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Effect of Different Tillage and Fertilization Interventions on Wheat (*Triticum aestivum*) Production

Eyaas Abu-Rabada, Rezq Basheer-Salimia*

Department of Plant Production and Protection, College of Agriculture, Hebron University, P.O.Box 40, Hebron, Palestine

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Abstract Wheat (*Triticum aestivum*) is considered the main aspect of food security in the Middle-East including Palestine. This important crop testifies a sharp decline in its productivity due to many reasons including climate change and its consequences in particular. This study was carried out in the eastern slopes of Bethlehem governorate that are classified as arid to semi-arid areas in the growing season 2018/2019. The experiment was laid out in a factorial randomized block design, for the aim of investigating the effect of different tillage (conventional tillage (CT) and three conservation tillage systems, reduced tillage (RT), conservation tillage at 8 cm (C8) and conservation tillage at 4 cm depth (C4)). In addition to their combination with different fertilization types (sheep manure (M), tri-superphosphate (TSP) and ammonium sulfate (AS)) and ratios as the following (manure 6m^3/dunum ($M_{6m}{}^3$), manure 3m^3/dunum+ TSP 6.25 kg/dunum+ AS 6.25 kg/dunum ($M_{3m}{}^3/TSP_{6.25kg}/AS_{6.25kg}$), manure 3m^3/dunum+ TSP 12.5 kg/dunum ($M_{3m}{}^3/TSP_{12.5kg}$) and manure 3m^3/dunum+ AS 12.5 kg/dunum ($M_{3m}{}^3/AS_{12.5kg}$)) in addition to the control that was tilled without any fertilization treatments. Generally, our results revealed the superiority of the RT× $M_{6m}{}^3$ in term of grain yield production. On the other hands, RT× $M_{3m}{}^3/TSP_{12.5kg}$ is recommended to increase straw production. This short-term study is definitely not sufficient to reveal the impact of the examined tillage and fertilization practices, but it gives indicators for the possible effects of these practices that need more investigation on longer term.

Keywords *Triticum aestivum,* Drought, Tillage System, Fertilization, Yield, Palestine

1. Introduction

Wheat is considered the most important human food and the top used cereal worldwide. Its significance is not only raised from being human food, but also as animal fodder. In addition, the gluten and wheat starch are used in many industries such as food additives, baby foods, cosmetics etc. [1]. In Palestine, wheat grain is commonly used in the Palestinian cuisine for bread, freekeh, jresheh, burghul and some other products, in addition its straw is used as animal fodders [2]. In spite of this importance, wheat production in Palestine testifies a steep decline during the last decades [3,4], where wheat production has fallen by 46% between 2010 and 2018 [5]. Main reason beyond this deterioration is climate change particularly with regard to heat and drought [6,7], and their impacts on crop growth, development and production [8,4]. Indeed, plants are influenced variously according to the plant species, life stage and stress degree [9]. This influence manifests when heat and/or drought exceed the threshold levels and last for sufficient time to cause irreversible damage [10].

In general, wheat facing drought by different strategies and mechanisms including but not limited to morphological, anatomical, physiological, biochemical, and molecular modifications and changes [4]. In fact, these strategies are usually used jointly and complexly by the plant depending mainly on the plant species (genotypes) and the developmental stages [11].

Climate change impacts especially drought could be mitigated and adapted by improving drought tolerance species [12] which is a long-term process; increasing moisture storing capacity of soils [13]; and using appropriate soil management and soil amendments [14]. Since soil is the more manageable part, researchers manipulate the agricultural practices like tillage systems, mulch, sowing rate and fertilization to improve soil properties that lead to better water use efficiency and thus higher yield [10]. Indeed, suitable management of soil practices has proven to influence wheat production, in which minimal tillage operations as a mean of conservation agriculture revealed higher production and morphological traits over the conventional systems over the long-term [15,16]. Furthermore, soil amendment by means of organic and inorganic fertilizations is found to increase wheat productivity; however organic fertilizers (manure) are found also to improve soil health and decrease water pollution [17].

