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Different Tillage Possibilities for Second Crop in Green Bean Farming

Yilmaz Bayhan, Emin Güzel, Ömer Barış Özlüoymak, Ahmet İnce, Abdullah Sessiz

***Abstract*—**In this study, determining of reduced tillage techniques in green bean farming as a second crop after harvesting wheat was targeted. To this aim, four different soil tillage methods namely, heavy-duty disc harrow (HD), rotary tiller (ROT), heavy-duty disc harrow plus rotary tiller (HD+ROT) and no-tillage (NT) (seeding by direct drill) were examined. Experiments were arranged in a randomized block design with three replications. The highest green beans yields were obtained in HD+ROT and NT as 5,862.1 and 5,829.3 Mg/ha, respectively. The lowest green bean yield was found in HD as 3,076.7 Mg/ha. The highest fuel consumption was measured 30.60 L ha^{-1} for HD+ROT whereas the lowest value was found 7.50 L ha^{-1} for NT. No tillage method gave the best results for fuel consumption and effective power requirement. It is concluded that no-tillage method can be used in second crop green bean in the Thrace Region due to economic and erosion conditions.

***Keywords*—**Soil tillage, green bean, vegetative, generative, yield.

I. Introduction

MOST farmers change farming methods according to the cost of fuel related to tillage operations [5]. Minimum tillage and direct seeding is a method applied recently by farmers for long-term erosion-free farming with lower fuel cost. Considering the negative effect of intensive farming in the field, direct seeding has become more vital for farmers. Weed density and other residues create problems for the application of direct seeding, especially in the short-term. Although most of these problems disappear in the long-term, some insecticide problems remain. By observing the negative short-term effect of direct seeding, it was concluded that the application of this technique requires regional adaptation regarding the soil type and plant production [15]. A review of the conditions for no-tillage showed that they are about the same as for shallow tillage, but the lack of a seedbed and a large amount of plant residues at the soil surface can result in poor establishment [12]. Weed problems are also often more pronounced with no-tillage than in a system with shallow tillage [2].

Although organic matter content and productivity of the soils are low in the Thrace region (Turkey), a sunflower (*Helianthus annuus* L.) - wheat (*Triticum aestivum* L.) or barley (*Hordeum vulgare* L.) crop rotation system has been used in this region. Crop rotation has many agronomic, economic and environmental benefits compared to a monoculture system [16]. The common bean (*Phaseolus vulgaris* L.) has many advantages, green or grain in these crop rotations, after wheat or barley harvesting such as increasing organic matter in the soil, improving soil degradation, fixing atmospheric nitrogen through symbiosis with *Rhizobium* bacteria biologically. This system reduces the need for inorganic nitrogen fertilizer inputs, decreasing potential diseases, weeds and pest cycles established in continuous plant species of other families. In this rotation, beans will also provide increased revenues. As well, the current increase in the acreage and availability of the bean will likely develop its acceptance by farmers of this region.

The objective of this study is to determine reduced tillage techniques in green bean farming as a second crop after harvesting wheat. These techniques are examined in terms of the vegetative and generative properties of the plant, as well as power and fuel consumption of equipment.

II. Materials and Methods

The experiments were conducted in a field at the Tekirdag Viticulture Research Station, 40°59'N latitude and 27°35'E longitude, between 2012 and 2013. The altitude is 10 m above sea level. The average annual temperatures of air and soil, relative humidity, and rainfall are given in Table I. The climate of Tekirdag is characterized by the Mediterranean type with mild and rainy winters and hot and dry summers at the coast, while the Continental type climate prevails inland [17].

TABLE I
Monthly Averages of Soil and Air Temperatures, Relative Humidity and Rainfall at Tekirdag Measured in 2012 and 2013

	May	June	July	August	Sept.
Air temperature (°C)	18. 8	23. 3	25. 9	26. 0	21. 9
Soil temperature (°C)	17. 8	19. 2	25. 2	25. 2	19. 5
Relative humidity (%)	80. 5	73. 5	65. 1	62. 5	67. 5
Rainfall (mm)	34. 9	19. 0	2. 9	3. 9	11. 5

The soils are classified as Typic Xerfluvent in the US Soil Taxonomy. The soil in the experiment field was a clay loam soil with a texture of 29.3% clay, 38.8% silt and 31.9% sand, well drained and the available water holding capacity within 1.20 m of the soil profile is approximately 0.18 m.

