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Effect of Tillage Time and Plastic Mulch on Growth and Yield of Okra (*Abelmoschus esculentus*) Grown under Rain-fed Conditions

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ABSTRACT

Field experiments were carried out to study the effect of tillage time and plastic mulch on growth, yield and quality of okra under rain-fed conditions. The field was divided into three blocks, in which each block was assigned to three tillage times (tillage was done three times, two times & only one time during early spring). Soil cover treatments (black plastic mulch or no mulch) were randomly distributed according to split plot arrangement with randomized complete block design. Soil tilled three times produced significantly higher yield than other tillage treatments. Average fruit weight of okra was not affected by different tillage treatments. Generally, fresh and dry weights of okra were not significantly affected by different treatment combinations. In general, soil moisture content was higher in soil ploughed three times compared with other tillage times. Using plastic mulch as soil covering was significantly increased yield of okra and their components compared with bare soil. Total yield of okra and fruit number by using plastic mulch was about two times more than without mulching. It is concluded that using black plastic mulch as soil covering enhanced okra vegetative growth and yield. Consequently farmers of the high land are recommended to till the soil three times and using black plastic mulch to produce higher yield.

Key Words: Okra; Tillage time; Plastic mulch; Rain-fed conditions; Soil moisture

INTRODUCTION

The scarcity of water resources is one of the main challenges in the world and it is considering as a limiting factor for economic development especially for agriculture. Also, the demand on water resources is increasing with time for both agriculture and non-agricultural purposes. The climate of Jordan is generally arid and semi-arid, with more than 90% of the total area receiving less than 200 mm rainfall per year (Raddad, 2005). In addition, the pattern of rainfall is characterized by uneven distribution over various regions and there is a strong fluctuation from year to year in terms of quantity and timing.

Proper soil management practices such as mulching and tillage have been suggested by several authors (Khatibu *et al*., 1984; Mohler & Callaway, 1995; Kouwenhoven *et al.*, 2002) to improve crop growth and productivity through enhancing water and nutrient uptake. Several water conservation methods for preventing evaporation from soil surface have been reported: mulching (Unger & Parker, 1976; Verplance *et al.*, 1988; Steiner, 1989), use of different tillage methods at different dates of initial seedbed preparation (Njihia, 1988), different tillage practices and mulch (Pervaiz *et al.*, 2009).

Mulching the soil surface favourably influences the soil moisture regime by controlling evaporation from the soil surface (Anikwe *et al.*, 2007), improves infiltration (Jones & Sing, 2000), soil water retention (Bhagat & Acharya, 1987; Anikwe *et al*., 2007). Peters and Johnson (1962) stated that the use of plastic mulch reduced 50% in evaporation water losses in groundnut. Similarly, Abu-Awwad (1998) showed that covering the soil surface reduced irrigation requirement in pepper by about 14 to 29% as a result of elimination of soil evaporation. Tillage method is one of the most influential technical factors on the outcome of a crop, since it changes both the physical properties and moisture content of the soil (Thompson & Taylor, 1982; Varco *et al.*, 1989; Ahadiyat & Ranamukhaarachchi, 2007). This is particularly important in hot arid climates (De Giorgio & Fornaro, 1998). Certain tillage management practices could improve some soil physical properties and soil fertility as well as, increase the conservation of soil moisture (Abu-Hammad & Battikhi, 1995).

During the past three decades, summer vegetables planting under rain-fed conditions of Jordan have dramatically reduced due to low and fluctuation of rainfall. Okra (*Abelmoschus Esculentus* L.) is considered as an important summer vegetable crop in Jordan as well as, many other countries especially under rain-fed conditions. Therefore, low status of soil moisture in the root zone usually limits productivity of rain-fed summer crops in Jordan. Conserving moisture that has accumulated in the root zone during the previous rainy season can increase

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productivity of rain-fed summer crops in dry season. Therefore, objective of this study was to examine the effect of tillage time and black plastic-film mulch on growth and yield of okra under rain-fed conditions.

MATERIALS AND METHODS

Field experiments were conducted during, 2005/2006 growing season at Agricultural Research Station, Faculty of Agriculture, Mu'tah University, Jordan. The region has a Mediterranean climate, in which it is characterized as semi-arid, with cold rainy winters and hot dry summers with annual mean rainfall of 350 mm, as most of it occurs from December to February. During, 2005/2006 season, the rainfall was 320 mm. The soil used was sandy clay loam with the following characteristics: pH 7.78, electrical conductivity (EC) 1.28 ds/m, organic matter 1.63%.