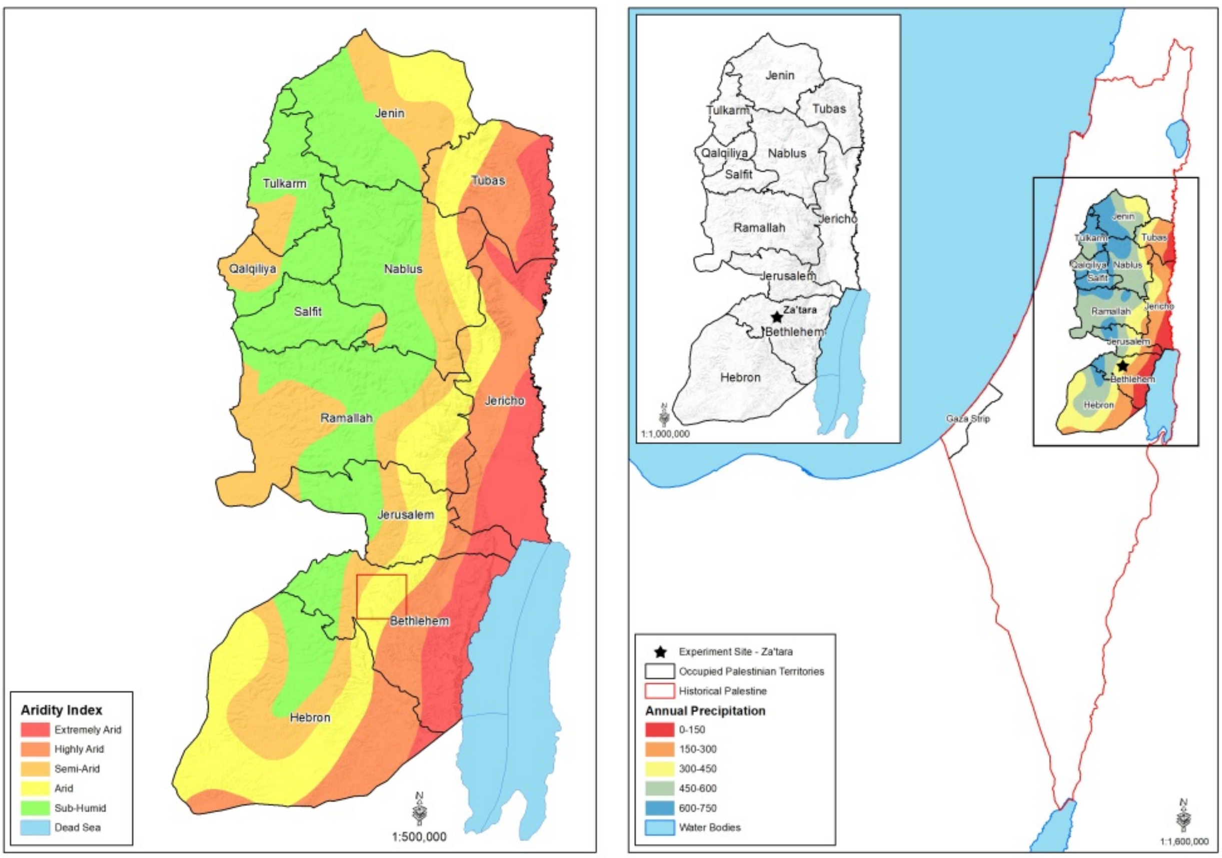
Here, different tillage operations (number and depth) as well as diverse fertilizations (organic and inorganic with different ratios) as a mean of conservation agriculture were studied to determine their effects on the productivity of wheat (var. Yellow Heteya) especially in semi-arid areas. This variety has been targeted since it showed superiority production [4], among the most common cultivable wheat genotypes grown in Palestine.

2. Materials and Methods

2.1. Site Description

2.1.1. Location

The experiment was taken place in Za'tara town in the eastern slopes of Bethlehem governorate at an altitude of 577m above sea level. Generally, the area is classified as semi-arid region (Figure 1).



Source: Land Research Center, GIS & remote sensing unit database

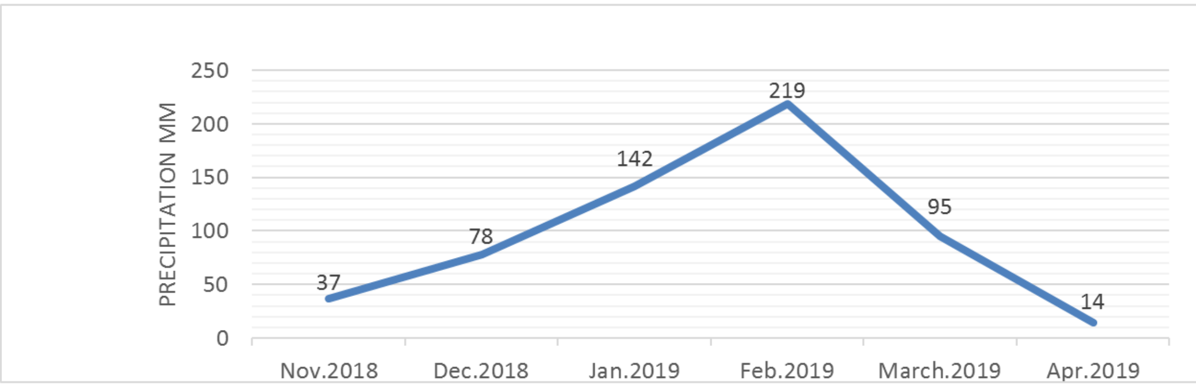
Figure 1. Maps showed the aridity index of targeted study site (the left) and the average annual precipitation (the right)

2.1.2. Soil Characteristics

Before plantation, soil sampling was conducted on October, 2018 via collecting 10 representative samples from 10–30 cm depth. Samples were then homogenized and subjected to different analyses that were conducted at the laboratory of soil and water, Hebron University. Soil texture has been determined by pipette method [18]. For macro element, total nitrogen analysis was achieved by Kjeldahl method [18], phosphorus and potassium by atomic absorption spectrophotometer [19]. Organic matter was analyzed by Walkley-Black method and acidity by pH meter and salinity by the electrical conductivity meter [20]. Soil moisture was analyzed by the drying method in the oven [18]. Soil analysis revealed clay-loamy texture (containing 34.76% clay content), neutral pH (pH=7.26), low organic matter content (1.38%), low salinity (EC= 0.249 ds/m), low phosphorus and nitrogen content (8.19 ppm and 0.119% respectively) and high potassium content (291.43 ppm).

