KSÜ Tarım ve Doğa Derg 27 (Ek Sayı 2), 453-462, 2024
KSU J. Agric Nat 27 (Suppl 2), 453-462, 2024
https://doi.org/10.18016/ksutarimdoga.vi.1504127

Tokat Kazova'da Sürdürülebilir Üretim İçin Toprak İşleme ve Doğrudan Ekim Sistemlerinin Ekim Kalitesi Yönünden Değerlendirilmesi

Esra Nur GÜL[1]✍, Engin ÖZGÖZ[2], Nurhan MUTLU[3]
[1,2]Tokat Gaziosmanpasa University, Faculty of Agriculture, Department of Biosystems Engineering, Tokat, Türkiye, [3]Middle Black Sea Transitional Zone Agricultural Research Institute, Tokat, Türkiye
[1]https://orcid.org/0000-0002-9865-1228, [2]https://orcid.org/0000-0003-0615-9613, [3]https://orcid.org/0000-0002-6680-4445
✉: gulesranur1@gmail.com

ÖZET

Geçit iklim kuşağında yer alan Tokat şartlarında yürütülen çalışmada ikinci üründe ekim kalitesi belirlenmiştir. Geleneksel toprak işleme sistemi (M1), azaltılmış toprak işleme sistemi-1 (M2), azaltılmış toprak işleme sistemi-2 (M3) ve doğrudan ekim (M4) sistemleri karşılaştırılmıştır. Ekim kalitesi tarla filiz çıkış derecesi, kabul edilebilir bitki aralığı, ikizlenme oranı, boşluk oranı, ekim indeksi, verim ve ekim derinliğine göre belirlenmiştir. Toprak işleme sistemlerinin önemli bir etkisinin olmadığı tarla filiz çıkış derecesinin en düşük ve en yüksek değerleri sırasıyla M4 (%64.53) ve M1 (%76.53) sistemlerinde elde edilmiştir. Toprak işleme sistemleri kabul edilebilir bitki aralığı ile ikizlenme oranı değerlerini P<0.01 ve boşluk oranı değerlerini P<0.05 seviyesinde istatistiksel olarak önemli bir şekilde etkilemiştir. Kabul edilebilir bitki aralığı, ikizlenme ve boşluk oranları değerleri bakımından M1, M2 ve M3 toprak işleme sistemleri arasında istatistiksel olarak önemli bir farklılık görülmemektedir. Toprak işleme sistemleri ikizlenme oranı bakımından değerlendirildiğinde M1 sisteminin iyi, M3 sisteminin orta ve M2 ile M4 sisteminin yetersiz olduğu görülmüştür. Ekim kalitesinin bir diğer göstergesi olan boşluk oranı değerlerine göre M1 ile M2 sistemlerinin orta ve M3 ile M4 sistemlerinin ise yetersiz olduğu belirlenmiştir. Çalışmanın sonuçları bölgedeki tarımsal üretimin sürdürülebilirliğine önemli katkı sağlayacaktır.

Tarımsal Mekanizasyon

Araştırma Makalesi

Makale Tarihçesi
Geliş Tarihi : 25.06.2024
Kabul Tarihi : 01.11.2024

Anahtar Kelimeler
Ekim kalitesi
Silajlık mısır
Boşluk oranı
İkizlenme oranı
Yeşil ot verimi

Evaluation of Soil Tillage and Direct Sowing Systems for Sustainable Production in Tokat Kazova in Terms of Sowing Quality

ABSTRACT

In the study carried out in Tokat conditions, located in the transition climate zone, the sowing quality of the second crop was determined. Conventional tillage system (M1), reduced tillage system-1 (M2), reduced tillage system-2 (M3), and direct seeding (M4) systems were compared. The sowing quality was determined according to the percentage of emerged seedlings, the quality of feed index, multiple index, mass index, planting index, yield, and sowing depth. The lowest and highest values of the percentage of emerged seedlings where soil tillage systems did not have a significant effect, were obtained in the M4 (64.53%) and M1 (76.53%) systems, respectively. Soil tillage systems significantly affected the quality of feed index and multiple index values at P<0.01 and miss index values at P< 0.05 levels. There was no statistically significant difference between the M1, M2, and M3 tillage systems regarding the miss index, multiple index, and quality of feed index values. When soil tillage systems were evaluated in terms of multiple index, it was observed that the M1 system was good, the M3 system was medium, and the M2 and M4 systems were inadequate. According to the miss index values, which is another indicator of sowing quality, it was determined that M1 and M2 systems were medium and M3 and M4 systems were inadequate. The study's results will significantly contribute to the sustainability of agricultural production in the region.

