Bulgarian Journal of Agricultural Science, 18 (No 5) 2012, 375-382
Agricultural Academy

EFFECTS OF STRIP WIDTH AND TRACTOR FORWARD SPEED ON SOWING UNIFORMITY OF MAIZE AND SUNFLOWER

S. ALTIKAT
Igdir University, Agricultural Faculty, Department of the Biosystem Engineering, 76000, Igdir, Turkey

Abstract

ALTIKAT, S., 2013. Effects of strip width and tractor forward speed on sowing uniformity of maize and sunflower. *Bulg. J. Agric. Sci.,* 19: 375-382

A two year - field experiment was conducted to investigate the effects of strip width and tractor forward speed on sowing uniformity of maize and sunflower. Being equipped to achieve purpose of this study, a row crop rotary hoe with C-type blades was used to obtain different strip widths. During the experiment, the field area was tilled in 22.5, 30 and 37.5 cm wide strips, respectively; these widths were obtained by changing the positions of flanges and blade connections of the rotary hoe. The rotary hoe was operated at a constant rotor rotation speed of 370 min^{-1}, in a tillage depth of 10 cm and at 3 different tractor forward speeds (1.8, 3.6 and 5.4 km h^{-1}) in order to get various soil fragmentation values.

Because of increasing the forward speed during the tillage, coefficient variations of sowing depth uniformity, intra and inter-row seed distribution uniformity and seed distribution area for both maize and sunflower seeds decreased. The precision of the distribution of the seeds along the length of the row for the forward speeds was well below 29%; and therefore, it was acceptable for both maize and sunflower seeds. However, the strip width did not have a significant effect on the sowing performance parameters. Tractor forward speed became effective on soil fragmentation, and accordingly the distribution of smaller soil particles decreased with the increase in the speed. This study demonstrated that the most acceptable tractor forward speed for the strip tillage method in terms of the sowing uniformity parameters was 1.8 km h^{-1} for all of the experiment years.

Key words: Sowing depth, seed distribution, miss index, multiple index, quality of feed index, sowing performance

Introduction

The strip tillage is a technique, which is applied generally to row-crops such as maize and sunflower as well as wheat and soybean (Reeder, 2002). In strip tillage technique, only up to 25 - 30% of the total field surface is tilled (Wysocki, 1986). The strip width varies between 10 cm and 30 cm in general; although the distance between the strips is based on the plant type, it ranges from 40 to 100 cm (Wysocki, 1986; Bolton and Booster, 1981; Morrison, 2002a, b; Licht and Al-Kaisi, 2005; Lowther et al., 1996). In addition to special tools and machines designed for this purpose, cultivators, subsoilers, and soil rotary tillers are used in strip tillage technique (Bolton and Booster, 1981; Morrison and Sanabria, 2002; Lee et al., 2003).

Uniformity of sowing is described using some parameters such as mean spacing, standard deviation of the sowing between plants and variation coefficient, which are commonly affected by seed or plant density and longitudinal distribution of seed (Altikat, 2011).

Insufficient sowing depth results in a poor crop emergence while placing seeds deeply delays the plant emergence (Loeppky et al., 1989). Consistent sowing depth is an important parameter to achieve a uniform crop emergence (Choudhary et al., 1985; Stockton et al., 1996). Results of a study conducted (Gan and Stobbe, 1995) concluded that variable sowing depths reduced

Corresponding author: sefa.altikat@igdir.edu.tr

the wheat yield significantly in comparison to the uniform planting.

Kachman and Smith (1995) and Karayel (2009) recommended using the multiple indexes, miss index, quality of feed index, and precision for summarising the seed spacing uniformity of seed metering rather than mean or coefficient of variation of seed spacing. On other hand, the sowing depth (Heege, 1993; Karayel and Ozmerzi, 2001; Karayel, 2005) specifies seed distribution in the vertical plane relative to soil surface.