For preparation of the experiment field, a baler was used to pick up the hay, which covers 30% of the soil surface with

Y. Bayhan (PhD, Professor) is with the Namık Kemal University, Faculty of Agriculture, Department of Biosystems Engineering, Tekirdag, Turkey (corresponding author, phone: 90-282-2502265; e-mail: ybayhan@nku.edu.tr).

E. Güzel (PhD, Professor), Ö. B. Özlüoymak (PhD), A. İnce (PhD, Assoc. Professor) is with the Çukurova University, Faculty of Agriculture, Department of Agricultural Machinery and Technology Engineering, 01330 Adana, Turkey (e-mail: ebbguzel@cu.edu.tr, ozluoymak@cu.edu.tr, ainc e@cu.edu.tr).

A. Sessiz (PhD, Professor) is with the Dicle University, Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering, 21280 Diyarbakır, Turkey (e-mail: asessiz@dicle.edu.tr).

residue in the field after wheat harvesting. The mean stubble height was 200 mm. The experiment field consists of twelve plots used for wheat and sunflower rotation for several years. During the field trials, wheat and second crop green bean were planted only. Each plot was 50 m long and 9 m wide [13]. A randomized complete block design with three replications was used for the experiment. Analysis of variance was done using the MSTAT statistical package to examine the effects of treatments [1]. Duncan's Multiple Range Tests were also used to identify significantly different means within dependent variables at $P< 0.05$.

After harvesting wheat, the following four tillage methods were compared:

- Heavy-duty disc harrow + Cambridge roller + pneumatic seed drill (HD);
- Rotary tiller + Cambridge roller + pneumatic seed drill (ROT);
- Heavy-duty disc harrow + rotary tiller + Cambridge roller+ pneumatic seed drill (HD+ROT);
- No-tillage; seeding by direct drill (NT).

It is usually assumed that yields at the center of the plot are more typical of what happens in practice than are yields at the border [10]. Therefore, pod length, pod width, pod thickness, number of pods, plant height, stem diameter and yield values were measured only on the center of plot (about 28 m^2). Mentioned parameters were measured for 60 samples of each replication. The mature green beans were harvested and picked by hand for determining crop yield.

Number of emerged seedlings were measured in the rows and mean emergence dates (MED) and percentage of emerged seedlings (PE) were calculated using (1) and (2) [4], [3].

$$\text{MED} = \frac{N_1*D_1+N_2*D_2+\cdots+N_n*D_n}{N_1+N_2+\cdots+N_n} \quad (1)$$

where, N= Number of emerged seeds on days n, D= Number of days since sowing.

$$\text{PE} = \frac{\text{Total emerged seedling per meter}}{\text{Number of seeds planted per meter}} \text{ X } 100 \quad (2)$$

The tractor with 78 HP was used in the field. The fuel consumption of tractor was measured by using two flowmeters (Macnaught M05, Macnaught Pty. Ltd., Australia). One of the flowmeters was placed between the fuel tank and injection on the outbound line and the other was connected to the return line. The difference between two flowmeters gave the fuel consumption.

III. Results and Discussion

Mean emergence dates, percentage of emerged seedlings, pod length, pod width, pod thickness, number of pods, hundred bean weights, plant height, stem diameter and yield in this section were measured during the years of 2012 and 2013. Due to varying temperatures during the growing season of 2012 which was higher than in 2013, mean emergence dates, percentage of emerged seedlings, plant height and yield results were found to be significantly different; whereas, the values of pod length, pod width, pod thickness, number of pod, hundred bean weight and stem diameter were not significant (Table II).

