Potentiality of Wheat Productivity as Affected By Crop Rotations and Tillage Systems under Rainfed Conditions at Matrouh, Egypt

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ABSTRACT

Three field experiments were conducted during the three successive winter rainfall seasons of 2004 / 2005, 2005 / 2006 and 2006/ 2007 at El-Garawla (24 km east of Marsa Matrouh city) at the Northwest coastal zone of Egypt to find out the effect of tillage systems; i.e., limited tillage (LT), conservation tillage (CT) and traditional tillage (TT), and crop rotations; i.e., wheat after wheat (W/W), wheat after barley (W/B), wheat after fallow (W/F) and wheat after vetch (W/V), on bread wheat (*Triticum aestivum* L.) productivity under rainfed conditions. The field experiments were first established in the 2003/ 2004 season.

Concerning tillage systems effect, it could be concluded that TT system achieved the highest values of most wheat grain yield and its attributs, as well as water use efficiency (WUE), as compared with the lowest ones by LT system overall seasons. Furthermore, TT and CT systems were equal in their effects without significant differences on wheat yields, as well as WUE in the first two seasons. However, TT system overestimated the other two tillage systems for yield traits and WUE, according to rainfall amount and its distribution in the latter season (2006/ 2007). The results, also, revealed the superiority of W/ V rotation in grain yield and its attributes of wheat, as well as WUE, as compared with the other tried crop rotations during the three seasons. While, W/W and W/B rotations were similar, without significant differences in recording the lowest wheat yields and WUE overall seasons. In the meantime, results showed that W/ V rotation gave the highest wheat yields and WUE when TT system was applied, while, the lowest ones were recorded from W/W and/ or W/B rotations with application of LT system overall seasons. However, there were insignificant differences between W/ V and W/ F rotations in wheat yields and WUE when TT or CT system was applied during the two first seasons that received a low amount of rainfall. Generally, under the adverse conditions of rainfed areas, potentiality of wheat production might be enhanced by sowing in a two-course rotation; i.e., after a leguminous forage, such as adapted common vetch, followed by fallow summer season, particularly, with application of traditional or conservational tillage systems.

Key words: Crop rotations, tillage systems, limited tillage, conservational tillage, traditional tillage, water use efficiency, wheat yield attributes.

INTRODUCTION

Rainfed agriculture in Egypt occupies 2 to 3% of total agricultural area, mainly in the Northwest coastal (NWC) zone, Sinai and in the Southeast corner. Although this may not appear significant in relation to the total irrigated areas, but, it is important to local communities and economics and to the national security. The poorest households are living in such these areas. Better management would contribute to the conservation of natural resources and better sustain the livelihood of local communities. These are important objectives of government of Egypt. The rainfed areas of the NWC are characterized by fragile farming systems. There are several principal physical, biotic and socioeconomic constraints to agricultural sustainable development. The major constraint for wheat production, under rainfed conditions in the NWC, is the insufficient soil moisture content to meet crop water requirements. Therefore, the physical limitations of land and water resources indicate that horizontal expansion of wheat growing is a limited option in such rainfed areas.

Farmers in the NWC are making pressure on available land in the time of low level of mechanization and risky rainfall seasons. These farming systems seem to be vulnerable to continuous degradation environmental conditions (MRMP, 2002). Indigenous conservation tillage systems are prevalent in areas with water-deficit conditions. A traditional tillage practice has led to advanced soil erosion, which has decreased crop productivity and led to decline opportunities for sustainable development. Direct seeding in dry soil is widely used in the NWC. The technique consists of handle broadcasting the seeds in dry soil and covered with one chisel plowing (15 cm depth), using a tractor before rainfall precipitation. This practice is carried out by farmers in order to meet their production objectives rather than protecting the soil from hazards, as disturbed soil surface is exposed to wind erosion, which may occur before rainfall precipitation. Tillage practices may have direct or indirect impact on plant growth. Conservation tillage practices are very important in arid and semi-arid zones, where water is the limiting factor for crop development under rainfed conditions (Bond *et al.*, 1971; Wilhelm *et al.* 1982; Wilhelm *et al.*, 1989 and Wilhelm, 1998).