Tillage treatments started after harvest of previous crop (wheat). The field was divided into three blocks by following three tillage times (T_1, T_2 & T_3) with the help of traditional plough (disc plough).

T_1: tillage was done three times; the first tillage was done after harvesting of previous crop (15/8/2005), while the second tillage was during winter (1/12/2005) and the third tillage was taken place during early spring before seed planting (1/4/2006).

T_2: tillage was done two times; the first tillage was during winter (1/12/2005) and the second tillage was done during early spring before seed planting (1/4/2006).

T_3: tillage was done only during early spring before seed planting (1/4/2006).

For seedbed preparation, all tillage treatments were followed by two disking with a disc harrow at a depth of 8 cm approximately.

Soil cover treatments (black plastic mulch or no mulch) were randomly distributed according to split plot arrangement with randomized complete block design. Each subplot consisted of 4 rows of 2.40 m length. Inter- and intra- row spacing was 1m x 0.40 m. The experimental beds were manually prepared with traditional hoes. Black plastic-film (100 cm width & 125 micron thick) was used to cover the appropriate plots before planting (mid April) and two sides of the film were held down with soil. Okra seeds of Clemson spineless were sown at April 15, 2006.

The soil moisture was measured at 30, 60, 90 and 120 days after sowing up to 30 cm depth by gravimetric method (Black, 1965). The soil from 0-30 cm depth was sampled by manual coring and gravimetric moisture content (g/g) of the soil samples was calculated on oven dry weight basis and converted into volumetric moisture content (cm^3/cm^3) and then expressed as profile water content in 0-30 cm soil depth.

Days to 50% emergence was recorded from seeding date until the emergence of the cotyledons above the soil surface. Number of days to 50% flowering was calculated from seeding date until 50% of the plant started flowering. For plant height and number of branches four plants were randomly selected, tagged and sampled after 45 (at first flower appearance) and 75 days after planting. Fruits were harvested at the immature stage, counted and weighed. Fruit yield was separated into: early, mid and total yield as well as, fruit number was recorded. Okra was harvested from July 19 to September 17, 2006.

MSTAT-C statistical package was used to analyze the data that obtain from the experiments. Least Significant Differences (LSD) test was used to separate means at 5% probability level (Steel and Torrie, 1980).

RESULTS

The soil moisture content (SMC) varied among the experimental treatments. At 30 and 60 days after planting, there was a significant interaction between tillage time and mulching for SMC at 30 cm depth (Table I). Bare plots (non-mulched plots) had the lowest SMC than black plastic mulched (BP mulch) plots. After 30 days of planting the highest SMC (25.94) was recorded in plots tilled three times (T_1) and covered with BP mulch followed by plots tilled two times (T_2) and covered with BP mulch (23.27). At 60 days after planting, SMC was significantly highest, when plots covered with BP mulch regardless of tillage times. In general, SMC at 90 and 120 days after planting were not significantly affected by different treatment combinations.

Seeds planted in soil tilled three times with mulching took minimum time to emerge as compared to seeds sown in non-mulched soil and tilled less than three times (Table II). It appears that covering the soil with BP mulch had more pronounced effects on seed germination compared with tillage treatments. Flowering time was also affected mainly by using BP mulch. Okra plants reached 50% flowering 3-6 days earlier than in the unmulched plots. Fresh and dry weights of okra plants after 75 days of planting were significantly higher, when the soil tilled three times and covered with BP mulch compared with other treatment combinations (Table II). On the other hand, the lowest fresh and dry weights were obtained, when the soil tilled one time in spring without using BP mulch.

Height of okra plants after 45 days of planting was higher, when the soil tilled three times and covered with BP mulch compared with other treatment combinations (Table III). Covering the soil surface with BP mulch significantly increased plant height compared with bare soil under different tillage treatments. Number of lateral branches per plant 45 days after planting was not significantly affected by BP mulch and tillage combination treatments. However, number of branches at the end of growing season was significantly highest, when the soil was tilled three times and covered with or without BP mulch compared with other treatments (Table III).

