EFFECTS OF DIFFERENT SOIL TILLAGE-SOWING SYSTEMS ON PLANT DEVELOPMENT AND EMERGENCE TRAITS OF SECOND CROP SOYBEAN

EFEITOS DE DIFERENTES SISTEMAS DE SEMEADURA DIRETA NO DESENVOLVIMENTO DE PLANTAS E CARACTERÍSTICAS DE EMERGÊNCIA DE SOJA EM SEGUNDA SAFRA

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ABSTRACT: Effects of different soil tillage and sowing systems (Conventional Soil Tillage – CST: Moldboard plow + gobble disc + disk harrow + harrow + sowing machine; Reduced Soil Tillage – RST: rototiller-combined soil tillage machine + sowing machine; Ridge Sowing – RS: gobble disc + ridge-sowing machine; Direct Sowing – DS – no-till) on plant development and emergence traits of second-crop soybean were investigated in this study under Antalya provincial conditions. Experiments were conducted over the experimental fields of the Aksu Branch of Bati Akdeniz Agricultural Research Institute for 3 years (2013, 2014, 2015) as a fixed experiment. The number of days to 50% emergence, number of days to 50% flowering, plant height, number of pods per plant, the first pod height, number of plants per m^2, 1000-seed weight, and yield were considered as plant development parameters. Mean emergence time, germination rate index, emergence ratio, space ratio, tillering ratio, and acceptable plant spacing ratio were considered as plant emergence parameters. Different soil tillage and sowing systems generally had significant effects on investigated traits at $p < 0.01$ and $p < 0.05$ levels.

KEYWORDS: Conversation. Emergence. Soil. Tillering.

INTRODUCTION

Soil fertility is the primary condition for optimum plant growth and development since plants get entire nutrient and water needs from the soil. Soil fertility largely depends on available biological, physical, and chemical processes within the seedbed or root zone of the plants. Sustainability of such processes is possible only with proper soil tillage practices (TEZER; SABANCI, 1990). Soil upper zones are mixed mechanically through soil tillage. Such a mixing process alters soil physical, chemical, and biological characteristics. Such an effect influences not only the microorganisms living in soil but also ongoing biochemical cycles within the soil profile (YALCIN; SUNGUR, 1991). Soil tillage significantly influences plant growth and development, physicochemical soil characteristics, soil microbial activity, and ultimately crop yields. In brief, soil biological, physical, and chemical balances are preserved and regulated by soil tillage. Among the plant production factors, soil tillage has a contribution of up to 20% (GOZUBUYUK et al., 2017). Soil tillage methods are composed of overturning, loosening, crumbling, mixing, and leveling processes (DEMIR et al., 2000). However, soil compaction is evident while soil stillage because of heavy traffic over the field, and resultant compaction then negatively influences plant growth and development (OZGUVEN; AYDINBELGE, 1990). Frequent soil tillage to get a good soil structure also negatively influences soil structure. Redundant soil tillage increases crop costs and results in excessive decomposition of organic matter, thus negatively influences soil fertility (KAYISOGLU et al., 1996).

Recently, conservation soil tillage methods (mulch tillage, reduced tillage, strip tillage, zero tillage) are getting common in Turkey and different countries of the world to minimize or eliminate the negative aspects of soil tillage.

Several studies have been conducted to determine the effects of soil tillage practices on plant emergence, growth, and development. Jalota et al. (2008) compared conservation and conventional tillage systems in cotton and found that the minimum tillage system had lower yield and water productivity as compared to the conventional tillage.

Karamanos et al. (2004) showed that conservation tillage systems (no-tillage and minimum tillage systems) provided higher soil water content, cotton root growth, and cotton yield as compared to the conventional tillage. Merrill et al. (1996) showed that wheat root development increased up to 112% in the no-tillage system as compared to the conventional tillage. Reduced crop yields were reported for no-tillage systems (YALCIN; CAKIR, 2006; KORZENIOWSKA; STANISŁAWSKA-GLUBIAK, 2009). Eker and Ulger (1988) investigated the effects of different soil tillage equipment on soil and plant characteristics and determined germination, the number of leaves, plant height, and yield of sunflower plants. Based on plant leaf development and yield levels, researchers indicated subsoiler – chisel plow as the best soil tillage equipment under experimental conditions. Maurya (1988) comparatively assessed the conventional and zero-tillage in wheat and maize culture under different soil and climate conditions in Nigeria. Aykas and Onal (1996) investigated the operational characteristics and effects of different seedbed preparation equipment on wheat yield. Yalcin et al. (2009) investigated the potential use of ridge-sowing besides conventional production techniques in grain and silage maize culture.

Soybean is an important oil crop. Soybean seeds contain about 18-24% oil. The yellow and aromatic soybean oil is mostly consumed as margarine. Soybean oil is either used as foodstuff or raw material in the industry for various purposes. Soybean seeds contain about 36-40% protein. Soy protein includes highly valuable amino acids, thus nutritional value is quite high, almost equal to animal proteins (ARIOGLU, 2013).

In this study, effects of different soil tillage and sowing systems on plant emergence, growth, and development were investigated, relationships among these attributes were assessed and alternative soil tillage – sowing methods allowing crop culture with the minimum soil disturbance and without any degradations in soil physical, chemical and biological structure instead of conventional soil tillage -sowing methods for second-crop soybean culture in the region were put forth.

