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Effects of tillage systems and organic manures on soybean (*Glycine max*) yield and quality

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ABSTRACT

The study was conducted to analyze the responses of soybean [*Glycine max* (L.) Merr.] seed yield and quality to tillage and fertilization in Sanandaj, Iran over two years (2012 and 2013). The experiments were arranged in split-plot, based on randomized complete block design with three replications. Main plots consisted of tillage systems including conventional tillage (CT), minimum tillage (MT), and no-tillage (NT). Eight fertilization methods were employed in the sub-plots including (F1): farmyard manure (FYM); (F2): compost; (F3): chemical fertilizers; (F4): FYM + compost; (F5): FYM + chemical fertilizers; (F6): compost + chemical fertilizers; (F7): FYM + compost + chemical fertilizers; and (F8): Control (without fertilizer). The highest number of pods and seeds per plant and grain yield were obtained in MT-F7 treatment, in which compost, manure, and chemical fertilizers were applied simultaneously in a balanced manner under reduced tillage system. The highest content of seed oil belonged to farmyard manure application. The highest content of seed protein was related to combined fertilizer application and complete chemical fertilizer. This treatment can be considered as a step toward sustainable agriculture. We concluded that applying organic manures along with moderated chemical fertilizers and employing reduced tillage systems increased soybean yield.

Key words: Farmyard manure, Seed oil and protein content, Tillage

Soybean [*Glycine max* (L.) Merr.] is one of world's major crops due to its high protein and oil content (Kim *et al*. 2012). Compost is an organic fertilizer which has a great importance in increasing mineral elements, improving soil structure, and enhancing yield (Mohammadi *et al*. 2011). In a study, Keeling *et al.* (2003) showed that the use of compost increased root length, total dry matter, and seed yield of rapeseed. Farmyard manure is used to increase soil organic matter levels. Farmyard manures gradually release nutrients which reduces their loss by leaching and increases uptake by plants (Zamil *et al*. 2004). The effect of the combined application of organic fertilizers in soybeans showed that the combined use of farmyard manure and vermicompost led to a significant increase in grain yield compared to their application alone (Maheshbabu *et al*. 2008).

As a result of conventional tillage and many agricultural practices, soil fertility and organic matter decrease significantly (Heidari *et al*. 2016). The no-tillage system is one of the conservation tillage methods that minimizes interference of agricultural implements, creates least soil disturbance, and leaves significant amount of crop residue on the soil surface (Celik *et al*. 2011). Minimum tillage is another conservation tillage method. In this system, the number of passes over the field is reduced, the soil structure is maintained, and organic matter and soil moisture are increased due to the maintenance of residues on the soil (Celik *et al*. 2011). Alijani *et al.* (2012) in a study on the effects of tillage methods and corn residues on yield of wheat showed that the highest grain yield was obtained from minimum tillage treatment. Results of a study on maize showed that there was no significant difference between conventional tillage systems and conservation tillage methods in terms of grain yield (Sassiz *et al*. 2010). The present study was done to analyze use of conservation tillage practices and whether applying organic manures would cause shifts in soybean yield and quality relative to conventional tillage practices and chemical fertilizers, respectively.

MATERIALS AND METHODS

The experiments were carried out at the Research Farm of the University of Kurdistan, Sanandaj, Iran during 2012-13. This area had already been farmed prior to the experiments. The experimental fields had been planted under no-tillage system over 2 years. The soil of experiment site was sandy loam with slightly alkaline in reaction (*p*H 7.6), and electrical conductivity 0.56 dS/m. The available organic carbon was 16.2 g/kg. Soil P and K contents were 4.91 and 76.65 mg/kg, respectively. The experiments were arranged