Ozmerzi et al. (2002) examined the effect of sowing maize at different depths (*Zea mays* L.) in terms of horizontal and vertical distribution of seeds. Horizontal distribution was not different for sowing depths of 40, 60 and 80 mm. In terms of vertical seed distribution uniformity, the most suitable sowing depth was 60 mm. Tillage methods did not have an effect on horizontal distribution pattern, emergence rate index, and mean emergence time. The uniform sowing depth and maximum percentage of emergence were obtained while using mouldboard plough, disc harrow, and roller.

Material and Methods

The experiment was performed in a wheat stubble field at the Atatürk University, Faculty of Agriculture farm between 2004 and 2005. Silage maize and sunflower after spring wheat were planted at the field harvested by a combine with 10 cm stubble height. A pneumatic precision planter with 4 rows was used at 6 km h^{-1}forward speed and 5-cm sowing depth for seeding. For maize, the selected variety was Szegedi TC 513 F1 maize seed, and the sowing was performed at 50 kg ha^{-1} seed rate. As for sunflower, the selected variety was Serina sunflower seed, and the sowing was performed at 60 kg ha^{-1} seed rate. 180 kg ha^{-1} AN and 70 kg ha^{-1} DAP fertilizers were applied during the sowing and the rest was applied when the plant reached up to 15-cm height for both maize and sunflower. For maize and sunflower, processes of soil tillage and sowing were carried out in the second week of May in 2004 and 2005.

The process of irrigation was performed at first when height of plants was around 15-20 cm. During growing period, 3 surface irrigations were made in interval of three weeks for whole year and all seeds. In the experiment, a Ford 5000 S tractor with 49.4 kW (2100 min^{-1}) power and speed radar was used. Table 1 illustrates some of important physical properties of the experiment field soils. Table 2 illustrates the average monthly temperature and rainfall.

Table 1
Some of the important physical properties of the experiment field soils

Soil properties	2004	2005
Soil moisture, content, %	11.04	13.17
Soil bulk density, Mg m^3	1.11	1.18
Penetrasyon resistance, MPa	0.94	1.02
Organic matter, %	2.13	2.3
Residue cover rate, %	62.5	67.1
Soil texture class (%: clay:47.5; sand:30.7; silt:21.8)	Clay loam	

Table 2
Average monthly temperature and rainfall data

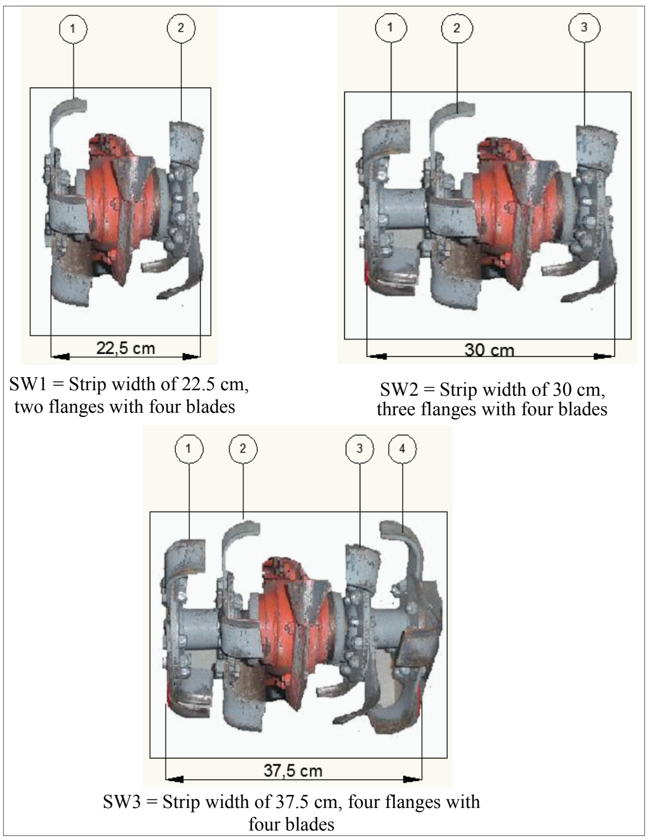
Months	Temperature, C°		Rainfall, mm	
	2004	2005	2004	2005
May	9.71	10.56	121.7	92.1
June	14.48	13.86	40.7	70.0
July	17.90	20.23	2.4	20.3
August	19.58	20.43	1.3	24.3
September	13.84	14.04	6.0	15.4
Average/Total	15.10	15.82	172.1	222.1