MATERIAL AND METHOD

The soybean cultivar of "ATAEM-7" registered by the Bati Akdeniz Agricultural Research Institute in 2006 was used as the plant material. ATAEM-7 is a mid-early high-yield cultivar. Flower color is white, 1000-seed weight is around 150-160 g, ripening duration is 110-145 days and yield is around 350-450 kg da^{-1}.

Experiments were conducted over the experimental fields of Aksu-Central Enterprise (36°56'37.9"N - 30°52'45.1"E) of Directorate of Bati Akdeniz Agricultural Research Institute during the second crop growing season after wheat harvest.

Soil samples were taken from the 0-30 cm soil profile at 3 different locations of the experimental site. Samples were analyzed at soil laboratory and soil physical and chemical characteristics are provided in Table 1.

Table 1. Soil analyses results of the experimental site

Soil Analyses Results		
pH (1:2.5)	7.5	Slightly alkaline
Lime (%)	19,6	High
EC (micromhos/cm, 25ºC)	195	Unsaline
Sand (%)	21	
Clay (%)	33	Clay-loam
Silt (%)	46	
Organic matter (%)	1,8	
P (ppm, Olsen)	16	
K ppm	250	
Ca ppm	4585	
Mg ppm	409	

Monthly total precipitation, average temperature, and relative humidity for the second-crop soybean growing season are provided in Table 2 as the long-term (1929-2016) averages.

Table 2. Long-term climate data for the research site (Antalya province) (1929-2016)

	May	June	July	August	September	OctoberEkim
Average temperature (°C)	20.4	25.4	28.4	28.1	24.7	19.8
Average maximum temperature (°C)	25.9	31.3	34.4	34.3	31.3	26.7
Average minimum temperature (°C)	14.8	19.4	22.5	22.4	19.1	14.9
Average sunshine duration (h)	9.5	11.4	11.5	11.3	9.5	8.0
Average number of precipitated days	5.0	2.4	0.7	0.5	1.7	5.4
Average monthly total precipitation	29.3	7.1	3.3	1.6	11.0	74.8

Source: https://mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?k=A&m=ANTALYA

Experiments were conducted in randomized blocks design with 3 replications for 3 years over 15 plots as a fixed design under mellow soil conditions. Experimental plots were 25 m long and 5.6 m wide and 3 m spacing was provided between each plot. Each plot had 6 plant rows. Two side rows were omitted as to consider side effects and the harvest was performed from the inner 4 rows and observations were also made from these 4 rows. Throughout the experiments for 3 years, cultural practices (fertilization, chemical application, hoeing, and irrigation) were practiced similarly in all plots in accordance with Arioglu (2013).

Four different soil tillage and sowing systems were compared in this study.

- DS: Direct sowing onto stubble (no-till)
- RS: Ridge-sowing (Gobble disc harrow + ridge sowing)
- RST: Reduced soil tillage (rototiller-combined soil tillage machine + seeding machine)
- CST: Conventional soil tillage (plough + gobble disc harrow + disc harrow + harrow + seeding machine)

To find out the effects of soil tillage and sowing systems on plant growth and development, days to 50% emergence, days to 50% flowering, plant height (cm), the number of pods per plant, the first pod height (cm), the number of plants per m^2, 1000-seed weight (g) and yield (kg da^{-1}) were determined in accordance with Kolay (2007).

To find out the effects of soil tillage and sowing systems on seed distribution uniformity, germination, and plant emergence, the number of emerged plants was counted daily from the randomly selected row of each plot. Following the constant emergence, mean emergence time (MET), emergence rate index (ERI), and emergence rate (ER) were calculated with the aid of the following equations (BILBRO; WANJURA, 1982; BARUT, 1996):

$$MET = \frac{B_1 G_1 + B_2 G_2 + \cdots\cdots\cdots + B_n G_n}{B_1 + B_2 + \cdots\cdots\cdots + B_n} \quad (1)$$

$$GRI = \frac{N_b}{MET} \quad (2)$$

$$ER = \frac{N_b}{n} \quad (3)$$

Where; MET = Mean emergence time (day), GRI = Germination rate index (plant/day m), ER = Emergence rate (%), B = Number of plants emerged after preceding counting, G = Number of days passed after sowing, N_b = Number of plants emerged over a unit length (plant/m), N = Number of seeds sown over a unit length (seed/m). To find out the effects of soil tillage and sowing systems on on-row plant uniformity, following the constant emergence, on-row plant spacing (X), space ratio (SR), tillering rate (TR), and acceptable plant spacing ratio (APSR) were calculated with the aid of the following equations (ANONYMOUS, 1989; KACHMAN; SMITH, 1995):

$$X = (\sum n_i Z_i)/n_1 \quad (4)$$
$$SR = (n_o/n)100 \quad (5)$$
$$TR = (n_2/n)100 \quad (6)$$
$$APSR = (n_1/n)100 \quad (7)$$

Where; X = Average distance between two plants (cm), Z = The distance to be between two plants (cm), SR = Space ratio (%), TR = Tillering rate (%), APSR = Acceptable plant spacing ratio (%), n = Total number of plant spacing, n_i = Number of plants in spacing i, n_1 = Number of plant spacing between (0.5-1.5)Z, n_o = Number of plant spacing greater than 1.5 Z, n_2 = Number of plant spacing less than 0.5 Z.

