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Effect of Different Tillage Operations on Soil Water Storage, Water Use Efficiency and Productivity of Durum Wheat (*Triticum durum* Desf.) in Semi-arid Region

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ABSTRACT

Background: The low amount of rainfall and high loss of soil water through evaporation during spring; there are the dominant factors affecting crop production in semi-arid region.

Methods: A field study was conducted during two cropping seasons of durum wheat (*Triticum durum* Desf.) to compare the effect three tillage operations *viz*., no-tillage, minimum tillage and conventional tillage.

Result: There was variation in precipitation between the experimental years (dry and rainfall seasons). All the parameters registered significant differences between the cropping seasons. Soil water storage to a depth of 0.4 m was higher under no tillage (NT) and minimum tillage (MT) in the first year as compared to conventional tillage (CT) in the first year. During the second year, the soil water content was same under different tillages. The thousand-kernel weight registered significant differences among the tillage operations *viz*., no till (36.09-50.36 g), minimum tillage (30.93-46.81g) and conventional tillage (28.31-45.05 g) in the two seasons, respectively. Under no till treatment water use efficiency was high from grain production. The no till also recorded high grain yield of 1.07 t/ha and 4.7 t/ha during first and second year, respectively. The lack of rain was more detrimental in conventional tillage system as compared to no till and minimum tillage.

Key words: Conventional tillage, Minimum tillage, No tillage, Semi-arid condition, Soil water storage, Water use efficiency, Wheat yield.

INTRODUCTION

The climate change is a factor responsible for the decline in production in all crops (Ram and Kaur, 2020). Water is the major factor limiting wheat crop yield in semi-arid area of Algeria (Chennafi *et al.*, 2006; Alem *et al.*, 2002). In high plateau regions, the agriculture is mostly rainfed (Sebbane *et al.*, 2023). During the last few years, the rainfall is low and erratically distributed. Insufficient rainfall and irregular distribution could be a serious limitation to agricultural production with crop failure and low yields (Benites and Castellanos, 2003). The cultural practices making better utilization of rainwater are required.

The new concept of conservation agriculture minimize soil degradation with lesser use of chemicals (Hobbs, 2007 and Araya *et al.*, 2012). The Food and Agriculture Organization (FAO) has defined three linked principles of conservation agriculture (CA) *viz*., no or minimal mechanical soil disturbance (minimum tillage or no-till), maintaining a permanent biomass in the form of soil mulch cover on ground surface and diversification of crop species (practice of rotation) (Kassem *et al.*, 2018; Kaweesa *et al.*, 2018 and Rodenburg *et al.,* 2020). Conservation agriculture has been regarded as an ideal field management strategy to profoundly benefit water use and therefore crop production (Xiao *et al.*, 2020; and Sun *et al.*, 2018a).

In Algeria durum wheat (*Triticum durum* Desf.) is grown under rainfed conditions in the high plateaus region and the yield observed is the lowest in the North African countries. Therefore, reduction of costs wheat production while maintaining yield level through no till (NT) system is necessary and it is highly useful for the wheat growers of the Setif region (Chennafi *et al.*, 2011).

Environmentally, the soils of semi-arid region suffer from degradation due to intensive tillage practices (Mrabet, 2000). Roy *et al.* (2018) and Abolla *et al.* (2020) reported that No-till systems effect are more beneficial in enhancing soil chemical propriety and soil fertility compared to tillage practices. It is also reported that direct crop seeding reduce about 80% of soil erosion as compared to conventional tillage (Thierfelder and Wall, 2009). Further conventional tillage systems are more expensive as compared to

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reduced or zero tillage practices (Crosi and Muminjanov, 2019).

This research was carried out to study the soil water profile during different stages of crop growth in durum wheat and its impact on yield under different tillage practices.

MATERIALS AND METHODS

Site and experimental details

Field trials were carried out during 2016-2017, 2017-2018 cropping seasons under rainfed conditions at the Technical Institute of Field Crop, Setif. It is located in eastern high plateaus of Algeria (36° 08′ N latitude and 5° 20′ E longitude) at 962 m altitude. The experimental area experienced cold and humid winter and a hot and dry summer typical of semi-arid climate (Chennafi *et al.*, 2006). The soil of the experimental site was shallow calcareous classified as brown steppe soil, with a basic pH and a low organic matter content. The durum wheat variety "Boussalem" was used for the study. The experiment was laid out in strip blocks with a single factor in replications. Each treatment plot was 5m wide and 50m long. The three treatments *viz.*, conventional tillage (CT), minimum tillage (MT) and no tillage (NT) or zero till were tested.