Agricultural Mechanization

Research Article

Article History
Received : 25.06.2024
Accepted : 01.11.2024

Keywords
Sowing quality
Silage maize
Miss index
Multiple index
Green grass yield

Atıf Şekli: Gül, E.N., Özgöz, E. & Mutlu, N. (2024). Tokat Kazova'da Sürdürülebilir Üretim İçin Toprak İşleme ve Doğrudan Ekim Sistemlerinin Ekim Kalitesi Yönünden Değerlendirilmesi. *KSÜ Tarım ve Doğa Derg 27* (Ek Sayı 2), 453-462. https://doi.org/10.18016/ksutarimdoga.vi.1504127

To Cite : Gül, E.N., Özgöz, E. & Mutlu, N. (2024). Evaluation of Soil Tillage and Direct Sowing Systems for Sustainable Production in Tokat Kazova in Terms of Sowing Quality. *KSU J. Agric Nat 27* (Suppl 2), 453-462. https://doi.org/10.18016/ksutarimdoga.vi.1504127

INTRODUCTION

Sowing is placing and closing the seeds in the seedbed at a certain depth to the requirements of the seed with a proper distribution in the horizontal and vertical plane (Karayel and Özmerzi, 2005). The main purpose of the precision planter is to plant the seeds in a way that provides the most suitable environment for their homogeneous emergence. Proper placement of the seed is essential to provide sufficient moisture, which is one of the most important criteria for germination and improving conditions that affect germination (Grassbaugh and Bennett, 1998). The benefits of sowing maize seeds with precision planter seed savings include fewer working hours, sowing depth, homogeneous row spacing, and, as a result, a more consistent yield (Turan et al., 2014). The planting process should result in the expected seed distribution and homogeneous emergence in the unit area. The most common methods used to assess planter performance include uniformity of plant distribution and emergence rate (Staggenborg et al., 2004). Precision maize sowing is aimed to achieve high efficiency by ensuring a certain plant output per unit area. For this reason, uniform seed sowing should be done to reduce the competition of plants for soil moisture and nutrients (Yazgi, 2016).

The most critical factor in obtaining maximum efficiency from the unit area is precision planting technology. By distributing the seeds evenly in the seedbed, the competition of the plants with each other for water, light, nutrients, and air is reduced, and the yield obtained from the unit area is increased (Liu et al., 2012; Wang et al., 2012). Sowing maize seeds at irregular intervals reduces the yield by 5% to 10% (Searle et al., 2008). In 2023, approximately 524860.9 hectares of silage maize was planted in Turkey. The production amount is 28653531 tons. The yield is 54670 kg/ha (TÜİK, 2023). Using the 2023 average sales price of 0.15 US Dollars per kilogram (TOBB, 2023), a 10% decrease in yield means 829.57 US Dollars per hectare and a 434824283.56 US Dollars income decrease in the production amount in Turkey. Doerge et al. (2002) stated that the yield could increase by 84 kg ha^{-1} with every centimeter decrease in the standard deviation of the row distance. Nielsen (2001) found that when the standard deviation was greater than 5 cm, corn grain yield decreased by an average of 62 kg ha^{-1} for every cm increase in the standard deviation of plant spacing.

Precision Planting of the United States developed the 20/20 SeedSense monitoring system using WaveVision sensors (Anonymous, 2024a). The Sistema Full Semina precision planting system, developed by MC in Italy, can electronically monitor the sowing of medium-sized and large seeds (Anonymous, 2024b). Özgöz et al. (2020) used the statistical process control approach when determining sowing quality, and Dursun and Dursun (2000) used the sticky bant system made in the laboratory environment to assess the uniformity of distribution on the row in sowing machines. Mean and standard deviation of seed or plant row spacing (Parish et al., 1991; Hollowell, 1992), miss index, multiple index (Brooks and Church, 1987), and coefficient of variation (Jasa and Dickey, 1982; Hofman, 1988) are used to determine the performance of the planter (Singh et al., 2005; Kuş, 2014).

The general objective of this study was to evaluate the sowing quality depending on the seedbed characteristics created by different soil tillage systems compared to utilizing the vegetation period effectively in the transition climate zone. In this study, the effect of different tillage and sowing systems on sowing quality was investigated for sustainable production during the silage maize vegetation period (July 2022-October 2022) following a five-year rotation (winter wheat + second crop silage maize, triticale-vetch mixture + second crop silage maize) on a clay loam soil under transition climate zone conditions. For this purpose, the percentage of emerged seedlings, the quality of feed index, multiple index, miss index, planting index, green grass yield, and sowing depth were determined.

MATERIAL and METHOD

Experimental Area

The study was conducted as a continuation of the TAGEM project titled "Comparison of Soil Properties, Yield, and Energy Efficiencies in Main and Second Crop Rotations of Different Soil Processing Methods" conducted by Afacan et al. (2023) between 2017 and 2021.

The soil tillage, crop rotations, and cultural operations of the project continued. In this study, primary crop silage triticale-vetch mixture + second crop silage maize rotation was carried out in the same experimental plots.

The study was carried out in Tokat-Kazova, located in the transition climate zone between the Eastern Black Sea and Central Anatolia regions, on the land of the Middle Black Sea Transitional Zone Agricultural Research Institute (Figure 1). The soil of the experimental area is clay loam and homogeneous. Some chemical properties of the experimental area soils before the experiment are given in Table 1.