RESULTS AND DISCUSSION

Plant growth and development

Effects of different soil tillage and sowing (conventional, ridge-sowing, reduced tillage and direct sowing - no-till) systems on some plant characteristics of second crop soybean for 3 years are provided in Tables 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13.

In the first year of the experiments, the effects of different soil tillage systems on the number of days to 50% flowering were not found to

be significant (Table 3). Soil tillage systems had significant effects on the number of days to 50% emergence, plant height, number of pods per plant, number of plants per m^2, 1000-seed weight, and yield at p<0.01 level and had significant effects on the first pod height at p<0.05 level. The greatest plant height (82.66 cm), number of pods per plant

(92 pods), number of plants per m^2 (55 plants), 1000-seed weight (181.17 g), and yield (373.39 kg da^{-1}) were obtained from the reduced soil tillage system. The greatest number of days to 50% emergence (5.20 days) was obtained from the conventional soil tillage system.

Table 3. Variance analysis and comparison of means for plant characteristics of the first year.

Parameters	Treatments				Variance analysis		
	DS	RS	CST	RST	CV	LSD	SL
Days to 50% emergence	5.00 c	4.80 d	5.20 a	5.12 b	0.54	0.05	**
Days to 50% flowering	41.66	42.20	43.40	43.07	-	-	n.s
Plant height (cm)	69.69 d	74.67 c	80.00 b	82.66 a	1.08	1.66	**
Number of pods per	83.45 c	87.97 b	89.20 ab	92.00 a	1.88	3.31	**
First pod height (cm)	7.00 a	6.00 b	7.00 a	7.00 a	5.46	0.73	*
Number of plants per m^2	46.75 b	50.60 b	54.80 a	55.00 a	0.61	0.63	**
1000-seed weight (g)	166.00 c	176.83 a	176.71 b	181.17 a	1.02	3.57	**
Yield (kg da^{-1})	280.46 c	350.33 b	346.25 b	373.39 a	1.23	8.29	**

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same row are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference, SL: Significance level

In the second year, the effects of different soil tillage and sowing systems on the first pod height were not found to be significant (Table 4). Soil tillage systems had significant effects on the number of days to 50% emergence, number of days to 50% flowering, plant height, number of pods per plant, number of plants per m^2, 1000-seed weight, and yield at p<0.01 level. The greatest plant height

(82.32 cm), number of pods per plant (92.65 pods), number of plants per m^2 (55.65 plants), 1000-seed weight (188.43 g), and yield (374.03 kg da^{-1}) were obtained from reduced soil tillage system. The greatest number of days to 50% emergence (5.02 days) and the greatest number of days to 50% flowering (44.05 days) were obtained from the conventional soil tillage system.

Table 4. Variance analysis and comparison of means for plant characteristics of the second year

Parameters	Treatments				Variance analysis		
	DS	RS	CST	RST	CV	LSD	SL
Days to 50%	4.83 c	4.63 d	5.02 a	4.95 b	0.46	0.04	**
Days to 50%	40.36 c	42.03 b	44.05 a	42.90 ab	1.66	1.40	**
Plant height (cm)	68.10 d	74.49 c	80.65 b	82.32 a	0.71	1.09	**
Number of pods per	84.52 d	88.03 c	89.84 b	92.65 a	0.97	1.73	**
First pod height (cm)	6.00	7.00	6.00	6.00	-	-	n.s
Number of plants per	47.89 c	50.42 b	55.44 a	55.65 a	1.63	1.70	**
1000-seed weight (g)	163.43 d	179.04 b	175.68 c	188.43 a	0.23	0.82	**
Yield (kg da^{-1})	282.27 c	352.69 b	346.89 b	374.03 a	1.49	10.15	**

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same row are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference, SL: Significance level

In the third year, soil tillage systems had significant effects on the number of days to 50% emergence, plant height, number of pods per plant, number of plants per m^2, 1000-seed weight and yield at p<0.01 level and had significant effects on the number of days to 50% flowering and the first

pod height at p<0.05 level (Table 5). The greatest plant height (85.45 cm), number of pods per plant (93.45 pods), number of plants per m^2 (56.68 plants), 1000-seed weight (189.07 g), and yield (382.10 kg da^{-1}) were obtained from the reduced soil tillage system. The greatest number of days to 50%

flowering (44.13 days) was obtained from the conventional soil tillage system. The greatest first pod height (7.00 cm) was observed in the conventional and reduced soil tillage systems. The greatest number of days to 50% emergence (5.13 days) was obtained from the direct sowing system.

