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A New Breaking Strength Tester BSTW-1

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Abstract

The author developed a new apparatus BSTW-1 to measure the breaking strength and compared the measurements of the breaking strength of plastic straws, wheat and rice culms using BSTW-1 and EO-3. It was concluded that BSTW-1 was more convenient and more useful to measure the breaking strength in studies on lodging resistance. Also, the number of samples required to measure the breaking strength at the basal part of the rice culm was discussed.

Discipline: Crop production/Experimental apparatus and method
Additional key words: breaking strength, development of apparatus, estimation of number of samples, lodging resistance

Introduction

Lodging resistance is one of the most important characters for crop cultivation. As it has been reported that the breaking strength of culm or stem affects the lodging resistance[4,6,11], several apparatus to test the breaking strength were developed[1,3,5,8,9,15]. In Japan, the "straw fracture tester, model EO-3"[2] (referred to as EO-3) is broadly used in studies on lodging resistance. This apparatus, however, is not portable and requires skill to obtain accurate measurements.

To improve these shortcomings, the author developed a new apparatus, "breaking strength tester BSTW-1"[12,13] (referred to as BSTW-1). As BSTW-1 is lighter and smaller, and its manipulation is very easy, anyone can use it to measure the breaking strength in the field as well as in the laboratory. In this paper, the characteristics of BSTW-1 and a comparison of its performance with EO-3 will be introduced. Also, the number of samples required to measure the breaking strength with this apparatus will be discussed.

Description of BSTW-1[12]

As shown in Plate 1 and Fig. 1, BSTW-1 is composed of a measuring part and a stage part. The measuring part consists of a digital force gage, a balance using a load cell with which the compressive and tensile forces are measured. The force is expressed by digital figures. The stage part which was newly designed consists of an aluminum base, a guide rail, and a sample holder. The measuring part is attached to the guide rail. The overall dimension of BSTW-1 is about 300 × 110 × 55 mm and the weight is about 1,200 g.

The fragments of tested culm or stem are placed across a pair of vertically aligned pins which are set at a variable distance. The testing is carried out by applying pressure gradually against the tested material by manually moving the force gage using a suitable form of pointed tools until the tested material breaks. Then the breaking strength can be expressed with digital figures.

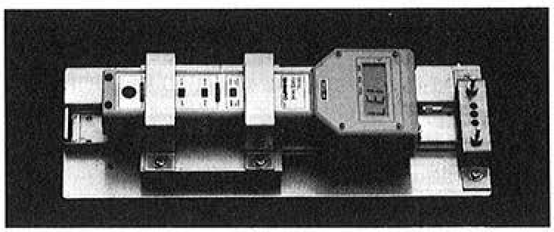

Plate 1. Breaking strength tester BSTW-1

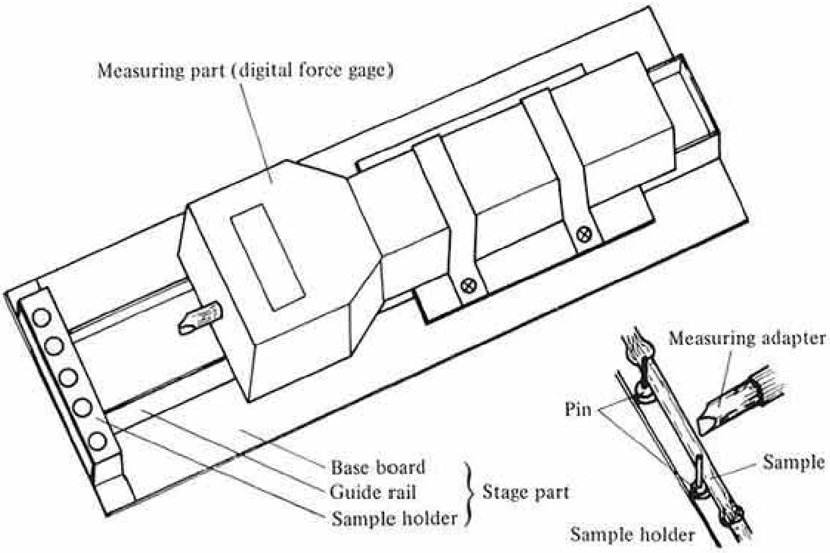

Fig. 1. Schematic representation of the breaking strength tester BSTW-1

Table 1. Comparison of the breaking strength of plastic straws measured with BSTW-1 and EO-3[a)]

Kind of sample / Apparatus	Plastic straw (1)		Plastic straw (2)	
	BSTW-1	EO-3	BSTW-1	EO-3
No. of samples	20	20	20	20
Mean (gf cm)	432.92	438.75	772.70	733.00
Standard deviation (gf cm)	31.351	31.949	147.719	132.907
Uniformity of variance	$F = 1.039^{non}$		$F = 1.235^{non}$	
Difference of mean	$t = 0.583^{non}$		$t = 0.893^{non}$	

a): Data were transformed to the moment at breaking (= breaking strength × span length between pins/2), because the span length was different between the two apparatus.