For strip tillage, the row crop rotary hoe equipped according to purpose of this study was used. The field surface was tilled respectively with 22.5, 30 and 37.5 cm wide strips, obtained by changing the positions of the blades and flange connections of the rotary hoe (Figure 1). Various soil particle sizes were aimed to be obtained in 3 different tractor forward speeds (1.8, 3.6 and 5.4 km h^{-1}) using 370 min^{-1} constant rotor rotational speed and 10-cm tillage depth. In order to drive the experiment tractor at the determined speeds, a multi-purpose DJCMS 100 type monitor and DJRVS II speed radar were used.

Following the strip tillage, for the purpose of determining the soil particle size distribution, the soil samples collected from the tilled strips were directly put into the 400 × 400 × 50 mm sample boxes using a sampling shovel, were taken to the laboratory and left for air dry. Dried soil samples were sieved through a set with eight sieves having the mesh sizes of 63, 32, 16, 8, 4, 2 and 1 mm. The process of sieving was performed using a sieving machine, Retsch type S-S, 80 W. The sieving time was 30 s, the frequency was approximately 50 Hz and the oscillation amplitude was 2 mm. The amounts of soil particles remaining on each sieve were weighed using a 0.01 g precision scale. In the sieve analysis, 1-8 mm diameter group, which was accepted to be the optimum particle size for seedbed, and particle diameters, which were bigger (>8 mm) and smaller (<1 mm) than this diameter group, were taken into consideration (Altikat and Celik, 2011). The particles smaller than 1 mm are not recommended due to risk of the wind erosion (Lyles and Woodruff, 1962; Altikat and Celik, 2011).

Measurement of the sowing depth was taken in the vertical plane. Mean sowing depth and coefficient of variation were determined by measuring the mesocotyl length of 30 maize and sunflower plants for all treatments and replications. Uniformity of inter and intra row seed distribution was checked using the distances between emerged plants randomly selected at 1 m distance in each plot. Theoretical inter and intra row distances were used to calculate the standard deviation, the variation coefficient and means (Altikat, 2011).

The method of ellipse criterion was used to determine the seed distribution area (Karayel and Ozmerzi, 2007). In this criterion, seed points were drawn on a graph and their distribution met the ellipse criterion (Figure 2). Semi-lenght of major axis of ellipse was standard devia-



SW1 = Strip width of 22.5 cm, two flanges with four blades

SW2 = Strip width of 30 cm, three flanges with four blades

SW3 = Strip width of 37.5 cm, four flanges with four blades

Fig. 1. Application of tillage strip widths by modification of rotary hoe.

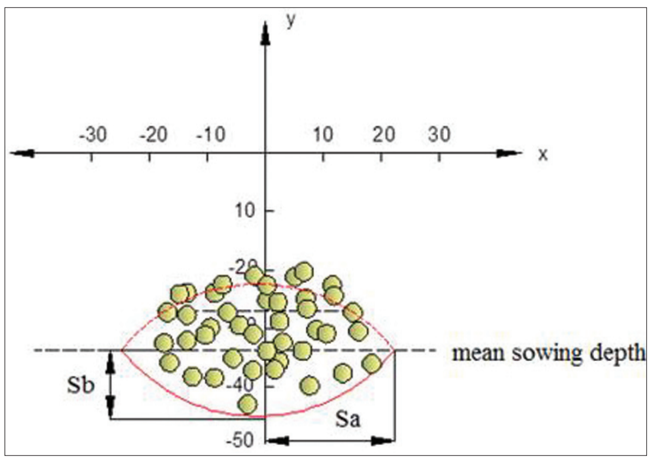


Fig. 2. Determination of seed distirbution area using with elipse criterion
Sa: Standard deviation from row center of seed and Sb: Standard deviation of sowing depth