Table 5. Variance analysis and comparison of means for plant characteristics of the third year

Parameters	Treatments				Variance analysis		
	DS	RS	CST	RST	CV	LSD	SL
Days to 50% emergence	5.13 a	4.76 c	4.95 b	4.65 d	0.69	0.06	**
Days to 50% flowering	41.11 b	42.34 b	44.13 a	42.26 b	1.62	1.38	*
Plant height (cm)	72.10 d	76.25 c	80.65 b	85.45 a	1.20	1.88	**
Number of pods per plant	85.80 c	89.10 b	88.48 b	93.45 a	1.10	1.96	**
First pod height (cm)	6.00 b	6.00 b	7.00 a	7.00 a	6.58	0.85	*
Number of plants per m²	49.13 c	51.62 bc	54.71 ab	56.68 a	3.32	3.52	**
1000-seed weight (g)	164.77 d	184.43 b	175.03 c	189.07 a	0.94	3.38	**
Yield (kg da⁻¹)	283.50 c	352.85 b	353.82 b	382.10 a	1.10	7.58	**

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same row are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference, SL: Significance level

The numbers of days to 50% emergence of different years for different soil tillage systems are provided in Table 6. Year*treatment interactions were found to be significant (p<0.01). Therefore, the years were assessed separately. Ridge-sowing had positive impacts on plant emergence in 2013 and 2014 and resulted in relatively early emergences. In 2015, reduced tillage had positive impacts on emergence. Such a case may be attributed to the increased temperature of the ridges. Ozturk (2015) reported the number of days to 50% emergence as 5.5 days. Kolay (2007) indicated insignificant effects of soil tillage systems on the number of days to 50% emergence.

Table 6. Days to 50% emergence values of tillage and sowing methods

Treatments	Years			
	2013	2014	2015	Average
DS	5.00 c	4.83 c	5.13 a	4.98
RS	4.80 d	4.63 d	4.76 c	4.73
CST	5.20 a	5.02 a	4.95 b	5.05
RST	5.12 b	4.95 b	4.65 d	4.91
Average	5.03	4.86	4.87	
CV	0.54	0.46	0.69	
LSD	0.05**	0.04**	0.06**	
**Year x Treatment: Significant ** **				

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

The numbers of days to 50% flowering of different years for different soil tillage systems are provided in Table 7. Year*treatment interactions were not found to be significant. Therefore, the years were not assessed separately. Three-year (2013, 2014, 2015) results of treatments were assessed together. The earliest number of days to 50% flowering was obtained from the direct sowing and the latest number of days to 50% flowering was obtained from the conventional tillage. Ozturk (2015) reported the average number of days to 50% flowering as 40 days. Kolay (2007) also reported similar findings with the present ones.

Table 7. Days to 50% flowering values of tillage and sowing methods

Treatments	Years			
	2013	**2014**	**2015**	**Average**
DS	41.66	40.36	41.12	41.05 c
RS	42.20	42.03	42.34	42.19 b
CST	43.40	44.05	44.14	43.86 a
RST	43.07	42.90	42.27	42.75 b
Average	42.58	42.34	42.47	42.46
CV				1.59
LSD				0.67
Year x Treatment: Insignificant				

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

Concerning plant heights (cm) of different soil tillage systems in different years, again year*treatment interactions were found to be significant (p<0.05) (Table 8). Therefore, the years were assessed separately. Reduced soil tillage had positive impacts on plant heights in 2013, 2014, and 2015. The lowest plant heights in 3 years were obtained from the direct sowing treatments and the greatest plant heights were obtained from the reduced soil tillage systems.

Table 8. Plant height values of tillage and sowing methods

Treatments	Years			
	2013	**2014**	**2015**	**Average**
DS	69.69 d	68.10 d	72.10 d	69.96
RS	74.67 c	74.49 c	76.25 c	75.14
CST	80.00 b	80.65 b	80.65 b	80.43
RST	82.66 a	82.32 a	85.45 a	83.48
Average	76.76	76.39	78.61	
CV	1.08	0.71	1.2	
LSD	1.66**	1.09**	1.88**	
Year x Treatment: Significant *				

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

Present plant heights were similar to the ones reported by Arslan and Arıoglu (2001) but were conflicting with the ones reported by Temperly and Borges (2006) reporting greater and significantly different plant heights for no-till systems (88.7 cm) than the conventional soil tillage systems (82.5 cm). Onat (2012) reported the lowest plant height as 71.95 cm and the greatest plant height as 97.37 cm.

Regarding the number of pods per plant of different soil tillage systems in different years, year*treatment interactions were not found to be significant (Table 9). Therefore, the years were not assessed separately. Three-year (2013, 2014, 2015) results of treatments were assessed together. The greatest number of pods per plant was obtained from the reduced soil tillage and the lowest number of pods per plant was obtained from the direct sowing treatments. Arslan and Arioglu (2001) conducted a study on second-crop soybean in the Çukurova region and reported similar findings with the present ones. Yetim (2008) reported the lowest number of pods per plant as 55.75 and the greatest number of pods per plant as 91.92.

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Table 9. Number of pods per plant of tillage and sowing methods

Treatments	Years			
	2013	**2014**	**2015**	**Average**
DS	83.45	84.52	85.80	84.59 c
RS	87.97	88.03	89.11	88.37 b
CST	89.20	89.85	88.48	89.17 b
RST	92.00	92.65	93.46	92.71 a
Average	88.16	88.76	89.21	88.71
CV				1.37
LSD				1.21
Year x Treatment: Insignificant				

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

The first pod heights (cm) of different soil tillage and sowing systems in different years are provided in Table 10. The year*treatment interactions were found to be significant (p<0.01). The greatest first pod heights were obtained from the conventional and reduced soil tillage systems.

