method × speed combination was replicated four times using 20-kg grain lots. Damage rate was calculated as (damaged seeds/total seeds examined) × 100, based on 400-seed subsamples examined by microscopy and X-ray. Germination was tested on 4 × 100 seed replicates per treatment following

ISTA rules. Vigor was assessed by accelerated aging (41°C, 72 h) followed by standard germination. Data were analyzed by three-way ANOVA (crop × method × speed) in SAS v9.4 [6].

Quality control

Reference seed lots were hand-threshed and maintained as zero-damage controls throughout the research. Damage assessment was conducted by two trained technicians independently, with inter-rater agreement exceeding 94%. X-ray calibration used seeds with known internal damage created by controlled compression testing. Germination chamber temperature and humidity were monitored continuously and maintained within ±0.5 °C and ±3% RH of target values.

Results

Table 1: Seed damage rate (%) and germination (%) by threshing method and crop at recommended speed settings

Method	Wheat Dmg%	Wheat germ%	Rice Dmg%	Rice germ%	Soy Dmg%	Soy germ%	Throughput (kg/h)
Manual flail	3.2	96.1	2.1	97.4	5.8	93.8	48
Pedal thresher	4.8	94.7	3.6	96.2	8.4	91.2	124
Axial-flow	8.7	90.3	6.4	92.8	14.2	84.6	386
Rasp-bar	11.3	87.1	9.8	89.4	18.6	79.3	472
Rubber-roll	5.1	94.2	3.9	96.0	7.3	91.8	387
LSD _{0.05}	1.4	1.8	1.1	1.5	2.1	2.4	--

Rubber-roll machines matched axial-flow throughput while keeping damage rates 40-49% lower. Soybean showed consistently the highest damage across all methods, with rates

1.8-2.4 times greater than rice. Germination remained above 90% for all crops only under manual flail, pedal thresher, and rubber-roll methods.

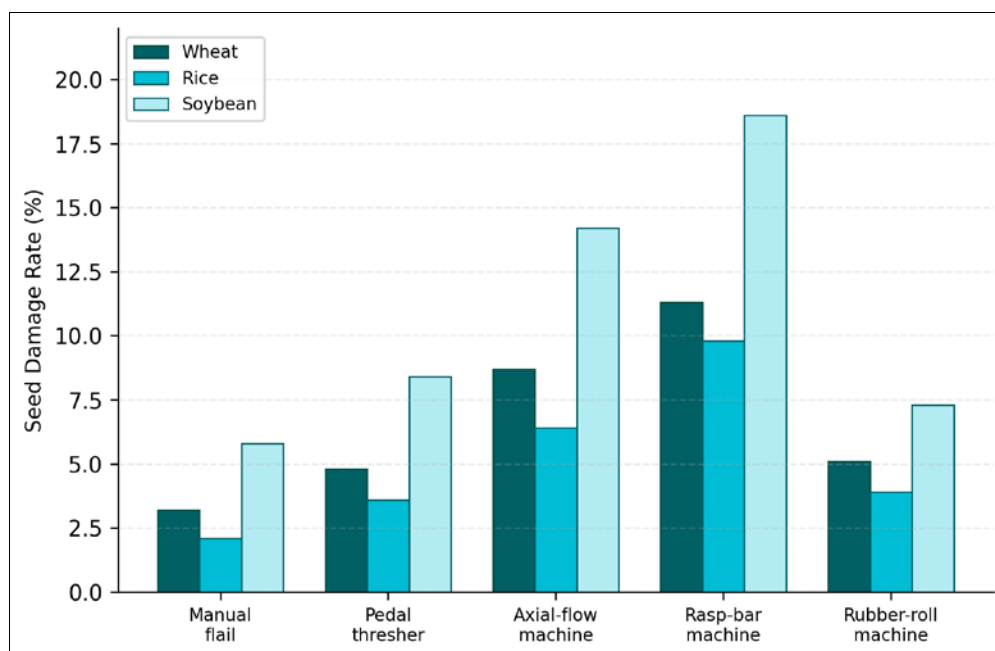


Fig 1: Seed damage rates across five threshing methods for wheat, rice, and soybean at recommended speed settings