Figure 1. Experimental area
Şekil 1. Çalışma alanı

Table 1. Some chemical properties of the experimental area soils before the experiment
Çizelge 1. Çalışma alanı topraklarının çalışma öncesi bazı kimyasal özellikleri

Soil tillage system	Depth (cm)	Electrical Conductivity (mmhos /cm)	Total Salt (%)	pH	Lime (%)	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Organic matter (%)
M1	0-10	1.14	0.04	7.69	10.85	48.8	733.6	2.02
	10-20	1.13	0.04	7.70	10.59	44.4	754.8	2.05
M2	0-10	0.95	0.04	7.87	10.98	52.0	803.6	2.24
	10-20	1.05	0.04	7.77	10.85	40.2	674.8	2.06
M3	0-10	0.85	0.03	7.90	10.59	55.7	832.0	2.32
	10-20	1.04	0.04	7.89	11.11	60.9	684.5	2.06
M4	0-10	0.86	0.04	7.84	10.98	86.4	915.1	2.60
	10-20	0.81	0.03	7.81	10.98	18.7	665.2	2.11

M1: Conventional soil tillage, M2: Reduced tillage-1, M3: Reduced tillage-2, M4: Direct sowing.

Climate Characteristics

According to the climate data of the province for many years (1929-2023), the maximum temperature is 18.8 °C, the minimum temperature is 7.2 °C, the average temperature is 12.5 °C, the average monthly total rainfall is 435 mm, and the average sunshine duration is 5.8 h (MGM, 2024). Climate data for the silage maize vegetation period (July 2022-October 2022) are shown in Table 2.

Experimental Design, Soil Tillage Systems, and Cultural Treatments

The experiment was established with three replications according to the randomized block design and the plots were 50 m x 5.6 m in size. The space around the study plots is 2 meters. Some technical details of the soil tillage and sowing machines used in the experiment are given in Table 3. Four different tillage and sowing systems were carried out in the study:

Table 2. Climate data for the silage maize vegetation period (July 2022- October 2022) (MGM, 2022)
Çizelge 2. Silajlık mısır vejetasyon süresine ait iklim verileri (Temmuz 2022- Ekim 2022) (MGM, 2022)

	Climate data				
Months	**Total precipitation (mm)**	**Average temperature (°C)**	**Maximum temperature (°C)**	**Minimum temperature (°C)**	**Average relative humidity (%)**
July	0.0	20.7	34.1	8.5	69.5
August	4.7	24.9	38.2	13.4	68.4
September	27.4	19.4	38.8	3.5	67.9
October	35.3	13.3	30.4	-1.1	76.2

Table 3. Some technical details of the soil tillage and sowing machines used in the experiment (Afacan et al., 2023)
Çizelge 3. Denemede kullanılan toprak işleme ve ekim makinalarının bazı teknik özellikleri (Afacan et al., 2023)

Machines	**Number of units**	**Working width (cm)**	**Working Depth (cm)**	**Weight (kg)**
Moldboard plough	4	120	20-25	470
Chisel plow	7	210	20-25	400
Vertical axis rotary cultivator	16 blades	200	15-20	900
Disc harrow	18	200	10-15	930
Spring tine cultivator and rolling harrow combination	29	300	10-15	900
Pneumatic precision seeder	4 rows with axe	290	5	845
Pneumatic precision seeder for direct seeding	4 rows with disc	210	5	1000

M1- Conventional soil tillage: Moldboard plough + disc harrow + spring tine cultivator and rolling harrow combination,

M2- Reduced tillage-1: Chisel plow + disc harrow,

M3- Reduced tillage-2: Vertical axis rotary cultivator and

M4- Direct sowing: No tillage is done on the plots in this application. Sowing was performed with a direct seeder.

First crop triticale-vetch mixture + second crop silage maize rotation were carried out. The data on the second crop silage maize rotation was used in this study. Soil tillage was done on July 05, 2022, sowing on July 06, 2022, and harvest on October 27, 2022. Sowing was done at 70 cm between rows and 16 cm in-row at a depth of 5 cm. With the sowing, 200 kg ha^{-1} DAP was applied, and on August 10, 2022, Nitropower (33N%) was used at 220 kg ha^{-1} (Upper). Before sowing, 3000 ml ha^{-1} of total herbicide was applied directly to the sowing plots. When the plant height is 20-25 cm, Ghibli (220 g l^{-1} Dicamba + 50 g l^{-1} Nicosulfuron) Mospilan 20 SP (20%) Acetamiprid) was administered

Determination of Sowing Quality

The percentage of emerged seedlings (PES), an important parameter used to evaluate sowing success, was determined according to Equation 1 (Önal, 2006).

$$PES = \left(\frac{N_x - N_0}{N_i}\right) * 100 \qquad (1)$$

Where Nx is the total number of all plant spacing at a given row length, No is the total number of intervals less than 0.5*Z, Ni is the theoretical total number of plants, and Z is the seed distance within the row.

To determine the seed distribution uniformity in the rows of silage maize, the distances between plants were measured in 3 rows of 10 m in length, randomly chosen over the rows immediately after germination. The in-row plant distribution homogeneity was determined using the values obtained from these measurements (Karayel and Özmerzi, 2005). The multiple index, the miss index, and the quality of the feed index, which indicate the evenness of distribution over the row were determined according to Table 4. The uniformity of plant distribution on the row was evaluated by considering the criteria (Anonymous, 1999) shown in Table 5.