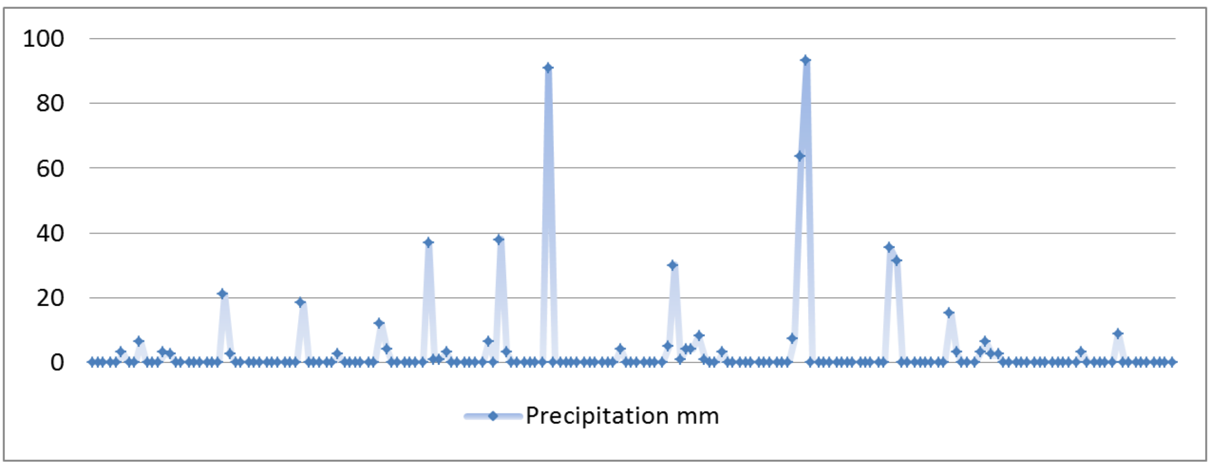
2.1.3. Climate

During the last decade, an average annual rainfall of about 390 mm is characterized the experimental area, however the total rainfall in the rainy season of 2018/2019 was exceptional with 621 mm and the peak was in February, 2019 (Fig. 2). Yet, uneven rainfall distribution and erratic precipitation characterized that season, but also the rain was fallen in 41 rainy days (Fig. 3) starting from Oct 25th, 2018 till April 21st, 2019. In addition, about 40% of the rain was fallen in three heavy raining days. During the growing season, minimum temperature was recorded in January 2019 with 8.1°C and maximum temperature was registered in April 2019 with 22.2°C (Fig. 4).



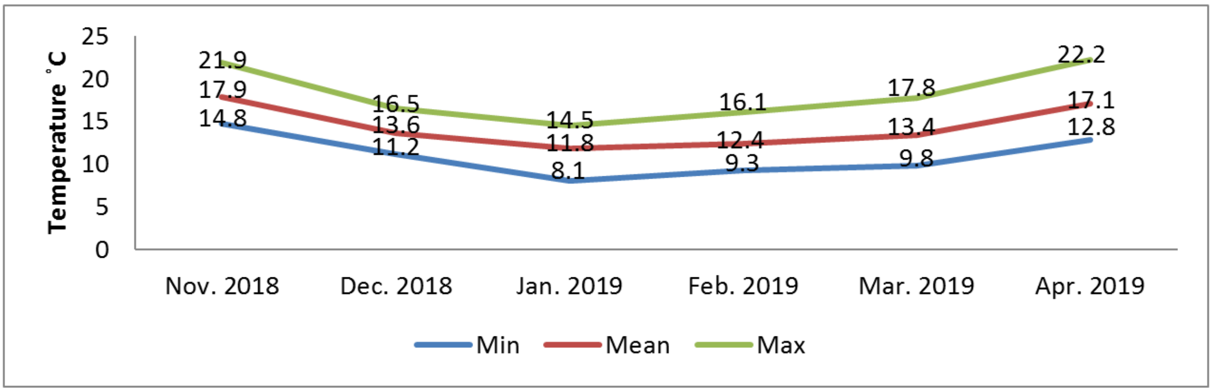
Source: Za'tara Secondary School rainfall monitoring station database

Figure 2. Monthly precipitation (mm) in the experimental area during November 2018 – April 2019



Source: Za'tara Secondary School rainfall monitoring station database

Figure 3. Daily rain (mm) in the experiment area November 2018 – April 2019



Source: The Palestinian Astronomical Society database

Figure 4. Minimum, Maximum, and Mean monthly temperatures °C in the experiment area during November 2018 – April 2019

2.2. Plant Materials, Experimental Design, and Plantation

To avoid any previous plantation effects, the experimental site has not been planted in the last three years and the plant residue was less than 10%. Here, a field investigation using wheat *Triticum aestivum* (var. Yellow Heteya) was implemented in November 2018. This variety is commonly planted in Palestine and it is characterized by a moderate grain production, high straw production, and medium maturity [21]. The targeted variety was investigated depending on the number of tillage practices in combination with different quantities/ratios of organic and non-organic fertilizers including sheep manure, tri-superphosphate (TSP), and ammonium sulfate (AS) as the following:

2.2.1. Tillage Treatments

Conventional tillage (**CT**), twice tilled: This operation system is commonly used (10-12 cm depth) by the Palestinian farmers. Here, the plot was tilled twice by using sweep duck foot cultivator, one before the first rainfall and the second in November 25, 2018 (when the land is partially dry to enable tillage). In this type, sowing occurred manually.

