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Effects of Different Soil Tillage Systems on Plant Emergence and Yield Parameters in Safflower Farming of Central Anatolia of Turkey (First Year)

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ABSTRACT: The present study was conducted to determine the effects of soil tillage system to be used in safflower farming in Sivas, Turkey in terms of plant emergence and yields characteristics. Soil tillage systems were arranged as; conventional soil tillage system-1 (STS-1) with moldboard plough, conservation soil tillage system-2 with gobble disk (STS-2) and conservation soil tillage-3 with chisel plough (STS-3). Linas and Remzibey-05 safflower varieties were used in experiments. In Linas and Remzibey-05 varieties, the greatest and the lowest mean emergence dates were respectively observed in STS-3 and STS-2; the greatest and the lowest percentage of emerged seedlings were respectively observed in STS-2 and STS-1. In Linas and Remzibey-05 varieties, the greatest mean emergence date was observed in STS-3 with chisel and the greatest emerged rate index and the greatest percentage of emerged seedlings were observed in STS-2 with gobble disk. Plant yield parameters were greater in conventional soil tillage system. The system with gobble disk has the lowest values as plant yield parameters, except for first branched height and number of secondary branches per plant. Seed yields varied between 72.82-88.55 kg da^{-1} in Linas and between 70.21-84.50 kg da^{-1} in Remzibey-05 variety.
Key words: *Conservational tillage, percentage of emerged seedlings, safflower yield.*

1. Introduction

Safflowers (*Carthamus tinctorius* L) contain about 30-50% oil content. Plants are mostly used for oil production, but also used in dye, varnish, margarine, feed industries, in pharmaceutical industry, as herbal tea and most important of all, in biodiesel production. Plants are also used for ornamental purposes as dry flower and green fence (Rahamatalla et al., 1998; Wang et al., 1999; Weiss, 2000; Öğüt and Oğuz, 2006).

Although climate and soil conditions of Turkey are quite available for oilseed farming, current production levels are not sufficient to meet the demands. Therefore, potential cultivated lands should be increase to meet vegetable oil and oilseed needs of the country. Safflower is highly tolerant to droughts and salinity provided that relevant agronomic measures are fully taken on time. Safflowers do not have serious pests and diseases and can reliably be incorporated into cropping patterns or can be grown as second crop. They also plant a great role in erosion prevention. Thus, safflower production should be increased to meet the vegetable oil and oilseed needs. Safflower is commonly incorporated into cropping patterns of Central Anatolia, East and Southeastern Anatolia regions and also grown over fallow lands of these regions (Kurt et al., 2011). The tools and equipment used in farming and soil preparation of cereals (wheat, barley and etc.) of the Central Anatolia region can also be used in safflower farming (Babaoğlu, 2007).

Conservation tillage systems are getting more common for soil and water resources preservation and environmental protection in Turkey. In safflower farming, instead of conventional farming practices, environment-friendly, soil-water preserving, energy saving and sustainable agricultural practices should be implemented. Energy costs and herbicide uses are continuously increasing in Turkey. Such negative issues force the farmers to use alternative soil tillage systems both in main and second crop farming. Previous studies on soil tillage systems revealed that effects of tillage systems on post-tillage soil characteristics, plant emergence, and crop yield and energy efficiency could reliable be determined with scientific researches (Doğan and Çarman, 1997; Barut et al., 2011).

Agricultural production activities not only consider profitability, but also take environmental, social and agricultural aspects into consideration (Berkman, 1996). Within agricultural production activities, agricultural mechanization practices are among the significant production factors to be considered in on-time performance of productivity and economic programs. While the share of agricultural mechanization in production inputs has the second place after fertilizers in developing countries, it has the greatest share in developed countries (Gifford, 1986). Such a share is almost equal to 50% of all production inputs and facility capital (Cross, 1998). In plant production activities, soil tillage has the greatest energy consumption. However, high energy use of today’s conventional soil tillage systems points out the necessity of alternative soil tillage systems in crop production activities. Considering the large size of lands over which conventional soil tillage systems are practiced in Turkey, it is clearly evident that practices with more efficient energy use and less detrimental impacts on environment could have great contributions to country economy (Gökçebay, 1983).

