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SOME MECHANICAL PROPERTIES OF SOYBEAN (*Glycine max*) STEMS AND SEEDS

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Abstract

Harvesting is the most important operation in soybean production. To develop a new harvesting machine with any cutting system, we have to exactly know cutting properties of stems and seeds. Firstly, the design of the machine was based on cutting properties.
This study was carried out to evaluate the stem cutting properties and mechanical behavior under compression load of soybean grains (Glycine max L.). This research was conducted at the Department of Agricultural Machinery and Technologies Engineering, University of Dicle, Diyarbakır, Turkey. The soybean cultivar, SA-88, used for this study. It was obtained from the local a commercial farm in Diyarbakir Province, Turkey.
In this research, Cutting force (CF), cutting strength and cutting energy (CE) for stems and seeds were measured by considering cross sectional area at during the harvesting season in year 2016.
Cutting properties of soybean stems and compression properties of seeds were measured by The Lloyd LRX plus materials testing machine.
The highest pod cracking force was observed as 13.43 N at vertical orientation, while the least value of cracking force was determined as 4.59 N at horizontal position. According to Tukey's multiple range tests, the internodes effects were not found significant effect on seed force and energy. The average cracking force and energy were obtained as 146. 62 N and 10.05 N.cm, respectively. Cutting force values increased linearly with the increase in stem diameters.

***Key words**: soybean, cutting properties, pod detachment, energy.*

INTRODUCTION

Harvesting and threshing are the most important operations in soybean production. Knowledge of the physical and mechanical properties of soybean stem and seeds are therefore particularly important for the optimization of harvesting, threshing, drying and storing processes, as it translates into minimization of losses and mechanical damage (Kuźniar et al., 2016). Soybean usually is harvested in the autumn season with high air relative humidity and possibility of rainfall. In this condition, the moisture content of soybean pods and stems are high, so during the harvesting and threshing operations, some problems can be occurred and conventional combine harvester can`t harvest of stem, thresh and separate the bean from its pod properly. Determination of mechanical properties of soybean pod is needed for designing and fabrication of pre-threshing dryer on combine harvester (Azadbakht et al., 2012). Pod distribution along the plants and the operational characteristics of existing combines require the entire crop to be cut before being threshed, separated and cleaned (Mesquita and Hanna., 1993; Sessiz, 2003). The threshing cylinder of a combine requires about 40% of the combine engine power. The cylinder is high because the cylinder processes the stem in addition to the pods. The amount of energy necessary to shatter soybean decreases as the moisture content of the soybeans decreases. A small amount of energy is necessary to open soybean pods at impact velocities similar to those imported by the reel and cutter-bar of a combine. The energy required to shatter soybean pod is significantly correlated with moisture content and impact velocity (Mesquita and Hanna., 1995; Sessiz, 2003). More information on the physical and mechanical properties of soybean is necessary for the efficient use of energy in harvesting and threshing of soybean. Specially designed equipment was developed to reduce harvesting losses, mainly due to pod shattering. Header components were modified to reduce impact on

soybean pods and to reduce the cutting height (Mesquita and Hanna., 1995). Shear force and shear strength of stems are important data in design of harvesting and threshing machine (Sessiz, 2003).
The objective of this study was to determine the relationship between soybean stem cutting properties and seed cracking force and energy at during the harvesting time depend on internodes along whole plant, to determine relationship between cutting properties, seed cracking and pod detachment force along ascendant nodes of the whole plant stems.

