Tarım Bilimleri Dergisi
Tar. Bil. Der.
Dergi web sayfası:
www.agri.ankara.edu.tr/dergi

Journal of Agricultural Sciences
Journal homepage:
www.agri.ankara.edu.tr/journal

TARIM BİLİMLERİ DERGİSİ — JOURNAL OF AGRICULTURAL SCIENCES 23 (2017) 268-275

Yield, Weed Infestation and Seed Quality of Soybean (*Glycine max* (L.) Merr.) under Different Tillage Systems

Dorota GAWĘDA[a], Małgorzata HALINIARZ[a], Rafał CIERPIAŁA[a], Irena KLUSEK[a]

[a]*University of Life Sciences in Lublin, Department of Herbology and Plant Cultivation Techniques, Akademicka 13, 20-950 Lublin, POLAND*

ARTICLE INFO
Research Article
Corresponding Author: Małgorzata HALINIARZ, E-mail: malgorzata.haliniarz@up.lublin.pl, Tel: +48 (81) 445 66 54
Received: 26 November 2015, Received in Revised Form: 24 December 2015, Accepted: 24 December 2015

ABSTRACT

Soybean is a very valuable crop plant and the soybean crop area is continually increasing in the world and in Poland. The effectiveness of soybean cultivation depends on soil and climatic conditions as well as on appropriate tillage. An alternative for plough tillage in the cultivation of soybean is to grow this crop using no-tillage, the popularity of which is constantly growing. The aim of this study was to compare the effect of conventional tillage (CT) and no-tillage (NT) on yield, weed infestation and qualitative seed composition of soybean grown under the conditions of the Lublin Upland. A field study was carried out over the period 2009-2012 at the Czesławice Experimental Farm (51° 18′ 23″ N, 22° 16′ 2″ E). The experiment was set up on loess-derived grey-brown podzolic soil as a split-block design in four replicates. The experimental factors were the following tillage systems: conventional tillage (CT) and no-tillage (NT). The soybean cultivar Nawiko was grown in the experiment. The present study showed that the soybean seed yield obtained under CT was higher by 24.3% than under NT. The main reason of the seeds yield decrease in the NT was less soybean plant density. The significant higher number and weight of weeds were recorded in NT, relative to CT. The oil content in seed harvested from the NT plots was found to be higher by 0.3%.

Keywords: *Glycine max*; Conventional system; No-tillage

Farklı Toprak İşleme Sistemlerinin Soya Fasulyesinde (*Glycine max* (L.) Merr.) Verim, Tohum Kalitesi ve Yabancı Ot Oranına Etkisi

ESER BİLGİSİ
Araştırma Makalesi
Sorumlu Yazar: Małgorzata HALINIARZ, E-posta: malgorzata.haliniarz@up.lublin.pl, Tel: +48 (81) 445 66 54
Geliş Tarihi: 26 Kasım 2015, Düzeltmelerin Gelişi: 24 Aralık 2015, Kabul: 24 Aralık 2015

