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A Comparison of Harvest Loss Measurement Methods

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ABSTRACT: *The aim of the study was to compare three different methods that are used to measure harvest losses under real field conditions for corn, soybean and cotton. A 1 m^2 frame parallel to the planting row spacing (Method 1: M1), 1 m^2 frame perpendicular to the planting row spacing (Method 2: M2) and three quarter m^2 (Method 3: M3) were used to calculate harvest losses. The M1, M2, and M3 methods were used to calculate the losses in the harvest of corn and soybean with combine harvester. Then the M1 and M2 methods were used to calculate the losses when harvesting cotton with a cotton picker. Five grids were established in the same field measuring 50 m x 50 m for M1, M2 and M3. The losses measured for corn at the end of the study were 2.8%, 3.4% and 4.7%; and 1.5%, 2.1% and 4.4% for soybean, according to the M1, M2, and M3 methods, respectively. The losses measured for cotton were 4.7% and 4.6%, according to the M1, M2 methods, respectively. It was determined that losses calculated from M1 to M3 increased and that there was a difference in the calculated losses of 59.6% between M1 and M3 for corn and 33.5% for soybean. There was no difference between M1 and M2 for cotton.*

Keywords: Crop losses, harvest machinery, shatter losses, corn, cotton, soybean.

Hasat Kaybı Ölçüm Yöntemlerinin Karşılaştırılması

ÖZ: *Çalışmanın amacı, bazı tarla bitkilerinde hasat kayıplarının ölçülmesinde kullanılan farklı ölçüm yöntemlerinin karşılaştırılmasıdır. Bu amaç doğrultusunda, gerçek tarla şartlarında biçerdöver operatörü ve üretici inisiyatifi altında yapılan hasatlarda 3 farklı kayıp ölçme yöntemi kullanılarak elde edilen sonuçlar değerlendirilmiştir. Mısır ve soyanın biçerdöverle hasadında, ekim sırasına paralel 1 m^2 çerçeve (1. yöntem) , ekim sırasına dik 1 m^2 çerçeve (2. yöntem) ve üççeyrek m^2 (3. yöntem), pamuğun ise pamuk toplama makinası ile hasadında ise 1. ve 2. yöntemler kullanılarak hasat kayıpları hesaplanmıştır. Ölçümlerde 3 yöntem için aynı tarlada 50m x 50m ebatlarında oluşturulan 5 grit kullanılmıştır. Çalışma sonunda, mısır için ölçülen kayıplar 1, 2, 3. yöntemlere göre sırasıyla %2,8, %3,4 ve %4,7, soyada %1,5, %2,1 ve %4,4 ve pamukta %4,7 ve %4,6 olarak gerçekleşmiştir. 1. yöntemden 3. yönteme doğru hesaplanan kayıpların arttığı ve mısırda 1 ve 3. yöntemler arasında %59,6 oranında, soyada ise %33,5 oranında hesaplanan kayıplarda farklılık olduğu tespit edilmiştir. Pamuk hasat kayıpları ölçümünde ise 1. ve 2. yöntemler arasında bir farklılık tespit edilememiştir.*

Keywords: Ürün kayıpları, hasat makinaları, dökülme kayıpları, mısır, pamuk, soya.

INTRODUCTION

Nowadays, the number of agricultural workers continues to decrease and all conditions must be modernized and mechanized to increase agricultural productivity and reduce unit costs of inputs (Sotnar *et al*., 2018). One of the main goals of agricultural mechanization practices is to increase productivity (Kutzbach, 2000). The benefits of mechanization of planting to harvesting of most field crops which has taken place from the last century to the present have manifested as increased planting areas, reduced labor and costs. Harvesting is the last and important stage in the agricultural production chain. Use of harvesters must ensure that mechanical damage and losses are kept at a minimum and yield is maintained. However, no harvester can provide 100% efficiency. The performance of a combine-harvester is evaluated by ensuring that the grain loss rates are within acceptable limits, which are used as an important parameter (Chaab *et al*., 2020). It is possible to increase the efficiency of the machine and reduce mechanical losses by adjusting the basic operating parameters of the combine-harvester and other harvesting machines by monitoring the harvest losses (Coen *et al.*, 2008). In Türkiye, approximately 75-80% of cultivated areas consists of cereals and approximately 75-80% of this area is harvested by combine harvesters. It is known that a significant part of the combine-harvester stock of our country has reached the end of its economic life. In this case, the grain losses are estimated to be around 3-4% on average for wheat harvests. An extra 1% loss in harvest corresponds to 180-200 thousand tons of product (Say *et al*., 2010). In addition, these losses do not only decrease the profit of the producer, but also cause problems by mixing seeds with the soil and facilitating the proliferation of weeds and pests for the next crops (Alonso and Avila, 2011; Jones and Dalal, 2017).