MATERIALS AND METHODS

The study was performed with SA-88 soybean variety. The samples were obtained from a commercial farm in Diyarbakır province, which is located in the southeastern part of Turkey. The cutting tests were carried out during the harvesting season in September 2016, soybean plants which have between three internodes that it is has different diameter were randomly harvested by hand from field. Harvested and collected soybean plants which have different internode were transported to laboratory of Department of Agricultural Machinery and Technologies Engineering, University of Dicle.
This study was conducted in two phases. The first phase consist of the determination of stem cutting force were measured. In the second phase, seed cracking force was determined under compressive load.
The initial moisture content of the stems and seeds were determined using ASABE standard involving the oven-drying method. In order to determine the initial moisture content of soybean stems, three samples of 30 g were weighed and dried in an oven of 105 ^{o}C for 24 hours (ASABE, 2006; Taghijarah et al., 2011; Sessiz et al., 2013; Sessiz et al., 2015), after oven drying, samples were removed from oven. Then samples reweighed to obtain the final moisture content using the gravimetrical method. The weights were measured using electronic scales with a capacity of 1.2 kg and with a precision of 0.01 g. The moisture content of stem was determined at 28.34% w.b.
The soybean stem cutting was determined along whole plant (stem and leaves) from first internode to three internodes during the harvesting time. Prior to the tests, the soybean stem was cutted into three different groups. The first group stems were selected between 0-20 mm plant heights; the second groups were selected between at 40-60 cm plan height. The third groups were selected between at 80-100 cm plant height. The average whole plant length and the first pod height was observed as 100.5 cm and 15.5 cm, respectively.
The cutting tests were performed by Lloyd LRX Plus Materials Testing Machine (Figure 1). In cutting tests, the test samples were placed on the machine loading table in its flat position. Loading was applied vertical direction. The cutting knife was steel, 50 mm width, 6 mm thickness and the blade angle of 17^{o}. Cutting measurement were performed at 100 mm/min fixed loading speed for all tests (Sessiz et al., 2013; Sessiz et al., 2015). Cracking force is one of the parameters in the mechanical properties (Putri et al., 2015).

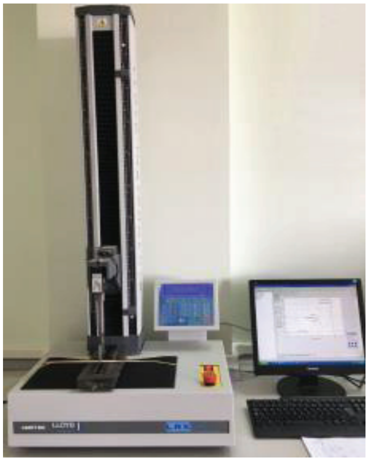

Figure 1. The Lloyd LRX Plus Materials Testing Machine

The cutting energy was calculated by measuring the surface area under the force-deformation curve (Chen et al., 2004; Heidari and Chegini, 2011; Sessiz at al., 2015; Nowakowski, 2016). The cutting energy and displacement was calculated by material testing machine. A computer data acquisition system recorded all the force-displacement curves during the cutting process.
Soybean grain cracking forces were determined by Lloyd LRX Plus Materials Testing Machine.

For each treatment, 20 soybean grains were randomly selected to measure the cracking force and pod cracking force in horizontal and vertical orientation under compressive load by the testing machine. Also, pod detachment force from stem of plant were measured by using a pull digital force gauge (Model FG-20, Lutron Instrument) (Figure 2).

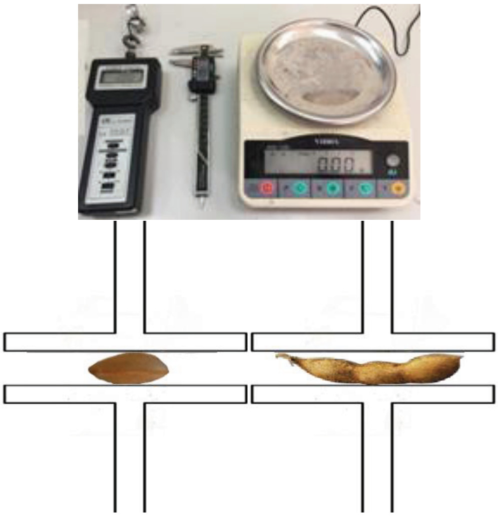

Figure 2. Force gauge and loading directions

The experiment was planned as a completed randomized plot design, and data were analyzed using The General Linear Model (GLM). Mean separations were made for significant effects with LSD and the means were compared at the 1% and 5% levels of significance using the Tukey multiple range tests in JMP software, version 11.