Three introduced conservation tillage systems: any form of tillage that minimizes the number of tillage passes to reduce soil erosion and compaction, these including:

- Reduced/minimal tillage (RT), one time tillage with 10-12 cm depth which was taken place in November 25, 2018. Here, sowing also occurred manually.
- Conservation tillage (C8) at 8 cm depth, also done at the same date.
- Conservation tillage **(C4)** at 4 cm depth, also done at the same date.

The latest two conservation tillage systems have been accomplished via modifying local sowing machine (Fig. 5) that was equipped with shovels to split the soil surface for seed placement, in which the sowing depth was adjusted to 8cm and 4cm and the amount of seeds per dunum was controlled to 12.5 kg/dunum (dunum=1000m^2) for all treatments. While CT and RT sites were tilled by using sweep duck foot cultivator.

Figure 5. Conservation tillage sowing machine

The conservation tillage sowing machine was heavy and more subjected for shaking due to the topsoil stones that were stuck in the shovels. To the contrary, the sweep duck foot cultivator was easier to move and less affected by shacking.

2.2.2. Fertilization Treatments

Fermented sheep manure (piled for one year) was added to the site at the beginning of November 2018. The tri-superphosphate (TSP) was added at the planting date. Later, the Ammonium sulfate (AS) was added in the 12th of February, 2019. The fertilization treatments were as the following:

- **($M_{6m}{}^3$)** Manure 6m^3/dunum.
- **($M_{3m}{}^3$/$TSP_{6.25kg}$/$AS_{6.25kg}$)** Manure 3m^3/dunum + 6.25kg/dunum TSP + 6.25 kg/dunum AS.
- **($M_{3m}{}^3$/$TSP_{12.5kg}$)** Manure 3m^3/dunum +12.5 kg/dunum TSP.
- **($M_{3m}{}^3$/$AS_{12.5kg}$)** Manure 3m^3/dunum +12.5 kg/dunum AS.

The experiment was laid out in a **factorial randomized block design** with 3 replications using the net plot size of 40 m^2 area (8m*5m) per replicate. To isolate the plots as well as to facilitate the follow-up process (cultural practices, measurements, etc.), one- meter corridors between and around the plots were used. Adoption rate of 500 gram of seeds / replicate (equivalent to 12.5 kg/dunum), was sown. Simple random sampling was carried out on the 21st of May, 2019, when the kernel became hard and cannot be dented by thumbnail and the moisture content of the kernel gets to 12-13%.

2.3. Measured and Evaluated Parameters

To evaluate the response of wheat to drought stress, many parameters are commonly used involving production characteristics (total yield weight, grain yield, straw yield, and morphological characteristics (tillering, stem length, spike length, spike length without awns and number of seeds per spike) [22, 23, 4, 24].

Sampling procedure was carried out in simple random sampling method which is suitable for the homogeneous small plots [25]. Samples were selected randomly (3 samples/plots) with the total amount of 96 samples of one meter square area that were harvested, labeled, weighed, measured, threshed and recorded separately. Accordingly, yield records were turned out to be kg/dunum.

2.4. Data Analysis

Data were statistically analyzed using one-way analysis of variance (ANOVA), followed by Least-Significance difference (LSD) that was used to compare the mean of individual parameter and Kruskal–Wallis test for some characteristic parameters that infract the assumptions of ANOVA by SPSS 22, at 95% confidence.

3. Results

Results revealed statistically significant differences within the examined tillage's (CT, RT, C8 and C4) and fertilization types ($M_{3m}{}^3$, $M_{3m}{}^3/TSP_{6.25kg}/AS_{6.25kg}$, $M_{3m}{}^3/TSP_{12.5kg}$ and $M_{3m}{}^3/AS_{12.5kg}$) as well as their interactions for the three yield components including total yield, grain yield and straw yield (Table 1). Moreover, large effect sizes (η^2) were indicated by both treatments and their interactions as well, however the greatest yield parameters were mainly related to tillage interventions rather than the assessed fertilizers (Table 1).

Regarding the morphological parameters, tillers and stem length variables were significantly affected by the treatments and their interactions (Table 2). In addition, significant variations were also observed for spike length, spike length without awns and a number of grains per spike due to the tillage and fertilization treatments, but there were no significant differences due to their interactions (p-value > 0.05). Hereafter, the effect sizes demonstrated the highest values with tillage treatments for the tillers, stem length and spike length. Meanwhile fertilization effect size presented the highest effect with spike length without awns as well as a number of grains per spike variables (Table 2).