Monitoring and controllability of losses during harvest have also become an important issue for precise and smart agriculture applications (Lian *et al*., 2021). In parallel with this approach, control services to reduce harvest losses have been implemented in Türkiye for many years. In accordance with articles 32 and 40 of the Decree of the Council of Ministers number 5326, controls are carried out for many products every year within the scope of the "implementation instructions on the execution of control services in harvesting products with combine harvesters". Provincial Governorships allow mechanical harvest losses of 2-3% for corn, 3-6% for soybean and 5-6% for cotton, and penal sanctions are applied when necessary. Mechanical losses from harvesting machines vary depending on many factors such as harvest time, harvesting method and management, mechanical settings, operator training, maturity level of the plant, climate and topography.

According to statistical records, the grain losses of Türkiye are given in Table 1 (TUIK, 2022).The data reveal that the highest losses occur in barley, wheat, corn, red and green lentils and soybeans, respectively. These losses cover the losses incurred during harvesting and transportation and do not include damages such as breakage, peeling, cracking, and crushing caused by harvesting machines.

Table 1. Production amount and harvest losses for some selected plant products (TUIK, 2022).
Çizelge 1. Seçilmiş bazı bitkisel ürünlerde üretim miktarı ve hasat kayıpları.

Products	Production (Tonnes)	Area sown (ha)	Harvest losses* (Tonnes)	Measured loss rate (%)
Barley	7,600,000	2,869,072	456,000	6
Wheat	19,000,000	6,846,327	1,045,000	5.5
Corn	6,000,000	638,829	180,000	3
Oats	265,000	109,823	2,120	0.8
Rye	310,000	112,164	4,030	1.3
Rice	600,000	126,419	6,000	1
Red beans	225,000	88,939	2,475	1.1
Red lentils	31,000	242,776	8,060	2.6
Chickpeas	630,000	520,595	8,190	1.3
G. lentils	43,631	39,612	1,134	2.6
Sunflowers	2,100,000	752,632	16,800	0.8
Canola	180,000	52,515	2,340	1.3
Cotton seed	1,320,000	477,868	26,400	2
Soybean	150,000	35,295	1,200	0.8

*Harvest losses correspond to the losses incurred during harvest including losses incurred during the transportation from the plot to the seat of the holding.

