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Research Article

Seed Damage Test for Roller-Type Device Designed at Different Flute Helical Angles

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Abstract. The crop producers who cannot buy a second planter due to its cost, have been seeking to take advantage of the planter with the roller-type metering device in dry bean sowing. While seemingly adequate for dry bean sowing, if the roller structural properties and operating parameters suitable for the seed dimensions are not used, it can cause an increase in the seed damage ratio. In this text, a mission was undertaken to determine the damaged seeds ratio caused by the roller-type metering device under the influence of the flute diameter and helical angle, ground speed, and seeding rate. Seed damage was measured by collecting and weighing seeds from each replication during seed flow. Flute diameter (18, 20, and 22 mm), helical angle (0, 10, and 20°), ground speed (1.0, 1.5, and 2.0 m s^{-1}), and seeding rate (100, 150, and 200 kg ha^{-1}) independent variables and seed damage rate were selected as the dependent variable, to measure seed damage level. According to the results, the ground speed definitely affects the seed damage rate, while the helical angle and flute diameter quite affected. The increase in the seeding rate, ground speed, helical angle, and flute diameter reduced the seed damage rate. The lowest seed damage rate values were obtained at 200 kg ha^{-1} seed rate, 2 m s^{-1} ground speed, 22 mm flute diameter, and 20° helical angle.

Farklı Oluk Helis Açılarında Tasarlanan Makaralı Tip Ekici Düzen için Tohum Hasarının Belirlenmesi

Anahtar kelimeler:
Oluk çapı, ilerleme hızı, ekim normu, ekim makinası, kuru fasulye

Özet. Maliyetinden dolayı ikinci bir ekim makinası satın alamayan üreticiler, kuru fasulye ekiminde oluklu makaralı ekici düzenli ekim makinalarından yararlanmaktadırlar. Oluklu makaralı ekici düzenli ekim makinaları kuru fasulye ekimi için yeterli görünmekle birlikte, tohum boyutlarına uygun makara yapısal özellikleri ve işletme parametreleri kullanılmazsa tohum hasarı oranında artışlara neden olabilir. Bu çalışma, farklı oluk çapı, oluk helis açısı, ilerleme hızı ve ekim normunun etkisi altındaki makaralı tip ekici düzende meydana gelen hasarlı tohum oranını belirlemek için gerçekleştirilmiştir. Tohum hasarı oranı, her bir tekerrürde makaradan akan tohumların bir kapta toplanıp tartılmasıyla belirlenmiştir. Zedelenmiş tohumları belirlemek amacıyla bağımsız değişken olarak oluk çapları (18, 20 ve 22 mm), helis açıları (0, 10 ve 20°), ilerleme hızları (1.0, 1.5 ve 2.0 m s^{-1}) ve ekim normları (100, 150 ve 200 kg ha^{-1}) bağımlı değişken olarak tohum hasar oranı seçilmiştir. Elde edilen sonuçlara göre, ilerleme hızı tohum hasar oranını önemli bir şekilde etkilerken, helis açısı ve oluk çapı oldukça etkilediği görülmüştür. Ayrıca, ekim normu, ilerleme hızı, helis açısı ve oluk çapındaki artış tohum hasar oranını düşürmüştür. En düşük tohum hasar oranı değerleri 200 kg ha^{-1} ekim normunda, 2 m s^{-1} ilerleme hızında, 22 mm oluk çapında ve 20° helisel açıda elde edilmiştir.

INTRODUCTION

Roller-type metering systems seeds out of the hopper and unloads them to the seed tube in accordance with the determined seeding rate. The roller-type-metering systems, which are widely used in cereal seeding, can also be used in the seeding of coarse-grained seeds such as dry beans, soybeans, and chickpeas, provided that structural parameters suitable for their physical properties are determined.