Comparison with EO-3

The accuracy and the ease of manipulation of BSTW-1 were compared with those of EO-3.

1) *Evaluation of the accuracy of BSTW-1 using plastic straws*[12)]

Two kinds of plastic straws were used to evaluate the accuracy of the breaking strength measurements. Twenty samples of each kind of straws were cut off at the center. In one part the breaking strength was measured using BSTW-1 and in the other EO-3 was used.

The results are shown in Table 1 which indicates that the means and standard deviations did not differ between BSTW-1 and EO-3. Therefore, it was inferred that BSTW-1 and EO-3 would give similar measurements of the breaking strength.

2) *Comparison of measurements of breaking strength and manipulation efficiency in wheat culms*[13)]

To evaluate the manipulation efficiency and the accuracy of the measurements, the breaking strength of wheat culms was measured using BSTW-1 and EO-3. Materials consisted of culms of the leading cultivar Norin 61. On June 5, 1989, 55 days after heading, 40 culms were sampled randomly from two fields to compare each apparatus. These culms were measured at the center of the third internode. The span between the pins of BSTW-1 was 4.2 cm and that for EO-3 was 4.0 cm. Therefore, the measurements obtained with the two apparatus were compared after converting them into values of the moment at breaking (gf cm).

Measuring time for 10 culms is shown in Table 2. The measuring time required for BSTW-1 was 39% of that for EO-3 and the effort was less than a quarter of the latter.

Analysis of variance of the breaking strength is shown in Table 3. The variance between fields was statistically significant at 1% level, while the variance between the apparatus and the interaction was not significant.

From these results, it was inferred that BSTW-1 may enable to measure the breaking strength more quickly than EO-3, with a similar level of accuracy.

Table 2. Operation efficiency for measuring the breaking strength of 10 culms[a)]

Equipment	BSTW-1	EO-3
Time required (sec)	75	190
No. of persons	2.0	3.0

a): Including preparation of culms after sampling, measurement and recording.

Table 3. Analysis of variance for the breaking strength[a)] of wheat culms

Source	d.f.	M.S.	F-value
Apparatus	1	5,513.0	0.045
Field	1	1,176,698.6	9.628**
Interaction	1	40,360.5	0.330
Error	156	122,217.9	

a): Analyzed after transformation to the moment at breaking (= breaking strength × span length between pins/2)

** Significant at 1% level.

Table 4. Analysis of variance for the breaking strength of rice culms with the sheath at the basal part[a)]

Source	d.f.	M.S.	F-value
Apparatus	1	350,621.8	2.816
Hill position within row	7	160,656.5	1.290
Interaction	7	131,311.4	1.055
Error	64	124,492.3	

a): Analyzed after transformation to the moment at breaking (= breaking strength × span length between pins/2)

3) Comparison of measurements of breaking strength of rice culms[13)]

The same procedures were applied to rice culms from the cultivar Nipponbare. Measurements were performed on Sept. 29, 1989, 38 days after heading. Five culms each from 8 hills were sampled in the order of decreasing length. These culms were measured with the sheath at a point located 5 cm above the base. Span between the pins of BSTW-1 was 5.4 cm compared with 4.0 cm for EO-3. The measurements were thus compared after transformation of the breaking strength to the moment at breaking.

Histogram and statistical parameters for the moment at breaking are shown in Fig. 2. The means and standard deviations were not significantly different between BSTW-1 and EO-3.

Results of analysis of variance applied to 2 factors, apparatus and hill position within row, are shown in Table 4. The variance due to the apparatus, the hill position and also the interaction was not significant.

Accordingly, it was assumed that the measurements

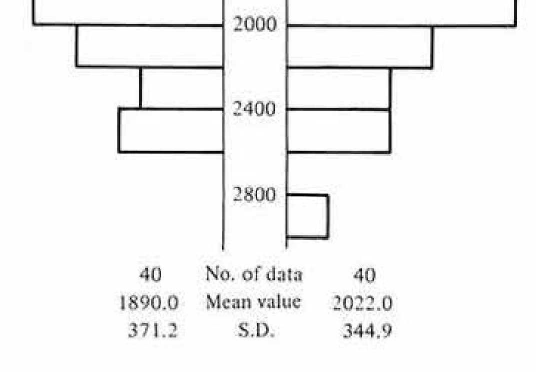

Fig. 2. Comparison of histogram of moment at breaking in rice
Uniformity of variance: $F = 1.158^{non}$.
Difference of mean: $t = 1.653^{non}$.

of the breaking strength of rice culms with the sheath at the basal part using BSTW-1 would be similar to those using EO-3.