Measurements

The soil water storage during different stages of crop growth were recorded at two depths (0-20 cm) and (20-40 cm) '15 days interval through soil samples drawn using auger. The fresh soil samples were dried in oven at a temperature of 105°C for 24 hours.

The soil water percentage "H%" was computed by the following formula:

$$H\% = \frac{100 \times \text{Wet soil weight - Dry soil weight}}{\text{Dry soil weight}}$$

Water use efficiencies (WUE) were calculated by the following formula:

$$WUE_{GY} = \frac{GY}{CWU}$$

$$WUE_{BIO} = \frac{BIO}{CWU}$$

(Ram and Kaur, 2020; Chennafi *et al.,* 2011; Mellouli *et al.*, 2007; Mrabet, 2000 and Katerji *et al.*, 1984).

Crop water use $CWU = R + ASW_{seeding} - ASW_{harvest}$

Where

R = Rainfall (mm).

$ASW_{seeding}$ = Available soil water at seeding (mm).

$ASW_{harvest}$ = Available soil water at harvest (mm).

$$ASW\ (mm) = \frac{(H\%-WP) \times h \times \rho b}{100}$$

Where,

H% = 100 (Wet soil weight-Dry soil weight)/ Dry soil weight.

WP (Wilting point) = 11%, average of the soil of the experimental site,

h = Soil profile depth in mm.

ρb (Bulk density) = 1.3.

Grain yield (GY) was converted from g/m² to t/ha and number of spikes (NS) were recorder per meter row length for each treatment and then converted to square meter. Thousand kernel weight (TKW, g) was obtained after threshing of spikes from the mass of 250 grains sample per plot. Harvest index was computed by the ratio of grain yield to total biomass yield multiplied by 100.

Statistical analysis

All the observation recorded for diffeent traits were subjected to a one-way analysis of variance (ANOVA) to test the differences among tillage practices at 5% probability level. ANOVA was used to test for statistical differences in each treatment *viz.*, tillage practices in terms of stroge water, water use efficiency and crop parameters. Data were analyzed using the Costat Statistica software 'Costat Version 6.400'.

RESULTS AND DISCUSSION

Rainfall

In the first crop year, the accumulated rainfall from September to June was 195.12 mm, with high variability in distribution. This growing season was considered as dry compared at the medium of long term (355 mm) ; June was the rainiest month with a rainfall of 55.5 mm and it coincided with the grain ripening stage. There was no rain in March and very little rainfall in April and May and it coincided with the third leaf stage and the grain formation stage.

The cumulative rainfall per second year of experimentation (2017/2018) was 419.2 mm. The months of March, April and May recorded a higher rainfall during second year. This period coincided with the critical growth stage of wheat crop. The total grain yield recorded was 4.33 t/ha in second year and it was quite higher as compared with that of first year yield of 0.83 t/ha.

In rain-fed agriculture, accumulated rainfall affects crop growth and crop yield.

There was higher rainfall and better distribution in the second year as compared to first year (Fig 1). This will help us to better understand the behavior of wheat crop under different plowing situations under varying climatic conditions.

Stored water in the soil (water profile H%)

In the semi-arid areas cumulative rainfall directly affect the soil water content. Further the humidity was higher in the second agricultural season as compared to the first year (Fig 2). During initial stage of crop growth, the tillage practices *viz.*, no-till and minimum tillage, recorded relatively high soil water contents at 0-20 cm soil profile as compared to conventional tillage recording 23%, 23% and 22% soil moisture, respectively. The soil water storage rate in the