Roller-type metering devices have been in use for over 300 years and are the most widely metering devices used in today's mechanical cereal seeders (Brown, 2003; Maleki *et al.,* 2006; Li *et al.,* 2016; Yang *et al.,* 2018). Flute diameter, flute shape, and helical angle of the flute are considered the most important factors affecting the seed dropping process from the flute in this metering devices (Ryu and Kim, 1998; Kuş and Yıldırım, 2009; Yıldırım and Kuş, 2014). The size, weight, and shape of the seeds to be planted may also affect it (Ryu and Kim, 1998; Yıldırım and Kuş, 2016). The overall goal of previous studies performed about roller metering devices was seed flow rate uniformity, due to its design, simplicity, ease to manufacture, lightweight, easy flow rate adjustment, and suitable for high-speed sowing (Ryu and Kim, 1998; Brown, 2003; Ess *et al.,* 2005; Jin *et al.,* 2018; Kuş *et al.,* 2018).

For decades, a great deal of research has been conducted in the performance evaluation of roller-type metering devices. Today, modern evaluation methods are also used in determining the performance of roller-type metering devices. Öztürk *et al.* (2012) optimized the effect of flute shape, active flute length, and flute rotation speed on flow uniformity using the Taguchi method. Huang *et al.* (2018) used the discrete element method (DEM) to determine the effect of roller length, flap angle, and roller rotational speed on flow uniformity in the roller-type metering device. On the other hand, Yu *et al.* (2019) evaluated the performance of the seed and fertilizer application rate measuring system they developed using a roller-type metering device on a grain drill.

When the studies conducted so far are examined, the roller-type metering devices are in three types in terms of their structural design: fixed type (Lv *et al.,* 2013; Huang *et al.,* 2018), flapped type, and brushed type (Ryu and Kim, 1998; Zeng *et al.,* 2020). Zeng *et al.* (2020), stated that the common point of these roller types is the fluted roller itself (forced layer) where the flow is relatively stable and the space between the roller and the wall of the metering device (driving layer). However, Önal (2011), stated that there are three layers in roller-type metering devices. The first of these is the layer through which the seeds are transported by the flutes, the second the active layer formed with the rotational movement of the roller, and the third also the passive layer under the active layer that the seeds are transmitted by internal friction (Figure. 1).

Zeng *et al.* (2020) reported that the friction between the seed grains in the driving layer and between the seed grains and the roller was affected by the rotational speed of the roller, structural factors, and material properties. Nukeshev *et al.* (2016) proposed a new design of roller pin, where the pins are in the form of a truncated pyramid to prevent passive layer (third layer); they reported this configuration allowed the metering devices to operate properly in humid product conditions as well as slow roller speed. Also, Sugirbay *et al.* (2020) showed that the discharge uniformity of the pin and the discharge amount increase by optimizing the design parameters of the new pin-roller for variable-rate and variable-speed applications.

In the row seeding process, the seeds should be transferred to rows with minimal damage by roller-type metering systems. As the germination power and percentage emergence rate of seeds damaged by the metering device during sowing will be weakened, the yield may be affected as a result. Especially different shaped or shapeless seeds may suffer high damage when being transferred with the roller-type metering device. Since these devices are used not only for small-grained seeds but also for planting medium and coarse-grained seeds, detection of grain damage rate that may occur during seed flow will make these devices more reliable.

Most of the studies performed about roller-type metering devices were concerned with seed flow uniformity. Studies determining the effect of the metering device on seed damage were in the minority. These studies were limited to the comparison of different planters or seed metering devices. Therefore it seems important to detect seed damage during the seeding of seeds of different shapes and sizes with roller-type metering devices. In this context, this study aimed to determine the seed damage rate of fluted rollers designed at different flute diameters and flute helical angles for different roller rotational speeds and seeding rates.

MATERIALS AND METHODS

The experiment was carried out at the Workshop of Agricultural Machinery, Atatürk University, Turkey. Dry bean seeds cleaned from foreign materials other than seeds were used in tests. Thousand-grain weight, angle of repose, sphericity, bulk density, and moisture content values of dry bean seeds were 312 g, 20°, 65%, 773 kg m^{-3}

and 10%, respectively. In addition, seed sizes (length, width, and thickness) ranged from 9-14 mm, 6-9 mm, and 3-6 mm, respectively.