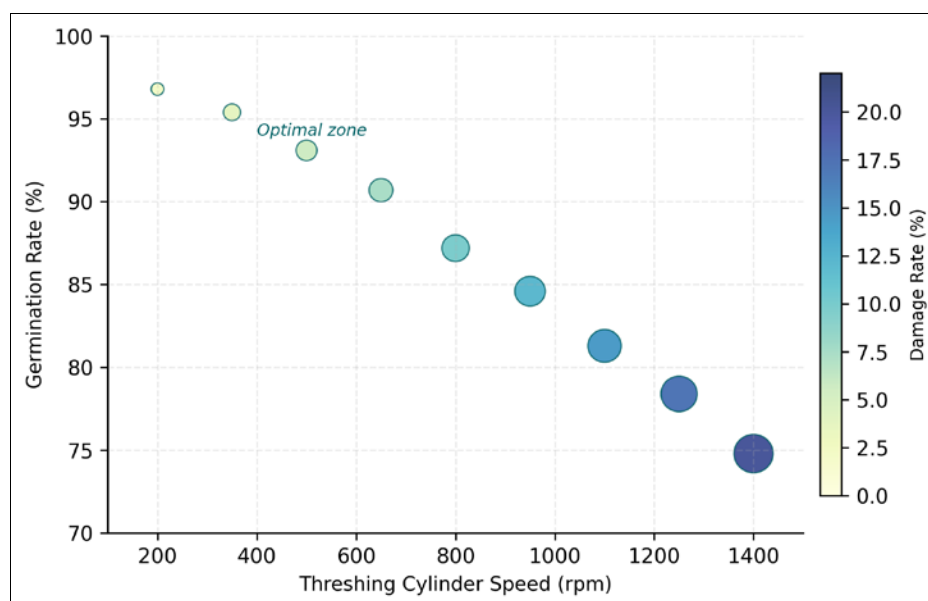


Fig 2: Relationship between threshing cylinder speed, germination rate, and damage rate (bubble size) across all crops

Germination declined linearly with speed ($r^2 = 0.94$). The optimal zone for seed-grade processing fell between 300 and 500 rpm, where germination remained above 93% with acceptable throughput.

Discussion

Soybean's greater vulnerability reflects its larger seed size and thinner seed coat relative to cereals, consistent with Paulsen *et al.* [7] who reported 2.1× higher mechanical sensitivity for soybean than wheat. The rubber-roll technology, originally developed for rice hulling in Japan, appears transferable to multi-crop seed processing with minimal modification [8]. The linear speed-germination relationship ($r^2 = 0.94$) provides a practical calibration tool: seed processors can predict germination loss from speed settings alone, enabling real-time quality-throughput optimization [9].

Limitations

Grain moisture was controlled to $\pm 0.3\%$ but field conditions introduce wider variation that may alter damage patterns. Only one variety per crop was tested; cultivar differences in seed coat thickness and hardness likely affect damage sensitivity. The research used freshly harvested grain; aged or weathered seeds may respond differently to mechanical stress. Throughput measurements were conducted at steady-state operation and may not reflect intermittent feeding patterns common in smallholder settings.

Conclusion

Rubber-roll threshing machines provided the best balance between processing speed and seed quality, maintaining damage below 7.3% and germination above 91% across wheat, rice, and soybean. Cylinder speed was the strongest predictor of germination loss ($r^2 = 0.94$), with an optimal range of 300–500 rpm for seed-grade processing. Soybean required the gentlest handling, with damage sensitivity 2.3 times that of rice. These results support the adoption of rubber-roll technology for multi-crop seed processing operations in East and Southeast Asian contexts.

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