The cultural practices in the NWC are conventional, without mineral fertilizers or a planned crop rotation system. Under rainfed conditions, wheat is usually grown after summer fallow. Sheep and goats manure is the only available source of organic matter, where it cannot provide enough nutrients to sustain yield production, particularly, the conventional mono-cropping system. Many studies concluded that crop rotations, especially cereal – legum, rotations and biological nitrogen fertilizers were effective in rainfed areas to safeguard production, reduce chemical use, help to protect the environment and attain sustainability (Karaca *et al.*, 1991). Leguminous crops provide nitrogen for subsequent cereals in the crop rotations (Reeves, 1991; Papastylianou and Panayiotou, 1993). Under rainfed conditions at Syria, Pala (1994) reported that total production of biomass and protein was only marginally reduced if vetch was grown with barley in the two-course rotation, but, in comparison between barley-leguminous fodder rotations and barley-fallow rotations, he found a large advantage in favor of the legume rotations. Under rainfed conditions in the NWC of Egypt, Moselhy (1999) found that barley-vetch rotation gave higher in performance and was economically more than rotation with pulse crops under lower rainfall precipitation at the NWC of Egypt.

The present study was aimed to find out the optimum tillage system and suitable crop rotation, which could sustain wheat productivity under rainfed conditions. Also, to show the main advantages derived from the two-course crop rotations on wheat performance and to formulate recommendations in order to improve farming systems in the NWC of Egypt.

MATERIALS AND METHODS

Three field experiments were carried out under rainfed conditions at El-Garawla (24 km east of Marsa Matrouh city) at the NWC of Egypt, during the 2004 / 2005, 2005 / 2006 and 2006/ 2007 winter growing seasons, This study aimed to investigate the effect of different tillage systems and crop rotations on grain yield and its components of wheat. The applied treatments were the three tillage systems, limited tillage (LT), conservation tillage (CT) and traditional tillage (TT), as well as the four crop rotations; wheat after wheat (W/W), wheat after barley (W/B), wheat after fallow (W/F) and wheat after vetch (W/V). The field experiments were first established in the 2003/ 2004 season, where the plots of vetch, barley and wheat were sown as preceding crops and plots were left as fallow without planting.

The sowing date was done after the first effective rainfall precipitation on November 10th, 15th and 17th for the first, second and third seasons, respectively. Where, common wheat seeds (***Triticum aestivum*** L.) of Giza 168 cv. were used at the rate of 35 Kg/fad (one faddan equals 4200 m^2). Seeds of common vetch (*Vicia monantha* L.) were treated with soaking in warm water (50 C°) for 12 hours before sowing, as a preceding crop, with a seeding rate of 40 Kg/ fad. Chisel disc plowing was made at 15 cm depth to prepare the seed beds. Harvest was carried out on May 7th, 12th and 15th in the first, second and third seasons, respectively.

The soil of these trials was loamy-sand in texture, >1.5 m depth, which was called Nous in Bedouin terminology, it had 0.022 – 0.025 % available nitrogen, 16-23 ppm phosphorus and high Ca Co_3 content (22 – 25 %).

The general average of rainfall in the NWC is 140 mm / year (mean for last ten years). However, the amount of rainfall precipitated (manual rain cages) were 91.0, 95.7 and 211.0 mm / year in the first, second and third season, respectively. It is noticed that the amounts of rain during the first two seasons were lower than the general average. However, the third season received the highest amount of rainfall precipitation, as shown in Fig. (1).

The experiments were laid out in a strip-spilt plot design, with four replicates. The tried tillage systems were allocated in the main plots, while, crop rotations were allocated in the sub-plots. Each sub-plot area was 100 m^2 (5 m wide x 20 m long).

At harvest time, 75 m^2 from each sub-plot were used to determine grain yield attributes, as well as grain, straw and biological yields. Water use efficiency (WUE) for grain production per mm of rain water was calculated. The collected data were statistically analyzed, according to Snedecor and Cochran (1967). Duncan's multiple range test was used for comparison among means (Duncan, 1955).