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as split plot based on randomized complete block design with three replications for two years. Main plots consisted of tillage systems including moldboard plowing with an average depth of 30 cm + two shallow disks (conventional tillage - CT), and chisel plowing with an average depth of 15 cm + one shallow disk (minimum tillage - MT) and no-tillage (NT), where crop residues cut by the combine were chopped and spread evenly with a combine-attached chopper. Furthermore, the NT treatments were seeded with an NT seed drill. In the CT and MT treatments, soybean seeds were sown using a row planter. The following eight strategies were employed to supply the basal fertilizer requirements of soybean in the subplots: (F1): 5400 kg FYM/ha (cattle manure); (F2): 2500 kg compost/ha; (F3): 90 kg triple super phosphate/ha + 60 kg Urea/ha; (F4): 2700 kg FYM /ha + 1250 kg compost/ha; (F5): 2700 kg FYM/ha + 45 kg triple super phosphate/ha + 30 kg Urea/ha ; (F6): 1250 kg compost /ha + 45 kg triple super phosphate/ha + 30 kg Urea/ha; (F7): 1800 kg FYM/ha + 833 kg compost/ha + 30 kg triple super phosphate /ha+ 20 kg Urea/ha, and (F8) control (without fertilizer). The farmyard manure and compost used in the experiment has N 5.1, P 4.8, and K 4 g/kg and N 10.9, P 11.9, and K 5.4 g/kg, respectively. Soybean seeds were sown on May 10 and 12 in 2012 and 2013 growing seasons by employing Williams's cultivar. At maturity stage, the yield and yield components were determined by harvesting two square meters in each plot. In this stage, traits such as 1000-seed weight, seed number per plant, grain yield, biological yield, and harvest index were measured. The seed oil content was measured using Soxhlet apparatus (AOAC 1990). The percentage of protein was determined by Kjeldahl method (Licitra *et al.* 1996).

Using SAS software (SAS Institute 2003), the data underwent analysis of variance (ANOVA). The combined analysis of variance was applied to a 2-year period data and the least significant difference (LSD) was employed to compare the means ($P<0.05$).

None of the interactions between the experimental factors and the year were statistically significant for studied variables (Table 1). Therefore, an average of data from 2 years was used for interpretation.

RESULTS AND DUSCUSSION

Seed yield components: The effects of tillage, various fertilizer sources, and their interaction were significant on the number of pods per plant, number of seeds per plant and 1000-seed weight (Table 1). The highest number of seeds per plant was found in NT-F7, MT-F7, and C-F3 treatments, which had a significant difference with treatments receiving no fertilizer in all tillage levels (Table 2). The use of compost and farmyard manure, along with chemical fertilizers, causes more availability of nitrogen and phosphorus by increasing the enzymatic and microbial activity of the soil (Hatch *et al*. 2007).

The highest number of seeds per plant was observed in MT-F7 treatment and the lowest values were recorded in NT-F8. In conventional tillage (CT) system, the highest number of seeds per plant was obtained from F7 and F3 fertilizer treatments (Table 2). In the minimum tillage (MT) system, addition of farmyard manure and compost (F4) resulted in the production of number of seeds per plant equal to F7 (compost + farmyard manure + chemical fertilizer) whereas in the conventional tillage (CT) system, only complete chemical fertilizer application (F3) produced a seed number equal to F7. It seems that in the minimum tillage system, the plant's nutritional needs are provided well especially in the critical stages of growth due to the slow and continuous supply of nutrients originating from the organic manures mineralization. Organic fertilizers act as a valuable food source and organic acids are produced due to their decomposition, which in turn release slowly the absorbed ions during the growth period and lead to increased yield and yield components of crops (Maheshbabu *et al*. 2008).

The highest 1000-seed weight was obtained from MT-

Table 1 Combined analysis of variance over years (2012 and 2013) for yield, yield components and quality of soybean affected by tillage and fertilization systems

Source of variation	DF	Number of pods per plant	Number of seeds per plant	1000-seed weight	Seed yield	Biological yield	Harvest Index	Seed oil content	Seed protein content
Year (Y)	1	ns	ns	ns	ns	ns	ns	ns	ns
R/Year	4	**	**	**	**	**	ns	**	**
Tillage systems (T)	2	**	**	**	**	**	**	ns	ns
T*Y	2	ns	ns	ns	ns	ns	ns	ns	ns
Error a	8	-	-	-	-	-	-	-	-
Fertilization methods (F)	7	**	**	**	**	**	**	**	**
F*Y	7	ns	ns	ns	ns	ns	ns	ns	ns
F*T	14	*	**	**	**	**	*	ns	ns
F*T*Y	14	ns	ns	ns	ns	ns	ns	ns	ns
Error b	84	-	-	-	-	-	-	-	-

ns, * and ** non-significant and significant at 1% and 5% probability levels, respectively