ÖZET

Soya fasulyesi önemli bir bitkidir ve dünyada ve Polonya'da ekiliş alanı artmaktadır. Soya fasulyesi yetiştiriciliğinin etkinliği toprak ve iklim faktörlerinin yanında uygun toprak işlemesine de bağlıdır. Soya fasulyesi yetiştiriciliğinde pullukla devirerek toprak işlemeye alternative bir yöntem de güncelliği giderek artan toprak işlemesiz soya fasulyesi yetiştiricilğidir. Bu çalışmanın amacı geleneksel toprak işleme (CT) ile toprak işlemesiz (NT) soya fasulyesi yetiştiriciliğinin Lublin, Polonya koşullarında verim, kalitatif tohum kalitesi ve yabancı ot oranına etkisini karşılaştırmaktır. Bu amaçla 2009-2012 yıllarında Czeslawice Araştırma Çiftliğinde (51° 18′ 23″ N, 22° 16′ 2″ E) bir tarla denemesi yürütülmüştür. Deneme, lös oluşumlu grikahverengi podzol toprak üzerinde 4 tekerrürlü olarak bölünmüş parseller deneme deseninde yürütülmüştür. Araştırmada; geleneksel toprak işleme (CT) ve toprak işlemesiz (NT) toprak işleme faktörleri olarak ele alınmıştır. Soya fasulyesinin Nawiko çeşidi kullanılmıştır. Çalışmadan elde edilen sonuçlar; soya fasulyesi tohum veriminin toprak işlemesiz (NT) yetiştiriciliğe göre geleneksel toprak işlemeli (CT) yöntemde % 24.3 daha fazla olduğunu göstermiştir. Toprak işlemesiz yöntemde bitki sıklığının az olması tohum veriminin az olmasında temel etken olmuştur. Geleneksel toprak işlemeye (CT) oranla, toprak işlemesiz (NT) yöntemde ağırlık ve sayı olarak yabancı ot önemli derecede yüksek olmuştur. Toprak işlemesiz yöntemde (CT) hasat edilen tohumların yağ içeriği % 0.3 daha yüksek olmuştur.

Anahtar Kelimeler: *Glycine max*; Geleneksel toprak işleme; Toprak işlemesiz

1. Introduction

Soybean is a species that enjoys a growing popularity in the world. In the last ten years, soybean production has increased by 45%. The cultivation of this crop is concentrated mainly in North and South America. In 2013, these two regions accounted for as much as 87.1% of the production of this crop. The United States, Brazil, Argentina as well as China and India are the largest soybean producers. Over the last decades, Europe's soybean production has increased more than three times and in 2013, it made up 2.2% of the total global production. In Poland, the area of this crop has doubled since 2003, standing at 855 ha in 2012, while the soybean production increased more than five times in the same period (FAOSTAT 2015).

In soybean cropping, climatic conditions, primarily temperature and rainfall, are the factors that limit the yield potential of this crop plant. In areas with low levels of rainfall, it is very important to prepare the soil in a way that will ensure retention of the highest possible amount of rainwater. Agronomic practices involving the replacement of the plough with implements that do not turn the soil over or the complete abandonment of mechanical tillage (no-tillage) offer this possibility to agricultural producers. As a result of the use of no-tillage, there are changes in soil density and compactness, while the moisture and nutrient content in the soil upper layers increase (Majchrzak et al 2004; Martinez et al 2008; Çelik 2011). The effectiveness of no-tillage is dependent on the type of soil and its moisture conditions and using of appropriate seeder type (Altikat & Çelik 2012). Many authors stress that no-till should not be used in light soils (Munkholm et al 2003; De Vita et al 2007; Martinez et al 2008; Włodek et al 2012). No-tillage frequently results in excessive weed infestation of the crop and the weed structure changes as a result of long-term use of this tillage system (the proportion of perennial weeds increases) (Blecharczyk et al 2004). This problem can be solved, among others, by using non-selective systemic herbicides before sowing or by sowing soybean seeds in a cover crop (Oliveira et al 2013; Bernstein et al 2014). As a result of the use of no-tillage, reduced crop yields are recorded (Yalcin & Cakir 2006; Korzeniowska & Stanisławska-Glubiak 2009), but its soil protective effect and lower energy inputs on no-tillage operations, compared to conventional tillage, offer a huge opportunity to spread this tillage system (Dzienia et al 2006; Yalcin & Cakir 2006).

The aim of this study was to compare the effect of plough tillage and no-tillage on yield, qualitative seed composition and weed infestation of soybean grown under the conditions of the Lublin Upland.

2. Material and Methods

2.1. Materials and plant experiment

A field study was carried out over the period 2009-2012 at the Czesławice Experimental Farm (51° 18′ 23″ N, 22° 16′ 2″ E), belonging to the University of Life Sciences in Lublin. In 2010, the soybean plantation was terminated due to adverse weather conditions and the resultant inhibited plant emergence. The area of each experimental plot was

96 m^2. The soybean cultivar Nawiko was grown in the experiment. The study factors were the following tillage systems.