The most important measure taken to reduce losses is the systematic controls made using some methods in the field at the time of harvest. These methods are known to be generally time consuming and can differ according to the experience of the practitioner (Bomoi *et al.*, 2022). An examination of international studies indicates that this experience is universal. For example, Sotnar *et al*. (2018) reported that a 10.4 m wide harvester table with a working width of 10.4 m and 0.0961 m wide frames was used to complete 1 m^2 to determine harvest losses. They emphasized that the measurements were carried out by placing the frames in a perpendicular position to the planting direction. Andrews *et al*. (1992) developed and applied a method to measure losses for rice harvesting. In general, a model has been established for the most appropriate adjustment stages by making separate evaluations for each part of the combine harvester where losses occur. Zhao *et al.* (2011) designed an instantaneous trackable grain flow sensor to determine simultaneous harvest losses. They determined that the error rate of the loss measurement made by using the frame manually with the sensor was 12%. Srivastava *et al.* (2006) and Mairgyhany *et al*. (2018), on the other hand, reported that calculations can be made using 50 cm x 50 cm frames to measure various grain losses. Wang *et al.* (2021) did a literature study and reported that the measurement of harvest losses in the USA was generally done with 1 m^2 frames, taking into account the working width of the combine. Pre-harvest losses were also calculated with the same framework before harvesting losses were determined. The same study reported that the Ministry of Agriculture in Brazil had issued instructions to use a table width of 2 m^2 to measure grain harvest losses, and calculate cob losses on 30 m^2 based on table width. It is emphasized that in China, controllers make measurements with three replications according to the grain moisture values in a 2 m^2 area, again taking into account the width of the mowing table to determine corn harvest losses. Liang et al. (2015) reported that the measurement of rice harvest losses was carried out by counting seeds in an area corresponding to straw outlet width and 30 m in length. These measurements are carried out by overlooking the 5 m entrance and 5 m exit distances of this area. Suismono (2012) determined the loss measurement method used in paddy fields in Madagascar in his study. The biological yield was calculated for 5 m x 5 m according to this method, and the amount of loss was determined with nine frames measuring 40 cm x 14 cm in size placed randomly into the field before and after the harvest. A guide was established for the controllers for calculating harvest losses in rice practically by establishing a conversion table. Different methods are used to determine the loss amount (Siebenmorgen *et al*., 1994), which is the most important performance indicator of harvesters. However, the differences between these methods are not well known. In Türkiye, the three-quarter m^2 loss measurement method is widely used especially in wheat and barley harvests. At the same time, the use of this method for controllers is facilitated with various plates. Different methods have been used to determine the harvest losses of other products, however they have not been clarified.

Mechanical grain losses during harvest are affected by many factors such as the combine-harvester tune-up, the experience of operator, the structure of the plants, harvest maturity, climate and topographic conditions. In order to protect the national wealth in agricultural production, some countries monitor the shatter, grain losses during the harvest period every year, and ensure that the necessary measures are taken. Different methods can be used to monitor, measure and evaluate these losses in field conditions. However, differences in the results of these methods have not been determined. No study has been found among previous studies which compare different loss measurement methods. The aim of this study is to compare different harvest loss measurement methods used in harvest loss control and determine the differences between them.

MATERIALS AND METHODS

Materials

The study data consist of measurements taken from corn, soybean and cotton fields in Adana province Çukurova Region. During the harvest, the operator controlled the speed of the combine. The measurements were calculated in field as 5 repetitions with grids of 50 m x 50 m. The averages of the results obtained were compared on a product basis according to the methods.

The measurements were taken in the production areas where the DKC 6590 corn variety, Arısoy soybean variety and Carisma cotton variety are grown in Çukurova. Corn and soybean were grown in second crop conditions while cotton was grown in main crop conditions. Soybean and corn were planted with 70 cm row spacing and cotton with 75 cm row spacing in the fields where the study was carried out. Case 2555, John Deere 9970 and Newholland TC-56 combines were used in cotton, soybean and maize harvesting, respectively. All settings of the combines were made according to the operator's experience.

Method

Three different harvest loss measurement methods for corn and soybean and two different methods for cotton were compared. Evaluation results were given as ratio and proportion. The methods and application forms are represented in Figure 1. Application of the measurement methods:

Method 1 (M1): A 1 m^2 frame was placed vertical to the planted rows (corn, soybean, cotton); Method 2 (M2): A 1 m^2 frame was placed parallel to the planted rows (corn, soybean, cotton); Method 3 (M3): The three-quarter m^2 method (corn, soybean).

M1: a 72 cm x 140 cm (1.008 m^2) frame was placed perpendicularly for maize and soybean and adjusted to an average of 1 m^2 according to 70 cm row spacing, and a 67 cm x 150 cm (1.008 m^2) frame was adjusted for 75 cm row spacing for cotton were used. The amount of crop losses for cotton, corn and soybean to cover 2 rows pre and post-harvest were measured with these frames. The amount of soybean seed/corn kernels/cotton bolls remaining in the frame was counted/weighed and used to make the necessary calculations. Natural losses were determined by using a 1 m^2 frame perpendicular to the rows pre-harvest.