Onat (2012) reported the lowest first pod height as 10.58 cm and the greatest first pod height as 15.10 cm. Sessiz et al. (2009) reported the first fruit height as 3.70 cm in conventional soil tillage, 4.70 cm in reduced soil tillage, and 3.66 cm in no-till systems.

Table 10. First pod height values of tillage and sowing methods

Treatments	Years			
	2013	**2014**	**2015**	**Average**
DS	7.00 a	6.00	6.00 b	6.33
RS	6.00 b	7.00	6.00 b	6.33
CST	7.00 a	6.00	7.00 a	6.67
RST	7.00 a	6.00	7.00 a	6.67
Average	6.75	6.25	6.50	
CV	5.46	6.84	6.58	
LSD	0.73*	0.85	0.85	
**Year x Treatment: Significant ** **				

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

About the number of plants per m^2 of different soil tillage systems in different years, year*treatment interactions were not found to be significant (Table 11). Therefore, the years were not assessed separately. Three-year (2013, 2014, 2015) results of treatments were assessed together. The greatest number of plants per m^2 was obtained from the reduced soil tillage and the lowest number of plants m^2 was obtained from the direct sowing treatments.

Bakoglu and Aycicegi, (2005) reported the number of plants per m^2 as 29.80. Also, Oztürk (2015) indicated insignificant effects of different soil tillage systems on the number of plants per m^2. Arslan and Arioglu, (2001) conducted a study with second-crop soybean in the Çukurova region and

reported the lowest number of plants per m^2 for direct sowing in both years and the greatest number of plants per m^2 for gobble disc + gobble disc soil tillage in the first year and for plow + gobble disc soil tillage in the second year.

Table 11. Number of plants per m² values [of] tillage and sowing methods

Treatments	Years			
	2013	**2014**	**2015**	**Average**
DS	46.75	47.90	49.13	47.93 c
RS	50.60	50.43	51.62	50.88 b
CST	54.80	55.45	54.71	54.99 a
RST	55.00	55.65	56.68	55.78 a
Average	51.79	52.36	53.04	52.39
CV				2.19
LSD				1.13
Year x Treatment: Insignificant				

** Significant at $P < 0.01$; * Significant at $P < 0.05$; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

The 1000-seed weights (g) of different soil tillage systems in different years are provided in Table 12. The year*treatment interactions were found to be significant (p<0.01).

Reduced soil tillage systems had positive impacts on 1000-seed weights in the third year of the experiments. The lowest 1000-seed weights were obtained from the direct sowing treatments of 3 years. Yetim (2008) reported the lowest 1000-seed weight as 146.9 g and the greatest 1000-seed weight as 163.7 g. Pedersen and Lauer (2003) reported about 2% greater 1000-seed weight for no-till systems than for conventional soil tillage. Singer et al. (2008) indicated insignificant differences in 1000-seed weights of soil tillage systems in the first year (11.4 g), reported the greatest 1000-seed weight (15.2 g) for no-till system and the no-till system was significantly different from the plow tillage system.

Table 12. 1000-seed weight values of tillage and sowing methods

Treatments	Years			
	2013	**2014**	**2015**	**Average**
DS	166.00 c	163.43 d	164.77 d	164.74
RS	176.83 b	179.04 b	184.43 b	180.10
CST	176.71 b	175.68 c	175.03 c	175.81
RST	181.17 a	188.43 a	189.08 a	186.23
Average	175.18	176.65	178.33	
CV	1.02	0.23	0.94	
LSD	3.57**	3.82**	3.38**	
Year x Treatment: Significant **				

** Significant at $P < 0.01$; * Significant at $P < 0.05$; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

Regarding yields (kg da⁻¹) of different soil tillage systems in different years, year*treatment interactions were not found to be significant (Table 13). Therefore, the years were not assessed separately. Three-year (2013, 2014, 2015) results of treatments were assessed together. The greatest yield was obtained from the reduced soil tillage and the lowest yield was obtained from the direct sowing treatments. Kosutic et al. (2005) reported the greatest yield for reduced soil tillage and the lowest yield for direct sowing onto stubble. Helaloglu et al. (1989) reported the greatest yield for no-till stubble drill. Ocaktan (1989) reported the greatest yield for Anatolian plow + disc harrow + harrow and chisel + disc harrow + harrow treatments in heavy-textured soils and for gobble disc + harrow treatments besides the previous ones in medium-textured soils. Borin and Sartori (1995) reported that among conventional tillage, minimum tillage, and no-tillage in maize culture, the greatest yield was obtained from the conventional tillage.

Table 13. Yield (kg da⁻¹) values of tillage and sowing methods

Treatments	Years			
	2013	**2014**	**2015**	**Average**
DS	280.46	282.28	283.51	282.08 c
RS	350.33	352.69	352.86	351.96 b
CST	346.25	346.90	353.82	348.99 b
RST	373.39	374.04	382.11	376.51 a
Average	337.61	338.98	343.07	339.89
CV				1.28
LSD				4.33
Year x Treatment: Insignificant				

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

Plant emergence

In second-crop soybean culture, effects of different soil tillage and sowing systems (conventional tillage, ridge-sowing, reduced tillage, and direct sowing) on mean emergence time (MET), germination rate index (GRI), emergence rate (ER), space ratio (SR), tillering ratio (TR) and acceptable plant spacing ratio (APSR) are provided in Tables 14, 15, 16, 17, 18, 19, 20, 21 and 22 for 3 years. In the first year, soil tillage and sowing systems had significant effects on germination rate, emergence rate, space ratio, tillering ratio, and APSR at $p<0.01$

level, and effects on mean emergence time were found to be significant at $p<0.05$ level (Table 14). The greatest emergence time and space ratio values were obtained from the direct sowing (no-till) system. The greatest germination rate was observed in ridge-sowing and reduced soil tillage systems. The greatest emergence ratio was observed in reduced tillage, the greatest tillering ratio was observed in conventional tillage and the lowest emergence and tillering ratios were observed in direct sowing systems.