Table 4. Evaluation of plant distribution evenness on rows (Aykas et al., 2013)
Çizelge 4. Sıra üzeri bitki dağılım düzgünlüğünün değerlendirilmesi (Aykas ve ark., 2013)

Plant spacing in rows	**Definition**
<0.5 Z/PES	Multiple index
(0.5-1.5) Z/PES	Quality of feed index (QFI)
>1.5 Z/PES	Miss index

PES: Percentage of emerged seedling

The planter index developed by Jasa and Dickey (1982) was used to evaluate seed spacing uniformity. The percentage error value was assigned an intermediate value from 0 to 5. 5 indicates less than 10 percent error. More than 50 percent of errors were assigned a value of 0. Both multiple and miss indexes have a value of 0. The index assignment is summarized in Table 6.

Table 5. Evaluation of quality of feed index, multiple index, miss index (Aykas et al., 2013)
Çizelge 5. Kabul edilebilir bitki aralığı, ikizlenme oranları ve boşluk oranlarının değerlendirilmesi (Aykas ve ark., 2013)

QFI (%)	Multiple index (%)	Miss index (%)	Evaluation
>98.6	<0.7	<0.7	Very good
>90.4 ≤98.6	≥0. 7 - <4.8	≥0. 7 - <4.8	Good
≥82. 3 - 90.4	≥4. 8 - ≤7.7	≥4. 8 - ≤10	Middle
<82.3	>7.7	>10	Insufficient

QFI: Quality of feed index

Percent miss from ideal spacing (İe)= $\left(\frac{Actual\ distance - Ideal\ spacing}{Ideal\ spacing}\right) * 100$ (2)

Table 6. Evaluation of planter index (Jasa and Dickey, 1982)
Çizelge 6. Ekim indeksinin değerlendirilmesi (Jasa ve Dickey, 1982)

Percent error in seed placement	Planting index
0-10	5
10.1-20.0	4
20.1-30.0	3
30.1-40.0	2
40.1-50.0	1
>50	0

The sowing depth was observed with 20 seedlings in each plot, which seedlings were pulled out carefully and their root depths remained in the soil and were close to white measured. According to Önal (2006), the coefficient of variation (%) in the sowing depth distribution was accepted as a reference value as not being more than 20%. During the sowing process, the tractor's forward speed was determined as 6.69km h^{-1}.

For silage maize yield, plants in 3 strips of 6 m length, randomly selected from the experimental area, were cut 5 cm above the soil surface, weighed, and calculated as green grass yield per hectare.

Statistical Analysis

Before starting statistical analyses, a normal distribution test (Shapiro-Wilk) was applied to the data sets. Appropriate transformation procedures were performed to transform non-normally distributed data sets into normal distributions (Webster, 2001). Analysis of variance (ANOVA) and DUNCAN, a multiple comparison test, were used to compare the data obtained for sowing quality and to determine similar tillage systems. Statistical analyses of the relevant parameters were performed using the SPSS 17.0 software (SPSS, 2017).

RESULTS and DISCUSSION

Determination of Second Crop Silage Maize Sowing Quality

In the study, descriptive statistics were performed on the data sets obtained by using the measurements made in the field. The maximum, minimum, and mean values, standard deviation, coefficient of variation, variance, skewness, and kurtosis values, which are accepted as indicators of normal distribution, are given in Table 7.

After germination, the distance between plants in 3 rows of 10 m length randomly determined in each plot was evaluated to determine the homogeneity of seed distribution in each row. The evaluation of in-row plant distribution uniformity, quality of feed index, miss index, multiple index, and were made according to Tables 4 and 5. The percentage of emerged seedling, quality of feed index, multiple index, miss index, planter index, and yield values for silage maize are given in Table 8; percentage of emerged seedling, quality of feed index, miss index, multiple index, planter index and yield values for second crop silage maize are given in Table 9.

The soil tillage systems did not show a statistically significant effect on the percentage of emerged seedlings. The minimum and maximum values of the percentage of emerged seedlings were obtained in the M4 (64.53%) and M1 (76.53%) systems, respectively (Table 8). Korucu and Arslan (2009) received the minimum percentage of emerged seedling rate of 80.3% in direct sowing and the maximum percentage of emerged seedling rate of 88.0% in modified direct sowing (2) for second crop silage maize. As a result of their study, they reported that tillage alone did not affect the degree percentage of emerged seedlings; they pointed out the similar performances of conventional tillage and direct sowing systems. Karaağaç and Barut (2007) determined that the effect of different tillage and sowing methods on emergence percentage in second crop silage maize was statistically significant at P<0.01 level, and the maximum percentage of emerged seedlings was 100% in the conventional tillage system and the minimum percentage of emerged seedling was 72% in direct sowing system. The results found in this study support this study.

Soil tillage systems significantly affected the multiple index and quality of feed index values at p<0.01 and miss index values at P<0.05 levels. There is no statistically significant difference between M1, M2, and M3 tillage systems regarding the multiple index, quality of feed index, and miss index values (Table 8).