M2: a frame of 70 cm x 143 cm (1.001 m^2) was placed parallel to the planted rows spacing and adjusted to an average of 1 m^2 according to the distance between rows of 70 cm for corn, soybean, and a frame of 75 cm x 134 cm (1.005 m^2) between the rows spacing of cotton planted with 75 cm row spacing was used. Crop losses were determined for 1 row pre and post-harvest with this frame. The amount of seeds or cotton bolls losses remaining in the frame was counted or weighed and used to make the necessary calculations. Natural losses were determined by using a 1 m^2 frame parallel to the rows pre-harvest.

M3 (the three-quarters m^2 method): The three-quarter square meter method was used to determine the losses corresponding to 1 m^2. The three-quarters m^2 frames measuring 50 cm x 50 cm were used for corn and soybean, and the amount of crop losses pre-harvest was taken into account in the loss calculation.

The method used for the determination of post-harvest losses was used to determine the amount of loss pre-harvest. The frame sizes used to evaluate the 1 m^2 area according to the distance between rows and methods are given in Table 2. Since the third method is generally used for cereals, it was not used to determine cotton harvest losses.

Biological yield was calculated in 1 m^2 representing each grid to determine the general average of the field. (Sotnar *et al.,* 2018). The number of cobs, pods or bolls on the plants was taken into account for the number of plants in 1 m^2 area for corn, soybean and cotton for the calculations. The yield calculation methods used according to the products are given in Table 3.