Sivas province with 27 202 km^2 surface area located in Central Anatolia region is the second largest province of Turkey. Although cereal farming is dominant in the province, a significant increase has recently been observed in oilseed cultivated lands. In this sense, oilseed cultivated lands increased to 19 110 decare in 2016. Safflower is the greatest oilseed of the province and Gürün town with 750 tons of production from 10 000 decare is the greatest safflower producer (Anonymous, 2016). Of the agricultural lands of Sivas province, 2 519 043 hectares are subjected to wind and water erosion. Therefore, a transition should be made to sustainable agricultural production systems and conservation soil tillage systems should be practiced to preserve soil and water resources and to reduce erosion risks over the fields (Anonymous, 2014).

There aren’t any studies about soil tillage systems in safflower farming in Turkey and thus in Central Anatolia region. Potential use of alternative soil tillage systems instead of conventional tillage systems in safflower farming in Sivas province of Central Anatolia region will provide significant contributions to soil preservation and yield improvement and will also constitute a ground for the selection of the best soil tillage system. The primary objective of the present study was to determine the best soil tillage system for safflower farming in dry-farming lands in Sivas province of Central Anatolia region. Linas and Remzibey-05 safflower varieties were grown in the different soil tillage systems as potential alternatives to conventional tillage system. Soil tillage systems were compared in terms of plant emergence parameters (mean emergence dates, emerged rate index, percentage of emerged seedlings), plant yield parameters (plant height, first branch height, number of secondary branches per plant, number of head per plant, head diameter, seed yield).

2. Material and Method

The research was conducted over the safflower cultivated fields of a farmer in Kavak village of Gürün town of Sivas province in Central Anatolia region. The research site has an altitude of 1 260 m and a slope of 0-2%. Experimental site has a soil depth of 0-120 cm. Fields were normal dry farming lands without a stoniness problem. Semi-terrestrial climate is dominant in Gürün town of Sivas province. The first frost date to be considered in agricultural production is generally 25 October and the last frost date is around 28 March. Experiments were conducted in growing season of 2017. The 2017 climate data for Gürün town and long-term meteorological data of Sivas province are presented in Table 1.

Table 1. Climate data for the research site (Anonymous, 2017a).

Months	Average Temperature (°C)	Maximum Temperature (°C)	Minimum Temperature (°C)	Total Precipitation (mm)	Relative Humidity (%)
January	-1.7	11.4	-17.2	23.9	76.9
February	2.1	19.6	-11.5	26.8	72.9
March	5.6	21.1	-9.0	36.5	62.2
April	10.7	26.4	-4.2	32.5	53.2
May	15.1	30.0	3.5	42.6	54.2
June	19.5	37.3	6.2	23.8	44.6
July	23.4	38.7	0.0	10.4	36.7
August	24.3	37.3	0.0	3.3	34.9
September	18.7	35.6	0.0	6.0	42.1
October	12.1	27.3	-2.0	29.0	54.8
November	5.8	20.5	-7.1	42.7	57.0
December	-0.1	14.5	-14.7	40.3	69.4
Total	135.5	319.7	-56.0	317.8	658.9
Average	11.3	26.6	-4,6	26.4	54.9
Maximum	24.3	38.7	6.2	42.7	76.9
Minimum	-1.7	11.4	-17.2	3.3	34.9

Soils were clay-loam in texture (34% clay, 35% silt and 31% sand). Soil samples from 0 to 30 cm soil profile had an average organic matter content of 2.17%, total N of 0.015%, available P of 3.65 ppm, available K of 6.30 ppm. The average precipitation from safflower planting in April to harvest in October was 21.09 mm, relative humidity was 45.79% and temperature was 17.71°C. Terrestrial climate is dominant in the research site (Konak et al. 2004). Physical and chemical soil properties are provided in Table 2.