Table 7. Descriptive statistics of sowing quality parameters
Çizelge 7. Ekim kalitesi parametrelerine ait tanımlayıcı istatistik bilgiler

STS	SQP	N	Minimum	Maximum	Mean	Standard deviation	Coefficient of variation	Skewness	Kurtosis
M1	PES	6	70.40	81.60	76.53	4.22	5.51	-0.32	-1.17
	QFI	6	78.26	98.04	88.24	6.84	7.75	-0.07	0.10
	MUI	6	0.00	6.52	3.09	2.91	94.17	0.010	-2.25
	MI	6	1.96	15.22	8.67	4.56	52.60	-0.10	0.17
	PI	6	2.38	3.24	2.70	0.37	13.70	0.84	-1.56
	GGY	6	59000	112500	96250	21127.59	21.95	-1.40	1.11
M2	PES	9	51.20	78.40	68.09	9.16	13.45	-0.78	-0.38
	QFI	9	64.71	91.67	80.77	8.50	10.52	-0.50	0.22
	MUI	9	2.08	20.59	9.30	5.54	59.57	0.86	1.13
	MI	9	3.85	15.38	9.92	3.71	37.40	-0.02	-0.35
	PI	9	1.18	3.26	2.34	0.63	26.92	-0.26	0.60
	GGY	9	63000	132500	89444.44	19687.31	22.01	1.24	2.61
M3	PES	9	56.00	81.60	69.16	10.30	14.89	-0.35	-1.75
	QFI	9	69.44	92.31	83.62	7.17	8.57	-0.93	0.54
	MUI	9	1.92	16.67	6.09	4.96	81.44	1.37	1.50
	MI	9	5.77	14.29	10.29	3.28	31.88	-0.11	-1.41
	PI	9	1.29	2.79	2.21	0.54	24.43	-0.54	-1.05
	GGY	5	69000	104000	94300	14294.23	15.16	-2.12	4.61
M4	PES	6	56.00	75.20	64.53	8.51	13.19	0.15	-2.53
	QFI	6	51.43	80.00	63.88	12.22	19.13	0.32	-2.33
	MUI	6	8.00	27.03	17.34	8.28	47.75	0.13	-2.59
	MI	6	10.53	22.86	15.16	4.73	31.20	1.03	-0.22
	PI	6	1.65	2.91	2.29	0.51	22.27	-0.17	-2.00
	GGY	9	67000	122000	98111	15551.88	15.85	-0.52	1.56

STS: Soil tillage systems, M1: Conventional Soil Tillage. M2: Reduced tillage-1, M3: Reduced tillage-2, M4: Direct sowing, SQP: Sowing quality parameters, PES: Percentage of emerged seedling (%), QFI: Quality of feed index (%), MUI: Multiple index (%), MI: Miss index (%), PI: Planting index, GGY: Green grass yield (kg ha^{-1})

Table 8. Percentage of emerged seedling, quality of feed index, miss index, multiple index, planter index, and yield values for second crop silage maize
Çizelge 8. İkinci ürün silajlık mısır için tarla filiz çıkış, kabul edilebilir bitki aralığı, boşluk oranı, ikizlenme oranı, ekim indeksi ve yeşil ot verimi değerleri

STS	Percentage of emerged seedling (%)	Quality of feed index (%)	Multiple index (%)	Miss index (%)	Planter Index	Green grass yield (kg ha^{-1})
M1	76.53±4.22	88.24±6. 84a	3.09±2.91b	8.67±4.56b	2.70±0.37	96250±21127.6
M2	68.09±9.16	80.77±8.50a	9.30±5.54b	9.92±3.71b	2.34±0.63	89444±19687.3
M3	69.16±10.30	83.62±7.17a	6.09±4.96b	10.29±3.28b	2.21±0.54	94300±14294.2
M4	64.53±8.51	63.88±12.22b	17.34±8.28a	15.16±4. 73a	2.29±0.51	98111±15551.9
F value	2.04^{ns}	9.19**	7.34**	3.17*	1.08^{ns}	0.38^{ns}

STS: Soil tillage systems, M1: Conventional Soil Tillage, M2: Reduced tillage-1, M3: Reduced tillage-2, M4: Direct sowing. ** Significant at P< 0.01 level, * Significant at P < 0.05 level, ns: Insignificant value. There is no statistical difference between the values shown with the same letter in the columns.

Table 9. Evaluation of quality of feed index, miss index, and multiple index
Çizelge 9. Kabul edilebilir bitki aralığı, ikizlenme ve boşluk oranlarının değerlendirilmesi

STS	Quality of feed index (%)	Multiple index (%)	Miss index (%)
M1	Middle	Good	Middle
M2	Insufficient	Insufficient	Middle
M3	Middle	Middle	Insufficient
M4	Insufficient	Insufficient	Insufficient

STS: Soil tillage systems, M1: Conventional soil tillage, M2: Reduced tillage-1, M3: Reduced tillage-2, M4: Direct sowing.

In respect of the quality of the feed index, M1 and M3 systems are moderate, while M2 and M4 systems are insufficient. When the tillage systems were evaluated in terms of multiple index, it was observed that the M1 system was good, the M3 system was average, and the M2 and M4 systems were inadequate. According to the miss index values, another indicator of sowing quality, it was determined that M1 and M2 systems were moderate and M3 and M4 systems were inadequate (Table 9). These results indicate that precautions should be taken regarding the sowing process. Karaağaç and Barut (2007) compared different tillage and sowing methods in second-crop silage maize. They determined the miss index as 2.37%, 5.84%, and 37.73% in conventional, reduced tillage system and direct sowing, respectively, and the multiple index as 1.59%, 5.84%, and 0.00%, and the quality of feed index as 96.04%, 94.17% and 62.07%, respectively. Karayel and Özmerzi (2002), in their study on the effect of tillage systems on the sowing quality (uniformity) of maize, stated that the multiple index and miss index rates were not significantly affected by tillage systems.