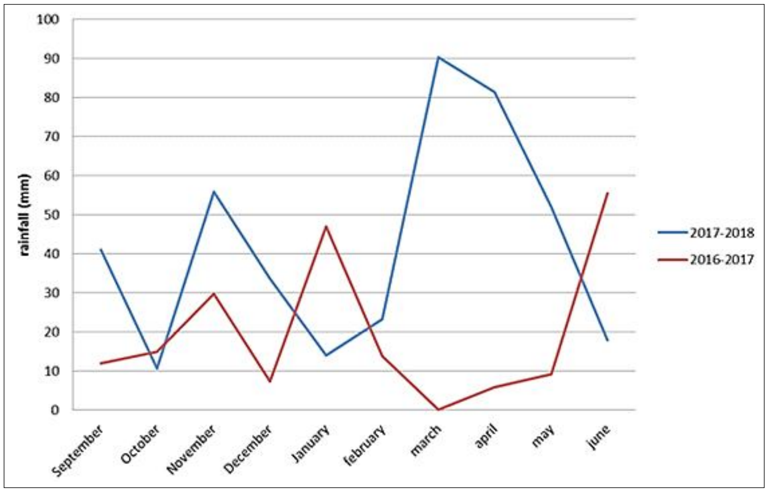


Fig 1: Rainfall pattern in two experimental years.

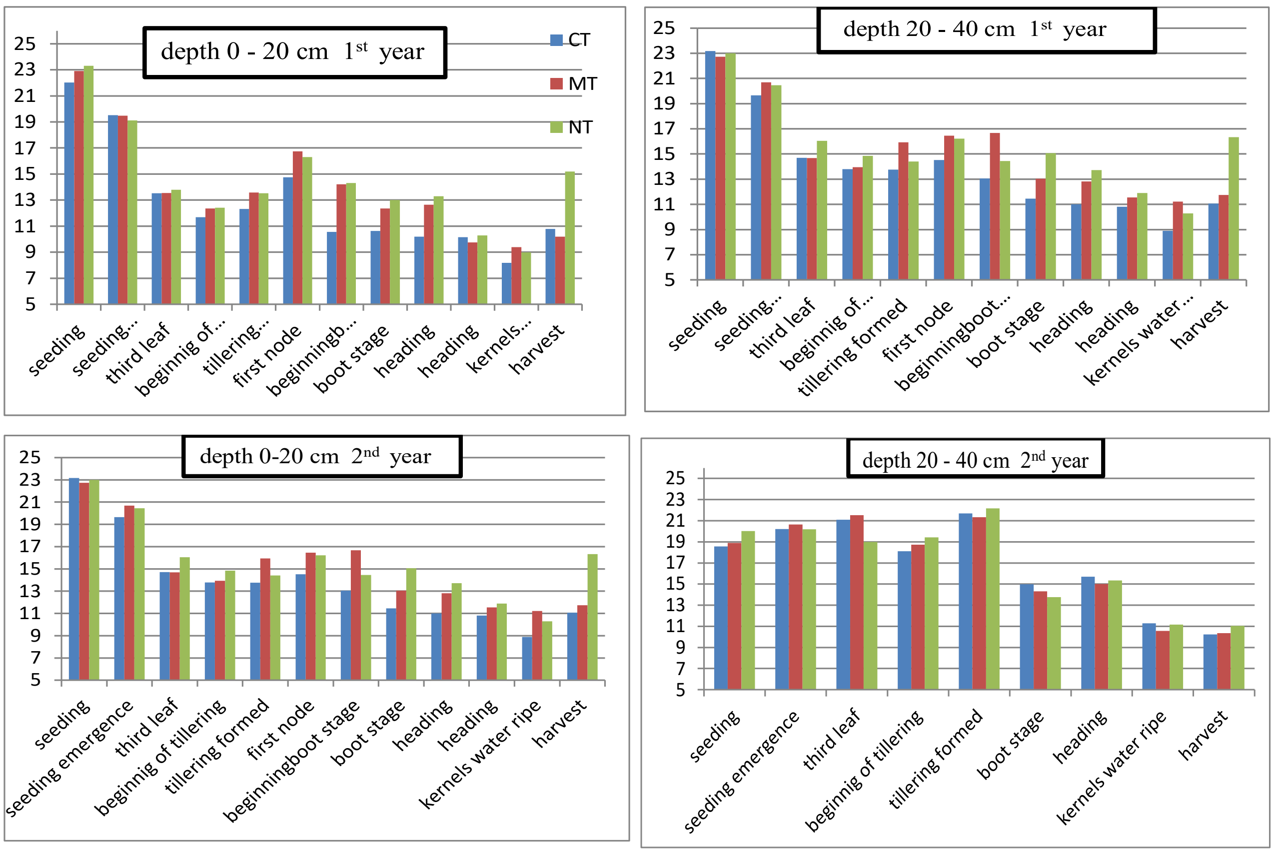


Fig 2: Soil moisture pattern from seeding to harvest.

three tillage techniques too decreased until the third leaf stage.