tion from row centre of seeds and semi-lenght of minor axis of ellipse was the standart deviation of sowing depth. The seed distribution area (A) was calculated using the following equation:

A= Sa x Sb x π

Sa: Standard deviation from row centre of seeds (mm)

Sb: Standard deviation of sowing depth (mm)

A: area (mm^2)

The sowing uniformity of the distribution pattern along the length of the row was analysed using the methods described in Kachman and Smith (1995). The multiple index is the percentage of plant spacing that are less than or equal to half of the nominal spacing and indicates the percentage of multiple seed drops. Miss index is the percentage of plant spacing greater than 1.5 times the nominal seed spacing and indicates the percentage of missed seed locations or skips. Quality of feed index (QFI) is the percentage of plant spacing that is more than half but no more than 1.5 times the nominal spacing. A practical upper limit of precision is 29%. While there is a theoretical upper limit of 50% on the precision, values consistently, greater than 29% should be viewed with suspicion.

Analysis of the variance (ANOVA) was conducted on the mean values to assess effects of the strip width and tractor forward speed on soil physical properties and seed emergence. Significant differences among the means were determined using the protected least significant difference (LSD) tests at probability level of 0.05 (Celik and Altikat, 2010).

Results and Discussion

Table 3 illustrates the result of the sieve analysis made to determine the fragmenting condition of the soil

Table 3
Distribution of soil particles

Maize							
Treatments		2004 – Particle diameter			2005 – Particle diameter		
		< 1 mm	1-8 mm	> 8 mm	< 1 mm	1-8 mm	> 8 mm
Strip width	SW1	24.8	45.8 ns	29.4 ns	33.2 ns	31.5 ns	35.3 ns
	SW2	32.3a	41.6 ns	26.2 ns	34.1 ns	31.3 ns	34.6 ns
	SW3	28.5ab	42.2 ns	29.2 ns	33.0 ns	31.6 ns	35.4 ns
	P	0.048	0.610	0.724	0.144	0.910	0.423
Tractor forward speed	FV1	30.5a	39.6 ns	30.0a	38.6a	34.1a	27.3c
	FV2	25.3a	45.4 ns	29.3a	31.9b	31.4b	36.7b
	FV3	29.8a	44.6 ns	25.6a	29.8c	28.9c	41.3a
	P	0.165	0.389	0.596	0.001	0.001	0.001
Sunflower							
Treatments		2004 – Particle diameter			2005 – Particle diameter		
		< 1 mm	1-8 mm	> 8 mm	< 1 mm	1-8 mm	> 8 mm
Strip width	SW1	23.7	46.0 ns	30.3 ns	33.2 ns	31.5 ns	35.3 ns
	SW2		44.4 ns	31.1 ns	34.1 ns	31.3 ns	34.6 ns
	SW3		43.4 ns	31.3 ns	33.0 ns	31.6 ns	35.4 ns
	P		46.0 ns	30.3 ns	33.2 ns	31.5 ns	35.3 ns
Tractor forward speed	FV1	30.2 a	44.6 a	25.2 c	37.5 a	33.9 a	28.6 c
	FV2	29.6 b	40.2 b	30.2 b	32.4 b	31.4 b	36.2 b
	FV3	23.3 c	41.3 b	35.4 a	30.2 c	28.9 c	40.9 a
	P	0.001	0.001	0.001	0.001	0.001	0.001

[a] SW1=23.7 ns cm, SW2=24.5 ns cm and SW3=25.3 ns

[b] FW1=1.8 km h^{-1}, FW2=3.6 km h^{-1} and FW3=5.4 km h^{-1}

[c] SEM: Standard error of means

[d] Means within the same column followed by the same letter are not significantly different at α = 0.05 (LSD test)

tilled in strips. As illustrated in this table, while generally there was no effect of strip width on particle size, for both maize and sunflower.