Table 14. Variance analysis and comparison of means for plant emergence in the first year

Parameters	Treatments				Variance analysis		
	DS	**RS**	**CST**	**RST**	**CV**	**LSD**	**SL**
Mean emergence time (day)	12.10 a	10.57 b	11.42 ab	10.78 b	3.80	0.85	*
Germination rate index (plant/day)	1.25 c	1.43 a	1.33 b	1.43 a	2.85	0.07	**
Emergence rate (%)	0.756 c	0.793 b	0.813 ab	0.816 a	1.37	0.02	**
Space ratio (%)	11.26 a	8.67 b	6.40 d	7.45 c	3.50	0.59	**
Tillering ratio (%)	0.53 c	1.11 b	1.83 A	0.90 b	0.78	0.01	**
APSR (%)	88.21 c	90.21 b	91.89 a	91.50 a	0.27	0.49	**

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same row are not significantly different; CV: Coefficient of variation, LSD: Least significant difference, SL: Significance level

In the second year, soil tillage systems did not have significant effects on mean emergence time and germination ratio (Table 15). Different soil tillage systems had significant effects on emergence rate, space ratio, tillering ratio, and APSR at $p<0.01$ level. The greatest emergence rate was obtained from the conventional soil tillage and the lowest emergence rate was obtained from the direct sowing (no-till) system. The greatest space ratio was observed in direct sowing and the greatest tillering

ratio and APSR were observed in the ridge-sowing system.

Table 15. Variance analysis and comparison of means for plant emergence in the second year

Parameters	Treatments				Variance analysis		
	DS	RS	CST	RST	CV	LSD	LS
Mean emergence time	12.23	11.25	11.12	10.55	-	-	n.s
Germination rate index	1.38	1.42	1.45	1.36	-	-	n.s
Emergence rate (%)	0.650 c	0.746 b	0.786 a	0.753 b	1.83	0.026	**
Space ratio (%)	14.31 a	5.42 d	8.64 b	7.51 c	2.88	0.51	**
Tillering ratio (%)	0.60 d	1.62 a	0.85 c	1.13 b	2.89	0.06	**
APSR (%)	85.08 d	92.97 a	90.50 c	91.65 b	0.57	1.04	**

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same row are not significantly different; CV: Coefficient of variation, LSD: Least significant difference, SL: Significance level

In the third year, different soil tillage systems did not have significant effects on mean emergence time, germination rate index, and germination rates (Table 16). But different soil tillage systems had significant effects on space ratio, tillering ratio, and APSR at p<0.01 level.

Table 16. Variance analysis and comparison of means for plant emergence in the third year

Parameters	Treatments				Variance analysis		
	DS	RS	CST	RST	CV	LSD	LS
Mean emergence time	12.25	11.31	11.12	11.46	-	-	n.s
Germination rate index	1.60	1.52	1.46	1.50	-	-	n.s
Emergence rate (%)	0.653	0.803	0.809	0.786	-	-	n.s
Space ratio (%)	10.62 a	4.22 c	9.29 ab	7.92 b	8.66	1.38	**
Tillering ratio (%)	0.69 c	2.02 a	0.77 c	1.32 b	4.08	0.097	**
APSR (%)	88.68 c	93.77 a	89.96 b	90.76 b	0.69	1.25	**

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same row are not significantly different. CV: Coefficient of variation, LSD: Least significant difference, SL: Significance level

Regarding the mean emergence times of soybean plants, the lowest value (10.57 days) was observed in the ridge-sowing treatment of the first year and the greatest value (12.25 days) was observed in direct sowing treatment of the third year. Mean germination times of direct sowing (no-till) systems were greater than the other soil tillage systems. Taser and Kara (2005) reported mean germination times of maize at different soil compaction levels as between 12.08 - 12.25 days. Bayhan et al. (2006) reported the shortest plant emergence time for direct sowing systems.

Regarding the effects of different soil tillage systems on the emergence rate index and APSR, ridge-sowing, conventional soil tillage, and reduced soil tillage were placed in the same statistical group. Taser and Kara (2005) experimented with different soil compaction levels in second-crop silage maize and reported the lowest germination rate index as 0.47 seed/m.day. Based on 3-year data, conventional soil tillage yielded greater field emergence levels than the no-till system. As can be inferred from the present tables that the lowest field emergence level

(65.00%) was observed in direct sowing treatments of the second year and the greatest value (81.60%) was observed in reduced soil tillage systems of the first year. Bayhan et al. (2006) reported the greatest emergence levels for direct sowing treatments.

Cakır et al. (2006) compared conversation soil tillage and direct sowing systems and reported the greatest field emergence level as 74%. Ozpinar and Isik (2004) experimented with conventional and reduced soil tillage systems and ridge and normal row sowing methods and reported field emergence levels of cotton as between 72 – 88%.