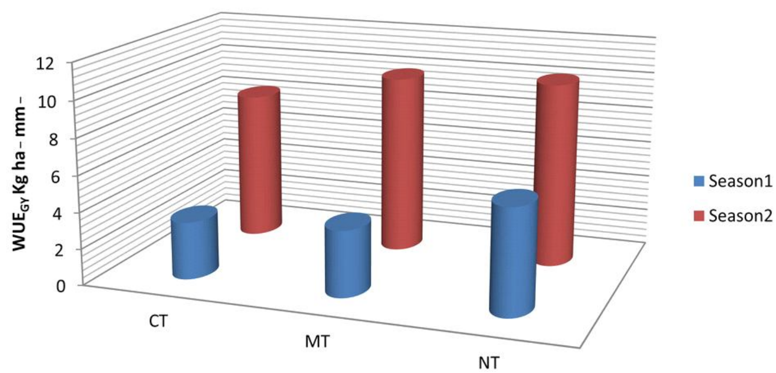
The water content increased in soil after receipt of rain at third leaf stage to first node, low rainfall decreased soil water content to grain maturity. The NT and MT practices stored more soil water than CT practices by 2% to 4%. This period coincided with ear formation stage of crop. At 20-40 cm profile, CT registered least soil water content as compared to NT and MT during most of vegetative phase with 2% different maximum difference. The MT registered a rise in water content between tillering stage and beginning of boot stage. So NT was higher in the other stages. Soil water content was almost equal in two depths 0-20 and 20-40 cm under different tillage practices. At the seeding stage, NT registered high moisture content as compared to MT and CT. At the second and the third leaf stage, NT registered a decline in soil water content as compared to CT and MT, which increased during this period.

Water use efficiency

about the water use efficiency between two years recorded significant difference. However there was no significant difference among tillage operations *viz.*, NT, MT and CT (Fig 3).

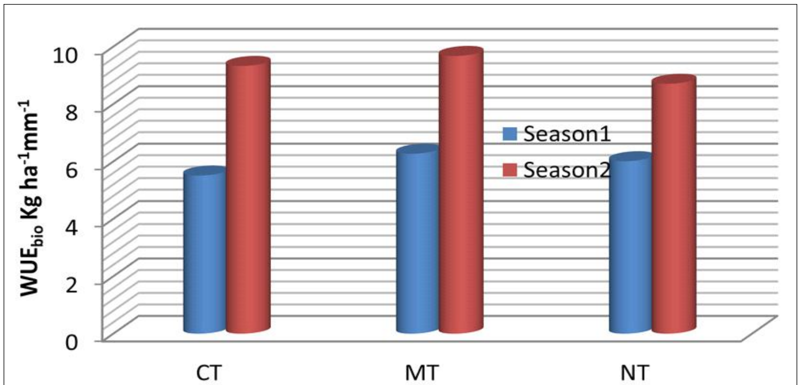
Grain yield water use efficiency WUE_{Gy} was higher in no-till (NT) during both the seasons with 5.775 and 10.138 kg/ha/ mm, respectively. Minimum tillage (MT) recorded 3.638 and 9.854kg/ha/mm, respectively for the first and second season. the conventional tillage (CT) recorded the least grain yield water use efficiency of 3,160 and 8.203 kg/ ha/mm, respectively for the first and second season (Fig 4).

Water use efficiency for above ground biomass production (WUEbio) for CT were 6,269 and 9,675 kg/ha/ mm for MT, 6.007 and 9.326 kg/ha/mm and for NT were 5.508 and 8.704 kg/ha/mm.