Early, mid and late okra yields and fruit number were significantly higher, when soil was tilled three times (T_1) and covered with BP mulch compared with other treatment combinations (Table IV & V). These results indicated that tilled three times (T_1) had the highest early, mid, late and total yield of okra and fruit number, followed by tilled two

Table I. Effect of tillage time and plastic mulch on soil moisture content (%) of okra grown under rain-fed conditions

Tillage time*	Black plastic mulch	Soil moisture content (%)			
		(30 days)	(60 days)	(90 days)	(120 days)
T_1	with	25.94 a	16.42 a	12.87 a	10.68 a
	without	20.58 c	14.44 c	11.2 b	10.41 a
T_2	with	23.27 b	16.24 b	12.17 ab	10.49 a
	without	21.05 c	13.73 c	11.97 ab	10.34 a
T_3	with	22.37 bc	17.48 a	12.34 ab	10.71 a
	Without	20.25 c	14.92 c	11.78 ab	10.23 a
LSD at 0.05		2.136	1.195	1.280	N.S

*In this and other tables T_1: tillage was done three times; T_2: tillage was done two times and T_3: tillage was done one time

Table II. Effect of tillage time and plastic mulch on germination, flowering and fresh and dry weight of okra plant under rain-fed conditions

Tillage time*	Black plastic mulch	Fresh wt. (g/plant)	Dry wt. (g/plant)	Germination time (days)	Flowering time (days)
T_1	with	156.1 a	36.33 a	13.7 b	62.67 b
	without	107.8 b	25.78 b	19.0 a	68.00 a
T_2	with	117.0 b	26.65 b	16.3 ab	65.33 ab
	without	107.1 b	24.33 b	19.0 a	68.00 a
T_3	with	114.8 b	26.44 b	16.3 ab	65.33 ab
	without	88.67 c	19.33 c	19.0 a	68.00 a
LSD at 0.05		18.18	4.673	4.941	4.939

Table III. Effect of tillage time and plastic mulch on plant height and number of branches of okra grown under rain-fed conditions

Tillage time*	Black plastic mulch	Plant height (cm)		Number of branches plant^{-1}	
		45 days after planting	75 days after planting	45 days after planting	75 days after planting
	with	33.5 a	68.7 a	5.0 a	14.4 a
T_1	without	25.5 bc	65.0 ab	4.3 a	12.9 ab
	with	31.5 a	54.3 bc	4.7 a	10.7 bc
T_2	without	24.0 c	55.8 bc	4.9 a	11.0 bc
	with	29.6 ab	50.9 c	4.8 a	10.7 bc
T_3	without	23.6 c	51.6 c	4.0 a	10.3 c
LSD at 0.05		5.533	12.75	NS	2.334

times (T_2) and then by tilled one time (T_3). Plastic-film mulched plots significantly increased okra yield (early mid, late & total yield) compared with bare plots. While, the highest total okra yield (5.42 ton ha^{-1}) was produced, when soil tilled three times (T_1) and covered with BP mulch. The lowest total yield (1.38 ton ha^{-1}) was produced, when the soil tilled one time (T_3) and no mulch. The same trends were also observed for early, mid and late yield. Early average fruit weight was not significantly affected by different tillage time and soil covering treatment combinations (Table VI). While, med average fruit weight was the lowest (4.56 g), when soil tilled one time (T_3) without using the BP mulch. Tilled the soil three times (T_1) with BP mulch produced the highest med fruit weight (5.18 g). Regardless of treatment combinations, average fruit weight was decreased during med and late season comparing with those produced in the early season.

Table IV. Effect of tillage time and plastic mulch on yield of okra grown under rain-fed conditions

Tillage time*	Black plastic mulch	Yield distribution (ton/ha)			
		Early	Mid	Late	Total
T_1	With	2.163 a	2.377 a	0.877 a	5.416 a
	Without	0.877 d	1.003 bc	0.329 b	2.202 c
T_2	With	1.684 b	1.241 b	0.335 b	3.261 b
	Without	0.817 d	0.785 cd	0.179 c	1.955 c
T_3	With	1.325 c	0.795 cd	0.177 c	2.297 c
	Without	0.615 d	0.595 d	0.165 c	1.375 d
LSD at 0.05		0.263	0.352	0.138	0.491

Table V. Effect of tillage time and plastic mulch on fruit number of okra grown under rain-fed conditions

Tillage time*	Black plastic mulch	Fruit number (1000 ha^{-1})			
		Early	Mid	Late	Total
T_1	With	303.6 a	458.1 a	209.2 a	971.3 a
	Without	130.2 c	197.0 bc	81.1 c	407.8 c
T_2	With	236.3 b	237.7 b	91.7 b	565.3 b
	Without	133.9 c	154.7 d	51.4 c	333.3 d
T_3	With	200.6 b	162.2 cd	50.9 c	413.8 c
	Without	109.0 c	127.4 d	43.6 c	279.5 d
LSD at 0.05		48.52	42.02	38.50	57.28