Conventional tillage (CT)-skimming, double harrowing, autumn ploughing to a depth of 25 cm. In the spring, harrowing, cultivating, harrowing, sowing.

No-tillage (NT)-without mechanical tillage. In the spring, only Roundap Energy 450 SL (active ingredient (a.i.)-glyphosate) was applied at a rate of 3 L ha^{-1}.

Mineral fertilizer was applied to soybean crops before sowing at the following rates: N-50 kg ha^{-1}, P-35 kg ha^{-1}, K-83 kg ha^{-1}. Mineral fertilizer rates were determined based on the nutritional requirements of soybean and soil nutrient availability.

Each year, soybean was sown at the turn of April and May in a field after winter wheat. The row spacing was 20 cm, seeding depth 3 cm, and planned plant density 100 plants m^{-2}.

Before sowing, soybean seeds were inoculated with *Bradyrhizobium japonicum* bacteria and the seed dressing Vitavax 200 FS (a.i. carboxin, thiuram) was applied at a rate of 400 mL 100 kg^{-1} seed. Immediately after sowing, a mixture of the herbicides Afalon Dyspersyjny 450 SC (a.i. linuron)+Dual Gold 960 EC (a.i. S-metolachlor) was applied at the rate of 1 L+1.8 L ha^{-1}. Each year, the soybean crop was harvested in the first 10-day period of September.

2.2. Soil conditions

The soil was characterized by slightly acidic pH (in 1 M KCl= 6.2), high phosphorus and potassium availability as well as medium magnesium availability. The humus content was 1.2%.

2.3. Meteorological conditions

During the first growing season of soybean (2009), the average air temperature in individual months was generally higher than the long-term mean (Figure 1). Lower temperatures were only recorded in May and June. The rainfall in 2009 exceeded the long-term mean only in May and June (Figure 2). The next growing season (in 2010) proved to be unfavorable for soybean, primarily due to a rather low temperature in the month of sowing (April) and heavy rainfall in May which much exceeded the long-term mean. On account of unsatisfactory emergence, the soybean plantation was terminated in the second year of the experiment. The year 2011 turned out to be favorable for soybean development in terms of thermal conditions. In particular months of the growing season, higher or similar (May, July) temperatures were generally recorded compared to the long-term mean. Lower than average rainfall was recorded during the initial period of soybean growth (April and May) as well as during maturation and harvest (August and September). The last year of the study (2012) was very warm and quite dry. A higher than average temperature was recorded in

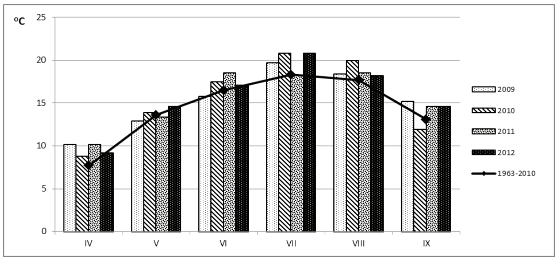

Figure 1- Mean monthly in 2009 and 2012, and long term air temperature (°C) at the Czesławice Meteorological Station

Şekil 1- Czesławice Meteoroloji İstasyonu 2009-2012 yılları ve uzun dönem aylık ortalama hava sıcaklığı (°C) verileri

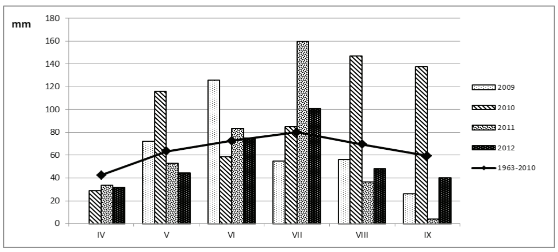

Figure 2- Long term and monthly rainfall in 2009-2012 at the Czesławice Meteorological Station

Şekil 2- Czesławice Meteoroloji İstasyonu 2009-2012 yılları ve uzun dönem aylık ortalama yağış (mm) verileri all the months. The total rainfall exceeded the long-term mean in June and July.