Conventional soil tillage system (STS-1) was performed with moldboard plow + cultivator + planter; conservation soil tillage systems were performed with gobble disk + planter (STS-2) and chisel + disk harrow + planter (STS-3). Technical specifications for tractor, agricultural machines and tools used over the experimental fields are provided in Table 3.

Table 2. Physico-chemical soil properties (0-30 cm).

Analyses	Value	Assessment
Soil texture	34% clay, 35% silt, 31% sand	Clay-loam
Moisture content (0-15 cm) (%)	16.51	-
Moisture content (15-30 cm) (%)	18.25	-
Penetration resistance (0-15 cm) (MPa)	1.26	-
Penetration resistance (15-30 cm) (MPa)	2.52	-
pH	7.63	Slightly alkaline
Salinity (%)	0.03	Unsaline
Lime (%)	30.017	Limy
Organic matter (%)	2.17	Medium
Total N (%)	0.015	Low
Available P (ppm)	3.65	Low
Available K (ppm)	6.30	Excessive
Fe (ppm)	0.09	Low
Zn (ppm)	0.06	Low
Cu (ppm)	0.18	Low
Mn (ppm)	0.02	Low

Table 3. Technical specifications for tractor, agricultural machines and combine harvester used in the experimental fields.

Machines	Type of Connection	Number of units	Width (mm)	Depth (mm)	Weight (kg)	Operational Speed (km h^{-1})
Moldboard plow	Mounted	3 moldboards	900	250	335	5.41
Chisel	Mounted	7 foot	2100	250	420	5.76
Cultivator	Mounted	11 foot	2700	100	540	5.49
Gobble disk	Mounted	20 disks	2200	150	1 390	5.58
Disk harrow	Mounted	22 disks	2250	100	506	5.74
Centrifugal broadcasters	Mounted	Single disk	1 000	-	220	9.88
Planter	Pulled	18 rows	2 556	40	1 010	5.79
Sprayer	Mounted	16 spray nozzles	8 000	-	380	8.31
Tractor (TÜMOSAN 8075)	4WD	-	-	-	3 500	-

Effects of soil tillage systems on yields of safflower varieties were investigated in this study. Linas and Remzibey-05 safflower varieties were used in experiments. Linas variety is commonly used in Sivas province of Central Anatolia region. To assess the effects of soil tillage systems on different varieties, Remzibey-05 variety which was considered as adapted to regional conditions was selected. Linas variety with orange-leaved flower head has 85-90 cm plant height, 37-38% oil content, 71.3% linoleic and 17.9% oleic acid and thousand seed mass 43 g. Remzibey-05 variety with yellow-leaved flower head has 60-80 cm plant height, 35-38% oil content, 69% oleic and 21% linoleic acid and thousand seed mass 46-50 g (Anonymous, 2017 b).

Experiments were conducted in randomized blocks – split plots experimental design. Each plot has a size of 200 m^2 and total area was 200 x 18 = 3 600 m^2. About 4 m spacing was provided between the varieties and 1 m spacing was provided between the experimental plots. Before soil tillage in 2017, safflower stubble density of the experimental fields was 8.166 kg da^{-1} and stubble height was 24.15 cm. Experiments were conducted as three replications for soil tillage systems and safflower varieties (Figure 1).

Sowing was performed with 10-day delay because of climate conditions (snowfall). Measurements for soil physical characteristics after sowing were performed on 23 April 2017. Row spacing was 12.5 cm, sowing depth was 5 cm and sowing rate was 5.13 kg da^{-1}. As base fertilizer at sowing (22 April 2017), 20 kg were applied from 20.20.0.+Zn fertilizer per decare with planter. 15 kg were applied from Ammonium Sulphate ($(NH_4)_2SO_4$) per decare as top fertilizer on 30 April 2017. Formula Super 5 SC with 50 g l^{-1} Quizalofop-p-ethyl active substance was used for weed control for all parcels on 2 July 2017. Side effects were removed and 3 different 1 m^2 sections were harvested in each plot on 2 October 2017.