TABLE II
Effects of Vegetative and Generative Characteristics on Different Tillage Methods

Properties	Tillage methods			
	HD	ROT	HD+ROT	NT
Mean emergence dates (MED)	8.74^{A}	7.75^{B}	7.40^{C}	6.67^{D}
Percentage of emerged seedlings (%PE)	60.62^{C}	82.12^{B}	83.33^{B}	96.29^{A}
Pod length (mm)	133.3^{ns}	133.7^{ns}	134.0^{ns}	133.3^{ns}
Pod width (mm)	12.7^{ns}	13.3^{ns}	13.3^{ns}	13.0^{ns}
Pod thickness (mm)	5.7^{ns}	5.7^{ns}	6.3^{ns}	5.7^{ns}
Number of pod	4.3^{ns}	5.7^{ns}	6.7^{ns}	5.7^{ns}
Hundred bean weight (g)	679.1^{ns}	5.7^{ns}	6.7^{ns}	5.7^{ns}
Plant height (mm)	148.0^{A}	146.3^{AB}	144.7^{BC}	143.7^{C}
Stem diameter (mm)	9.7^{ns}	8.6^{ns}	9.3^{ns}	8.7^{ns}
Yield (Mg/ha)	3.076^{B}	5.794^{A}	5.862^{A}	5.829^{A}

A. Mean Emergence Dates

Average of mean emergence dates were high significantly ($F = 79.20^{**}$). The lowest MED was found for NT with 6.67 days and the highest MED was for HD with 8.74 days. The MED decreased with NT method means that it can be harvested earlier. This is an advantage for second crop production in the region, which has short vegetation time. Similar results were reported by [14] in the method of no-till and conservation tillage systems.

B. Percentage of Emerged Seedlings

Tillage methods affected the percent of emergence of green bean significantly ($F =72.17^{**}$). The lowest PE was found in HD with 60.62% and the highest PE of 96.29% was in NT method. It was clear that NT had higher water content at planting depth according to other methods. Therefore, the best PE result was found in NT. Reference [8] also pointed out that no tillage and reduced tillage had higher water content and obtained higher emergence rates. PE was found to be the lowest in method of HD due to soil tillage. Meanwhile, [12] showed that they are about the same as for shallow tillage, but that the lack of a seedbed and a large amount of plant residues at the soil surface can result in poor establishment. Most types of direct drill implements have been found to provide faster emergence and stronger early growth when the seeding tool is followed by a presswheel that packs soil onto the seed [3]. Reference [7] concluded that applying presswheels usually improved emergence of lupins and wheat by an additional 6% and 2%, respectively. Reference [9] evaluated soil loading effects of planter depth-gauge wheels on early corn growth. They found that the emergence rate of corn plants was affected by the loading and soil moisture conditions. No-tillage gave faster emergence than reduced tillage.

C. Pod Length, Pod Width, Pod Thickness, Number of Pod, and Hundred Bean Weights

All tillage methods did not affect statistically the average of pod length, pod width, pod thickness, number of pods, and hundred bean weights. The lowest pod length was 133.30 mm

for HD and the highest pod length was 134.00 mm for HD+ROT. Other treatments showed the same results (Table II).

D. Plant Height and Stem Diameter

The means of plant height were significantly different (F = 6.64*). The lowest plant height was 143.70 mm for NT and the highest was 148.00 mm for HD.

Investigations showed that there were not significant differences among tillage methods on the average of stem diameter (F = 0.41). The lowest stem diameter was 8.60 mm for HD+ROT and the highest was 9.70 mm for HD.

E. Yield

The differences among methods in the average of green bean yield were found to be significant (F =1,763.04**). The highest yield with 5,862.1 Mg ha^{-1} was found in HD+ROT, and the lowest, 3,076.7 Mg ha^{-1} in HD. In spite of shallow tillage in HD, low crop yield was found due to the low percentage of emergence in this method. Shallow tillage which is disc harrow gave similar or slightly lower yield than reduce tillage and no-tillage. Results showed that the percentage of emergence had an important effect on the green bean yield. Similar results were found by [14], [11], [8], [6].

F. Working Characteristics of Methods

The working characteristics, consumptions, draught force, power requirement, PTO power requirement and total power requirement of each tool are given in Table III. The highest fuel consumption was observed in HD+ROT method, whereas the lowest value was found in NT method. In the disc HD+ROT method, fuel consumption and total power requirement with 30.60 l ha^{-1} and 67.80 kW were the highest. The lowest fuel consumption and effective power requirement were found in the NT method with 7.50 l ha^{-1} and 29.40 kW, respectively. Fuel consumption of NT method was four times less than the HD+ROT method. There are direct relations between fuel consumption and total power requirement. It is obvious that direct seeding gives the best results for all parameters. Similar results were found by [5], [6].