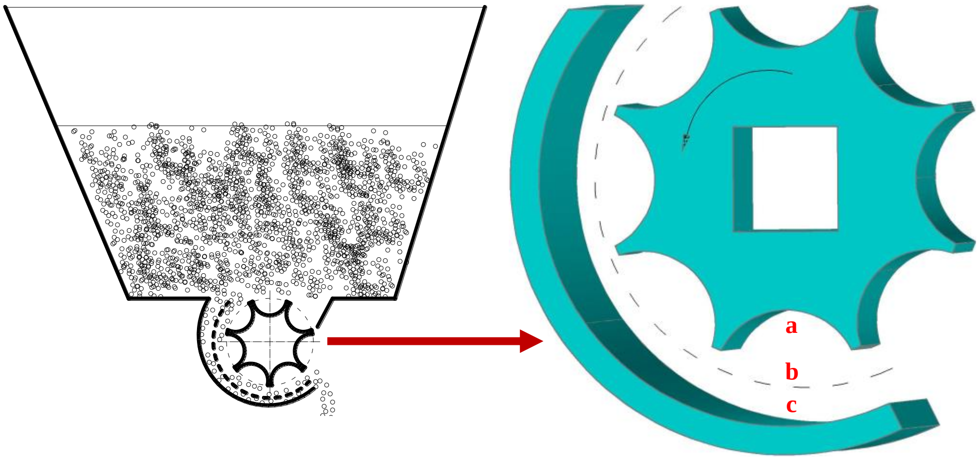


Figure 1. Fluted roller-type seed metering device; transporting by flutes (a), active layer (b), and passive layer (c).
Şekil 1. Oluklu makaralı tohum dağıtım düzeni; oluklarla iletim (a), aktif tabaka (b), pasif tabaka (c).

The tests were conducted using an experimental setup used by Yıldırım and Kuş (2013) (Figure 2). The roller-type metering device tested in this setup was mounted under a stationary seed planter test stand. A speed motor and control unit was used to drive the fluted roller device and control the rotational speed. The active roll length for determining the flow rate of the roller was manually adjusted by a screw mechanism. The distance between the tip of the flap belonging to the seed housing and the fluted roller was 13.5 mm, depending on the seed dimensions.

The experimental planning was designed for three replications according to the full factorial arrangement. For the tests performed a total of 243 experiments with four different parameters (with three levels of each). The parameters selected to be optimized were the flute diameter, flute helical angle, seeding rate, and ground speed (or roller rotational speed). Considering the standard dimensions of the roller-type metering devices used in the cereal seeding planters, nine fluted rollers made of Delrin material with flute diameters of 18, 20, and 22 mm and helical angles of 0, 10, and 20° were manufactured. The flute numbers and flute depths of rollers manufactured with flute diameters of 18, 20, and 22 mm were obtained as 9, 8, and 7 and 9, 10, and 11 mm, respectively, depending on the characteristics of the roller.