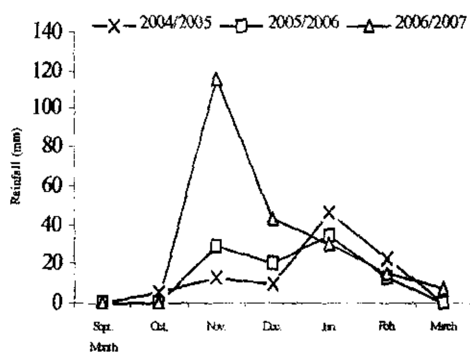

Fig. 1: Monthly rainfall distribution (mm) during the three winter seasons of the study.

RESULTS AND DISCUSSION

A. Grain yield attributes:

A. 1. Effect of tillage systems:

Data presented in Table 1 showed that there were significant differences among different tillage systems in the three seasons of study. It is evident that the applied tillage systems had significant effects on plant height, numbers of tillers and spikes/m^2, spike length and number of grains/ spike in favor of traditional tillage (TT) system in the three seasons. However, 1000-grain weight was not significantly affected by different tillage systems overall seasons. Moreover, the results confirmed the superiority of TT system, followed by conservational tillage (CT) system, compared to limited tillage (LT) system in such traits in the first season. Meanwhile, TT and CT systems were similar without significant differences, having the tallest plants, much numbers of tillers and spikes/ m^2, as well as longer spikes and much number of grains/ spike in the second and third seasons. It was clear that, in the case of good distribution and higher rainfall during the winter seasons, as occurred in the third and second seasons, there were no significant differences between TT and CT systems in having the highest values of the above mentioned traits, as compared with the case of the first season, which had received lower rainfall, where TT system surpassed the other two tried tillage systems in all grain yield attributes herein. However, LT system recorded the lowest values of all traits, during the three seasons of study. At the NWC of Egypt, Moselhy (2010) concluded that traditional or conservational tillage systems produced the highest values of grain yield attributes of wheat and barley under rainfed conditions.

A. 2. Effect of crop rotations:

As shown in Table 1, results indicated that crop rotations had significantly affected the grain yield attributes of wheat in the three seasons, except for 1000-grain weight throughout the latter two seasons. Wheat after vetch (W/V) rotation produced the highest values of plant height, numbers of tillers and spikes/ m^2, as well as spike length and number of grains/ spike throughout the three seasons. The case was the same for 1000-grain weight only in the first season. Nevertheless, the lowest values of these traits were recorded either by applying continuous wheat plantation system (W/W) or by wheat/ barley (W/B) rotation. Generally, the performance of different crop rotations for grain yield attributes of wheat was significantly different, depending on the preceding crop and rainfall precipitation overall growing seasons. In the meantime, the superiority of wheat grain yield attributes, in the case of B/ V rotation over the other tried crop rotations might be due to the fact that fixed nitrogen by legume plants, as a preceding crop, was used by subsequent wheat plants. Generally, this might led to the accumulation of fixed nitrogen and improvement of organic matter by legumes. Also, leguminous crops provide nitrogen for subsequent cereal crops in crop rotations (Reeves, 1991; Papastylianou and Panayiotou, 1993).

A. 3. Effect of interactions:

Analyzed data indicated that there were significant effects of the interaction between the studied tillage systems and crop rotations for plant height, number of tillers/ m^2, number of spikes/m^2, spike length and 1000-grain weight, while, number of grains/spike was not significantly affected. This was clear only in the third season. However, there were no significant effects on all grain yield attributes throughout the first two seasons (Table 1).

Results in Table 2 showed that the tallest wheat plants were obtained when W/ V and/ or W/F rotations were applied under tried traditional tillage (TT) or conservational tillage (CT) systems without significant differences, while, the shortest plants were produced by continuous wheat planting when limited tillage (LT) system was applied. The case was the same for number of spikes/ m^2. Meanwhile, the largest number of tillers/ m^2 and longest spikes were recorded by applying W/V and W/F at par without significant differences when TT system was applied, followed by CT system, while, the lowest spike number/ m^2 and the shortest spikes were recorded by W/ W rotation under the application of LT system. In reverse, the application of either W/W or W/B rotation, with limited tillage system, gave the heaviest 1000- grain weight, while, the lightest one was recorded by applying W/V and/or W/F rotation with TT system. This might be due to its efficiency to produce much number of spikes/ m^2 and more grains/spike. These results are in harmony with those observed under rainfed conditions of the NWC of Egypt by Abdel Aleem and Sabry (1994) and Moselhy (1999).