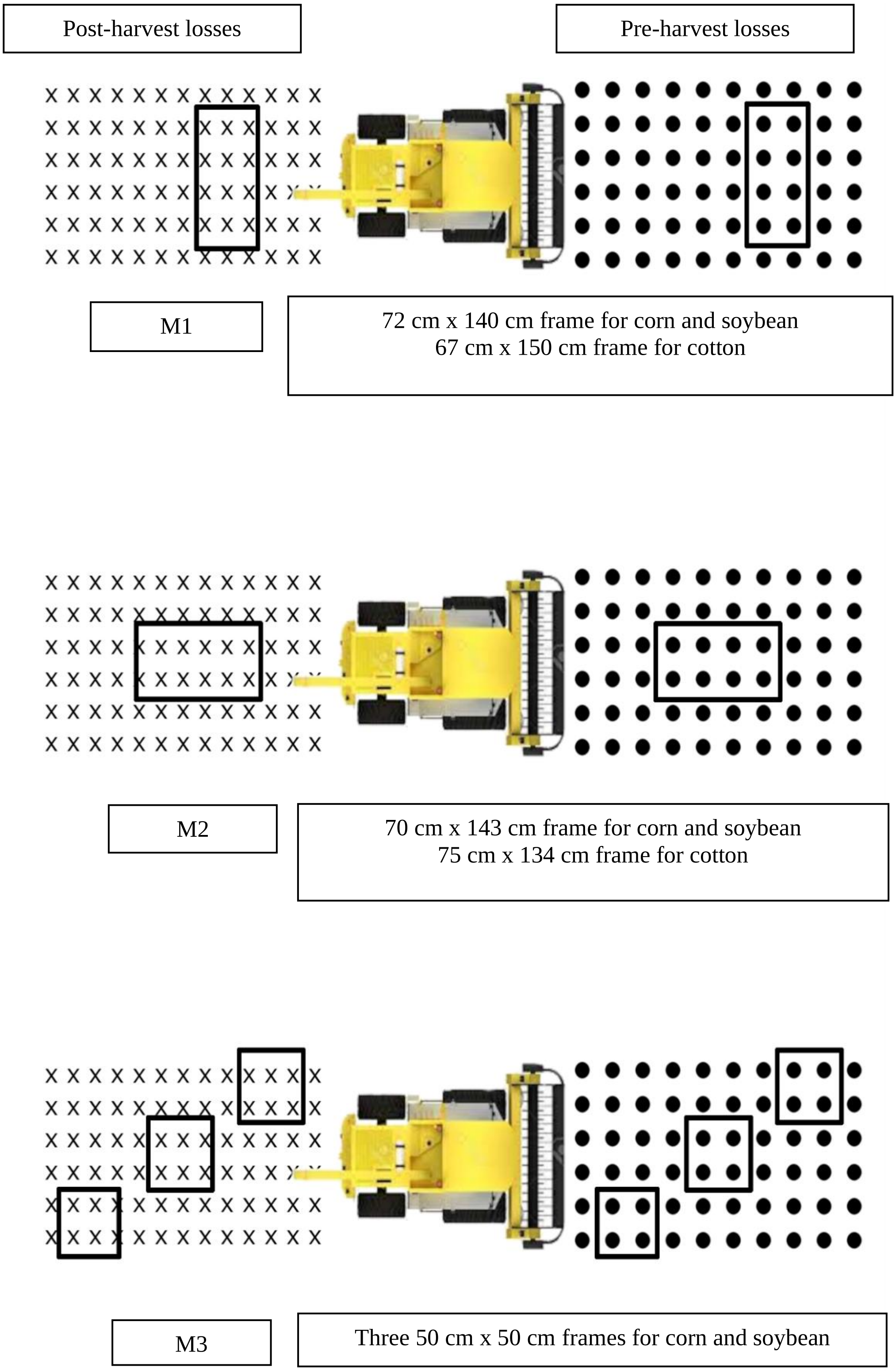

Figure 1. Representative images of measurement methods.
Şekil 1. Ölçüm yöntemlerinin temsili görüntüleri.

Table 2. Frame sizes used in the measurement of harvest losses according to the methods.
Çizelge 2. Hasat kayıplarının ölçmesinde yöntemlere ve ürüne göre kullanılan çerçeve ebatları.

Plant	Row spacing (cm)	M1 (cm)	M2 (cm)	M3* (cm)
Corn	70	72 x 140	70 x 143	50 x 50
Soybean	70	72 x 140	70 x 143	50 x 50
Cotton	75	67 x 150	75 x 134	-
Placement of the frames		Perpendicular to the row	Parallel to the row	Intrarow and edge

*Conversion factor was used; M1: Frame placement perpendicular to planted rows; M2: Frame placement parallel to planted rows; M3: The three-quarter square meter method.

Table 3. Equations used in calculating biological yield according to plant.
Çizelge 3. Ürünlere göre biyolojik verim hesaplamada kullanılan eşitlikler.

Plant	Biological yield	Explanation	Reference
Corn	$MV = (KS\ x\ DS\ x\ DA)/1000$	MV: Corn yield (kg ha^{-1}) KS: Corn cob per m^2 (cob m^{-2}) DS: Number of kernels on the cob (kernels cob^{-1}) DA: 1000 kernels weight (g)	Anonymous, 2011; Sotnar *et al.*, 2018
Soybean	$SV = (BS\ x\ BB\ x\ BD\ x\ DA)/1000$	SV: Soybean yield (kg ha^{-1}) BS: Plant per m^2 (piece m^{-2}) BB: Pod number plant (pod plant^{-1}) BD: Seeds number per pod (seed pod-^{1}) DA: 1000 seed weight (g)	Anonymous, 2011; Sotnar *et al.*, 2018
Cotton	$PV = KS\ x\ KA$	PV: Cotton yield (kg ha^{-1}) KS: Cotton burr per m^2 (pieces m^{-2}) KA: Burr weight (g)	Anonymous, 2007; Sotnar *et al.*, 2018

The equations used in calculating the losses according to each product and method are given in Table 4.

RESULTS AND DISCUSSION

Harvest losses for corn

The measurements and calculations are given in Table 5. The average biological yield for the second crop corn was calculated as 9358 kg ha^{-1}.

Crop losses calculated according to the methods are provided in Table 6. The trials showed no pre-harvest losses in corn harvesting. Losses due to combine harvesting were determined as 2.8% for Method 1, 3.4% for Method 2 and 4.7% for Method 3. Comparison of methods showed a 59.5% difference between Method 1 and Method 3. This shows how high the margin of error rate can be between the controller who prefers Method 1 and Method 3. It is thought that it can be possible to see these margin of error increase even more, especially in harvest with high crop losses. In addition, it is thought that Method 3 is generally used in the loss calculation of grains such as wheat and barley, which may lead to an overestimation of corn harvest losses. Sessiz & Demirel (2021) measured harvest losses in corn using 1.5 m^2 frames in a 3.5 m x 0.43 m area pre-harvest harvest in their study. They placed the frames perpendicular to the planted rows. Liangyu Hou et al. (2021) carried out a study to determine the factors affecting corn harvest losses in farmer conditions in China. They used 10 m long rectangular frames covering 4-6 rows parallel to the planting direction to determine corn harvest losses in the field which was done by counting the kernels remaining in this area.