RESULTS AND DISCUSSIONS

The mean values of the pod cracking force and pod detachment force at different nodes are presented in Table 1. As shown in Table 1, the variance analysis of the obtained data indicated that the effect of internode diameter and plant height point on pod cracking force both horizontal and vertical orientation under compressive, and pod detachment force from stem was significant at 5 % possibility level. There was no significant difference between force levels vertical and horizontal oriental. There were not found differences between the second and third internodes results ($p>0.05$). But, there was found significant differences between the first internodes values and other internodes ($P<0.05$). This may be explain that at the first internode exactly was pod not opened. However, there was no differences among the nodes along the plant length in terms of pod detachment force ($p>0.05$). This results similar was found by Sessiz (2003) and Mesquita and Hanna (1995). Detachment force for each per pod was observed approximately 6.5 N by Sessiz (2003). The highest pod cracking force was observed as 13.43 N at vertical orientation, while the least value of cracking force was determined as 4.59 N at horizontal position. The forces required to detach pods from stems were not correlated with pod location along ascendant nodes for the SA-88 cultivar.

Table 1. The pod cracking and pod detachment force depending on along plant stem height

Internode (cm)	Vertical Force (N)	Horizontal Force (N)	Mean Force (N)	Pod Detachment Force (N)
N1[2] (20-40)	13.44[a1]	8.19[a]	10.81[a]	4.55[ns]
N2(40-60)	8.94[b]	5.52[b]	7.23[b]	4.37[ns]
N3 (80-100)	8.77[b]	4.45[b]	6.68[b]	4.06[ns]
LSD	0.1226	0.1226	0.119	0.122
Mean	10.38[a]	6.10[b]	8.24	4.33[ns]

[1]means followed by the same letter in each column are not significantly different by Tukey's multiple range test at the 5 % level.
[2]IN1, IN2 and IN3: first, second and third internodes, respectively

The mean values of seed cracking force and cracking energy at different internodes are shown in Table 2. According to Tukey's multiple range tests, the internodes effects was not found significant effect on seed cracking force and energy under load. The seed cracking force was changed between 143.78 N and 149.45 N. The average values of cracking force and energy were obtained as 146.62 N and 10.05 N.cm, respectively (Table 2).

Table 2. The average values of seed cracking force and energy

Height (cm)	Cracking Force (N)	Cracking Energy (N.cm)
N1 (20-40)	149.45	10.17
N2 (40-60)	146.65	8.16
N3 (80-100)	143.78	11.83
Mean	146.62	10.05

The average results of cutting force and cutting energy are shown in Table 3. According to Tukey's tests result, cutting force values increased with an increase in the stem internodes depend on plant height. But, there were no significant differences between the cutting forces along internodes (Table 3). However, the cutting energy requirement increased depends on internodes. There were found significant differences between internodes ($p<0.05$). At top internode, the cutting energy value is lower than the other internodes (Table 3). The lowest cutting forces were determined at top internode of whole plant.

Table 3. The average values of cutting force and cutting energy depend on cut height

Height (cm)	Maximum Cutting Force (N)	Cutting Energy (N.cm)
N1 (20-40)	303[a]	211.99[a]
N2 (40-60)	230[a]	146.48[ab]
N3 (80-100)	218[a]	116.48[b]
LSD	0.1214	0.1214
Mean	250.63	158.31

CONCLUSIONS

The highest pod cracking force was observed as 13.43 N at vertical orientation, while the least value of cracking force was determined as 4.59 N at horizontal position. The forces required to detach pods from stems were not correlated with pod location along ascendant nodes for the SA-88 cultivar.

According to Tukey's multiple range tests, the internodes effects were not found significant effect on seed force and energy. The average cracking force and energy were obtained as 146. 62 N and 10.05 N.cm, respectively.

Cutting force values increased linearly with the increase in stem diameters. But, there were no significant differences between the cutting forces along internodes (Table 3). However, the cutting energy requirement increased depends on internodes. There were found significant differences between internodes ($p<0.05$). At top internode, the cutting energy value is lower than the other internodes (Table 3).

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