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Effect of Mechanical Damage on Soybean Germination

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Abstract

The physical and mechanical characteristics of soybean were studied in this study. The effects of grain damage on soybean increase if the damaged seed is stored, as has often to be done in practice. During storage, harvesting and threshing the mechanically damaged seed loses its germination capacity more rapidly than the undamaged seed, and as a result the seedling percentage decreases. Therefore, in this research introduced the effects of impact velocities (IV), number of impact loadings (NL), and time (T) on percentage of grain damage and percentage of loss in germination to soybean seeds. The result showed significant influenced percentage of grain damage and percentage of loss in germination. As the extent of grain damage increased, capability of germination decreased**.** Increasing the impact velocities from 12.4 to 22 m/s (IV_1=12.4, IV_2=16, IV_3=22 ms^{-1}) and number of impact loading from 1 to 3 times (NL_1: one brunt, NL_2: two brunt and NL_3: three brunt) and time to 3 month (T_1: when impact loading to seed, T_2: after 45 days and T_3: after 3 months) caused an increase in percentage of grain damage from 2.76 to 24.29% and increase in percentage of loss in germination from 28 to 96, respectively.

Keywords: Soybean, Grain damage, Impact velocity, Number of loading, Germination

Nomenclature

IV	Impact velocity
MTG	Mean time to germination
NL	Number of loading
T	Time

Introduction

Soybean (Glycine max (L.) Merrill) seed susceptibility to mechanical damage during harvesting, threshing, and storage operations has decreased seed quality by reducing seed germination ability and seedling vigor, mainly in tropical and subtropical environments (Carbonell and Vello, 2001). Mechanical and physical properties of grains are necessary in designing, handling and processing equipment for them. The resistance to impact, among other mechanical and physical properties, play a very important role in the design of threshers, equipment for loading and unloading, storage structures, harvesting machines, drying equipment, conveyors, spouting and free-fall dropping equipment (Baryeh, 2002; Khazaei et al., 2008).

These problems are expected to be severe in head-stripper combines with successive impact loadings of stripping and threshing units. In these combines, seeds are first impacted by the stripping unit, with a high impact velocity (IV) of 10 to 25 ms^{-1}, and then they are impacted in the threshing unit with an IV of 15 to25 ms^{-1}, and finally are lifted by the elevator cups to be discharged into the combine's storage tank with an IV of 3 to 7 ms^{-1}. These successive impact loadings may cause mechanical damage (micro and macro-damage) to seeds, diminishing their biological value (Khazaei et al, 2008).

Researchers have used different methods to conduct impact tests on grains and seeds, such as pendulum impacting device, centrifugal impactor, and freefall test method (Baryeh, 2002; Khazaei et al., 2008; Parde et al., 2002). The physical damage to grains and seeds is a complex interaction involving some parameters which affect the final quality of the materials. These factors range from impact velocity (IV), seed size and number of impact loadings (NL) on seeds. Each of these factors has varying degrees of effects on physical damage (Baryeh, 2002; Sosnowski, 2006) and germination (Khazaei et al, 2008).

The objectives of this study were to determine, under field conditions, the percentage of grain damage and percentage of germination.

Material and methods

Materials

The most common soybean variety grown in Iran, L-17, was used for testing. The experiment was conducted at the Department of Agricultural Technical Engineering, College of Abooreihan, University of Tehran, Iran. The tests were conducted in laboratory conditions of about 25 to 30°C. The seeds were cleaned and get rid of all foreign matter and broken and immature grains. Shriveled (seeds that were misshapen or had wrinkled seed coats, depressions in the seed, or were not the normal spherical shape) and abnormal (seeds that were severely shrunken, flattened, or diseased, including very small seeds that were nearly flat discs) seeds were removed and only normal seeds (spherical yellow seeds with no visible imperfections) were tested.

To determine the size of the seeds 100 grains were randomly selected and their linear dimensions namely the longitudinal axis containing the major dimension (length, L), the transverse axis containing the minor dimension (width, W), and the transverse axis containing the minimum

dimension (thickness, T) were measured. The mass of seed and thousand seed mass were measured by an electronic balance to an accuracy of 0.01 g. To evaluate thousand seed mass, 1000 randomly selected seeds from the soybean were weighed and averaged (Güner, 2007). The seed quality was evaluated as mechanical damage and germination test.

Determination of moisture content

The moisture content of soybean was determined by oven dry method (ASAE, 2003). Four replications of 15 g seed were kept in a hot air oven at 103˚C for 72 h. The samples were then weighed and moisture content calculated on a dry mass basis. The grain mass was measured using an electronic scale of 0.01 g sensitivity.