B. Wheat grain yields and water use efficiency:

B. 1. Effect of tillage systems:

Data in Table 3 showed that the tried tillage systems had significant effects on grain, straw and biological yields, as well as water use efficiency (WUE), except for harvest index overall seasons. In the meantime, traditional tillage system gave the highest values of wheat grain yield trait and the highest efficiency of rain water use throughout the three growing seasons. Meanwhile, TT and CT systems were similar in their effects on wheat grain yield and WUE during the first and second seasons, but, in the third season, TT system surpassed the other two tillage systems. This might be due to the amount and distribution of rainfall precipitation that occurred in the latter season. However, limited tillage system recorded the lowest values of the above mentioned traits in the three seasons. These results are in harmony with those obtained by Moselhy (2010).

Table 1: Effect of tillage systems and crop rotations on wheat grain yield attributes during the three seasons.

Main effects and interactions	Plant height (cm)	No. of tillers/ m^2	No. of spikes/ m^2	Spike length (cm)	No. of grains/ spike	1000-grain wt. (g)
Tillage systems (T):			2004/2005			
LTS	48.6 c	205.3 c	158.1 c	4.94 c	23.02 c	26.03
CTS	51.7 b	208.4 b	160.2 b	5.36 b	24.56 b	26.61
TTS	52.7 a	211.1 a	162.4 a	5.79 a	25.85 a	27.01
F. test	*	*	*	*	*	N.S
Crop rotations (R):						
W/W	45.2 c	196.6 b	145.1 d	4.68 d	22.41 c	24.89 b
W/B	45.6 c	198.5 b	146.4 c	4.78 c	22.71 b	25.08 b
W/F	55.7 b	218.2 a	173.9 b	5.96 b	26.30 a	28.02 a
W/V	57.6 a	219.8 a	175.0 a	6.04 a	26.49 a	28.22 a
F. test	*	*	*	*	*	*
Interaction:						
T x R	N.S	N.S	N.S	N.S	N.S	N.S
Tillage systems (T):			2005/2006			
LTS	48.7 b	203.9 b	158.3 b	4.92 b	23.8 b	25.23
CTS	52.2 a	208.2 a	161.6 a	5.58 a	24.68 a	24.75
TTS	52.4 a	208.3 a	160.1 a	5.72 a	25.06 a	24.91
F. test	*	N.S	*	*	*	N.S
Crop rotations (R):						
W/W	45.1 c	196.2 c	143.8 c	4.69 c	22.17 c	25.05
W/B	46.0 c	198.8 b	148.8 b	4.82 b	22.57 b	24.94
W/F	55.9 b	214.8 a	172.7 a	6.05 a	26.11 a	24.93
W/V	67.3 a	217.3 a	174.8 a	6.08 a	26.23 a	24.93
F. test	*	*	*	*	*	N.S
Interaction:						
T x R	N.S	N.S	N.S	N.S	N.S	N.S
Tillage systems (T):			2006/2007			
LTS	69.9 b	214.6 b	164.3 b	5.14 b	25.18 b	25.28
CTS	74.0 a	235.3 a	169.9 a	6.24 a	26.61 a	24.40
TTS	74.6 a	238.2 a	169.7 a	6.29 a	26.76 a	24.05
F. test	*	*	*	*	*	N.S
Crop rotations (R):						
W/W	65.2 c	208.8 d	150.5 d	5.08 c	24.62 d	25.55
W/B	65.8 c	210.1 c	151.6 c	5.15 b	24.82 c	25.33
W/F	79.4 b	248.0 b	184.1 b	6.52 a	27.30 b	25.78
W/V	81.0 a	250.6 a	185.6 a	6.55 a	27.53 a	25.63
F. test	*	*	*	*	*	N.S
Interaction:						
T x R	*	*	*	*	N.S	*

*: Significant at 0.05 level of probability, values followed by similar letters are not significantly different at $P < 0.05$ by Duncan's multiple range test, N.S: Not significant.