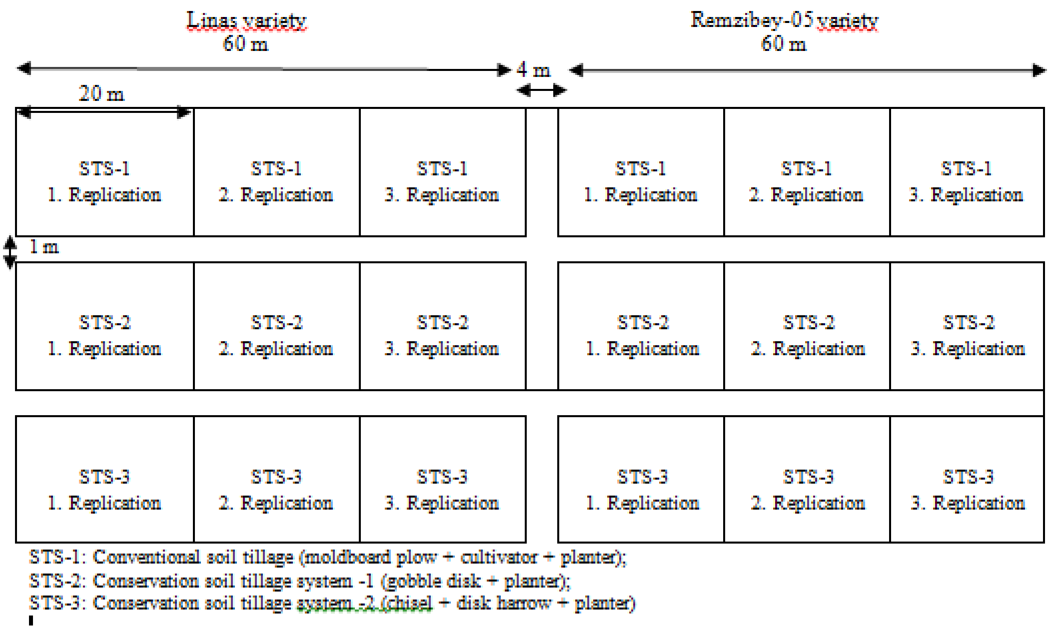

Figure 1. Experimental design

For plant emergence characteristics, 3 rows of each plot were considered and 3 strips (1 m long) were taken into consideration (a total of 9 strips in each plot). These randomly selected strips were monitored throughout the emergence period. Emerged plants were counted and mean emerging dates (MED) (day), emerged rate index (ERI) (number m day^{-1}) and percentage of emerged seedlings (PE) were calculated by using the Equations 1-3 (Konak and Çarman, 1996).

$$MED = \left(\frac{N_1D_1 + N_2D_2 + ... + N_nD_n}{N_1 + N_2 + ... + N_n} \right) \quad (1)$$

ERI = number of emerged seedlings per meter/MED (2)

PE (%)= (total number of emerged seedlings per meter/ number of seeds planted).100 (3)

Where; N is the number of seedlings emerging since the previous count, and D is the number of days after planting.

Plant growth and development parameters (plant height, first branch height, number of secondary branches per plant, number of head per plant, head diameter) were measured over randomly selected 10 plants from each plot (Uysal, 2006; Erbaş and Baydar, 2009). Side effects were removed and 3 different 1 m^2 sections were harvested in each plot Seeds were separated, weighted and seed yield per decare was determined. For seed yields, 10 plants were used from each soil tillage systems and varieties. To put for the differences between safflower variety and soil tillage systems, resultant values were subjected to variance analyses and multiple comparison tests (LSD) with SPSS 17 statistical software.