Table 4. Equations used in calculating losses according to plants and methods.
Çizelge 4. Ürün ve yöntemlerine göre kayıp hesaplamada kullanılan eşitlikler.

Plant	Harvest Losses	Explanation	Reference
Equations used to calculate losses for M1 and M2			
Corn	K= $((S-E)xDAx100)/MV$	K: Kernels loss (%) E: Loss pre-harvest (piece kernel m^{-2}) S: Post-harvest loss (piece kernel m^{-2}) DA: 1000 kernel weight (kg) MV: Yield (kg ha^{-1})	Anonymous, 2012; Alizadeh and Allameh, 2013; Sessiz and Demirel, 2021
Soybean	K= $((S-E)xDAx100)/SV$	K: Seed loss (%) E: Loss pre-harvest (seed m^{-2}) S: Post-harvest loss (seed m^{-2}) DA: 1000 seed weight (kg) SV: Yield (kg ha^{-1})	Anonymous, 2012; Alizadeh and Allameh, 2013
Cotton	K= $(((KK+MK)-DK)x\ 100/PV)$	K: Cotton bolls losses (%) KK: Cotton bolls remaining on the plant (g) MK: Cotton bolls losses on the ground post-harvest (g) DD: Natural losses pre- harvest (g) PV: Yield (kg ha^{-1})	Gemtos and Mygdakos, 1998; Kazama *et al*., 2018
Equations used to calculate losses for M3			
Corn	$K=(133\ x\ (a+b+c))/MV$	K: Seed/kernels loss (%) a: Seed/kernels weight in the frame placed on the left side of the harvester (g) b: Seed/kernels weight in the frame placed at the center point of the harvester (g) c: Seed/kernels weight in the frame placed on the right side of the harvester (g) MV: Corn yield (kg ha^{-1}) SV: Soybean Yield (kg ha^{-1}) 133: constant to convert three-quarter square meter to $1m^2$	Srivastava *et al*., 2006; Anonymous, 2011; Aulakh *et al*.,2013; Paixão *et al*., 2017
Soybean	$K=(133\ x\ (a+b+c))/SV$		
Cotton	-	-	-

Table 5. Measured parameters for biological yield calculations in corn trial fields.
Çizelge 5. Mısır alanlarında biyolojik verim hesaplamaları için ölçülen parametreler.

Rep.	Number of cobs per plant (cob plant^{-1})	KS	DS	DA	TDS	MV
1	1	11	300	290	3300	9570
2	1	8	352	290	2816	8166
3	1	13	250	290	3250	9425
4	1	10	336	290	3360	9744
5	1	9	377	290	3393	9838
Ave	1	10.2±1.9	323±49.4	290	3223.8±234.5	9358±679.9

KS: Number of plants per m^2 (plant m^{-2}); DS: Number of kernels per cob (kernels cob^{-1}); DA: Standard 1000 kernels weight (g); TDS: Total kernels on the cob (kernels cob^{-1}); MV: Yield (kg ha^{-1}).

Table 6. Harvest losses calculated according to the methods in the corn harvest.
Çizelge 6. Mısır hasadında yöntemlere göre hesaplanan hasat kayıpları.

Rep	E	Crop losses post-harvest					
		M1		M2		M3	
		S	K	S	K	S	K
1	0	8	2.4	10	3.1	13	5.2
2	0	10	3.5	12	4.2	12	5.6
3	0	8	2.4	10	3.0	11	4.5
4	0	12	3.5	14	4.1	13	5.1
5	0	7	2.1	9	2.6	9	3.5
Ave.	0	9±2	2.8±0.6	11±2	3.4±0.7	11.6±1.69	4.7±0.8

M1: Frame placement perpendicular to planted rows; M2: Frame placement parallel to planted rows; M3: The three-quarter square meter method; E: Pre- harvest losses (Natural lost) (number m^{-2}); S: Number of lost kernels (number m^{-2}); K: Total crop Losses (%).