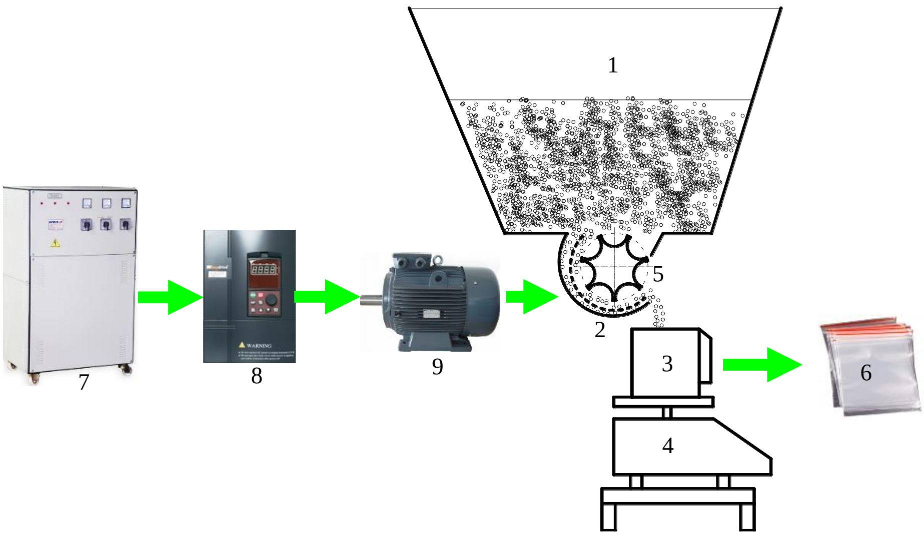


Figure 2. The instruments and equipment used in the experimental test rig: hopper (1), metering device (2), cup (3), electronic scale (4), fluted roller (5), and bug (6), regulator (7), speed control unit (8), and speed motor (9).
Şekil 2. Deneme düzeneğindeki ekipmanlar: depo (1), tohum dağıtım düzeni (2), kap (3), hassas terazi (4), oluklu makara (5) örnek poşetleri (6), regülatör (7), hız kontrol ünitesi (8), elektrik motor (9).

The feed shaft speeds of 8, 13, and 18 min^{-1} were used for the ground speeds of 1.0, 1.5, and 2.0 m s^{-1}, respectively, by selecting a 0.32 transmission value in the study. The predicted feed shaft speeds were selected considering the speed range (9-17 min^{-1}) recommended by Önal (2011) for planting coarse-grained seeds such as beans, chickpeas, and corn without breaking. The dry bean mostly is sown in inter-row spacings of 40-60 cm and the seed rates of 60-180 kg ha^{-1} based on the big of seeds. The seed rates of 100, 150, and 200 kg ha^{-1} for dry beans were used in the tests. The seeding rates were provided by changing the active lengths of the fluted roller. The inter-row spacing of dry beans was selected at 45 cm according to the values used in practice.

Before starting the tests, the hopper was filled with the dry bean seeds. A cup was placed just under the fluted roller metering device to determine the damage rates formed during the flow of dry beans in tests. As the fluted-roller metering device rotated, dry bean seeds were gathered down into a container for each replicate. Then, these samples were transferred to numbered bags and weighed with a precision balance. Weighing values consist of seeds flowing in 30-35 seconds from the fluted roller. By taking out the damaged seeds in the weighing values, the rate of seed damage per replication was calculated by using Equation 1 (Anantachar *et al.,* 2010).

$$SD = \left(\frac{W_d}{W_t}\right) x100 \qquad (1)$$

SD : Seed damage rate, %

W_d : Weight of damaged seeds per repetition, g

W_t : Seed weight per repetition, g

Analysis of variance (ANOVA) and Duncan multiple range tests were applied to the data obtained from the test rig to evaluate the rate of the damaged seeds in dry beans. With these tests, the effect of the roller-type device on the damage rate of dry bean seeds was determined depending on the parameter levels.

RESULTS AND DISCUSSION

The performance of the roller designed at different flute diameters and helical angles was evaluated for prescribed ground speeds and seeding rates experimentally (Table 1).

Table 1. The results of variance analysis and Duncan's Multiple Range Test (DMRT).
Çizelge 1. Varyans analizi ve Duncan Çoklu Karşılaştırma Testi sonuçları.

Variance sources	Seeding rate (kg ha^{-1})								
	100			150			200		
	df	MS	P	df	MS	P	df	MS	P
Ground speed (GS)	2	2.051	0.000	2	1.427	0.000	2	0.855	0.000
Flute diameter (FD)	2	0.515	0.000	2	3.238	0.000	2	0.147	0.006
Helical angle (HA)	2	0.330	0.000	2	5.320	0.000	2	0.404	0.000
GS x FD	4	0.065	0.149	4	0.047	0.614	4	0.063	0.057
GS x HA	4	0.106	0.032	4	0.057	0.527	4	0.006	0.929
FD x HA	4	0.522	0.000	4	1.578	0.000	4	0.481	0.000
GS x FD x HA	8	0.080	0.045	8	0.026	0.933	8	0.030	0.338
Error	54	0.037		54	0.070		54	0.026	
Total	80			80			80		