For the plant of maize, the effect of tractor forward speed on the soil fragmentation was not significant in 2004 in comparison to the three particle size groups. However, there were statistically significant differences between tractor forward speeds in 2005 (Table 3). In 2005, as the forward speed increased, the amount of particle size smaller than 1 mm decreased and the amount of 1-8 mm size increased. However, in the field of sunflower, increasing the tractor forward speed affected soil particle size distribution and caused >8 mm particle size group to increase.

Multiple index, miss index, and quality of feed index (QFI) were combined for analysis of variance to determine significant differences in the variability in terms of the parameters. The results of the analysis concluded that for both maize and sunflower seeds, the tractor forward speed had a significant effect on the multiple indexes, miss index, and QFI of the distribution of the seeds along the length of the row (Table 4). On other hand, the strip tillage did not have a significant effect on these parameters. Increasing the tractor forward

Table 4
Uniformity of the sowing distribution pattern along the length of the row for maize and sunflower

Maize								
Strip width, SW	Miss index, %		Multiple index, %		Quality of feed index, %		Precision, %	
Year	2004	2005	2004	2005	2004	2005	2004	2005
SW 1	4.25 ns	6.83 ns	9.50 ns	6.88 ns	86.25 ns	86.29 ns	18.3	21.5
SW2	4.32 ns	7.15 ns	8.56 ns	7.20 ns	87.11 ns	85.65 ns	19.6	22.6
SW3	4.15 ns	8.99 ns	11.49 ns	6.70 ns	84.36 ns	84.32 ns	17.9	19.5
P	0.532	0.089	0.116	0.209	0.146	0.165		
Tractor forward speed								
FV1	3.90 b	4.54 c	7.59 b	7.01 ns	88.51 a	88.45 a	21.2	27.5
FV2	4.01 b	7.93 b	8.43 b	6.96 ns	87.56 a	85.11 b	22.3	29.2
FV3	4.82 a	10.50 a	13.53 a	6.81 ns	81.65 b	82.69 c	23.5	28.3
P	0.001	0.001	0.001	0.753	0.001	0.001		
Sunflower								
Strip width, SW	Miss index, %		Multiple index, %		Quality of feed index, %		Precision, %	
Year	2004	2005	2004	2005	2004	2005	2004	2005
SW1	5.24 ns	5.40 ns	5.10 ns	4.51 ns	89.66 ns	90.09 ns	21.6	24.3
SW2	5.12 ns	5.41 ns	5.19 ns	4.79 ns	89.70 ns	89.80 ns	22.8	19.6
SW3	4.93 ns	5.33 ns	5.22 ns	4.44 ns	89.85 ns	90.25 ns	27.9	28.7
P	0.41	0.875	0.869	0.396	0.811	0.216		
Tractor forward speed								
FV1	4.66 b	4.96 b	4.96 b	4.68 ns	90.03 a	90.36 a	22.3	25.6
FV2	5.01 b	5.16 b	4.75 b	4.48 ns	90.59 a	90.36 a	27.8	28.6
FV3	5.62 a	6.01 a	5.80 a	4.58 ns	88.58 b	89.41 b	29.1	25.8
P	0.002	0.001	0.001	0.761	0.001	0.002		