Table 2: Some grain yield attributes of wheat as affected by the interaction between tillage systems and crop rotations in 2006/ 07 season.

Tillage system	Crop rotation	Plant height (cm)	No. of tillers/ m^2	No. of spikes/ m^2	Spike length (cm)	1000-grain wt. (g)
LT	W/W	63.2 e	199.3 g	147.0 f	4.43 g	26.40 a
	W/B	64.2 de	200.5 g	149.0 e	4.60 f	26.30 a
	W/F	74.5 c	227.0 d	179.0 c	5.75 c	24.30 ef
	W/V	77.6 b	231.8 c	182.0 b	5.80 c	24.10 f
CT	W/W	65.5 de	212.3 f	152.5 d	5.25 e	25.50 b
	W/B	65.8 de	214.3 ef	153.8 d	5.30 e	25.20 c
	W/F	81.9 a	256.5 b	186.0 a	6.78 b	23.50 g
	W/V	83.0 a	258.3 b	187.3 a	6.83 b	23.40 g
TT	W/W	66.9 d	215.0 e	152.0 d	5.55 d	24.75 d
	W/B	67.3 d	215.5 e	152.0 d	5.55 d	24.50 de
	W/F	81.8 a	260.5 a	187.3 a	7.03 a	23.55 g
	W/V	82.3 a	261.8 a	187.5 a	7.03 a	23.40 g

Values followed by the same letters are not different at $P < 0.05$ by Duncan's multiple range test.

B. 2. Effect of crop rotations:

As shown in Table 3, there were significant differences among crop rotations in favor of W/V rotation, followed by W/F rotation overall seasons. In the meantime, the obtained data indicated that the tried crop rotations had significant effects on grain, straw and biological yields, as well as water use efficiency (WUE), except for harvest index in the three seasons. Moreover, results showed that the highest grain, straw and biological yields, as well as WUE were recorded by W/V rotation, followed by W/ F rotation, but, the lowest ones were recorded by W/W and/or W/B rotations at par without significant differences. This might be due to the harmful effect of continuous planting of cereal crops on soil fertility rather th.n the effect of rainfall precipitation. During the three seasons, rain water was used in grain production of wheat more efficiently with applied W/V rotation, compared to W/W and W/B rotations, which gave the similar lowest values. Generally, the performance of different crop rotations tried here for grain yield of wheat was significantly different, depending on the preceding crop overall growing seasons. These results are in harmony with those obtained by Pala (1994), Christiansen *et al* (1994), Moselhy (1999) and Angas *et al* (2003). In this respect, Pala (1994), investigating water use efficiency by barley in rotation with vetch and fallow under rainfed conditions in Syria, found that barley following green grazed vetch utilized 11 mm of rain water more than barley following mature-harvested vetch. Also, Harris (1989) found that soils stored very little water from a winter fallow over the summer for the next crop in the crop rotation.

Table 3: Effect of tillage systems and crop rotations on grain, straw and biological yields as well as harvest index and water use efficiency (WUE) in the three seasons.