DMRT

Seeding rate⁺	Ground speed (m s^{-1})			Flute diameter (mm)			Helical angle (º)		
	1.0	1.5	2.0	18	20	22	0	10	20
100 kg ha^{-1}	1.66a	1.30b	1.12c	1.37b	1.49a	1.22c	1.31b	1.49a	1.28b
150 kg ha^{-1}	1.71a	1.45b	1.25c	1.87a	1.33b	1.23b	1.96a	1.38b	1.08c
200 kg ha^{-1}	1.40a	1.15b	1.06c	1.16b	1.29a	1.16b	1.26a	1.28a	1.06b

⁺: Means followed by the same letter in each group are not significantly different at the 0.95 level.

Analysis of the seed damage data indicated the main effect of the fluted roller metering system was significantly different ($P<0.01$) at flute diameter, flute helical angle, ground seed, and seeding rate. The additional analysis did not indicate any statistically ($P>0.05$) significance interactions of the speed-diameter, speed-angle (except 100 kg ha^{-1}), and speed-diameter-angle, but was highly significant different ($P<0.001$) at diameter-angle interactions.

According to DMRT, the ground speed was shown to produce an absolute numerical decrease in mean seed damage of roller-type metering device for each seeding rate (Table 1). However, the increase in the flute diameter and helical angle did not indicate a steady state of increasing or decreasing the seed damage rate. Even so, as a general statement, the rate of damaged seed tended to decrease as the flute diameter and helical angle increased.

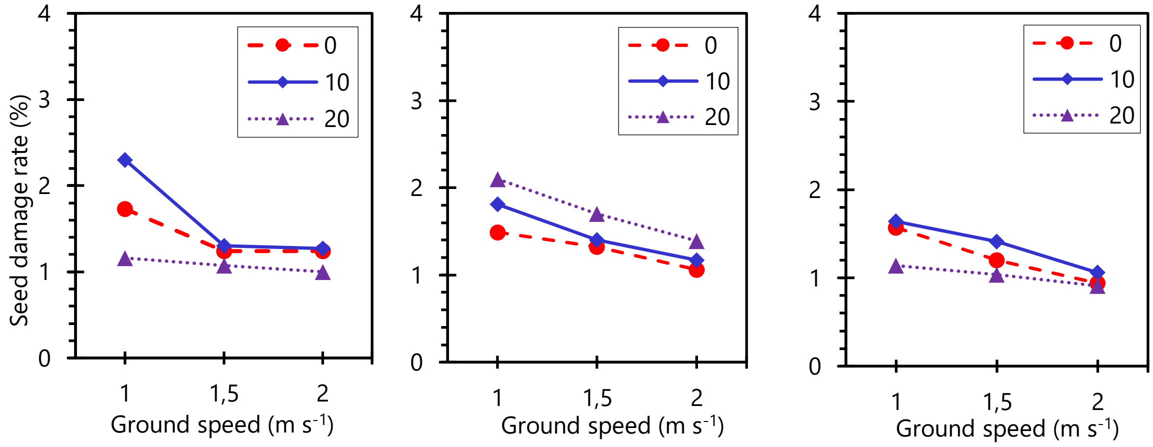
It was obtained from 22 mm flute diameter the lowest values of seed damage rate. As the flute diameter increases, the number of flutes decreases due to the construction feature of the roller-type metering devices. Önal (2011) states that in the rollers with fewer flutes, the active zone becomes thinner and therefore the seeds are less damaged. It was also noted from the results that the seed damage rate of the fluted roller-type metering device is influenced significantly by flute diameter-helical angle interaction. Accordingly, the reduction in seed damage rate is thought to be a result not only of the increase in flute diameter but also of the diameter-angle interaction.

In general, it performed a decrease in seed damage rate with flute helical angle. Depending on the helical angle, the lowest seed damage was obtained at 20° and this value decreased further with the increase in the seeding rate. This is showed that the conveying of seeds occurred by the flutes rather than by the active or passive zones. It shows that the seed damage rate decrease due to lower internal friction in flutes where the seed movement occurs. The helical angle in fluted rollers transfers seeds better than straight flutes. It is assumed that seeds transferred in this way suffer less damage.