SW1= 22.5 cm, SW2= 30 cm, SW3= 37.5 cm
FV1= 1.8 km h^{-1}, FV2= 3.6 km h^{-1}, FV3= 5.4 kmh^{-1}
ns: not significant $\alpha = 0.05$ (LSD test)

speed affected the particle size and the placement of the seeds, and caused quality of feed index to decrease. High values for quality of feed index indicate better performance compared to low values. In other words, the quality of feed index is a measure of how often the spacing is close to the nominal spacing (Kachman and Smith, 1995; Karayel, 2009). The highest quality of feed index was obtained using the tractor forward speed of 1.8 kmh^{-1}. The same result was obtained for both seed types and experimental years. Precision is a measure of the variability in spacings between plants after accounting for variability due to both multiples and skips. A practical upper limit for precision is 29%. Lower values for the precision indicate better performance compared to higher values (Kachman and Smith, 1995). The range of precision in this study was 17.9–29.2% for maize sowing and 19.6–29.1% for sunflower sowing.

Combined analysis of the maize and sunflower sowing data showed significant differences in mean coefficient variation of sowing depth, and intra and inter-row seed uniformity, occurring only for tractor forward speeds, during both maize and sunflower sowings, in 2004 and 2005 (Table 5). Increasing the tractor forward speed during the tillage affected performance of the sowing and the placement of the seeds, and caused the coefficient variation of depth to increase. The coeffi-

Table 5
Coefficient variation of sowing and seed distribution area for maize and sunflower

Maize								
Strip width	Sowing depth, % CV		Intra row seed distribution uniformity, %CV		Inter row seed distribution uniformity, % CV		Seed distribution area, mm^2	
	2005	2006	2005	2006	2005	2006	2005	2006
SW 1	6.77 ns	6.77 ns	4.63 ns	4.64 ns	3.45 ns	3.60 ns	293 ns	267 ns
SW2	6.79 ns	6.83 ns	4.60 ns	4.70 ns	3.60 ns	3.56 ns	291 ns	286 ns
SW3	6.97 ns	6.95 ns	4.66 ns	4.59 ns	3.49 ns	3.63 ns	293 ns	282 ns
P	0.492	0.734	0.875	0.771	0.311	0.944	0.875	0.248
Tractor forward speed								
FV1	6.31 b	6.64 b	4.40 b	4.29 b	3.53 ns	3.68 ns	284 b	255 b
FV2	6.67 b	6.45 b	4.34 b	4.35 b	3.60 ns	3.56 ns	281 b	261 b
FV3	7.55 a	7.46 a	5.15 a	5.28 a	3.40 ns	3.63 ns	311 a	320 a
P	0.000	0.002	0.000	0.000	1.151	0.054	0.000	0.000
Sunflower								
Strip width	Sowing depth, % CV		Intra row seed distribution uniformity, %CV		Inter row seed distribution uniformity, % CV		Seed distribution area, mm^2	
	2005	2006	2005	2006	2005	2006	2005	2006
SW 1	4.59 ns	4.59 ns	4.46 ns	4.43 ns	4.44 ns	4.56 ns	271 ns	249 ns
SW2	4.48 ns	4.53 ns	4.47 ns	4.41 ns	4.36 ns	4.56 ns	267 ns	247 ns
SW3	4.55 ns	4.62 ns	4.36 ns	4.70 ns	4.48 ns	4.59 ns	263 ns	252 ns
P	0.535	0.652	0.522	0.109	0.562	0.982	0.702	0.796
Tractor forward speed								
FV1	4.28 b	4.32 b	4.34 ns	4.24 b	4.02 b	4.13 b	266 ns	229 b
FV2	4.35 b	4.44 b	4.40 ns	4.29 b	4.18 b	4.41 b	262 ns	230 b
FV3	4.98 a	4.99 a	4.55 ns	5.01 a	5.09 a	5.17 a	273 ns	289 a
P	0.000	0.000	0.160	0.000	0.000	0.000	0.490	0.000

SW1= 22.5 cm, SW2= 30 cm, SW3= 37.5 cm
FV1= 1.8 km h^{-1}, FV2= 3.6 km h^{-1}, FV3= 5.4 kmh^{-1}
ns: not significant $\alpha = 0.05$ (LSD test)

cient variation of sowing depth for 5.4 kmh^{-1} is generally greater in comparison to the other tractor forward speeds for both maize and sunflower in 2004 and 2005. However, the strip width did not have an effect on coefficient variation of sowing depth for both sunflower and maize in all of the experiment years.