3. Results and Discussion

3.1. Plant emergence parameters

Mean emergence dates (MED), emerged rate index (ERI), and percentage of emerged seedlings (PE) of safflower varieties at different soil tillage systems are presented in Table 4. Effects of different soil tillage systems on mean emergence dates and emerged rate index values of the safflower varieties were found to be significant at $P<0.01$ and effects on percentage of emerged seedlings were found to be significant at $P<0.05$. With regard to mean emergence dates, emerged rate index and percentage of emerged seedlings, STS-1 and STS-3 treatments were placed into the same statistical group. The differences in emerged rate index and percentage of emerged seedlings of the varieties were not found to be significant.

Table 4. Plant emergence characteristics of safflower varieties under different soil tillage systems and statistical results.

Plant emergence characteristics	Safflower variety	Soil tillage systems			
		STS-1	STS-2	STS-3	Average
Mean emergence dates (MED, day)	Linas	16.65 (±0.34)	12.77 (±0.42)	16.75 (±0.74)	15.39 a*
	Remzibey-05	16.80 (±0.20)	13.73 (±0.48)	17.01 (±0.18)	15.81 b
	Average	16.72 a**	13.25 b	16.88 a	
Emerged rate index (ERI, number m day^{-1})	Linas	1.022 (±0.09)	1.495 (±0.07)	1.065 (±0.10)	1.19 ^{ns}
	Remzibey-05	1.009 (±0.04)	1.352 (±0.07)	1.010 (±0.04)	1.13 ^{ns}
	Average	1.015 b**	1.423 a	1.037 b	
Percentage of emerged seedlings (PE, %)	Linas	84.12 (±6.60)	95.56 (±0.95)	87.96 (±6.87)	88.88 ^{ns}
	Remzibey-05	87.15 (±6.28)	96.44 (±2.71)	90.05 (±2.66)	91.21 ^{ns}
	Average	85.63 b*	95.50 a	89.01 b	

****:** Differences between the means indicated with the same latter in the same row are not significant (P<0.01);
* : Differences between the means indicated with the same letter in the same row are not significant (P<0.05);
^{ns}: non-significant;
Values in parenthesis are standard deviations.
STS-1: Conventional soil tillage (moldboard plow + cultivator + planter); STS-2: Conservation soil tillage system -1 (gobble disk + planter); STS-3: Conservation soil tillage system -2 (chisel + disk harrow + planter)

In Linas and Remzibey-05 varieties, the greatest mean emergence date was observed in STS-3 with chisel and the greatest emerged rate index and percentage of emerged seedlings were observed in STS-2 with gobble disk. Mean emergence dates of STS-2 with gobble disk was approximately about 4 days less than the other soil tillage systems. Average percentage of emerged seedlings was 88.88% in Linas variety and 91.21% in Remzibey-05 variety. Although there was no significance significant difference, mean emergence date and percentage of emerged seedlings of Linas variety was respectively 2.73% and 2.62% lower, but emerged rate index was 5.31% greater than the values of Remzibey-05 variety (Table 4).

Adalı (2016), under Konya provincial conditions, reported mean emergence dates 28.67 days for Linas and as 26.33 days for Remzibey-05 variety and indicated the reason of such longer durations as the cold weather and insufficient soil temperatures (minimum 4.4 °C, optimum 15.6 °C) (Baydar and Turgut, 1993). Sefaoğlu (2017) reported mean emergence dates of Dincer and Yenice safflower varieties under Erzurum provincial conditions as 16.42 and 17.96 days. Mean emergence dates may vary based on sowing time, climate, soil temperature, soil moisture content and sowing depth (Oruç, 2014; Adalı, 2016; Sefaoğlu, 2017;). Mündel et al. (2004) indicated that soil temperature should be minimum 5°C for emergence of safflower seeds and seeds did not germinated at all under 2.5°C.