Main effects and interactions	Grain yield (Kg/ fad)	Straw yield (Kg/ fad)	Biological (Kg/ fad)	Harvest index (%)	WUE (Kg grains/ mm)
Tillage systems (T):			2004/2005		
LT	403.2 b	790.3 b	1193.5 b	33.86	4.24 b
CT	450.6 a	894.2 a	1344.7 a	33.75	4.74 a
TT	451.0 a	901.6 a	1352.6 a	33.63	4.75 a
F. test	*	*	*	N.S	*
Crop rotations (R):					
W/W	330.3 c	625.4 c	955.7 c	34.55	3.48 c
W/B	333.4 c	635.1 c	968.8 c	34.43	3.51 c
W/F	534.4 b	1067.5 b	1601.9 b	33.37	5.63 b
W/V	541.6 a	1120.2 a	1661.8 a	32.65	5.70 a
F. test	*	*	*	N.S	*
Interaction:					
T x R	*	*	*	N.S	*
Tillage systems (T):			2005/2006		
LT	402.4 b	797.4 b	1199.8 b	33.55	4.21 b
CT	452.8 a	897.8 a	1350.5 a	33.72	4.73 a
TT	453.1 a	904.4 a	1357.4 a	33.63	4.73 a
F. test	*	*	*	N.S	*
Crop rotations (R):					
W/W	330.9 c	636.2 c	967.1 c	34.21	3.46 c
W/B	334.0 c	642.8 c	976.9 c	34.18	3.49 c
W/F	536.0 b	1066.2 b	1602.2 b	33.45	5.60 b
W/V	543.4 a	1120.8 a	1664.2 a	32.68	5.68 a
F. test	*	*	*	N.S	*
Interaction:					
T x R	*	*	*	N.S	*
Tillage systems (T):			2006/2007		
LT	524.3 c	923.9 c	1448.2 c	36.14	2.49 c
CT	566.7 b	1014.6 b	1581.3 b	35.82	2.69 b
TT	578.3 a	1078.7 a	1656.9 a	35.04	2.74 a
F. test	*	*	*	N.S	*
Crop rotations (R):					
W/W	430.8 c	778.5 c	1209.3 c	35.62	2.04 c
W/B	436.0 c	782.4 c	1218.4 c	35.80	2.07 c
W/F	675.8 b	1225.3 b	1901.1 b	35.60	3.20 b
W/V	683.1 a	1236.7 a	1919.8 a	35.63	3.24 a
F. test	*	*	*	N.S	*
Interaction:					
T x R	*	*	*	N.S	*

*: Significant at 0.05 level of probability, values followed by similar letters are not significantly different at $P < 0.05$ by Duncan's multiple range test, N.S: Not significant.

C. 3. Effect of interactions:

Data of the study clearly indicated that there were significant effects of the interaction between tillage systems and crop rotations on grain, straw and biological yields, as well as water use efficiency for grain production in the three seasons (Table 3). Results presented in Table 4 showed that the highest grain yield was produced when W/ V and/ or W/ F rotations were applied with traditional or conservational tillage systems at par without significant differences in the first and second seasons. However, under high rainfall precipitation, as occurred in the third season, the highest grain yield was produced from the last two tried crop rotations (W/ V and W/ F) without significant differences only with the application of TT system. In the sametime, the highest straw and biological yields were obtained when W/ V rotation was applied under the conditions of tried TT or CT systems at par without significant differences in the first and second seasons. However, in the case of the third season, which had received the highest rainfall precipitation, the highest values of both yields were produced by W/ V and/ or W/ F rotations, without any significant differences when traditional tillage system was applied. Meanwhile, the lowest grain yields of wheat were recorded when W/ W and/ or W/ B were applied, with application of limited tillage system throughout the three seasons.

Table 4: Grain, straw and biological yields of wheat and water use efficiency (WUE) as affected by the interaction between tillage systems and crop rotations in the three seasons.