G. Yield between Fuel Consumption Relations

The relationship between average yield and fuel consumption for treatments are given in Fig. 1. The highest yield/fuel consumption ratio was found in the NT method with 0.772 Mg L^{-1}, while the lowest yield/fuel consumption ratio of 0.1916 Mg L^{-1} was found in the HD+ROT method. It is obvious that NT gives the best results in terms of yield and fuel consumption relations.

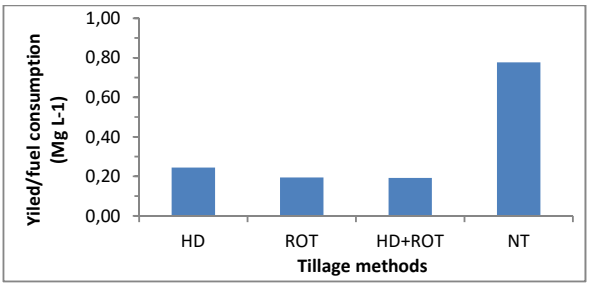

Fig. 1 Relationship between yield and fuel consumption

TABLE III
AVERAGES OF TILLAGE EFFICIENCY PARAMETERS FOR DIFFERENT TILLAGE METHODS

Method	Tillage Equipment	Travel Speed (m/s)	Fuel Consumption (L ha^{-1})	Draught Force (kN)	Power Requirement (kW)	PTO power Requirement (kW)	Total power Requirement (kW)
HD	Disc harrow	2.0	0.80	8.0	13.2	-	13.2
	Roller	2.0	4.00	2.1	4.0	-	4.0
	Seeder	1.8	5.10	4.8	8.6	3	11.6
	Irrigation machines (three times)	0.006	0.69	3.2	6.5	-	6.5
	Fertilizer spreader (three times)	2.0	0.96	3.1	6.4	-	6.4
	Sprayer (three times)	2.0	1.05	3.3	6.6	-	6.6
	TOTAL		**12.60**	**24.50**	**45.30**	**3.00**	**48.30**
ROT	Rotary tiller	1.4	18.00	-	-	19.5	19.5
	Roller	2.0	4.00	2.1	4.0	-	4.0
	Seeder	1.8	5.10	4.8	8.6	3	11.6
	Irrigation machines (three times)	0.006	0.69	3.2	6.5		6.5
	Fertilizer spreader (three times)	2.0	0.96	3.1	6.4		6.4
	Sprayer (three times)	2.0	1.05	3.3	6.6	-	6.6
	TOTAL		**29.80**	**16.50**	**32.10**	**22.50**	**54.60**
HD+ROT	Disc harrow	2.0	0.80	8.0	13.2	-	13.2
	Rotary tiller	1.4	18.00	-	-	19.5	19.5
	Roller	2.0	4.00	2.1	4.0	-	4.0
	Seeder	1.8	5.10	4.8	8.6	3	11.6
	Irrigation machines (three times)	0.006	0.69	3.2	6.5		6.5
	Fertilizer spreader (three times)	2.0	0.96	3.1	6.4		6.4
	Sprayer (three times)	2.0	1.05	3.3	6.6	-	6.6
	TOTAL		**30.60**	**24.50**	**45.30**	**22.50**	**67.80**
NT	Direct seeding machinery	1.8	4.80	5.5	9.9	-	9.9
	Irrigation machines (three times)	0.006	0.69	3.2	6.5		6.5
	Fertilizer spreader (three times)	2.0	0.96	3.1	6.4		6.4
	Sprayer (three times)	2.0	1.05	3.3	6.6	-	6.6
	TOTAL		**7.50**	**15.10**	**29.40**		**29.40**

IV. Conclusions

Results of this study indicated that green bean can be successfully grown in residue tillage systems and no tillage after harvesting of wheat. NT is recommended because it reduces field traffic and plant production cost and also prevents soil erosion. Even though the ROT method was in the middle position for yield, this method can also be recommended since most farmers of the region use a rotary tiller. It is confirmed that reduced tillage and no tillage methods can be used in green bean as a second crop in the region for more economic, long-term and erosion-free sustainable agriculture.

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