While there were not significant differences in field emergence levels of the varieties, there were remarkable differences between soil tillage systems based on seedbed and sowing quality. Mikkelsen et al. (2008) indicated that emergence time and field emergence levels of safflower varied based on soil texture and sowing depth and reported longer emergence durations and lower field emergence levels with increasing sowing depths. Yau et al. (2010) reported that there were not any significant differences in number of plants per m^2 in safflower farming between conventional soil tillage and minimum soil tillage with twice surficial disk harrow and no-till and indicated that safflower plants blossomed earlier in conventional soil tillage.

3.2. Plant yield parameters

While the effects of different soil tillage systems on plant height, first branched height, number of secondary branches per plant, head diameter and seed yield were found to be significant ($P<0.01$), the effects on number of heads per plant were not found to be significant. Safflower varieties had significant effects on plant height, first branched height and seed yield at $P<0.01$ level and on number of secondary branches per plant at $P<0.05$ level, but the effects of varieties on number of heads per plant and head diameter were not found to be significant (Table 5).

The yield parameters of safflower plants were greater in conventional soil tillage system. Except for first branched height and number of secondary branches per plant, conventional tillage was followed by the system with chisel and the system with gobble disk had the lowest values. Yao et al. (2010) indicated that there were not any significant differences between the soil tillage systems and reported greater plant heights for conventional soil tillage with plow than for the no-till and disk harrow tillage systems.

All of the investigated plant yield parameters had greater values in Linas variety than in Remzibey-05 variety. Such findings revealed 3.86% greater yield than Remzibey-05 variety and thus indicated that Linas was more favorable for the region (Table 5). Yao et al. (2010) compared the yields of different soil tillage systems and reported that conventional tillage had 23.55% greater yield in the first year and 22.22% in the second year than the disk harrow tillage system, conventional tillage had lower yields in the first year and greater yields in the second year than no-till system. Differences in seed yields were mostly resulted from the differences in climate and environmental factors.

Table 5. Yields parameters of safflower plants under different soil tillage systems and Duncan's test results

Yield parameters	Safflower variety	Soil tillage systems STS-1	STS-2	STS-3	Average
Plant height (cm)	Linas	91.29 (±7.83)	84.13 (±7.18)	86.45 (±5.61)	87.29 a**
	Remzibey-05	86.44 (±6.80)	79.83 (±6.26)	81.46 (±4.32)	82.58 b
	Average	88.87 a**	81.98 b	83.96 b	
First branched height (cm)	Linas	60.86 (±4.14)	55.77 (±4.88)	55.56 (±4.87)	57.40 a**
	Remzibey-05	56.78 (±5.33)	53.27 (±5.35)	52.83 (±4.40)	54.29 b
	Average	58.82 a**	54.52 b	54.20 b	
Number of secondary branches per plant	Linas	6.40 (±1.26)	5.80 (±1.23)	5.37 (±1.33)	5.86 a*
	Remzibey-05	5.63 (±1.13)	5.20 (±0.84)	5.17 (±1.57)	5.33 b
	Average	6.02 a**	5.50 b	5.27 b	
Number of head per plant	Linas	8.40 (±1.88)	7.43 (±1.22)	7.70 (±1.35)	7.84 ^{ns}
	Remzibey-05	7.83 (±1.47)	6.77 (±1.24)	7.53 (±1.00)	7.38 ^{ns}
	Average	8.12 ^{ns}	7.10 ^{ns}	7.62 ^{ns}	
Head diameter (mm)	Linas	26.28 (±2.42)	22.20 (±1.97)	24.37 (±2.81)	24.28 ^{ns}
	Remzibey-05	25.82 (±2.46)	21.71 (±3.42)	23.74 (±2.90)	23.76 ^{ns}
	Average	26.05 a**	21.96 c	24.06 b	
Seed yield (kg da^{-1})	Linas	88.55 (±2.05)	72.82 (±1.19)	78.40 (±1.22)	75.61 a**
	Remzibey-05	84.50 (±1.92)	70.21 (±1.57)	75.17 (±1.87)	72.69 b
	Average	86.52 a**	71.52 c	76.78 b	