It is clear from the data that the roller-type metering device carried out less seed damage at higher ground speed. The generally best performance of the fluted roller metering system was obtained from the ground speed of 2.0 m s^{-1}. Although the higher ground speed (i.e. roller rotation speed) brings about less damage to dry bean seed, however, due to the limited amount of seed to be sown in the field, higher speed could not be used. On the other hand, considering the literature on fluted roller planters, it is seen that the higher ground speed also causes an improvement in the seed flow of the fluted roller type metering device (Yıldırım and Kuş, 2014; 2016). This indicates that as long as the seed distribution uniformity in the field can be achieved, higher ground speeds can be used.

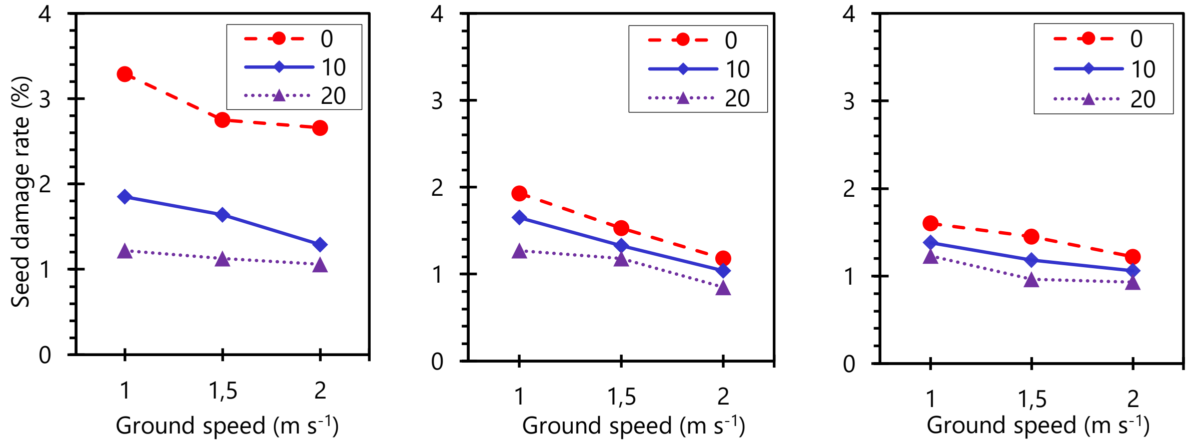
The values of seed damage rate, which are higher at the same ground speed and less seeding rate, increased the flute fill rate with the increase of the seeding rate and accordingly generally decreased the seed damage rate values. However, the decrease was not permanent, but unstable. In addition, the rate of decrease in the seed damage values that occurred at 100, 150, and 200 kg ha^{-1} seeding rates with the increase of the ground speed were 32%, 27%, and 24%, respectively. When working at lower roller rotation speeds at a lower seeding rate where a smaller effective roller length is used, the flutes are not sufficiently filled by seeds, resulting in a pulsed flow. For this reason, it is thought that the decrease in seed damage rates with the increase of the ground speed is not due to the better filling of the flutes, but by the faster rotating roller providing a more stable flow.

Figures 3, 4, and 5 show the effects of helical angle and ground speed on the damage rate of the dry bean seeds for each flute diameter depending on the seeding rate. The data point given for each flute depth in the figures is the average of three repeats. In general, seed damage decreased at 150 and 200 kg ha^{-1} seeding rates with the increase of ground speed and helical angle. However, at a 100 kg ha^{-1} seeding rate, these results were quite irregular. The reason for this may be speed-angle and speed-diameter-angle interactions, which are statistically significant in the 100 kg ha^{-1} seeding rate. In addition, as the seeding rate decreases in fluted roller metering devices, the active length of the roller decreases, so the flute volume to which the seed is transferred decreases. This may be one reason for the increase in seed damage. The more consistent reduction in seed damage rate was achieved at 150 kg ha^{-1} seeding rate for ground speed, flute diameter, and helical angle, while the lowest seed damage rates were obtained at 200 kg ha^{-1} seeding rate. The values of seed damage rates given in Figures 3, 4, and 5 vary between 0.5-3.5%. These results show that the limit value of the seed damage ratio recommended by Önal (2011) is below in the planting of coarse-grained seeds with fluted roller-type metering devices.