2.4. Sampling and plant analysis

Plant density after emergence and before harvest was estimated in two rows along a length of 2.5 m. The yield traits were determined based on a sample consisting of 30 randomly selected plants from each plot. The seed yield was weighed separately for each plot and the obtained results were expressed hectare basis. Weed infestation of the soybean crop was determined using the dry-weight-rank method at the pod and seed maturation stage (BBCH 81/82). The evaluation involved the determination of the botanical composition of weeds, their density and air-dry weight. The sampling area was delineated with a 1 m×0.5 m quadrat frame in two randomly selected places in each plot.

The content of protein, oil and fiber in soybean seed was determined using the phenomenon of light reflection within the range of near infrared of the analyzed substance, with the use of an Omega G computer transmission analyzer of the whole grain (Bruins Instruments, Germany) at the Department of Agricultural Ecology of the University of Life Sciences in Lublin.

2.5. Experimental design and statistical analysis

The experiment was set up on loess-derived grey-brown podzolic soil as a split-block design in four replicates. The results obtained in the years 2009, 2011, and 2012 were statistically analyzed using analysis of variance (ANOVA) using SAS programme (Statistical Analysis Software) and, the significance of differences was evaluated by Tukey's test at P≤0.05.

3. Results and Discussion

3.1. Yielding and structure of yield of soybean

On average for the three-year study, the soybean seed yield obtained in the CT treatment was higher by 24.3% compared to NT (Table 1). Most authors confirm that under NT conditions lower soybean

Table 1- Yield and selected characteristic of soybean yield structure

Çizelge 1- Toprak işleme sistemlerine gore soya fasulyesi verim ve verim ögeleri

Soil tillage (ST)	*Years*	*Yield* (*t ha^{-1}*)	*Plant density* *after emergence* (*No m^{-2}*)	*before harvest*	*Plant height* (*cm*)	*1000 seeds weight* (*g*)	*First pod height* (*cm*)
Conventional tillage (CT)	2009	3.02	58.0	48.3	85.4	126.4	10.6
	2011	3.19	97.0	95.0	97.4	139.2	13.0
	2012	2.86	41.8	34.8	73.7	106.0	10.6
	Mean	3.02	58.0	59.4	85.5	123.9	11.0
No tillage (NT)	2009	1.70	39.5	35.0	71.9	124.1	7.4
	2011	2.93	78.8	75.8	93.8	141.1	12.2
	2012	2.65	30.0	25.8	69.4	105.8	7.7
	Mean	2.43	49.4	45.5	78.4	123.7	9.1
Mean for years (Y)	2009	2.36	48.8	41.6	78.6	125.2	9.0
	2011	3.06	87.9	85.4	95.6	140.2	12.6
	2012	2.76	35.9	30.3	71.6	105.9	8.5
LSD (P= 0.05)							
ST		0.406	6.56	6.62	5.27	ns	1.61
Y		0.604	9.76	9.86	7.84	6.68	2.40
STxY		ns	ns	ns	ns	ns	ns

ns, not-significant

yields are obtained than under CT (Bujak et al 2001; Gawęda et al 2014; Monsefi et al 2014). Pikul et al (2001) showed that any modifications in tillage for sowing soybean negatively affect its yield potential and yields can be lower even by a dozen or so percent. Opposite results were obtained by Houx et al (2014) who proved a significant increase in soybean yield (by 4.8%) on loamy soil under NT compared to CT.