Tillage system	Crop rotation	Grain yield (Kg/ fad)	Straw yield (Kg/ fad)	Biological yield (Kg/ fad)	WUE (Kg grains/ mm)
		2004/ 2005			
LTS	W/W	304.1 e	586.5 e	890.6 e	3.20 e
	W/B	307.9 e	591.8 e	899.7 c	3.24 e
	W/F	496.0 c	982.0 c	1478.0 c	5.22 c
	W/V	504.9 b	1001.0 c	1505.9 c	5.31 b
CTS	W/W	342.8 d	644.0 d	986.8 d	3.61 d
	W/B	345.5 d	656.3 d	1001.8 d	3.64 d
	W/F	553.8 a	1108.8 b	1662.5 b	5.83 a
	W/V	560.3 a	1167.8 a	1728.0 a	5.90 a
TTS	W/W	344.0 d	645.8 d	989.8 d	3.62 d
	W/B	346.8 d	657.3 d	1004.0 d	3.65 d
	W/F	553.5 a	1111.8 b	1665.3 b	5.83 a
	W/V	559.8 a	1191.8 a	1751.5 a	5.89 a
		2005/ 2006			
LTS	W/W	303.0 e	599.5 e	902.5 e	3.17 e
	W/B	306.4 e	602.8 e	909.1 c	3.20 e
	W/F	494.9 c	981.8 c	1476.6 c	5.17 c
	W/V	505.5 b	1005.5 c	1511.0 c	5.28 b
CTS	W/W	344.3 d	653.3 d	997.5 d	3.60 d
	W/B	347.0 d	662.8 d	1009.8 d	3.65 d
	W/F	557.0 a	1107.8 b	1664.8 b	5.82 a
	W/V	562.8 a	1167.3 a	1730.0 a	5.88 a
TTS	W/W	345.5 d	655.8 d	1001.3 d	3.61 d
	W/B	348.8 d	663.0 d	1011.8 d	3.65 d
	W/F	556.0 a	1109.3 b	1665.3 b	5.81 a
	W/V	562.0 a	1189.5 a	1751.5 a	5.87 a
		2006/ 2007			
LTS	W/W	413.3 j	743.5 g	1156.8 g	1.96 i
	W/B	419.0 i	745.0 g	1164.0 g	1.99 i
	W/F	623.8 d	1089.8 d	1713.5 d	2.96 d
	W/V	641.0 c	1117.5 c	1758.5 c	3.04 c
CTS	W/W	433.5 h	784.0 f	1217.5 f	2.06 h
	W/B	439.0 g	789.5 f	1228.5 f	2.08 g
	W/F	696.0 b	1240.0 b	1936.0 b	3.29 b
	W/V	698.5 b	1244.8 b	1943.3 b	3.31 b
TTS	W/W	445.8 f	808.0 e	1253.8 e	2.11 f
	W/B	450.0 e	812.8 e	1262.8 e	2.13 e
	W/F	707.5 a	1346.3 a	2053.8 a	3.35 a
	W/V	709.8 a	1347.8 a	2057.5 a	3.36 a

Values followed by the same letters are not significantly different at $P < 0.05$ by Duncan's multiple range test.

Ultimately, it was evident that wheat plants used rain water efficiently for grain production when it was planted in crop rotation after vetch and/ or after fallow with the application of traditional and/ or conservational tillage systems at par without significant differences. This was true in the first and second seasons, since low rainfall precipitation was received. On the other side, under highly rainfall precipitation, as occurred in the third season, the highest WUE for grain production of wheat resulted from crop rotations of W/ V and W/ F, without significant differences with the application of traditional tillage system. While, the lowest values of WUE were recorded by W/ W and/ or W/ B rotations with the application of limited tillage system (Table 4). These results are in harmony with those observed under rainfed conditions of the Mediterranean region by Oweis *et al* (1999), Turner (2004), Wang *et al* (2005), Al-Issa and Samarah (2006), Cook (2006) and Moselhy (2010).

CONCLUSIONS

The present results of this study concluded that, under the adverse conditions of rainfed areas, wheat could be sown in crop rotation after a leguminous forage, such as the adapted common vetch, followed by fallow summer season or after fallow of winter and summer seasons. Potentiality of wheat production under these conditions might be enhanced by using traditional or conservational tillage systems during the promising rainfall seasons, particularly, with the suitable crop rotation.

REFFERENCES

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الملخص العربى

القدرة الانتاجية للقمح وتأثرها بالدورات الزراعية ونظم خدمة الأرض تحت ظروف الزراعة المطرية بمطروح- مصر