Table VI. Effect of tillage time and plastic mulch on average fruit weight of okra grown under rain-fed condition

Tillage time*	Black plastic mulch	Average fruit weight (g)			
		Early	Mid	Late	Total
T_1	With	7.078 a	5.18 a	4.09 a	5.59 a
	Without	6.667 a	4.92 a	3.94 ab	5.36 a
T_2	With	7.033 a	5.11 a	3.57 ab	5.67 a
	Without	6.233 a	5.04 a	3.36 b	5.34 a
T_3	With	6.511 a	4.89 a	3.47 ab	5.47 a
	Without	6.122 a	4.56 a	3.91 ab	5.07 a
LSD at 0.05		NS	NS	0.635	NS

DISCUSSION

The present results indicated that non-mulched plots had the lower SMC than BP mulched plots. It means that BP mulch prevents soil water evaporation and thus helps in retaining soil water. The combination of mulching with tillage in conserving soil moisture has been recognized by many researchers (Grevers *et al*., 1986; Bhagat & Acharya, 1987; Sarkar & Singh, 2007; Pervaiz *et al.*, 2009). According to Ramakrishna *et al*. (2006), evaporation from soil accounts for 25-50% of the total quantity of water used. Mulch prevents soil water evaporation and thus helps retain soil moisture (Ramakrishna *et al*., 2006). The results of the present study showed that the amount of moisture stored in the profile to a soil depth of 30 cm was significantly greater under BP mulch over bare soil. Similar trend was evaluated at 60 and 90 days after planting, while the difference in soil moisture storage was reduced. These findings are in accordance with Ramakrishna *et al*. (2006), who reported that optimum soil moisture ensures good emergence and seedling growth during early and mid season. According to

Sharma *et al*. (1990) higher moisture status increased root proliferation and thus enhanced availability of nutrients to crop roots. These figures also imply that greater moisture availability to mulched crop during the growing season helped to cope better with drought in mid and late season drought. Kouwenhoven *et al*. (2002) reported that shallow ploughing was generally associated with higher moisture content. Also they reported that water use efficiency was enhanced with mulching, but the response was more pronounced under reduced ploughing depth. The surface mulch favourably influences the soil moisture regime by controlling evaporation from the soil surface (Pawar *et al*., 2004; Adekalu *et al*., 2008) and facilitates condensation of soil water at night due to temperature reversals (Tisdall *et al*., 1991). Mulches also promote crop development, early harvest and increase yields as found by Adekalu *et al.* (2008). Observations on plant growth showed that the okra plants in polythene mulched plots were generally tall, more vigorous, more branches and reached 50% flowering 3 - 6 days earlier than in the un-mulched plots. These results were agreed with those results obtained by Olabode *et al.* (2007). The more favourable soil environment under the polythene, especially during the early part of the growing season, resulted in increased number of fruits per plant, average fruit weight and fruit yield/ha.

Jones (2000) and Jones and Sing (2000) pointed out tillage benefits are directly related to soil moisture conservation and available moisture during the growing season. Certain tillage management practices could improve some soil physical properties and soil fertility and increase the conservation of soil moisture (Abu-Hammad & Battikhi, 1995). Tilled three times have increased soil water content and crop resistance to drought. These results are agreed with Wang Zhongqing *et al*. (1995), who also reported that increased soil water content and crop resistance to drought are due to loose soil, increase soil small openings, increase pervious water content and decrease surface rain run-off. This is an indication that tillage influenced water storage in the soil and when this was combined with the fact that BP mulch reduced evaporation loss, the result is better environment for the crop. Plastic-film mulch not only increased soil temperature, which is beneficial to plants at the early stages of crop growth, but more importantly, it reduced evaporation losses thereby conserving soil moisture, which improved crop growth and development in dry and semi-dry conditions.

In conclusion, thrice tilling of soil resulted in higher vegetative growth and yield compared with other tillage treatments. Covering the soil surface with BP mulch enhanced vegetative growth and yield of okra compared with bar soils. From the present study we can recommend the farmers under these conditions to till the soil three times and using black plastic mulch as soil covering to produce higher okra yield through maintain soil moisture content.

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