It was determined that the effect of tillage systems on green grass yield was statistically insignificant (Table 8). Tillage systems were ranked as M4>M1>M3>M2 regarding silage maize yield. Some researchers have stated that equal plant spacing does not increase grain yield (Ehrbach et al., 1972; Muldoon and Daynard, 1981). Liu et al. (2004) determined in their experiments in different locations that maize grain yield was not affected by the variability in plant spacing. The results found by the researchers support this view. Buehring et al. (2002) reported that when the inter-row distance is lower than the appropriate value, the seeds compete with each other; that is, multiple index occurs, and when the distance is increased, the number of foreign plants increases due to the miss index between the rows. Korucu and Arslan (2009) reported that the yield of second-crop silage maize was the lowest (8590 kg ha^{-1}) in direct sowing and the highest (9016 kg ha^{-1}) in the conventional tillage system. Karaağaç and Barut (2007) reported that the highest second-crop silage maize green grass yield was obtained in a reduced tillage system, while the minimum yield was obtained in a banded tillage system. These results show the importance of determining the appropriate soil tillage system for sustainable production. Due to the protection and development of natural resources and economic advantages, sufficient effort and sensitivity should be shown to be successful in the application of direct sowing (Gültekin et al., 2017).

The four different systems applied do not affect the planter index values statistically significantly. The minimum and maximum values of the planter index were obtained in the M3 (2.21) and M1 (2.70) systems, respectively (Table 8). In the planter index developed by Jasa and Dickey (1982) to evaluate plant spacing for different tillage systems; they reported that even the best planters make 20% to 30% errors in seed placement and that the effect of the tillage system on the seeding index is quite small. They determined that the average measured planter index was 2.41, and sowing index values ranged from 1.21 to 4.22.

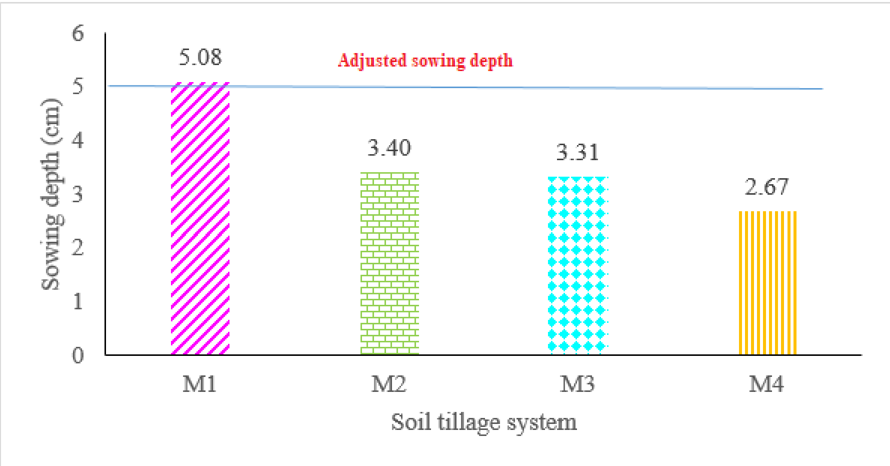

Figure 2. Adjusted and measured average sowing depth values
Şekil 2. Ayarlanan ve ölçülen ortalama ekim derinliği değerleri
(M1: Conventional soil tillage. M2: Reduced tillage-1, M3: Reduced tillage-2, M4: Direct sowing)

The treatments did not affect the measured sowing depth values at a statistically significant level. The measured sowing depth values were 5.08 cm, 3.40 cm, 3.31 cm, and 2.67 cm for M1, M2, M3, and M4 treatments, respectively (Figure 2). When the average sowing depth values measured in the plots are compared with the sowing depth values set on the seeder before sowing, it is seen that the actual sowing depth is lower. The conventional tillage system was the only system in which the measured value was close to the set value. Da Silva et al. (2004) stated that sowing depth is one of the vital factors affecting vegetative development and emergence homogeneity in maize (*Zea mays* L.). Korucu and Arslan (2009) reported that soil tillage systems had an effect of $P < 0.01$ on sowing depth in second-crop silage maize (*Zea mays* L.) and that the best sowing depth was realized in conventional tillage (5.99 cm) and the lowest sowing depth was realized in direct sowing system (2.90 cm). This result supports the sowing depth values determined in this study.

The coefficient of variation values of sowing depth for M1, M2, M3, and M4 treatments were 35.89%, 25.64%, 36.42%, and 34.03%, respectively. According to Önal (2006), the coefficient of variation in the sowing depth distribution was accepted as a reference value as not being more than 20%. According to these reference values, all soil tillage systems are above the reference values. Karayel and Özmerzi (2001) reported that seed distribution in the vertical plane was related to sowing depth.