Mean emergence times of different soil tillage systems in different years are provided in Table 17. Year*treatment interactions were not found to be significant. Therefore, the years were not assessed separately. Three-year (2013, 2014, 2015) results of treatments were assessed together. The earliest emergence was observed in reduced soil tillage and the latest emergence was observed in the direct sowing system.

Table 17. Mean emergence time (day) values of tillage and sowing methods

Treatments	Years			
	2013	2014	2015	Average
DS	12.11	12.23	12.25	12.20 a
RS	10.57	11.25	11.32	11.05 b
CST	11.42	11.12	11.12	11.22 b
RST	10.78	10.55	11.46	10.93 b
Average	11.22	11.29	11.54	11.35
CV				5.08
LSD				0.57
Year x Treatment: Insignificant				

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

Germination rate index values of different soil tillage and sowing systems in different years are provided in Table 18. Year*treatment interactions were found to be significant (p<0.01). Ridge-sowing and reduced soil tillage systems had positive impacts on the germination rate in 2013. Conventional soil tillage had positive impacts on the germination rate in 2014 and direct sowing in 2015.

Table 18. Germination rate index values of tillage and sowing methods

Treatments	Years			
	2013	2014	2015	Average
DS	1.25 c	1.38	1.60	1.41
RS	1.43 a	1.42	1.52	1.46
CST	1.33 b	1.45	1.46	1.39
RST	1.43 a	1.36	1.50	1.43
Average	1.36	1.40	1.52	
CV	2.86	4.51	4.23	
LSD	0.07**	0.12	0.12	
Year x Treatment: Significant **				

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

Emergence rates (%) of different soil tillage and sowing systems in different years are provided in Table 19. Year*treatment interactions were not found to be significant. Therefore, the years were not assessed separately. Three-year (2013, 2014, 2015) results of treatments were assessed together. The greatest emergence rate was observed in conventional soil tillage and the lowest value was observed in the direct sowing system.

Table 19. Emergence rate values of tillage and sowing methods

Treatments	Years			
	2013	2014	2015	Average
DS	0.76	0.65	0.65	0.69 b
RS	0.80	0.75	0.80	0.78 ab
CST	0.82	0.79	0.81	0.89 a
RST	0.82	0.75	0.79	0.78 ab
Average				0.79
CV				16.23
LSD				0.12
Year x Treatment: Insignificant				

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

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Space ratios of different soil tillage and sowing systems in different years are provided in Table 20. Year*treatment interactions were found to be significant (p<0.01). Conventional soil tillage system had positive impacts on space ratios in 2013. Ridge-sowing had positive impacts on space ratios in 2014 and 2015.

Table 20. Space ratio rate values of tillage and sowing methods

Treatments	Years			
	2013	2014	2015	Average
DS	11.26 a	14.31 a	10.63 a	12.07
RS	8.67 b	5.42 d	4.22 c	6.11
CST	6.41 d	8.64 b	9.29 ab	8.11
RST	7.45 c	7.51 c	7.92 b	7.63
Average	8.45	8.97	8.01	
CV	3.5	2.88	8.66	
LSD	0.59**	0.51**	1.38**	
Year x Treatment: Significant**				

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

Tillering ratios (%) of different soil tillage systems in different years are provided in Table 21. Year*treatment interactions were found to be significant (p<0.01). Direct sowing had positive impacts on tillering ratios in 2013, 2014, and 2015.

Table 21. Tillering ratio values of tillage and sowing methods

Treatments	Years			
	2013	2014	2015	Average
DS	0.54 d	0.60 d	0.69 c	0.61
RS	8.67 a	1.62 a	2.02 a	4.11
CST	6.41 c	0.85 c	0.76 c	2.67
RST	7.45 b	1.13 b	1.32 b	3.30
Average	5.76	1.05	1.19	
CV	4.97	2.89	4.08	
LSD	0.57**	0.06**	0.09**	
Year x Treatment: Significant**				

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

APSR values of different soil tillage systems in different years are provided in Table 22. Year*treatment interactions were found to be significant (p<0.01). Direct sowing had positive impacts on APSR values in 3 years.

Table 22. APSR (%) values of tillage and sowing methods

Treatments	Years			
	2013	2014	2015	Average
DS	88.21 c	85.08 d	88.68 c	87.32
RS	90.21 b	92.97 a	93.77 a	92.32
CST	91.90 a	90.50 c	89.96 b	90.79
RST	91.51 a	91.65 b	90.76 b	91.31
Average	90.45	90.05	90.79	
CV	0.27	0.57	0.69	
LSD	0.49**	1.04**	1.25**	
Year x Treatment: Significant**				

** Significant at P< 0.01; * Significant at P< 0.05; [1] The means indicated with the same letters in the same columns are not significantly different; DS: Direct sowing, RS: Ridge sowing, CST: Conventional soil tillage, RST: Reduced soil tillage, CV: Coefficient of variation, LSD: Least significant difference

CONCLUSION

Present experiments were conducted over the experimental fields of the Bati Akdeniz Agricultural Research Institute in Aksu town of Antalya province for 3 years in 2013, 2014, and 2015 as a fixed experiment. Soybean was sown as a second crop after the wheat harvest in June. Besides conventional soil tillage, three different alternative soil tillage and sowing systems (direct sowing – no-till, ridge-sowing, and reduced soil tillage) were experimented and the effects of different soil tillage and sowing systems on plant growth, development, and emergence traits were investigated. Assessments on 3-year data separately revealed that.