Table 1. Analysis of variance of yield parameters by different fertilization and tillage practices

Factorial analysis		**Total yield kg/dunum**			**Grain yield kg/dunum**			**Straw yield kg/dunum**		
Sources of variation	DF	F	Sig	η^2	F	Sig	η^2	F	Sig	η^2
Tillage (a)	3	79.83	0.00*	0.857	56.24	0.00*	0.808	74.74	0.00*	0.849
Fertilizers (b)	4	9.37	0.00*	0.484	12.01	0.00*	0.546	8.16	0.00*	0.449
Interaction (a X b)	12	2.95	0.01*	0.470	3.39	0.00*	0.504	3.10	0.00*	0.482

Table 2. Analysis of variance of morphological parameters by different fertilization and tillage practices

Factorial analysis		**Tillers**			**Stem length**			**spike length**			**Length of pike-awns**			**No. grains/spike**		
Sources of variation	DF	F	Sig	η^2	F	Sig	η^2	F	Sig	η^2	F	Sig	η^2	F	Sig	η^2
Tillage (a)	3	55.88	0.00*	0.81	43.91	0.00*	0.77	6.77	0.001*	0.34	11.01	0.000**	0.45	7.70	0.000*	0.37
Fertilizers(b)	4	25.75	0.00*	0.72	29.20	0.00*	0.75	3.88	0.009*	0.28	22.53	0.000**	0.69	8.75	0.000*	0.47
Interaction (a X b)	12	6.65	0.00*	0.67	2.72	0.01*	0.45	1.23	0.295	0.27	0.82	0.631	0.20	0.49	0.908	0.13

Table 3. Comparison of means of yield parameters due to tillage and fertilizer interaction effect

Variables	Tillage systems	(Fertilizers)					Test statistic	Sig
		Control	$M_{6m}{}^3$	$M_{3m}{}^3/TSP_{6.25kg}/AS_{6.25kg}$	$M_{3m}{}^3/TSP_{12.5kg}$	$M_{3m}{}^3/AS_{12.5kg}$		
Table 3.1. Total yield (kg/dunum)	CT	475 ±4b	1185±130a	625 ±71b	1068 ±204a	525 ±68b	7.879	0.004
	RT	639 ±42b	1105±198a	1105 ±73a	1133 ±25a	1050±180a	2.728	0.090
	C8	68 ±21c	271 ±63a	229 ±42a	149 ±22b	200 ±106a	7.367†	0.118
	C4	184 ±31a	408 ±96a	451 ± 115a	160 ± 11a	287 ±46a	9.133†	0.058
Table 3.2. Grain yield (kg/dunum)	CT	65 ±1ab	157 ±27a	66 ±8ab	83 ±38ab	50±1b	8.167†	0.086
	RT	54 ±4d	234 ±30a	151 ±15b	134 ±12bc	130 ±37bc	7.831	0.004
	C8	9 ±3a	27 ±4a	21 ±6a	12 ±1a	23.33±9.90a	1.734	0.219
	C4	15 ±2a	39 ±12a	54 ±72a	15 ±1a	18 ±2a	3.767†	0.439
Table 3.3. Straw yield (kg/dunum)	CT	410 ±5a	1028±105a	560 ±63a	985 ±200a	475 ±67a	11.33†	0.023
	RT	584 ±40b	871 ±168a	954 ±58a	1000 ±22a	920 ±144a	2.486	0.111
	C8	59 ±21a	244 ±65a	207 ±42a	136 ±21a	176 ±96a	8.267†	0.082
	C4	169 ±31a	370 ±83b	397 ±98a	145 ±10b	269 ±48ab	3.257†	0.059

- Comparison of means using one-way ANOVA and LSD.
†: Comparison of means using Independent samples kruskal wallis test.
- Different letters within row indicate a significant difference at the level 5%, the value represent means ± SE
- Conventional tillage (CT), Reduced tillage (RT), Conservation tillage at 8cm depth (C8), Conservation tillage at 4cm depth (C4).
- Manure (M), Tri superphosphate (TSP), Ammonium sulfate (AS).
- Manure 6m^3/dunum ($M_{6m}{}^3$), Manure 3m^3/dunum + 6.25kg/dunum TSP + 6.25 kg/dunum AS ($M_{3m}{}^3/TSP_{6.25kg}/AS_{6.25kg}$), Manure 3m^3/dunum +12.5 kg/dunum TSP ($M_{3m}{}^3/TSP_{12.5kg}$), Manure 3m^3/dunum +12.5 kg/dunum AS ($M_{3m}{}^3/AS_{12.5kg}$).

In general, RT and CT showed significantly higher wheat yield components than C4 and C8 respectively; however RT exhibited the highest production values among tillage types and fertilizers treatments as well as their interactions (Table 3).

For total production variable (Table 3.1), RT exhibited significantly higher total wheat production over the other tillage types followed by the CT. Meanwhile, no significant production values (narrow range between 1050 to 1133 kg/dunum) were observed among the examined fertilizers types in combination with RT.

Also, grain production was significantly affected by the tested practices (Table 3.2), where the reduced tillage presented the highest grain production among all the other treatments, while the lowest values were for the C4 and C8 respectively. Besides, there were significant variations among the fertilization treatments, where generally the $M_{6m}{}^3$ revealed significantly higher values than the other treatments and the highest value was recorded for RT×$M_{6m}{}^3$ (234 kg/dunum).