Generally, increasing the tractor forward speed resulted in an increase in coefficient variation of inter and intra row seed distribution uniformity. Numerous researchers indicated the importance of operating at the optimum depth and concluded that too shallow or too deep sowing results in loss of crop performance and yield. McGahan and Robotham (1992) showed by measuring farm equipment performance that not only is the control of the mean depth required, but also the variation in depth, which should be minimized. Morrison and Gerik (1985) showed that emergence of wheat, sorghum and soybeans followed a second-order polynomial relationship with sowing depth, by exhibiting a maximum emergence value at an optimum depth.

Table 5 illustrates seed distribution areas calculated using ellipse criteria. Tractor forward speeds had a significant effect on distribution area ($P < 0.01$). Generally minimum distribution areas of maize and sunflower seeds were obtained at 1.8 kmh^{-1} tractor forward speed in 2004 and 2005. However, seed distribution area did not have an effect on strip width.

Conclusions

Strip width was not affected sowing uniformity both maize and sunflower in 2004 and 2005 experiment years. However, the tractor forward speed during the tillage had a significant effect on sowing performance for all of the years and seeds. Increasing the tractor forward speed during the tillage decreased the sowing uniformity and the quality of feed index. However, the range of precision in this study was 17.9–29.2% for maize sowing and 19.6–29.1% for sunflower sowing; these percentages are nearly acceptable. The tractor forward speed became effective on soil fragmentation, and accordingly there occurred a reduction in the distribution of smaller soil particles with an increase in the speed.

Integrated data of maize and sunflower sowing showed significant differences in mean coefficient variation of sowing depth occurring only for tractor forward speeds in 2004 and 2005. Increasing the tractor forward speed during the tillage had an effect the performance of the sowing and the placement of the seeds, and caused to increase the coefficient of variation of depth. Minimum seed distribution areas of maize and sunflower seeds were obtained using 1.8 kmh^{-1} tractor forward speeds for both maize and sunflower in 2004 and 2005.

In consequence of this study, strip width was not affected sowing performance and, the most acceptable tractor forward speed determined at the strip tillage method for sowing uniformity of maize and sunflower was 1.8 km h^{-1}.

References

Altikat, S., 2011. The effects of different openers and tractor forward speeds on no till seeders on the power and fuel consumption, soil physical properties, stubble distribution and sowing performance. PhD Thesis. University of Atatürk, Erzurum, Turkey.

Altikat, S. and A. Celik, 2011. The effects of tillage and intra-row compaction on seedbed properties and red lentil emergence under dry land conditions. *Soil and Tillage Research*, **114:** 1-8.

Bolton, F. E. and D. E. Booster, 1981. Strip-till planting in dry land cereal production. *Transaction of the ASAE*, **24** (1): 59-62.

Celik, A. and S. Altikat, 2010. Effects of various strip widths and tractor forward speeds in strip tillage on soil physical properties and yield of silage corn. *Journal of Agricultural Sciences,* **16:** 169-179.

Choudhary, M. A., G. P. Yu and C. J. Baker, 1985. Seed placement effects on seedling establishment in direct-drilled fields. *Soil and Tillage Research*, **6:** 79–93.

Gan, Y. and E. H. Stobbe, 1995. Effect of variations in seed size and planting depth on emergence, infertile plants, and grain yield of spring wheat. *Canadian Journal of Plant Science,* **75** (3): 565-570.