According to 2013 data, different soil tillage and sowing systems had significant effects on the first pod height at $p<0.05$ level and the other traits, except for the number of days to 50% flowering at $p<0.01$ level. In 2014, different soil tillage and sowing systems had significant effects on all traits, except for the first pod height, at $p<0.01$ level. In 2015, different soil tillage and sowing systems had significant effects on the number of days to 50% flowering and the first pod height at $p<0.05$ level and the other traits at $p<0.01$ level.

With regard to the effects of different soil tillage and sowing systems on plant growth and development, assessments on year*treatment interactions based on 3-year averages revealed that.

• With regard to the effects of different soil tillage systems on the number of days to 50% emergence, year*treatment interactions were found to be significant at $p<0.01$ level. The greatest value (5.05 days) was obtained from conventional soil tillage and the lowest value (4.73 days) was obtained from the ridge-sowing system.

• With regard to the effects of different soil tillage systems on plant heights, year*treatment interactions were found to be significant at $p < 0.05$ level. The greatest value (83.48 cm) was obtained from the reduced soil tillage and the lowest value (69.96 cm) was obtained from the direct sowing (no-till) system.

• With regard to the effects of different soil tillage systems on the first pod height, year*treatment interactions were found to be significant at $p<0.01$ level. The greatest value (6.67 cm) was obtained from the reduced and conventional soil tillage and the lowest value (6.33 cm) was obtained from the direct sowing (no-till) and ridge-sowing systems.

• With regard to the effects of different soil tillage systems on 1000-seed weight, year*treatment interactions were found to be significant at $p<0.01$

level. The greatest value (186.23 g) was obtained from the reduced soil tillage and the lowest value (164.74 g) was obtained from the direct sowing (no-till) system.

• With regard to effects of different soil tillage and sowing systems on the number of days to 50% flowering, number of pods per plant, number of plants per m² and yield, year*treatment interactions were not found to be significant. The greatest values were observed in the reduced soil tillage system.

With regard to the effects of different soil tillage and sowing systems on plant emergence traits, assessments on 3-year data separately revealed that.

According to 2013 data, different soil tillage and sowing systems had significant effects on mean emergence time at $p<0.05$ level and the other traits at $p<0.01$ level. In 2014, different soil tillage and sowing systems had significant effects on all traits, except for mean emergence time and germination rate, at $p<0.01$ level. In 2015, different soil tillage and sowing systems did not have any significant effects on mean emergence time, germination rate index, and emergence ratio, but had significant effects on the other traits at $p<0.01$ level.

With regard to the effects of different soil tillage and sowing systems on plant emergence traits, assessments on year*treatment interactions based on 3-year averages revealed that.

• With regard to the effects of different soil tillage systems on germination rate index values, year*treatment interactions were found to be significant at $p<0.01$ level. The greatest value (1.46 plant/day) was obtained from the ridge-sowing system.

• With regard to the effects of different soil tillage systems on space ratios, year*treatment interactions were found to be significant at $p<0.01$ level. The greatest value (12.07%) was obtained from the direct sowing (no-till) system.

• With regard to the effects of different soil tillage systems on tillering ratios, year*treatment interactions were found to be significant at $p<0.01$ level. The greatest values were obtained from the ridge-sowing.

• With regard to the effects of different soil tillage systems on APSR values, year*treatment interactions were found to be significant at $p<0.01$ level. The greatest values were obtained from the ridge-sowing.

• With regard to the effects of different soil tillage systems on mean emergence time and

emergence ratio, year*treatment interactions were   not found to be significant.

RESUMO: Efeitos de diferentes sistemas de preparo do solo e de semeadura (preparo convencional do solo - CST: arado de aiveca + disco de pastilha + grade de disco + grade + semeadora; preparo do solo reduzido - RST: máquina de preparo do solo combinada com rototiller + máquina de semeadura; semeadura em crista - RS: disco de gobble + semeadora em crista; semeadura direta - DS - plantio direto) sobre o desenvolvimento da planta e as características de emergência da soja de segunda safra foram investigadas neste estudo nas condições da província de Antalya. Os experimentos foram conduzidos nos campos experimentais da filial de Aksu do Bati Akdeniz Agricultural Research Institute por 3 anos (2013, 2014, 2015) como um experimento fixo. O número de dias para 50% de emergência, número de dias para 50% de floração, altura da planta, número de vagens por planta, altura da primeira vagem, número de plantas por m^2, peso de 1000 sementes e rendimento foram considerados como parâmetros de desenvolvimento da planta. Tempo médio de emergência, índice de taxa de germinação, razão de emergência, razão de espaço, razão de perfilhamento e razão de espaçamento de plantas aceitável foram considerados como parâmetros de emergência das plantas. Diferentes sistemas de preparo do solo e de semeadura geralmente tiveram efeitos significativos nas características investigadas nos níveis p <0,01 e p <0,05.

PALAVRAS-CHAVE: Conversação. Emergência. Perfilhamento. Solo.

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