Soybean is a plant very sensitive to environmental stresses such as low and high temperature or drought. In cold climate countries, low temperatures are the factor that determines the production of this crop (Vollmann et al 2000; Ohnishi et al 2010). The critical periods in terms of water requirement and thermal conditions occur from sowing to full emergence as well as during flowering and seed maturation (Kołodziej & Pisulewska 2000; Thuzar et al 2010). Despite that the evaluated small-seeded soybean cultivar Nawiko is very sensitive to variable and adverse weather conditions (Kołodziej & Pisulewska 2000), its average yields obtained in this experiment were higher by 0.12 t ha^{-1} compared to cv. Aldana and by 0.37 t ha^{-1} in relation to cv. Augusta grown under the same agronomic, climatic and soil conditions (Gawęda et al 2014). In the present experiment, the highest soybean yield was harvested in the year 2011 which proved to be most favorable for the growth of this crop (Table 1). Moderate rainfall and the temperature in May and June at a level of the long-term mean guaranteed even emergence; this was translated into a high plant density, in particular under conventional tillage. Regardless of tillage system, soybean produced the worst yield in the first year of the study in which April was a rainless month, in May and June the rainfall much exceeded the long-term mean, whereas July, August and September were dry months. The air temperature slightly exceeded the long-term average. Rainfall was the yield-limiting factor in this growing season. Excessive rainfall at the initial growth stages disturbed the water and air relations and caused soil crusting and uneven emergence. The adverse weather conditions in 2009 had a particularly negative effect on the yield of soybean grown under NT. Relative to CT, the crop productivity was lower by 43.7%. Włodek et al (2012) proved that in the case where NT is used both an excess and deficiency of rainfall cause large changes in yields. In the present study, in 2009 an almost half lower yield was obtained under NT conditions compared to CT, which could have been caused by a high amount of rainfall during the initial growth stages of soybean; in grey-brown podzolic soil this resulted in excessive soil moisture. This problem was not observed when mechanical tillage was used. Lower yields were also obtained under NT, compared to CT, in the next two years of the study, but the differences between these tillage systems were smaller as 8.2% in 2011 and 7.3% in 2012.

As far as the soybean crop and yield components are concerned, the tillage systems used significantly modified only the plant density after emergence and before harvest, plant height, and first pod height (Table 1). Under CT, the plant density was found to be higher by 32.8% after emergence and by 30.5% before harvest compared to that found under NT. The plant height and first pod height were also higher in the CT treatment, respectively by 9.1 and 20.9%. The values for the above-mentioned crop and yield components were most favorable in the year 2011 in which the highest seed yield was obtained. Tillage system did not have a major effect on 1000 seed weight, number of seeds per pod, number of pods per plant as well as number and weight of seeds per plant (Tables 1 and 2). The number of pods per plant differed significantly depending on the interaction between factor of experience and years of research. In both soil tillage systems, the highest number of pods per plant were obtained in 2012. In their research, Gawęda et al (2014) also demonstrated similar trends in the changes in the soybean yield structure. Monsefi et al (2014) showed tillage system to have a significant effect on plant height only during the initial period of plant growth, whereas the soybean plant height before harvest was similar under CT and NT. On the other hand, Bujak et al (2001) proved that due to high weed infestation of the crop NT resulted in the lengthening of soybean plants and thus the higher first pod height compared to CT. In the present experiment, the 1000 seed weight and the number of seeds per pod were comparable under CT and NT. Monsefi et al (2014) proved however that the above-mentioned traits were significantly lower under NT compared to CT.

3.2. Weed infestation

On average for the three-year study period, the tillage systems used significantly modified the number and air-dry weight of weeds in the soybean crop (Table 2). In the NT treatment, compared to CT, the number of weeds was higher by 24.3 plant m^{-2}, whereas their dry weight by 40.1 g m^{-2}. The dry weight of weeds differed significantly depending on the tillage system throughout the study years. The highest weight of weeds was recorded in no tillage plots (NT) in the years 2012 and 2009, which were characterized by low rainfall. In conventional tillage (CT) weed growth was inhibited by a shortage of rainfall.