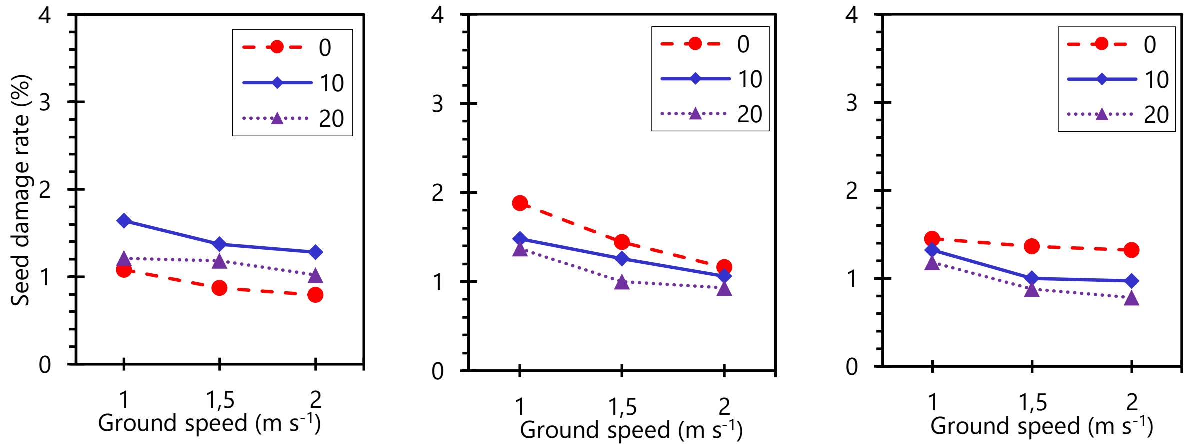
FD: 18 mm **FD: 20 mm** **FD: 22 mm**

Figure 3. The line graphs show seed damage values for a seeding rate of 100 kg ha^{-1}.
Şekil 3. 100 kg ha^{-1} ekim normu için tohum zedelenme oranı değerleri.



FD: 18 mm **FD: 20 mm** **FD: 22 mm**

Figure 4. The line graphs show seed damage values for a seeding rate of 150 kg ha^{-1}.
Şekil 4. 150 kg ha^{-1} ekim normu için tohum zedelenme oranı değerleri.



FD: 18 mm **FD: 20 mm** **FD: 22 mm**

Figure 5. The line graphs show seed damage values for a seeding rate of 200 kg ha^{-1}.
Şekil 5. 200 kg ha^{-1} ekim normu için tohum zedelenme oranı değerleri.

CONCLUSION

A seed metering system designed with more suitable constructural features for big-coarse seeds could instill confidence in a producer and encourage its use. The present study, intended to evaluate the structural and operational properties of a roller-type metering system for the detection of seed damage in dry beans with seeds bigger than cereals. Some of the results to be highlighted of study are as shown:

1. It was determined that the lower ground speed caused higher seed damage. It was shown that the ground speed definitely affects the seed damage rate, while the helical angle and flute diameter quite affected.
2. The seed damage tended to decrease with increasing flute diameter and flute helical angle.
3. Increasing the diameter (and so its depth) of flutes decreased the seed damage rate. Concerning the seed used in the experiments, the maximum value for flute diameter was 22 mm (and hence flute depth 11 mm) and resulted in a lower seed damage rate.
4. Results showed that ground speed has a higher impact on the seed damage for rollers with more flutes, compared to the roller with fewer flutes.

As a result, it is recommended to use a 200 kg ha^{-1} seeding rate, 2.0 m s^{-1} ground speed, 20° helical angle, and 22 mm flute diameter where the lowest seed damage is achieved when seeding dry beans with a fluted roller-type metering device.

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