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أجريت ثلاث تجارب حقلية تحت ظروف الزراعة المطرية بمنطقة الجراولة (٢٤ كم شرق مدينة مرسى مطروح) بمحافظة مطروح – مصر خلال ثلاث مواسم شتوية مطرية (٢٠٠٤/٢٠٠٥ ، ٢٠٠٥/٢٠٠٦ ، ٢٠٠٦/٢٠٠٧) على التوالى . وبدأت الدراسة بانشاء الدورات الزراعية فى الموسم السابق لبدء التجارب (٢٠٠٣/٢٠٠٤). وذلك بهدف دراسة تاثير الدورات الزراعية (قمح بعد قمح ـــ قمح بعد شعير ـــ قمح بعد بور قمح بعد بقيا) ونظم خدمة الأرض (خدمة محدودة- خدمة صيانة – خدمة تقليدية) على القدرة الانتاجية لمحصول قمح الخبز. وقد أظهرت النتائج ما يلى:

- أعطى نظام الخدمة التقليدية (TT) أعلى القيم لمعظم صفات محصول الحبوب ومكوناته ، وكذا كفاءة استخدام مياه الأمطار فى انتاج الحبوب مقارنة بنظام الخدمة المحدودة (LT) خلال الثلاث مواسم.
- أيضا أظهرت النتائج أنه لم يكن هناك فرق معنوى بين نظامى الخدمة التقليدية (TT) وخدمة الصيانة (CT) فى محصول الحبوب والقش والمحصول البيولوجى وكذا كفاءة استخدام مياه الأمطار خلال الموسمين الأول والثانى، بينما تفوق نظام الخدمة التقليدية (TT)على باقى نظم الخدمة فى هذه الصفات خلال الموسم الثالث، وقد يعزى ذلك الى اختلاف كمية وتوزيع الأمطار خلال الثلاث مواسم. كذلك لم يكن هناك تأثير معنوى لنظم الخدمة على دليل الحصاد.
- تفوقت الدورة الزراعية "قمح بعد بقيا" على باقى الدورات تحت الدراسة واعطت أعلى القيم فى معظم صفات محصول الحبوب ومكوناته وكذا كفاءة استخدام مياه الأمطار ، بينما سجلت الزراعة المستمرة للقمح وزراعة القمح بعد الشعير أقل القيم لمحصول الحبوب والقش والمحصول البيولوجى وكفاءة استخدام المياه ، وبدون فرق معنوى بينهما خلال المواسم الثلاث.

- أظهرت نتائج التفاعل بين نظم خدمة الأرض والدورات الزراعية أن الدورة الزراعية "قمح بعد بقيـا (W/ V)" أعطت أعلى انتاجية من الحبوب والقش والمحصول البيولوجي وكفاءة استخدام المياه عندما تـم تطبيـق نظـام الخدمة التقليدية (TT) ، بينما سجلت الزراعة المستمرة للقمح فى حالة تطبيق نظام الخدمة المحدودة (LT) أقـل انتاجية للقمح وأقل القيم لكفاءة استخدام المياه ، وكان ذلك جليا خلال المواسم الثلاث.
- لم يكن هناك فرق معنوى بين الدورة الزراعية "قمح بعد بقيا (W/V)" و"قمح بعد بور (W/F)" فى انتاج الحبوب وكفاءة استخدام المياه عند تطبيق نظامى الخدمة التقليدية و خدمة الصيانة بدون فـرق معنـوى ايـضاً خـلال الموسمين الأول والثانى المنخفضين فى معدلات الأمطار، بينما أعطت هاتين الدورتين (W/V & W/F) أعلـى انتاجية لمحصول الحبوب وكذا كفاءة استخدام المياه فى حالة تطبيق نظام خدمة الصيانة (TT) فقط خلال الموسم الثالث الذى تميز بزيادة معدل الهطول المطرى.
- يستنتج من هذه الدراسة انه يمكن زراعة القمح (زراعة مطرية) فى دورة زراعية ثنائية بعد بقيـا فـى الموسـم الشتوى ثم بور صيفا ، أو الزراعة بعد بور مع تطبيق نظام خدمة الصيانة (الحرث سكة واحدة بعد سقوط المطر الفعال ثم نثر التقاوى ثم التغطية بالحرث سكة أخرى متعامدة على الأولى). وهذا قد يساهم فى استدامة المـوارد الأرضية وعدم تدهورها والاستغلال الأمثل لمياه الأمطار فى مناطق الزراعة المطريـة ذات الـنظم المزرعيـة الهشة.