Table 2 Mean comparison for yield and yield components affected by different fertilization methods and tillage systems in combined analysis of two years of experiment

Tillage	Fertilization	Number of pods/plant	Number of seeds/plant	1000-seed weight (g)	Seed yield (kg/ha)	Biological yield (kg/ha)	Harvest Index
NT	F1	32.7	74.7	120.6	2237.1	7202	31.2
	F2	35.4	84.2	125.6	2622.5	7515	34.9
	F3	34.2	76.8	137.4	2599.7	7317	35.6
	F4	36.5	82.5	130.7	2667.2	7291	36.5
	F5	36.5	91.3	139.5	3185.3	8129	39.1
	F6	37.3	88.6	136.4	2965.1	7652	38.9
	F7	38.9	94.6	141.5	3346.9	8056	41.4
	F8	30.3	70.9	84.7	1561.7	5831	26.8
MT	F1	31.9	91.8	138.5	3175.2	8208	38.7
	F2	35.2	103.9	148.5	3858.5	8597	44.8
	F3	33.4	97.8	142.5	3482.8	8635	40.1
	F4	37.1	108.8	140.3	3814.5	8789	43.4
	F5	37.8	109.9	146.1	3910.9	8817	44.5
	F6	36.3	106.8	144.5	3854.8	8628	44.7
	F7	38.2	110.6	141.7	3926.7	8699	45.2
	F8	31.8	85.7	88.5	1899.5	6628	28.6
CT	F1	35.3	74.4	107.1	2135.9	7102	30.0
	F2	34.3	75.5	112.4	2161.6	7064	30.6
	F3	38.3	105.1	128.2	3382.5	8135	41.6
	F4	37.2	86.0	117.1	2510.1	7436	33.8
	F5	36.2	101.6	124.9	3092.7	8100	38.2
	F6	34.6	89.7	120.7	2458.8	7087	33.2
	F7	36.3	108.9	130.6	3355.4	8110	41.3
	F8	33.2	95.5	82.9	1986.1	7115	27.9
LSD value (5%)		4.7	8.5	7.5	265.2	591	4.7

F1: Farmyard manure; F2: compost; F3: chemical fertilizers; F4: farmyard manure + compost; F5: farmyard manure + chemical fertilizers; F6: compost + chemical fertilizers; F7: farmyard manure + compost + chemical fertilizers; F8: control & NT: No-tillage; MT: minimum tillage; CT: conventional tillage.

F2 treatment and the least amount was related to NT-F8 treatment (Table 2). Suitable amounts of surface residues caused by minimum tillage can increase water infiltration, reduce evaporation and enhance soil water storage (Lafond *et al*. 2006). Application of organic fertilizers such as compost alone or in combination with chemical fertilizers increases yield and yield components of crops by providing the energy necessary for soil microbial activity and biological fixation of nitrogen and increasing the solubility of unavailable forms of nutrients (Natsheh and Mousa 2014).

Seed yield: The effects of tillage, fertilizer sources, and their interaction were significant on soybean yield (Table 1). The highest seed yield (3926.7 kg/ha) belonged to MT-F7 treatment. The least seed yield was related to no-tillage and unfertilized treatment (NT-F8). In minimum tillage system, combined fertilizer treatments had the highest seed yield while in conventional tillage system, complete chemical fertilizer (F3) had more seed yield (Table 2). In fact, the simultaneous and moderated application of farmyard manure, compost, and chemical fertilizer produced the highest grain yield in minimum tillage system. Adding organic fertilizers, in addition to providing the nutrients required by the plant, provides suitable conditions for root development by improving the physical properties of the soil (Mohammadi *et al*. 2011). In a minimum tillage system, provision of suitable conditions for root development and less manipulation of soil structure increases seed yield by increasing the absorption of nutrients and improving the microbial population of the soil (Heidari *et al*. 2016). Reducing the yield in the no-tillage system compared to minimum tillage is caused by the increase in soil cone index and compaction and the lack of suitable conditions for root growth. This compaction affects the roots of the plant, and the roots cannot absorb well their required water and nutrients (Nunes *et al*. 2015). Busari and Salako (2015) showed that minimum tillage broke the compact soil surface that is often associated with no tillage system and prevented intense soil perturbation that occurred under conventional

tillage which could later minimize root growth. You *et al*. (2017) found that short-term reduced tillage and residue incorporation promoted maize yield by increasing soil physical-chemical property, root characteristics and biomass indices in the growing season. In no-tillage systems, although the vegetation cover helps to provide adequate moisture by reducing the amount of evaporation, in most cases, a suitable bed is not provided physically for plants in the early years. However, adding organic fertilizers such as farmyard manure and compost improves soil physical properties and decreases the bulk density of soil (Hati *et al*. 2006).