****:** Differences between the means indicated with the same letter in the same row are not significant (P<0.01);
* : Differences between the means indicated with the same letter in the same column are significant (P<0.05);
^{ns}: non significant;
Values in parenthesis are standard deviations.
STS-1: Conventional soil tillage (moldboard plow + cultivator + planter); STS-2: Conservation soil tillage system -1 (gobble disk + planter); STS-3: Conservation soil tillage system -2 (chisel + disk harrow + planter)

Tunçtürk (1998) indicated that although seed yield is a variety-specific characteristic, it could easily be influenced by ecological factors and cultural practices (Adalı, 2016). Yao et al. (2010) indicated that high penetration resistance of the upper soil less influenced safflower yield because of root system of the safflower as compared to barley and chickpea. In cold seasons, safflowers germinate faster than chickpea and slower than barley. Soil penetration resistance values presented in Table 2 were below the threshold value of 3 MPa (Hakansson and Lipiec, 2000). Current findings revealed that there were not any compacted layers hindering emergence and root growth within the root zone of the safflower plants.

There are several studies about safflower yield parameters carried out in different regions of Turkey. In studies carried out in Central Anatolia region (Konya, Ankara, Yozgat), Aegean region (İzmir) and Southeast Anatolia (Siirt) region, plant heights of Remzibey-05 variety were reported as between 49.60-114.99 cm, first branched heights as between 29.66-43.30 cm, number of secondary branches per plant as between 2.50-7.77, number of heads per plant as between 9.39-20.48, head diameters as between 1.82-2.7 cm and seed yields as between 88-211.61 kg da^{-1} (Adalı, 2016; Keyvanoğlu, 2015; Sayılır, 2015; Yurteri, 2016; Yılman, 2017; Yılmaz and Tunctürk, 2018). It is seen that the seed yields were found lower than mentioned works of literature in this study. The reason for this is that the study is carried out in the same product farming without falling fallow in dry agriculture.

Similarly, the studies carried out in Central Anatolia region (Konya), Aegean region (İzmir) and East Anatolia region (Muş), the plant heights of Linas varieties reported as between 78.3-107.7 cm, number of secondary branches per plant as between 6.06-8.20, number of head per plant as between 11.9-15.8, head diameters as between 1.92-2.17 cm and seed yield as between 167.49-244 kg da^{-1} (Adalı, 2016; Sayılır, 2015; Yurteri, 2016; Yılman, 2017; Yılmaz, 2017; Yılmaz and Tunctürk, 2018). Plant yield parameters vary mostly based on varieties, climate, soil characteristics, sowing time, seed bed quality and several other factors. Present values were within the ranges provided in literature. Yılmaz (2017) carried out a study about yield parameters of Linas variety under Muş provincial conditions and reported better values for soil tillage systems than for no-till systems. Seed yields vary mostly based on varieties, climate, soil characteristics, sowing time, seedbed quality and several other factors.

4. Conclusion

In this study, different soil tillage systems were compared for safflower farming with regard to plant emergence characteristics and yield parameters. Soil tillage systems had significant effects on mean emergence dates, emerged rate index and percentage of emerged seedlings of safflower varieties. With regard to mean emergence dates, emerged rate index and percentage of emerged seedlings STS-1 and STS-3 were placed in the same statistical group. The differences in emerged rate index and percentage of emerged seedlings of the varieties were not found to be significant. Plant yield parameters were greater in conventional soil system for Linas variety than the other soil tillage systems and this system was followed (except for the first branch height and number of secondary branches per plant) by chisel tillage system (STS-3). After that, it is planned to continue with the multi-year studies for the future. Thus, the effect of the soil tillage systems on plant emergence characteristics and yield parameters as multi-year studies will be determined. In this study conducted in dry farming conditions, the yield was lower due to the safflower farming for two consecutive years. Therefore, it is advised to the farmers consider the fallow application to achieve higher yields.

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