On the other hand, straw yield varied significantly among the treatments, in which the highest significant values were recorded for CT×$M_{6m}{}^3$ (1028 kg/dunum) followed by RT× $M_{3m}{}^3/TSP_{12.5kg}$ (1000 kg/dunum). However, the C4 and C8 and their interactions with the tested fertilizers were also revealed the lowest straw production values (Table 3.3).

In reference to the morphological traits; results exhibited significant highest values for tillering variable for the RT over the other tillage practices, furthermore its interactions with the examined fertilizers were also revealed significantly highest values in which the maximum tillering value was observed in RT×$M_{6m}{}^3$ (4.10) followed by RT× $M_{3m}{}^3/TSP_{12.5kg}$ (Table 4.1). Similar trends go also with RT and stem length trait, however its highest values were recorded for RT× $M_{3m}{}^3/TSP_{12.5kg}$ and CT× $M_{6m}{}^3$ (90 cm) (Table 4.2).

Concerning the spike length, RT exhibited significant higher values over the other evaluated tillage practices and examined fertilizers except with $M_{3m}{}^3/TSP_{6.25kg}/AS_{6.25kg}$ mixed fertilizer which showed slightly lower than CT. Here, the highest spike length was registered for RT×$M_{3m}{}^3/AS_{12.5kg}$ (14.99 cm) followed by RT× $M_{6m}{}^3$ (14.75 cm) (Table 4.3).

Regarding the spike length without awns trait, RT revealed significantly the highest values compared to the other tillage's and fertilizer's treatments, however no significant differences were presented between the fertilizer's types (Table 4.4). According to the number of seeds per spike variable, RT recorded significantly higher values over the other tillage treatments; but it revealed significantly lower value than the examined fertilizers (Table 4.5). Furthermore, the highest number of seeds per spike was recorded for RT× $M_{3m}{}^3/AS_{12.5kg}$ and RT× $M_{3m}{}^3/TSP_{6.25kg}/AS_{6.25kg}$ by 39.13 and 39.10 respectively.

Table 4. Comparison of means of morphological parameters due to tillage and fertilizer interaction effect

Variables	Tillage systems	(Fertilization treatments)					Test statistic	Sig
		Control	$M_{6m}{}^3$	$M_{3m}{}^3/TSP_{6.25kg}$ / $AS_{6.25kg}$	$M_{3m}{}^3/TSP_{12.5kg}$	$M_{3m}{}^3/AS_{12.5kg}$		
Table 4.1. Tillers (cm)	CT	2.00±0.29a	3.50±0.42a	1.60±0.15a	3.60±0.30a	2.20±0.06a	11.750†	0.019
	RT	2.00±0.06c	4.10±0.29a	3.13±0.20b	4.07±0.15a	3.87±0.39ab	13.095	0.001
	C8	1.45±0.03a	1.83±0.15a	1.80±0.10a	1.33±0.07a	1.90±0.23a	10.515†	0.033
	C4	1.20±0.06a	1.90±0.10a	1.60±0.20a	3.60±0.53a	1.53±0.12a	9.924†	0.042
Table 4.2. Stem length (cm)	CT	64 ±2.65c	90 ±1.55a	75 ±2.13b	87 ±4.48a	71 ±3.30bc	13.230	0.001
	RT	74 ±1.63b	86 ±2.13a	88 ±1.21a	90 ±3.22a	86 ±1.69a	9.028	0.002
	C8	47 ±1.69b	74 ±4.31a	66 ±5.27ab	64 ±0.12ab	64 ±2.39ab	9.317†	0.054
	C4	54 ±1.72b	70 ±3.62ab	72 ±4.14ab	85 ±6.70a	64 ±2.50ab	10.43†	0.034
Table 4.3. Spike length (cm)	CT	12.45±0.17b	13.86±0.29ab	14.47±0.35a	14.19±0.55ab	13.04±0.13ab	11.011†	0.026
	RT	14.34±0.65a	14.75±0.38a	13.94±0.12a	14.44±0.73a	14.99±0.38a	0.643	0.644
	C8	12.64±1.63a	13.81±0.50a	13.95±0.22a	13.48±0.42a	13.47±0.55a	1.110	0.404
	C4	12.75±0.17b	13.82±0.37ab	13.29±0.06ab	13.92±0.25a	13.61±0.58ab	1.941	0.180
Table 4.4. Spike length without awns (cm)	CT	4.21 ±0.3a	6.05±0.32ab	5.21±0.28ab	6.26±0.14a	5.29±0.21ab	11.32†	0.023
	RT	5.29 ±0.30b	6.38±0.15a	6.06±0.16a	6.29±0.17a	6.37±0.04a	6.393	0.008
	C8	4.09 ±0.42b	5.81±0.22a	5.10±0.32ab	5.76±0.45a	5.18±0.33ab	3.764	0.041
	C4	4.09 ±0.14c	5.54±0.22ab	5.18±0.46b	6.26±0.20a	4.95±0.35bc	7.092	0.006
Table 4.5. Number of grains per spike	CT	22.33±2.2b	33.13±3.17ab	28.87±1.01a	31.57±2.83a	32.60±1.75a	3.621	0.045
	RT	29.73±2.2a	35.47±2.94a	39.10±1.39a	34.80±6.38a	39.13±1.65a	4.533†	0.339
	C8	19.87±2.2b	34.57±2.02ab	28.93±2.56a	30.23±4.01a	30.33±3.31a	3.461	0.051
	C4	19.83±1.8b	31.37±1.07a	29.23±4.07a	30.30±3.29a	27.27±2.49ab	2.783	0.086