Biological yield: The effects of tillage, fertilizer sources, and their interaction were significant on soybean biological yield (Table 1). The highest value of biological yield belonged to MT-F5 treatment and the lowest value was related to no-tillage and non-fertilized (NT-F8) treatment. In minimum tillage system, combined fertilizer treatments had the highest biological yield whereas, in conventional tillage system, complete chemical fertilizer treatment (F3) had more biological yield than other fertilizer levels (Table 2). Increasing biological yield at combined fertilizer levels in the minimum tillage can be attributed to improved biological and physicochemical properties of soil such as increasing organic matter and supplying required nutrients of plants by organic fertilizer application (Alijani *et al*. 2012).

Harvest index: The effects of tillage, sources of fertilizer, and their interaction were significant on harvest index (Table 1). The highest harvest index belonged to MT-F6 combined treatment but it had no significant difference with MT-F2, MT- F3, MT-F4, MT-F5, and MT-F7 treatments. The higher harvest index in above-mentioned treatments can be attributed to the higher grain yield in these treatments (Table 2). The lowest harvest index, on the other hand, was related to no-tillage and non-fertilized (NT-F8) treatment. Some unfavorable conditions can lead to lower seed yield and harvest index in the no-till methods. Weed density and residue covering are important problems for no-till farming (Kisic *et al*. 2010).

Seed oil content: The effect of fertilizer sources was significant on seed oil content, but the effects of tillage and interaction between tillage and fertilization were not statistically significant (Table 1). The highest seed oil content was related to F1 treatment (21.58%) and the lowest values were obtained from F8 (14.46%) and F3 (17.14%) treatments. It seems that increased seed oil percentage in F1 treatment (farmyard manure application) was due to a reduced access to nitrogen compared to treatments having chemical fertilizers. However, in treatments that used farmyard manure and compost along with chemical fertilizers, less oil content was produced by the plant probably due to increased nitrogen absorption. Rathke *et al.* (2005) stated that high application rates of chemical nitrogen fertilizers reduce the availability of carbohydrates for the synthesis of oil while leading to an increase in protein synthesis. The synthesis of amino acids and fatty acids requires carbon compounds from carbohydrate degradation. Mohammadi *et al*. (2011) reported that the use of farmyard manure and compost alone increased the percentage of seed oil in soybean due to the reduced access to nitrogen; which is consistent with the results of the present experiment.

Seed protein content: The effect of sources of fertilizer was significant on seed protein content, but the effects of tillage and interaction between tillage and fertilization were not significant (Table 1). The highest amount of this trait was related to F7 treatment (35.27%). The higher content of protein in F7 treatment (farmyard manure + compost + chemical fertilizer) may be due to the increased solubility of essential nutrients by organic acids obtained from the decomposition of organic fertilizers, which in turn resulted in a greater access of root to the essential nutrients. In addition, the combined use of organic and chemical fertilizers improves the use of organic and inorganic food sources for more production and sustained soil health and increases the availability of nitrogen, phosphorus, potassium, and organic carbon (Ali *et al*. 2019).

Results of the present experiment showed that the highest number of pods and seeds per plant and, grain yield were obtained in MT-F7 treatment, in which compost, farmyard manure, and chemical fertilizers were used moderately and simultaneously in minimum tillage system. This combined treatment was superior to other treatments. Minimum tillage system is recommended as a suitable bed preparation method for reasons such as increased yield, accelerated sowing, plant early establishing, reduced energy consumption, and less investment in machinery purchases. Introducing a proper food management system that allows simultaneous application of both fertilizers is an effective way to achieve sustainable agriculture. In addition, application of organic fertilizers such as compost, while reducing the massive amount of waste and protecting the environment, can be effective in modulating the use of fertilizers in agricultural ecosystems.

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