Harvest losses for soybean

Considering the average of recurrences in second crop soybean, the average biological yield was calculated as 3310 kg ha^{-1}. (Table 7).

It was determined that natural losses occurred in soybean pre-harvest and the results of repeated counting according to the methods are given in Table 8. According to the methods, it was calculated that the total crop losses from the combine harvester were 1.5% for Method 1, 2.1% for Method 2 and 4.4% for Method 3, respectively. It was determined that the crop loss rates are different for the three different methods in soybean field just like in corn field. In particular, it was determined that the harvest losses calculated with Method 3 were at least 50% more than the harvest loss amounts obtained with other methods (Table 8). Loureiro Junior et al. (2014) compared frames of 1, 2, 3 m^2 to determine soybean harvest losses and reported that frame sizes did not make a difference in the loss rates. However, the effects of frame placement style differences on measuring harvest losses were not examined in this study. Camare *et al.* (2007) reported that 2 m^2 frames used in soybean harvest were not sufficient to measure harvest losses and that loss measurement data made with 3 m^2 frames could be more precise. Paixão *et al.* (2017) used the 3-quarter square meter method to determine the effect of differences in parcel sizes on soybean losses. They determined that the least loss occurred with the rectangular shaped parcel. The frames were placed perpendicular to the planting direction in all studies.

Table 7. Measured parameters for biological yield calculations in soybean trial fields.
Çizelge 7. Soya alanlarında biyolojik verim hesaplamaları için ölçülen parametreler.

Rep.	BS	BB	BD	DA	TBB	SV
1	18	55	2	160	110	3168
2	20	58	2	160	116	3712
3	23	53	2	160	106	3091
4	22	48	2	160	96	3379
5	20	50	2	160	100	3200
Ave.	20.6±1.9	52.8±3.9	2	160	105.6±7.9	3310±248.2

BS: Number of plants per m^2 (plant m^{-2}); BB: Number of pods per plant (pod $plant^{-2}$); BD: Number of seed per pod (seed pod^{-1}); DA: 1000 seed weight (g); TBB: Total seed per plant (piece); SV: Yield (kg ha^{-1}).

Harvest losses for cotton

The biological yield for cotton was calculated as 6597 kg ha^{-1} considering the repetition averages (Table 9).

Pre-harvest losses were determined in cotton and they were calculated according to Method 1 and Method 2. A comparison of the harvest losses caused by cotton harvesting when using the Method 1 and the Method 2 revealed that the total loss amounts were 4.7% and 4.6%, respectively (Table 10). Kirk *et al*. (2020) reported that they measured losses by using 2.4 m long frames covering 4 rows and collecting what was left on the ground in the center of the frames to measure losses from cotton harvesters.

When all the data were evaluated together, it was determined that the losses caused by harvesting machines differ according to the measurement methods used (Table 11). Considering the average yields, it was determined that a controller using Method 1 for corn harvest lost 261 kg/ha, a controller using method 2 lost 318 kg/ha and a controller using Method 3 incurred harvest loss of 439 kg/ha for corn. In this respect, considering that the acceptable total loss in corn harvest is 3%, only the controller using method 1 will incur total loss below this value. The same can be said for soybean where methods 1 and 2 are very close to each other and Method 3 incurs a high loss rate. The losses calculated for cotton with Methods 1 and 2 are similar. The difference between the methods will become more evident in harvests where losses are very high. However, it is absolutely necessary to carry out studies under controlled conditions to determine the method by which the actual loss amount is measured.

Table 8. Harvest losses calculated according to methods for soybean.
Çizelge 8. Soyada yöntemlere göre hesaplanan hasat kayıpları.

Rep	E			Crop losses post-harvest					
				M1		M2		M3	
	M1	M2	M3	S	K	S	K	S	K
1	20	26	21	49	1.46	62	1.81	55	2.28
2	11	10	17	30	0.81	43	1.42	63	2.63
3	4	7	9	35	1.27	53	1.88	118	5.94
4	22	30	17	61	1.84	82	2.46	66	3.08
5	5	6	9	43	1.90	68	3.10	133	8.26
Ave.	12.4±8.3	15.8±11.3	14.6±5.3	43.6±12.1	1.5±0.4	61.6±14.8	2.1±0.6	87.0±35.7	4.43±2.5

M1: Frame placement perpendicular to planted rows; M2: Frame placement parallel to planted rows; M3: The three-quarter square meter method; E: Pre- harvest losses (Natural lost) (seed m^{-2}); S: Number of lost seed (piece m^{-2}); K: Total crop Loss (%).