Heege, H. J., 1993. Seeding methods performance for cereals, rape and beans. *Transaction of the ASAE*, **36** (3): 653–661.

Kachman, S. D. and J. A. Smith, 1995. Alternative measures of accuracy in plant spacing for planters using single seed metering. *Transaction of the ASAE*, **38** (2): 379–387.

Karayel, D., 2005. Effects of coulters and depth control units of a seeder on sowing quality for precision sowing. PhD

Thesis. University of Akdeniz, Antalya, Turkey.

Karayel, D., 2009. Performance of a modified precision vacuum seeder for no-till sowing of maize and soybean. *Soil and Tillage Research,* **104:** 121-125.

Karayel, D. and A. Ozmerzi, 2001. Effect of forward speed and seed spacing on seeding uniformity of a precision vacuum metering unit for melon and cucumber seeds. *J. Fac. Agric. Akdeniz Univ. Antalya, Turkey*, **14** (2): 63–67.

Karayel, D. and A. Ozmerzi, 2007. Comparison of vertical and lateral seed distribution of furrow openers using a new criterion. *Soil and Tillage Research,* **95:** 69-75.

Lee, K. S., S. H. Park, W. Y. Park and C. S. Lee, 2003. Strip tillage characteristics of rotary tiller blades for use in a dry land direct rice seeder. *Soil and Tillage Research,* **71:** 25-32.

Licht, M. A. and M. Al-Kaisi, 2005. Strip-tillage effect on seedbed soil temperature and other soil physical properties. *Soil and Tillage Research*, **80:** 233-249.

Loeppky, H., G. P. Lafond and D. B. Fowler, 1989. Seeding depth in relation to plant development, winter survival, and yield of no-till winter wheat. *Agron. J.*, **81:** 125–129.

Lowther, W. L., R. F. Horrell, W. J. Fraser, K. D. Trainor and P. D. Johnstone, 1996. Effectiveness of a strip seeder direct drill for pasture establishment. *Soil and Tillage Research*, **38:** 161-174.

Lyles, L. and Woodruff, N. P., 1962. How moisture and tillage affect soil cloudiness for wind erosion control. *Agricultural Engineering,* **43** (3): 150-153.

Mc Gahan, E. J. and B. G. Robotham, 1992. Effect of planting depth on yield in cereals. Conference on Engineering in Agriculture, Albury, NSW, 4-7 October, pp. 121-126.

Morrison, J. E., 2002a. Strip tillage for "No Till" row crop production. *Applied Engineering in Agriculture,* **18** (3): 277-284.

Morrison, J. E., 2002b. Compatibility among three tillage systems and types of planter press wheels and furrow openers for vertisol clay soils. *Applied Engineering in Agriculture,* **18** (3): 293-295.

Morrison, J. E. and J. Sanabria, 2002. One-pass and two pass strip tillage for conservation row-cropping in adhesive clay soils. *Transaction of the ASAE,* **45** (3): 1263-1270.

Morrison, J. E. and T. J. Gerik, 1985. Planter depth control: I Predictions and projected effects on crop emergence. *Transactions of the ASAE*, **28** (5): 1415-1418.

Ozmerzi, A., D. Karayel and M. Topakci, 2002. Effect of sowing depth on precision seeder uniformity. *Biosystem Engineering,* **82** (2): 227–230.

Reeder, R. C., 2002. Maximizing performance in conservation tillage systems. ASAE Paper No: 021134, St. Joseph, MI-49085

Stockton, R. D., Krenzer Jr., J. Solie and M. E. Payton, 1996. Stand establishment of winter wheat in Oklahoma: a survey. *J. Prod. Agric.*, **9:** 571–575.

Wysocki, D., 1986. A strip-till planting system for no-till fallow. PNW Conservation Tillage Handbook Series. Chapter 2. System and Equipment No: 3.

Received October, 23, 2012; accepted for printing February, 2, 2013.