The tillage systems used significantly modified the floristic composition of weeds (Figure 3). Under NT, the perennial species *Elymus repens* was dominant. *Galinsoga ciliata* was also found in great numbers. The use of CT substantially reduced the numbers of most weeds occurring in the soybean crop, in particular *E. repens* and *G. ciliata*. Under CT, *Chenopodium album* was the most numerous, while among the perennial species it was *Equisetum arvense*. The increased numbers of perennial weeds in NT treatments are also confirmed by the studies of Halford et al (2001) and Bujak et al (2004). Gibson et al (2005) report that in soybean and maize crops weeds are a greater problem than diseases, nematodes and insects. Norsworthy (2003) and Vollmann et al (2010) also found that weed competition significantly reduced soybean yields.

Table 2- Some of characteristic of soybean yield structure and number and weight of weeds in soybean canopy

Çizelge 2- Toprak işleme yöntemlerine gore soya fasulyesi verim ögeleri ile yabancı ot sayı ve ağırlıkları

Soil tillage (ST)	*Years*	*Number of pods per plant (No)*	*Number of seeds per pod (No m^{-2})*	*Number of seeds per plant (No m^{-2})*	*Weight of seeds per plant (g)*	*Number of weeds (No m^{-2})*	*Weight of weeds (g m^{-2})*
Conventional tillage (CT)	2009	29.1	1.8	53.4	6.8	4.0	8.5
	2011	16.9	1.9	32.2	4.5	9.0	53.3
	2012	33.4	2.0	68.2	7.3	4.3	29.0
	Mean	26.5	1.9	51.3	6.2	5.8	30.3
No tillage (NT)	2009	24.9	2.0	48.6	6.0	20.2	86.2
	2011	18.3	1.8	33.5	4.8	33.2	33.0
	2012	39.6	2.0	78.9	8.6	36.8	92.0
	Mean	27.6	1.9	53.7	6.5	30.1	70.4
Mean for years (Y)	2009	27.0	1.9	51.0	6.4	12.1	47.4
	2011	17.6	1.8	32.8	4.6	21.1	43.2
	2012	36.5	2.0	73.6	8.0	20.6	60.5
LSD (P= 0.05)							
ST		ns	ns	ns	ns	13.02	16.13
Y		4.48	ns	10.46	1.38	ns	ns
STxY		7.88	ns	ns	ns	ns	12.24

ns, not-significant

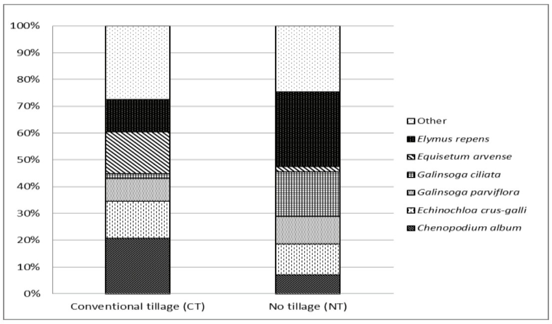

Figure 3- Percentage of dominant weeds species in soybean canopy (mean from 2009-2012)

Şekil 3- Soya fasulyesi deneme alanında 2009-2012 ortalaması olarak yaygın yabancı ot türleri

3.3. Qualitative seed composition

In the present study, tillage system did not have a significant effect on the seed protein and fiber content, but the oil content in seed harvested from the NT treatment was higher by 0.3% relative to CT (Table 3). In both tillage systems the highest fat content was recorded in 2012, characterized by a small but well-distributed rainfall during the growing season.