Tests Procedure and Impact Device

The seeds were impacted one-by-one by moving the slider toward the impact tips. A cloth bag behind the machine caught the impacted seeds. Impact velocity was adjusted by changing the velocity of the electromotor through an inverter set. The inverter is used to control the rotational speed of electromotor. The seeds subjected to such loads were evaluated in respect of the resulting mechanical damage, as well as the variation capability of germination. The device was used to assess the impact damage on soybean grains. The effects of IV (at 12.4, 16 and 22 ms^{-1}), NL (at 1, 2, and 3 successive impacts), and T (when impact loading to seed, after 45 days and after 3 month) were studied on percentage of physical damage and percentage of germination to soybean seeds.

For each test 250 seeds of soybean were used. After the first impact test was completed, the impacted seeds were sorted as either physically damaged or undamaged by visual inspection. Seeds with visibly cracked coats, broken, split, and halves loosely held together were considered as damaged. The undamaged seeds of the first trial were impacted for a second time and once again the physically damaged and undamaged seeds were separated. This procedure was repeated for a third time. The precise impact point on the seed is random and is considered an uncontrollable factor.

Germination test

In this study, the loss in germination percentage of soybean seeds was measured for determining the physiological damage to seeds under impact loadings. Undamaged seeds from each combination of variables were subjected to germination tests to check for physiological damage. All seeds used in this study were sterilized with 0.5% sodium hypochlorite solution for 1 min. Thereafter, they were washed twice with distilled water then they were surface sterilized using the fungicide. Germination was carried out in 9cm petri dishes containing one disk of Whatman No. 1 filter paper and 5ml of distilled water was added whenever there was a need to keep filter papers moist (Travlos et al., 2007).

Germination experiments were conducted in incubators at 25/15 °C of temperature under a photoperiod of 12-h light/ 12-h darkness. Three replicates of 25 seeds were used for each treatment. Seeds were considered to be germinated with the emergence of the radicles (Khan et al., 2004). Germinated seedlings were counted and removed every other day for 7 days (Egli, 2005; Güner,

2007; Khazaei et al., 2008; Kushwaha et al., 2005; Parde et al., 2002; Tavili and Biniaz, 2009). Seed germination was defined as the appearance of a radicle over 5 mm in length (Yang et al., 2007).

Normal germination included those seedlings, which showed continued development and grew, whereas abnormal germination seedlings did not grow when grown under similar conditions in incubator. Seed germination was recorded every day (Ttavlos et al., 2007) and Germinated seeds and rotted seeds were counted every other day and removed (Yang et al., 2007). At the end of the germination period, the germination percentage, rate of germination and the mean time to germination were calculated. Germination percentage was calculated using the equation (Yang et al, 2007):

$$\text{Final germination percentage} = \frac{\text{Namber of germination seeds}}{\text{Total namber of seeds planted}} \times 100 \qquad (1)$$

The rate of germination was estimated using a modified Timson index of germination velocity = ∑G/t; where G is the percentage of seed germination at every other day and t is the total germination period (Khan and Ungar, 1997). The greater value shows more rapid germination. Mean time to germination (MTG) was calculated by using below formula:

$$\text{MGT} = \sum_i ni \times di / \text{N} \qquad (2)$$

Where *n* is the number of seeds germinated at day *i*, *d* the incubation period in days and *N* the total number of seeds germinated in the treatment. These formulas used by other researchers (Khan et al., 2004; Tavili and Biniaz, 2009; Travlos et al., 2007; Zia and Khan, 2004).

1.1. Statistical analysis

The percentage of grain damage and percentage of germination data were individually subjected to analysis of variance and the difference between the means was determined by a least significant difference test. The data were analyzed to study the effects of IV, NL, and Time on percentage of grain damage and percentage of germination to soybean seeds. Data were analyzed using the SAS statistical software package (version 9.0).

Results And Discussion

The grains to be tested were at moisture content of 6.2%. Table 1 shows the some properties such as length, width, thickness and mass of 1000 soybeans.

Table 1.Some physical properties of soybean (average values)

properties	
Moisture content %	6.2
Seed length (mm)	7.06
Seed width (mm)	6.50

Seed thickness (mm)	5.38
Thousand seed mass (g)	155

Percentage of grain damage

Soybean seed is susceptible to mechanical damage. Figure 1 and Table 2 show that percentage of grain damage tended to increase as IV increased. Similar results have been reported for other grains by other investigators (Baryeh, 2002; Khazaei et al., 2008). Sosnowski (2006) found that with an increase in IV from 7 to 27 ms^{-1}, the mean value of physically damaged beans seeds of Wiejska variety increased from about 0 to 35%.