Table 9. Measured parameters for biological yield calculations in cotton trial fields.
Çizelge 9. Pamuk alanlarında biyolojik verim hesaplamaları için ölçülen parametreler.

Rep.	KS	BS	KA	PB	PV
1	7	15	5.79	86.85	6079
2	8	16	4.32	69.12	5529
3	9	19	4.25	80.75	7267
4	9	16	5.16	82.56	7431
5	8	17	5.06	86.02	6682
Ave.	8.2±0.8	16.6±1.5	4.91±0.6	81.50±7.1	6597±800.0

KS: Number of plants per m^2 (plant m^{-2}); BS: Number of burr per plant (piece $plant^{-1}$); KA: Average balls weight per burr (g $balls^{-1}$); PB: Single plant burr yield (g $plant^{-1}$); PV: Biological yield (kg ha^{-1}).

Table 10. Harvest losses calculated according to methods for cotton.
Çizelge 10. Pamukta yöntemlere göre hesaplanan hasat kayıpları.

Rep	DD		Post-harvest losses					
			M1			M2		
	M1	M2	MK	KK	K	MK	KK	K
1	19.3	17.1	40.49	8.10	3.9	33.52	6.70	3.8
2	20.1	18.2	26.79	10.18	3.1	44.72	10.25	6.6
3	18.1	9.2	35.04	28.89	6.3	27.44	20.12	5.3
4	7.3	8.4	38.09	8.72	5.3	21.27	10.19	3.0
5	22.8	19.1	49.41	7.90	5.0	40.22	9.70	4.5
Ave	17.5±5.9	14.4±5.1	37.96±8.2	12.75±9.0	4.72±1.2	33.43±9.4	11.39±5.0	4.6±1.3

M1: Frame placement perpendicular to planted rows; M2: Frame placement parallel to planted rows; DD: Pre-harvest losses (Natural lost) (g m^{-2}); MK: Left on the ground (g m^{-2}); KK: Remaining on the plant (g m^{-2}); K: Total loss rate (%).

Table 11. Mechanical harvest losses calculated according to plant and methods.
Çizelge 11. Ürünlere ve yöntemlere göre hesaplanan mekanik kayıplar.

Method	Corn		Soybean		Cotton	
	Calculated loss (%)	Total loss (kg ha^{-1})	Calculated loss (%)	Total loss (kg ha^{-1})	Calculated loss (%)	Total loss (kg ha^{-1})
M1	2.8	262	1.5	49	4.7	310
M2	3.4	318	2.1	69	4.6	303
M3	4.7	439	4.4	146	-	-

M1: Frame placement perpendicular to planted rows; M2: Frame placement parallel to planted rows; M3: The three-quarter square meter method

CONCLUSIONS

In conclusion, it was determined that there is a difference between measuring grain loss rate with 1 m^2 frames used in corn and soybean on the row and parallel to the sowing direction (Method 2), and measuring the grain loss of frames perpendicular to the rows (Method 1). Furthermore, it was determined that the grain loss rate obtained with the three-quarter square meter method (Method 3) used in soybean and corn incurred grain loss rate more than the other two measure grain loss methods. It is suggested that a grain collecting tent cover be used, which is fixed with magnets or another mechanism that provides grip under the combine harvester table to obtain more accurate results in the calculation of mechanical losses in corn and soybean.

It is thought that this condition can facilitate the process. A comparison of the calculated results for mechanical losses for cotton with Method 1 (Frame placement perpendicular to planted rows) and Method 2 (Frame placement parallel to planted rows) displayed similar results. However, it has been observed that these two methods are challenging for the controller in terms of application. There is a need to establish different methods in which alternative technological features are included in these commonly used methods for the measurement of losses. It can be said that there is a need for more detailed studies under controlled conditions to determine which grain loss measurement method should be used to achieve the most accurate results on a crop basis.

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