CONCLUSION

Depending on the characteristics of the seedbed created with different tillage systems, the systems were also evaluated in terms of sowing quality to use the vegetation period effectively in the second crop, especially in the study area located in the transitional climate zone. In respect of the quality of the feed index, M1 and M3 systems are moderate, while M2 and M4 systems are insufficient. When the tillage systems were evaluated in terms of multiple index, it was observed that the M1 system was good, the M3 system was average, and the M2 and M4 systems were inadequate. According to the miss index values, another indicator of sowing quality, it was determined that M1 and M2 systems were moderate and M3 and M4 systems were inadequate. These results indicate that measures should be taken regarding the sowing process. On the other hand, it was determined that the data on the values of the sowing quality parameters were better in the conventional tillage system compared to the different systems. It was concluded that tillage practices should be continued, and the changes that will occur in the long term should be monitored, along with taking necessary measures to improve the quality of cultivation. It is known that if the plant spacing on the row is smaller than the needs of the plants, the competition between plants for nutrients in the soil, water, and sunlight increases. In addition, this situation can limit the root system of the plants and negatively affect growth. On the other hand, if the plant spacing on the row is wide, it can make land use inefficient and cause soil erosion. It also causes a decrease in yield. Considering all these, attention should be paid to issues such as the homogeneity of the plant spacing on the row (missing index and multiple index), seeder working speed, feed quality index, percentage of emerging seedlings, and slippage. This study will contribute significantly to the sustainability of agricultural production in the region.

ACKNOWLEDGMENTS

This study was produced from the first author's doctoral thesis. The study was supported by Tokat Gaziosmanpaşa University Scientific Research Projects (BAP) Project No. 2021/7 (Determination of Sustainable Soil Tillage System According to The Soil Physical Quality and Evaluation in Terms of Sowing Quality in Tokat Kazova). The authors thank the Republic of Turkey Ministry of Agriculture and Forestry General Directorate of Agricultural Research and Policies (TAGEM)-Middle Black Sea Transitional Zone Agricultural Research Institute for technical assistance.

Contribution Rate Statement Summary of Researchers

The authors declare the contribution of the authors is equal.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

REFERENCES

Afacan, H., Başaran, B., Bal, M., Altıntaş, G., Yıldız, E., Mutlu, N., Taşlıoğlu, H.B., Eren, H. & Özgöz, E. (2023). Farklı toprak işleme yöntemlerinin ana ve ikinci ürün rotasyonlarında toprak özellikleri, verim ve enerji etkinliklerinin karşılaştırılması.T.C. Tarım ve Orman Bakanlığı Tarımsal Araştırmalar ve Politikalar Genel Müdürlüğü Orta Karadeniz Geçit İklim Kuşağı Tarımsal Araştırma Enstitüsü, Enstitü Yayin No: 340-214/T107, Proje Sonuç Raporu, Tokat.

Anonymous, (1999). Tarımsal Mekanizasyon Araçları Deney İlke ve Metodları. T.C. Tarım ve Köy İşleri Bakanlığı Tarımsal Üretim ve Geliştirme Genel Müdürlüğü, Ankara.

Anonymous, (2024a). 20/20 SeedSense Monitoring System. Available online: http://www.precision planting.com/Products/WaveVision/Default.aspx (accessed on 17.05.2024).

Anonymous, (2024b). MC Electronics. Sistema Full Semina. Available online: https://www. mcelettronica.it/it/prodotti/semina/semina-a-righe/fotocellula-blockage-pro-seeder_256c28.html (accessed on 17.05.2024).

Aykas, E., Yalçın, H. & Yazgı, A. (2013). Comparison of the seeding performance of the precision seeders equipped with hoe type coulter in different locations for maize seeding. *Journal of Agricultural Machinery Science 9*(1), 67-72.

Brooks, D. & Church, B. (1987). Drill performance assessment: A changed approach. *British Sugar Beet Review 55*(4), 50-51.

Buehring, N.W., Harrison, M.P. & Dobbs, R.R. (2002). Corn response to twin and narrow rows with selected seeding rates. *Annual Report*, 43-49.

Da Silva, R.P., Corá, J.E., Filho, A.C., Lopes, A. & Furlani, C.E.A. (2004). Effect of press wheels submitted to vertical loads in depths of sowing on corn crop development. *Engenharia Agrícola 24*(2), 396-404.

Doerge, T., Hall T. & Gardner D. (2002). New research confirms benefits of improved plant spacing in corn. *Crop Insights 12*(2): 1-5.

Dursun, İ.G. & Dursun, E. (2000). Ekim makinası sıra üzeri tohum dağılımının görüntü işleme yöntemi ile belirlenmesi. *Tarım Bilimler Dergisi 6*(4), 21-28.

Ehrbach, D.C., Wilkins, D.E. & Lovely, W.G. (1972). Relationships between furrow opener, maize plant spacing, and yield. *Agronomy Journal 64*:702-04.

Grassbaugh, E.M. & Bennett, M.A. (1998). Factors affecting vegetable stand establishment. *Scientia Agricola, 55*(1), 116-120.

Gültekin, İ., Partigöç, F., Gültekin, S., Kaya, Y., Arısoy, R.Z. & Taner, A. (2017). Orta Anadolu Bölgesi Kuru Koşullarında Buğday Tabanlı Üretimde Doğrudan Ekim. *KSÜ Doğa Bil. Derg.,* 20 (Özel Sayı), 283-287.

Hofman, V. (1988). Maximum yields need accurate planting. *The Sunflower, 14*(1), 10-11.

Hollowell, W. (1992). Drill performance assessments. British Sugar Beet Review, 50(3), 13-15.

Jasa, P.J. & Dickey, E.C. (1982). Tillage factors affecting corn seed spacing. *Transactions of the ASAE 25*(6), 1516-1519.