Table 2.Interaction effects of IV and NL on percentage of grain damage to soybean seeds.

NL	IV (m/s)	Grain damage %		
		1	2	3
1 brunt	12.4	5.45	7.25	6.82
	16	8.64	7.73	9.54
	22	20	18.52	20.37
2 brunt	12.4	4.83	3.45	2.76
	16	7.59	8.28	10.34
	22	18.67	13.33	17.33
3 brunt	12.4	7.14	8.57	4.29
	16	17.14	12.86	11.43
	22	20	18.57	24.29

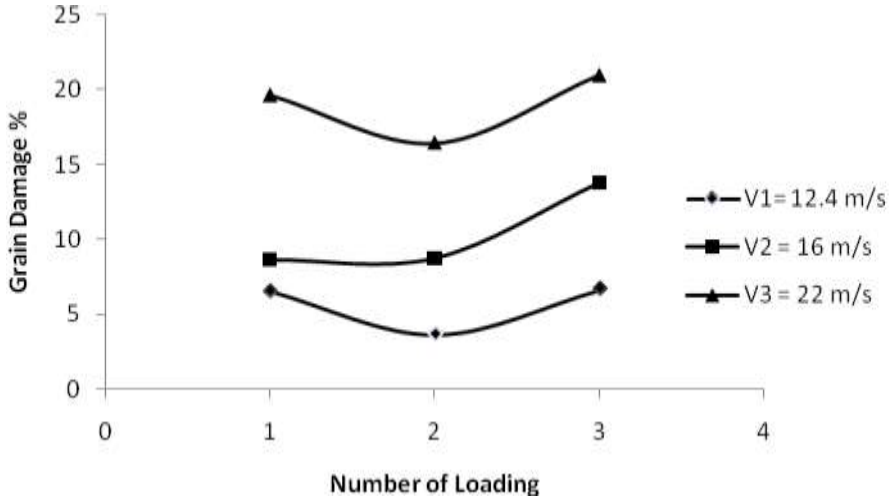


Figure.1. Percentage of grain damage variation with number of loading for different grain impact velocity.

Percentage of germination

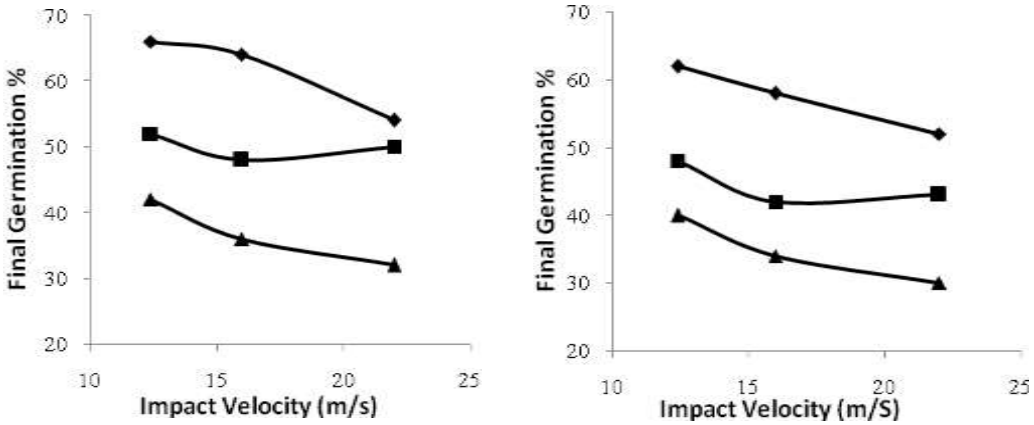
Percentage of final germination of soybean in 12/12 hr light/dark condition occurred in distilled water (Figure 2). The loss in germination of soybean seeds at 12.4 to 22 ms^{-1} was in the range of 28 to 68%. Seed germination was significantly affected by NL, IV and T, and Seed germination decreased with an increase in NL, IV and T. The lowest percentage of germination was obtained at three number of loading when IV was 22 m/s after three month. Analysis of variance indicated that all the three independent variables, namely, IV, T, and the NL, significantly influenced percentage of final germination of soybean seeds. NL had the most influence and T the least (Table 3).

Table 3.Interaction effects of IV, NL and T on percentage of final germination to soybean seeds.