Estimation of the number of samples required to measure the breaking strength of rice culms[14)]

Although the breaking strength is one of the most important characters for evaluating the lodging resistance, this measurement had not been performed frequently because no suitable instruments were available. The newly designed apparatus BSTW-1 is a convenient tool for the measurement of the breaking strength. Using this apparatus, the author was able to detect variations of the breaking strength of the basal part of the rice culm with the leaf sheath (abbreviated as BSBPRCLS).

In order to estimate the statistical parameters characterizing the whole population, an exhaustive testing of BSBPRCLS was carried out for all the culms of a total of 20 hills. The observed values were tabulated and statistically analyzed, taking into account the order of the culm length within each hill. Culms from the rice cultivar Nipponbare were tested 38 days after heading. The BSBPRCLS and coefficient of variance are shown in Fig. 3. The breaking strength decreased with the order of culm length within a hill, and the variations between hills were the least in the second longest culms.

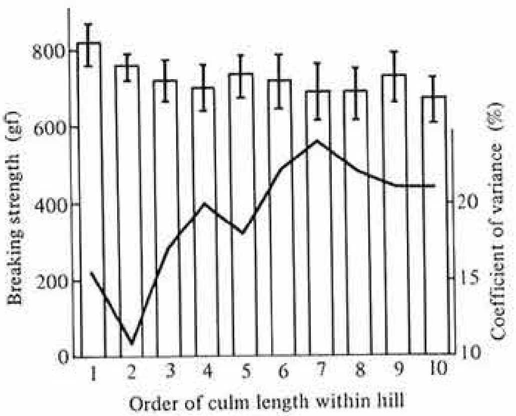

Fig. 3. Breaking strength of rice culm with leaf sheath at basal part and coefficient of variance
Culms were arranged in the decreasing order of culm length.
Vertical bars indicate 95% confidence interval.

The number of samples required for the measurement of the breaking strength could be estimated from the data mentioned above. The t values and coefficients of variation were calculated and compared by changing the hypothetical sampling size which is determined by the number of culms selected from each hill and the total number of hills for the sampling. If one culm per hill is to be sampled, the second culms arranged in the order of length should be measured from 8 hills. If 2 or more culms per hill are to be sampled, the longest 2 culms each from 5 hills, likewise 3 culms each from 4 hills, or the second and third longest culms each from 6 hills should be measured. From the viewpoint of accuracy and efficiency of work, it was concluded that the sampling of the second and third longest culms each from 6 hills was the most effective method.

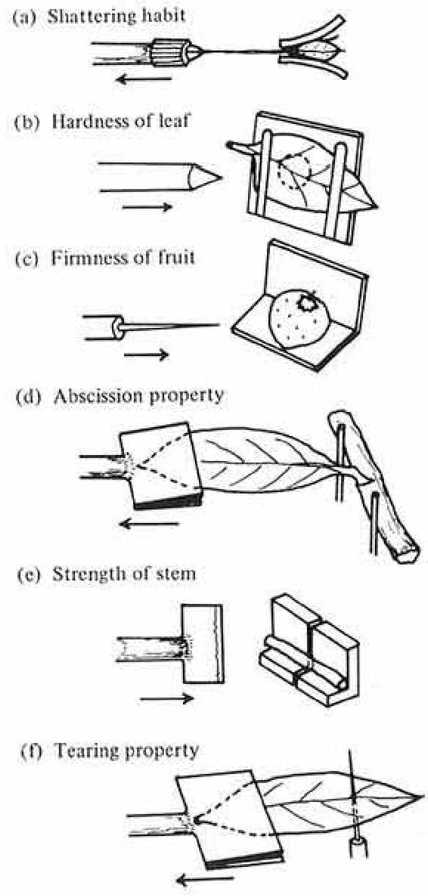

Fig. 4. Examples of applications and modifications of testing tools

Application of BSTW-1 to other fields

As BSTW-1 is employing a digital force gage, this apparatus can be applied to other characters for the evaluation of which the force is measured. For example, Saba et al.[7] and Tanaka et al.[10] modified the sample holder and the measuring adapter of BSTW-1 and measured the hardness of new shoots of tea. Other examples are illustrated in Fig. 4.

Conclusion

The author developed a new apparatus BSTW-1 to measure the breaking strength and compared the measurements between BSTW-1 and EO-3 for plastic straws, wheat culms and rice culms. The breaking strength measured with BSTW-1 did not differ significantly from that measured with EO-3. Also, the measuring effort required by BSTW-1 was less than a quarter of that for EO-3. Therefore the new apparatus BSTW-1 was considered to be convenient and useful to measure the breaking strength in relation to the lodging resistance and other characteristics.

The author estimated the number of samples required to measure the breaking strength of the basal part of the rice culm with the leaf sheath using this apparatus. Sampling of two culms consisting of the second and the third culms arranged in the order of culm length from 6 hills each was the most effective method.

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