Table 3- Selected quality properties in seeds of soybean

Çizelge 3- Soya fasulyesi tohumlarının kimi kalite özellikleri

Soil tillage (ST)	*Years*	*Protein*	*Fat*	*Fibre*
			(%)	
Conventional tillage (CT)	2009	35.3	17.1	5.0
	2011	35.0	17.1	5.0
	2012	29.5	18.6	5.5
	Mean	33.3	17.6	5.2
No tillage (NT)	2009	35.0	17.2	5.0
	2011	33.8	17.9	5.0
	2012	29.6	18.6	5.4
	Mean	32.8	17.9	5.1
Mean for years (Y)	2009	35.2	17.2	5.0
	2011	34.4	17.5	5.0
	2012	29.6	18.6	5.5
LSD (P= 0.05)				
ST		ns	0.20	ns
Y		1.02	0.29	0.09
STxY		ns	0.52	ns

ns, not-significant

Also, the results of other authors' research do not show that tillage system determines the content of major constituents of soybean seed. In the studies of Houx et al (2014), the use of NT did not modify significantly the seed protein and fiber content. In the research of Gao et al (2009), however, NT contributed to an increase in oil yield per hectare.

4. Conclusions

The soybean seed yield obtained under CT was higher by 24.3% relative to NT. The main reason of the seeds yield decrease in the NT was less soybean plant density, which contributed indirectly to increased weed infestation. A 5-fold higher number of weeds and an over 2-fold higher weed weight were recorded in the NT treatment compared to CT. A richer floristic composition of weeds in the soybean crop and an increase in the numbers of the dominant species, in particular *E. repens* and *G. ciliata*, were found under NT. In seed harvested from the NT plots the oil content was found to be higher by 0.3%.

Acknowledgements

Research supported by the Ministry of Science and Higher Education of Poland as the part of statutory activities of Department of Herbology and Plant Cultivation Techniques, University of Life Sciences in Lublin.

References

Altikat S & Çelik A (2012). Effects of different no-till seeders and tractor forward speeds on the soil physical properties and seed emergence of summer vetch and winter wheat. *Tarim Bilimleri Dergisi-Journal of Agricultural Sciences* **18**(1): 21-30

Bernstein E R, Stoltenberg D E, Posner J L & Hedtcke J L (2014). Weed community dynamics and suppression in tilled and no-tillage transitional organic winter rye-soybean systems. *Weed Science* **62**(1): 125-137

Blecharczyk A, Małecka I & Skrzypczak G (2004). Effect of reduced tillage on yield, weed infestation of maize and soil properties. *Acta Scientiarum Polonorum Agricultura* **3**(1): 157-163

Bujak K, Jędruszczak M & Frant M (2001). The influence of reduced tillage methods on soybean seed yield. *Biuletyn IHAR* **220**: 263-272

Bujak K, Jędruszczak M & Frant M (2004). Reduced tillage and foliar nutrition by macro- and microelements and weed infestation of soybean growing in monoculture. *Annales UMCS Sectio E Agricultura* **59**(2): 825-832

Çelik I (2011). Effects of tillage methods on penetration resistance, bulk density and saturated hydraulic conductivity in a clayey soil conditions. *Tarım Bilimleri Dergisi-Journal of Agricultural Sciences* **17**(2): 143-156

De Vita P, Di Paolo E, Fecondo G, Di Fonzo N & Pisante M (2007). No-tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in southern Italy. *Soil and Tillage Research* **92**(1-2): 69-78

Dzienia S, Zimny L & Weber R (2006). The newest trends in soil tillage and techniques of sowing. *Fragmenta Agronomica* **23**(2): 227-241

FAOSTAT (2015). Food and Agriculture Organization of The United Nations, Statistics Division. http://faostat3.fao.org/download/Q/QC/E (Erişim tarihi: 30.09.2015)

Gao J, Hao X, Thelen K D & Robertson G P (2009). Agronomic management system and precipitation effects on soybean oil and fatty acid profiles. *Crop Science* **49**(3): 1049-1057

Gawęda D, Cierpiała R, Bujak K & Wesołowski M (2014). Soybean yield under different tillage systems. *Acta Scientiarum Polonorum Hortorum Cultus* **13**(1): 43-54