Karaağaç, H.A. & Barut, Z. (2007). İkinci ürün silajlık mısır tarımında farklı toprak işleme ve ekim sistemlerinin teknik ve ekonomik yönden karşılaştırılması. *Tarım Makinaları Bilimi Dergisi 3* (1), 33-40.

Karayel, D. & Özmerzi, A. (2001). Hava emişli bir tek dane ekici düzen ile kavun ve hıyar ekiminde sıra üzeri uzaklık ve ilerleme hızının ekim düzgünlüğüne etkisi. *Akdeniz Üniversitesi Ziraat Fakültesi Dergisi 14*(2):63-67.

Karayel, D. & Özmerzi, A. (2002). Effect of tillage methods on sowing uniformity of maize. *Canadıan Bıosystems Engıneerıng 44*:2.23-2.26.

Karayel, D. & Özmerzi, A. (2005). Hassas ekimde gömücü ayakların tohum dağılımına etkisi. *Akdeniz Üniversitesi Ziraat Fakültesi Dergisi 18* (1), 139-150.

Korucu, T. & Arslan S. (2009). Effects of direct and conventional planting on soil properties and yield characteristics of second crop maize. *Tarım Bilimleri Dergisi 15*(2) 157-165.

Kuş, (2014). Pnömatik hassas ekim makinalarında tohum düşme yüksekliği ve ilerleme hızının geleneksel ve azaltılmış toprak işleme şartlarında ekim kalitesine etkilerinin belirlenmesi (Tez no 352175). [Doktora Tezi, Atatürk Üniversitesi Fen Bilimleri Enstitüsü Tarım Makinaları Anabilim Dalı]. Yükseköğretim Kurulu Ulusal Tez Merkezi.

Liu, W., Tollenaar, M., Stewart, G. & Deen, W. (2004). Within-row plant spacing variability does not affect maize yield. *Agronomy Journal 96*:275-80.

Liu, J., Cui, T., Zhang, D.X. & Yang, L. (2012). Trans. Chin. Soc. Agric. Mach. 43 43(02)

MGM, 2022. T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı Meteoroloji Genel Müdürlüğü Verileri.

MGM, 2024. T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı Meteoroloji Genel Müdürlüğü Verileri. https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=TOKAT

Muldoon, J.F. & Daynard, T.B. (1981). Effects of within-row plant uniformity on grain yield of maize. *Canadian Journal of Plant Science 61*:887-94

Nielsen, R.L. (2001). Stand establishment variability in corn. AGRY-91-1 (Rev. Nov.-01). West Lafayette: Dept. of Agron., Purdue Univ.

Önal, İ. (2006). Ekim bakım gübreleme makinaları. Ege Üniversitesi Ziraat Fakültesi Ders Kitabı, İzmir, 623 sy.

Özgöz, E., Altuntaş, E. & Kasap, A. (2020). Tokat-Kazova'da mısır yetiştiriciliğinde ekim kalitesinin değerlendirilmesinde istatistiksel proses kontrol yaklaşımı. *Turkish Journal of Agriculture - Food Science and Technology 8*(12), 2664-2676.

Parish, R.L., Bergeron, P.E. & Bracy, R.P. (1991). Comparison of vacuum and belt seeders for vegetable planting. *Applıed Engineering in Agriculture 7*(5), 537- 540.

Searle, C.L., Kocher, M.F., Smith, J.A. & Blankenship E.E. (2008). Field slope effects on uniformity of corn seed spacing for three precision planter metering systemsspacing for three precision planter metering systems. *Applied Engineering in Agriculture 24*(5): 581-586.

Singh, R.C., Singh, G. & Saraswat, D.C. (2005). Optimizing of design and operational parameters of pneumatic seed metering device for planting cottonseeds. *Biosystem Engineering 92*(4), 429-438.

SPSS, (2017). "SPSS for Windows". Student Version.Release 10.0.9 SPSS Inc IL USA.

Staggenborg, S.A., Taylor, R.K. & Maddux L.D. (2004). Effect of planter speed and seed firmers on corn stand establishment. *Applied Engineering in Agriculture 20*(5): 573-580.

TOBB, (2023). Bülten Yıllık. http://tarsustb.tobb.org.tr/B%C3%BClten/Y%C4%B1ll%C4%B1k/tabid/1988/Default.aspx (Accessed on: 20.05.2024).

Turan, J., Višacki, V., Mehandžić, S., Findura, P., Burg, P. & Sedlar, A. (2014). Sowing quality indicators for a seed drill with overpressure. *Acta Universitatis Agrıculturae Et Silviculturae Mendelianae Brunensis 62*(6): 1487-1492.

TÜİK, (2023). Bitkisel Üretim Istatistikleri. https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr

(Accessed on: 20.05.2024).

Wang, Y.Y., Li, J.D., Wan, D.W., Sun, Q.W., Yang, W. (2012). Trans. Chin. Soc. Agric. Mach. 43(S1), 54.

Webster, R. (2001). Statistics to support soil research and their presentation. *European Journal of Soil Science 52*, 331-340.

Yazgi, A. (2016). Effect of seed tubes on corn planter performance. *Applied Engineering in Agriculture 32*(6): 783-790.