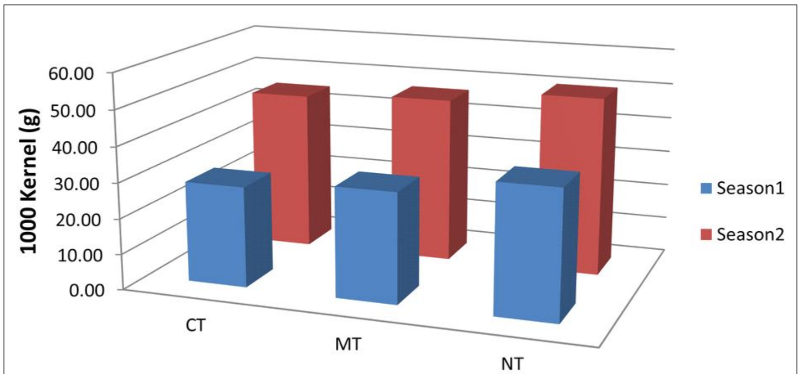
NT: No tillage, MT: Minimum tillage, CV: Conventional tillage

Fig 3: Grain yield water use efficiency (WUE_{Gy}) under different tillage operations during two growing seasons.



NT: No tillage, MT: Minimum tillage, CV: Conventional tillage

Fig 4: Biomass water use efficiency under different tillages operations during two growing seasons.



NT: No tillage, MT: Minimum tillage, CV: Conventional tillage

Fig 5: Thousand kernel weight in different tillage operations.

Yield parameters and yield

Thousand-kernel weight

The thousand-kernel weight recorded significant differences in NT (36.09 g and 50.36 g) as compared to MT (30.93 g and 46.81 g) and CT (28.31 g-45.05 g) in the first and second season, respectively (Fig 5).

Gain yield

The grain yield and biomass production between two years recorded significant differences (Fig 6). However there were no significant differences between the tillage operations *viz.*, NT, MT and CT.

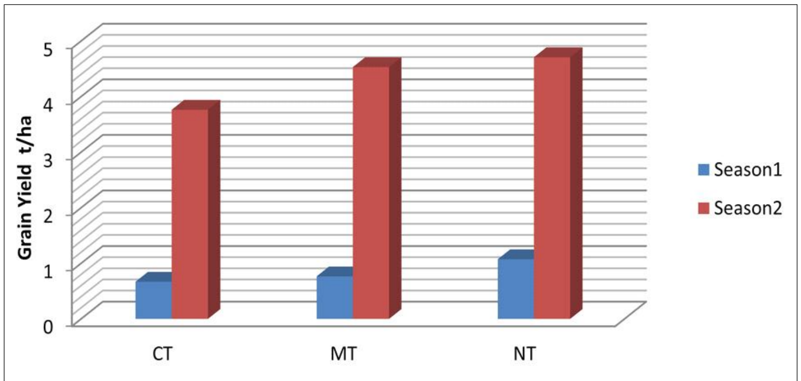
The no tillage (NT) recorded higher yield (1.072 and 4.71 t/ha) as compared to MT (0.76 and 4.53 t/ha) and CT (0.67 and 3.76 t/ha) in first and second season, respectively. The average crop yield was very low (0.94 t/ha) during first season.

Harvest index

The harvest index recorded significant differences in NT (0.95 and 1.20) as compared to MT (0.60 and 1.04) and CT (0.56 and 0.90) in first and second season, respectively (Fig 7).

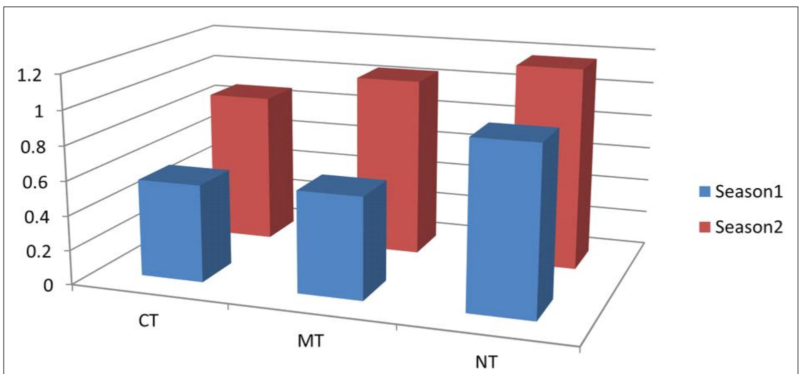
Correlation among characteristics

In the first season the water use efficiency and grain yield showed a high positive correlation with 1000 kernel weight, grain yield and harvest index and a high negative correlation with number of spikes per m². Grain yield showed a high positive correlation with 1000 kernel weight and harvest index and a strong negative correlation with number of



NT: No tillage, MT: Minimum tillage, CV: Conventional

Fig 6: Grain yield under different tillage operations during two growing seasons.