- Comparison of means using one-way ANOVA and LSD.
†: Comparison of means using Independent samples kruskal wallis test.
- Different letters within row indicate a significant difference at the level 5%, the value represent means ± SE
- Conventional tillage (CT), Reduced tillage (RT), Conservation tillage at 8cm depth (C8), Conservation tillage at 4cm depth (C4).
- Manure (M), Tri superphosphate (TSP), Ammonium sulfate (AS).
- Manure 6m^3/dunum ($M_{6m}{}^3$), Manure 3m^3/dunum + 6.25kg/dunum TSP + 6.25 kg/dunum AS ($M_{3m}{}^3/TSP_{6.25kg}/AS_{6.25kg}$), Manure 3m^3/dunum +12.5 kg/dunum TSP ($M_{3m}{}^3/TSP_{12.5kg}$), Manure 3m^3/dunum +12.5 kg/dunum AS ($M_{3m}{}^3/AS_{12.5kg}$).

4. Discussion

Drought stress as the main aspect of climate change is the key limiting factor for any crop growth, development and production. Generally, drought resulted in crop water deficit which mainly arises from insufficient or uneven precipitation and accordingly shortage of soil moisture [26,27]. Indeed, drought threats our existence with serious consequences like famine and food insecurity [28].

4.1. Climate

The crucial indicators for farmers and researchers to anticipate the growing season are rainfall and temperature [29]. Despite the low precipitation, the irregular rainfall distribution and erratic precipitation patterns also cause substantial negative influence on crops productivity [26]. In fact, light precipitation usually wets the soil surface which might not reach the sowing depth to activate seeds germination [30], resulting thereby in low crop production. In case of wheat, its growth and development are considered as a stage-dependent requirement crop [31], where the greatest wheat development occurs under deep-root water uptake from a usual depth of 20-50 cm. Accordingly most of light rain evaporates due to the effect of atmospheric and soil temperature [32]. Furthermore, temperature accelerates the evapotranspiration and reduces the water use efficiency [30]. Here, the harsh conditions including low precipitation and the high average temperature (Fig. 2 and Fig. 4) which characterize the region might explain the general significant low production in comparison to the world average wheat production. In addition, rainfall is not regularly distributed throughout the winter season, but rather the massive majority comes during short and intense periods of time (Fig. 2), which further worsens the problem of water availability for crop production [8], and increasing soil erosion as a result of water runoff [33] and nutrients leaching [34]. For that, efforts have been made to mitigate drought impact [35].

4.2. Production Indicators

The efficiency of the tillage practices as a tool to mitigate drought effect, improve soil properties (mainly soil moisture, nutrients uptake, soil organic matter), and increase wheat production under rain fed conditions has been documented by many researchers [36,37,38,39].

In this study, the higher values of CT compared to the RT in some yield and morphological parameters could be explained by the effect of the initial transition from the conventional to the conservation practices [40], indeed this is a short- term study (one season) and is definitely not sufficient to reveal the impact of the examined tillage and fertilization practices, but it gives indicators for the possible effects of these practices that need more investigation on longer term.

Nevertheless, the superiority of RT in most yield parameters could be related to the positive effect of the reduced tillage mainly on soil properties, in which RT was found to improve soil physical and biochemical properties more than CT in a five- year experiment, resulting thereby in higher wheat yield [36]. Furthermore, RT increases soil moisture content which resulted from lower bulk density [41], better water infiltration and soil conservation capacity [42], thus enhancing root number [43] as well as root development and water absorption [44], consequently, increasing the fertilization impact on yield parameters. This indeed explains the significant variation between the unfertilized and the fertilized treatments [45].

Other approach of the effects of RT practice on wheat production is also revealed via increasing the mycorrhizae spores number and total organic carbon which shown better soil quality in comparison to CT [46]. Furthermore, Ghaley et al. [47] attributed the highest wheat production to the high soil organic carbon that conserves more moisture and encourages nutrients uptake. Indeed, the Arbuscular mycorrhizal fungi mainly improve nitrogen (N) and phosphorus (P) uptake and accordingly increasing wheat yield [48]. Also the results of the same study indicated that wheat response to Arbuscular mycorrhizae is affected by wheat genotypes. Here, our tested genotype (var. Yellow Heteya) could be more responsive to Arbuscular mycorrhizae and may be one of the possible explanations of the exhibited higher yield values compared to a previous study on the performance of six Palestinian wheat genotypes [49].