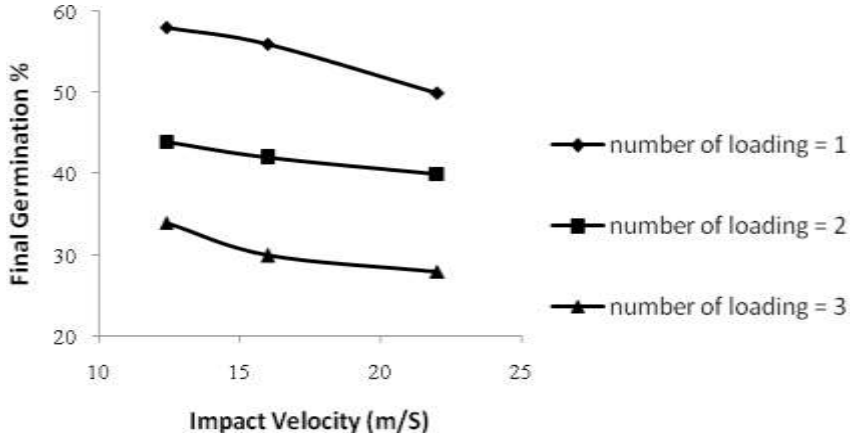
T	NL	final Germination %		
		V=12.4	16	22
T1	1	66	64	54
	2	52	48	50
	3	42	36	32
T2	1	62	58	52

	2	48	42	43
	3	40	34	30
T3	1	58	56	50
	2	44	42	40
	3	34	30	28

Final germination decreases from 66% to 42% at an impact velocity of 12.4 m/s in the number of loading range considered. Final germination decreases from 64% to 36% at an impact velocity of 16 m/s for the same number of loading range, while final germination decreases from 54% to 32% at an impact velocity of 22 m/s for the same number of loading range (Table 3 and Figure2). Sosnowski (2006) found that the germination capacity of bean seeds was decreased from about 90% at IV of 6.44 ms^{-1} to about 58% at IV of 13 ms^{-1}.



a) when impact loading to seeds (T_1) b) after 45 days (T_2)



c) after 3 months (T_3)

Figure.2. Final germination variation with impact velocity for different number of loading

Conclusions

The study shows that soybean variety''L-17'' is susceptible to deterioration after processing. Mechanical damage causes reduction of seed germination. To design and fabricate the equipment related to the post harvest processing, the physical and mechanical properties of the seeds are important design parameters. The device has been used successfully to determine impact damage on soybean seeds. It was found that the grain damage increases as the impact velocity increases. It is the authors hope that the work reported here will encourage engineers in developing countries to be innovative in designing such simple, inexpensive machines for the food industry.

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Table 4.Analysis of variance (Mean Square Error) for percentage of final germination to soybean seeds as affected by T, IV, and NL

Source of variation	df	Mean square error (MS)
Time (T)	2	8.39^{**}
Number of loading (NL)	2	159.13^{**}
Impact velocity (IV)	2	16.07^{**}
T*NL	4	0.38^{ns}
T*IV	4	0.24^{ns}
NL*IV	4	1.57^{*}
T*NL*IV	8	0.20^{ns}
error	29	0.60
CV=6.11		

*Significant at the 0.05 probability level.
**Significant at the 0.01 probability level.
ns, no significant

Table 5.Interaction effects of IV, NL and T on mean time to germination to soybean seeds.

T	NL	mean time to germination		
		V=12.4 m/s	16	22
T1	1	4.24	3.47	4.04
	2	3.46	3.71	3.64
	3	3.95	3.83	3.56
T2	1	4.23	4.03	4.50
	2	3.33	4.09	4.05
	3	3.85	4.41	4.47
T3	1	3.45	3.46	3.96
	2	3.41	3.62	4.00
	3	3.82	3.67	3.79

Table 6.Analysis of variance (Mean Square Error) for mean daily germination to soybean seeds as affected by T, IV, and NL

Source of variation	df	Mean square error (MS)
Time (T)	2	2.74^{**}

Number of loading (NL)	2	51.96**
Impact velocity (IV)	2	5.25**
T*NL	4	0.12ns
T*IV	4	0.08 ns
NL*IV	4	0.51*
T*NL*IV	8	0.06 ns
error	29	0.19
CV=6.12		

*Significant at the 0.05 probability level.

**Significant at the 0.01 probability level.

ns, no significant

Table 7.Interaction effects of IV, NL and T on mean daily germination to soybean seeds.

T	NL	Mean Daily Germination		
		V=12.4 m/s	16	22
T1	1	9.43	9.14	7.71
	2	7.43	6.86	7.14
	3	6.00	5.14	4.57
T2	1	8.86	8.29	7.43
	2	6.86	6.00	6.00
	3	5.71	4.86	4.29
T3	1	8.29	8.00	7.14
	2	6.29	6.00	5.71
	3	4.86	4.29	4