Gibson K D, Johnson W G & Hillger D E (2005). Farmer perceptions of problematic corn and soybean weeds in Indiana. *Weed Technology* **19**(4): 1065-1070

Halford C, Hamill A S, Zhang J & Doucet C (2001). Critical period of weed control in no-till soybean (*Glycine max*) and corn (*Zea mays*). *Weed Technology* **15**(4): 737-744

Houx J H, Wiebold W J & Fritschi F B (2014). Rotation and tillage affect soybean grain composition, yield, and nutrient removal. *Field Crops Research* **164**: 12-21

Kołodziej J & Pisulewska E (2000). Effect of climatic factors on seed yield, fat yield and fat content in seeds of two soybean cultivars. *Rośliny Oleiste-Oilseed Crops* **21**(3): 759-776

Korzeniowska J & Stanisławska-Glubiak E (2009). Comparison of production effects of zero and conventional tillage on sandy soil of South-west Poland. *Fragmenta Agronomica* **26**(4): 65-73

Majchrzak L, Skrzypczak G & Piechota T (2004). Impact of simplified soil tillage under maize on soil physical properties. *Fragmenta Agronomica* **3**(83): 107-119

Martinez E, Fuentes J, Silva P, Valle S & Acevedo E (2008). Soil physical properties and wheat root growth as affected by no-tillage and conventional tillage systems in a Mediterranean environment of Chile. *Soil and Tillage Research* **99**: 232-244

Monsefi A, Sharma A R, Rang Zan N, Behera U K & Das T K (2014). Effect of tillage and residue management on productivity of soybean and physico-chemical properties of soil in soybean-wheat cropping system. *International Journal of Plant Production* **8**(3): 429-440

Munkholm L J, Shjǿnning P, Rasmussen K J & Tenderup K (2003). Spatial and temporal effects on direct drilling on soil structure in the seedling environment. *Soil and Tillage Research* **71**: 163-173

Norsworthy J K (2003). Use of soybean production surveys to determine weed management needs of South Carolina farmers. *Weed Technology* **17**(1): 195-201

Ohnishi S, Miyoshi T & Shirai S (2010). Low temperature stress at different flower developmental stages affects pollen development, pollination, and pod set in soybean. *Environmental and Experimental Botany* **69**(1): 56-62

Oliveira P, Nascente A S, Kluthcouski J & Castro T A P (2013). Corn and soybean yields as affected by cover crops and herbicide timing under no-tillage system. *Planta Daninha* **31**(4): 939-946

Pikul J L Jr, Carpenter-Boggs L, Vigil M, Schumacher T, Lindstrom M J & Riedell W E (2001). Crop yield and soil condition under ridge and chisel-plow tillage in the northern Corn Belt, USA. *Soil and Tillage Research* **60**: 21-33

Thuzar M, Puteh A B, Abdullah N A P, Lassim M B M & Jusoff K (2010). The effects of temperature stress on the quality and yield of soya bean [(*Glycine max* L.) Merrill.]. *Journal of Agricultural Science* **2**(1): 172-179

Vollmann J, Winkler J, Fritz C N, Grausgruber H & Ruckenbauer P (2000). Spatial field variations in soybean (*Glycine max* [L.] Merr.) performance trials affect agronomic characters and seed composition. *European Journal of Agronomy* **12**(1): 13-22

Vollmann J, Wagentristl H & Hartl W (2010). The effects of simulated weed pressure on early maturity soybeans. *European Journal of Agronomy* **32**(4): 243-248

Włodek S, Biskupski A & Pabin J (2012). The amount of precipitation shortage on productivity of crops grown in simplified systems of tillage. *Soil Science Annual* **63**(2): 49-54

Yalcin H & Cakir E (2006). Tillage effects and energy efficiencies of subsoiling and direct seeding in light soil on yield of second crop corn for silage in Western Turkey. *Soil and Tillage Research* **90**(1-2): 250-255