Regarding the fertilization practices, the highest production values presented by $M_{6m}{}^3$ usage over the other fertilization treatments could be elucidated to the improvement in soil properties and nutrients availability that resulted from using the organic manure. In fact, organic manure increases water holding capacity, aggregates stability and nutrients uptake [50]. Moreover, organic manure reduces the soil pH and provides more carbon for the phosphate solubilizing bacteria that results more P availability [51]. In addition, it improves soil enzymatic activities (e.g. alkaline phosphatases, urease, dehydrogenase, β-glucosidasen) that indicate better soil quality and thus increase wheat yield [52]. On the other hand, the highest total yield for CT× $M_{6m}{}^3$ could be explained by the effect of the conventional tillage (twice tilled) that accelerates the manure decomposition and nutrients release compared to the conservation systems especially in the initial transformation stage from the conventional system towards the conservative system [53,54].

Also, the exhibited higher RT and CT values in combinations with $M_{3m}{}^3/TSP_{12.5kg}$ (1133 kg and 1068kg respectively) could be related to the higher P input and its high availability in the soil as a result of its enhancement with tillage practices [51,39].

However, the lower yield parameters of $M_{3m}{}^3/TSP_{6.25kg}/AS_{6.25kg}$ compared to the $M_{3m}{}^3/TSP_{12.5kg}$ might be related to the lower phosphorus and high nitrogen content in such mixed-fertilizers [55,51]. According to Ghaley et al. [47] it was found that the more the N fertilization increased, the less the effect of soil organic carbon and consequently the total wheat production. This remarkable decline of the nitrogen impact could be interpreted by the nitrogen immobilization that resulted from the higher C:N ratio [56, 57]. This result complies with our results, where RT× $M_{3m}{}^3/AS_{12.5kg}$ and CT× $M_{3m}{}^3/AS_{12.5kg}$ revealed the lowest total yield compared to the other RT and CT combinations.

Contrary to these findings, the conservation tillage (C8 and C4 and their combination with fertilizers) revealed the lowest production values. These low values could be related to the low seeds germination rate resulted from the shallower sowing depth that is highly affected by the atmospheric conditions especially moisture and temperature [58], in which the lack of soil mulch (straw mulch) exacerbates the effect of soil moisture evaporation and temperature fluctuation on seeds germination [59]. Also, the low wheat density which resulted from the low seeds germination could explain this low production [60]. Moreover, the low wheat density in C8 and C4 tillage systems gives way to higher weed density that competes with wheat and reduces the yield [61]. Duchemin et al. [62] found that lower wheat vegetation coverage induces soil water lose, which increases the drought effect on wheat.

Another possible explanation for the significant lower wheat production of C8 and C4 tillage systems compared to the RT and CT is the effect of rain pattern in the study area which is subjected to splash erosion due to its shallow tillage's, in addition to the low vegetation cover characteristics [63]. Indeed, such erosion that resulted from the intensive shadow rain increases water loss and causes nutrients leaching [33], resulting thereby in low wheat production in such tillage practices. Besides, wheat canopy characteristics (e.g. cover, structure etc.) may influence the wheat yield by modifying the temperature, respiration and evaporation rates, for example canopy temperature became more than the air temperature under drought stress [64] and this probably made C8 and C4 tillage systems that have low canopy cover and less water retention more affected by the heat stress.

Concerning the morphological characteristics, the highest presented values with RT practice and its combinations with different fertilizers might be related to the tillage effects and its effects on moisture and soil properties. For example, the superiority of RT in tillering as an important morphological trait could be related to the tillage effect [65,66] and its positive influence on soil moisture and soil properties [41]. Also, manure, nitrogenous and phosphorus fertilizers are found to improve tillers emergence, increase tillering and leaf areas as well as photosynthesis [67,68,69]. Contrary to these findings, significant lower tillering values revealed by C8 and C4 tillage systems which might be explained by the higher soil compaction implications [70].

Regarding the significantly high stem length values, it might be also related to the tillage effect and nitrogenous fertilizers [71], phosphorus fertilizers [67], manure [69] and the combination between the organic and inorganic fertilizers [72].

Similar positive trend goes also with the spike characteristics, which are also positively influenced by tillage system [66], fertilization treatments [72], as well as soil moisture content and tillering that are positively affected spike characteristics [73]. Indeed, the highest stem and spike length values were reflected on the total yield [74]. Khorami et al. [15] found an insignificant effect for the tillage system and a number of grain per spike. To the contrary of our results, Ali et al. [66] reported higher values for spike length and a number of kernels per spike for the conservation system over the conventional. This contradictory could be related to the soil characteristics and the absence of water stress in that experiment site; likewise Imran et al. [74] indicated higher results for RT comparing to CT (tillers, plant height, a number of grain per spike), but the conservative tillage gave the highest results.

5. Conclusions

Reduced tillage (RT) has proven its high efficiency in improving soil properties in semi-arid conditions, and consequently increasing wheat productivity. Furthermore, this practice is less cost, less efforts and more applicable than CT (twice-tilled). Compatibly, the manure treatment (M_{6m^3}) is highly recommended for sustainable wheat production and to increase the grain yield due to its availability and its positive impact on soil properties and also limiting the usage of inorganic fertilizers and its bad implications on soil and underground water as well. Moreover, $M_{3m^3}/TSP_{12.5kg}$ was the best choice to increase the straw yield. Finally, further researches are needed toward evaluating the effects of conservation tillage and its combinations with the organic fertilizers at a longer period.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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