NT: No tillage, MT: Minimum tillage, CV: Conventional

Fig 7: Harvest index in different tillage operations during two growing seasons.

Table 1: Correlation among characteristics in first season.

2016 /2017	WUEgy	WUE bio	GY	TKW	HI	NSM²
WUEgy	1					
WUEbio	0.34	1				
GY	0.99***	0.39	1			
TKW	0.98***	0.49	0.99***	1		
HI	0.99***	0.49	0.98***	0.95***	1	
NPM²	-0.99***	-0.27	-0.99***	-0.97***	-0.99***	1

Table 2: Correlation among characteristics in second season.

2017/2018	WUEgy	WUE bio	GY	TKW	HI	NSM^2
WUEgy	1					
WUEbio	-0.29	1				
GY	0.99***	-0.33	1			
TKW	0.83**	-0.76**	0.85***	1		
HI	0.94***	-0.57*	0.96***	0.96***	1	
NPM^2	-0.51*	0.97***	-0.54*	0.16	-0.75**	1

spikes per m^2. The 1000 kernel weight showed a high positive correlation with harvest index and a high negative correlation with number of spikes per m² and harvest index (Table 1).

However, in the second growing season, the water use efficiency grain yield showed a high positive correlation with 1000 kernel weight, grain yield and harvest index. Water use efficiency biomass production showed a high positive correlation with number of spikes per m^2 and a strong negative correlation with 1000 kernel weigh. However grain yield showed a high positive correlation with 1000 kernel weight and harvest index. The 1000-kernel weigh showed a high positive correlation with harvest index and harvest index showed a negative correlation with number of spikes per m^2 (Table 2).

Many studies have been conducted to compare and evaluate the effects of different tillage operations on soil moisture and crop behavior under conservation agriculture.

The cumulative rainfall recorded from crop sowing to harvest was 195.12 mm in 2016/17 and 419 mm in 2017/18. The deference was very clear and the first cropping season being a dry year, recorded lower productivity. In the first season zero and minimum tillage operations registered high soil water storage as compared to conventional tillage. It is reported that conservation tillage plays a significant role in improving soil moisture availability, especially under low rainfall conditions (Ghosh, 2015). The no tillage (NT) is proposed as a promising strategy to improve soil and water conservation, reduce input costs and to increase crop yield (Channafi *et al*., 2011). The results of Sun *et al*. (2018b) indicated that both deep ploughing and sub-soiling significantly increase soil water storage not only during fallow period, but also during growing season.

The grain yield and water use efficiency of grain yield were high under no and minimum tillage operations. Benniou (2012) reported that conservation agriculture (CA) increases soil water balance attributes as compared to conventional plowing Furthermore this system often resulted in higher water productivity as compared to conventional tillage system.

The results of second season indicated that wheat can be grown successfully under conservation tillage systems with yields equal or higher than those of conventional tillage in high rainfall condition.

Many of studies also reported that soil water use efficiency was higher under no tillage than the conventional tillage and this indicated that water was obsorbed from the soil by crops. It was observed that crops in conservation cultivation tolerate droughts and recessions in rainfall. Often yields are higher under dry season conditions in conservation tillage (Alheeti, 2019; Lampurlanés *et al*., 2016; Thierfelder and Wall, 2009; Mrabet, 2002).

CONCLUSION

The results of present study confirmed that durum wheat can make better use of soil water under no-till and minimum tillage oprations. Under the same climatic conditions, soil moisture was different in each tillage opration of soil and no tillage and minimun tillage operations recorded the best results. The water use efficiency in zero and reduced tillage recorded higher grain yield production in semi-arid conditions. The minimum tillage of soil is one of the principal solution for limiting the negatives effect of climate change including soil erosion.

Conflict of interest

All authors declared that there is no conflict of interest.

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