DF-438
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RESEARCH ARTICLE Agricultural Science Digest, Volume Issue : ()

Effect of Tillage Systems on Durum Wheat Production with Different Rotations in Semi Arid Area of Algeria

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ABSTRACT

Background: Durum wheat is the most important cereal in Algeria. The yield of durum wheat is low and depends on climatic conditions and technical operations.

Methods: The objective of this study is to compare the effect of the no-till system (NT) and conventional tillage system (CT) with three crop rotation sequences on wheat yield, yield components and some physiological traits under rain-fed conditions. The study was conducted at the technical institute of field crops-Sétif-in east of Algeria, over three crop seasons: 2016/17, 2017/18 and 2018/19.

Result: The number of plants/m^2, tillers/m^2, spikes/m^2 and grain yield were affected by the tillage system and the environmental conditions. Seed weight, straw yield, biological yield, leaf relative water content and leaf chlorophyll content were significantly affected by the environment but not by the tillage system. While the spike density, the harvest index and the grain yield were significantly higher under NT system than in the CT system. Furthermore, wheat grain yield was also higher following legumes than in wheat monoculture. These results indicate that no-tillage and crop diversification by adding leguminous in rotation improves grain legumes yield of durum wheat under semi-arid conditions of Algeria.

Key words: Crop succession, Durum wheat (*Triticum durum Desf.*), No-tillage, Semi-arid conditions, Yield.

INTRODUCTION

Wheat is one of world's major sources of dietary calories and proteins. In Algeria, wheat cultivation is mostly practiced in a fallow-wheat rotation under rain-fed conditions and the production covers only 30 to 35% of population needs (Haddad *et al.*, 2016). Wheat production is limited by several factors, primarily by the low and irregular annual precipitations, where nearly (70%) are receipted during the cold winter months (Belagrouz *et al.*, 2018). Furthermore, cultivation practices also remain a limiting factor for wheat productivity; the practice of conventional tillage creates a compact ploughsole under ploughing layer which restrains the movement of water and air and prevents root growth and thus, reduces crop yield (Huang *et al.*, 2012).

Conservation agriculture is emerging as a potential alternative for maintaining crop productivity, soil fertility and environmental sustainability (De Cárcer *et al.*, 2019). Several studies have shown that crop rotation combined with direct seeding improves wheat production; Woźniak *et al.* (2019) found that the yield of cereals in reduced tillage combined with crop rotation was 16.4% higher than the yield of monoculture cereals grown in reduced tillage. Huang *et al.* (2012) attributed the advantage in yielding of the no-till system to the improvement of moisture storage in the top cm layers of the soil which, increases water used efficiency. According to Kassam *et al.* (2018), in the no-till crop diversification system known as conservation agriculture; crop diversification through rotations improves pest control and no till system improves water use efficiency and preserve soils by increasing water infiltration, water storage in soil and also by reducing surface runoff and erosion (Souissi *et al.*, 2020). These benefits suggest that this system could improve sustainably durum wheat production in Algeria.

This study presents an evaluation of the effect of tillage and no tillage systems with different crop rotations on durum wheat yield and yield components under semi-arid conditions in Algeria.

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How to cite this article: Chouter, A., Benniou, R., Sebbane, M. and Louahdi, N. (2022). Effect of Tillage Systems on Durum Wheat Production with Different Rotations in Semi Arid Area of Algeria. Agricultural Science Digest. DOI: 10.18805/ag.DF-438.

Submitted: 11-12-2021 **Accepted:** 23-08-2022 **Online:** 14-09-2022

MATERIALS AND METHODS

Experimental site

The study was conducted over three crops seasons (S1= 2016/17, S2= 2017/18, S3= 2018/19) at the Technical Institute of Field Crops, in Sétif (Algeria) (36°08 N and 05°20 E, 962 m). The climate of this region is semi- arid with a cold rainy winter and a hot dry summer (Benider *et al.*, 2021).

The climatic conditions recorded during experiment period are mentioned in Fig 1. The soil of the site had a silty-clay structure, low alkaline water pH and a moderate level of limestone. The soil had also low contents of organic matter available, potassium; magnesium and available sodium, while the nitrogen content was average and the levels of available phosphorus were high (Table 1).

Treatments and cultural practices

The two tillage systems: conventional tillage and no-tillage, were tested on durum wheat with three crop rotations: wheat/ wheat (W/W), wheat/ lentil/ wheat (W/L/W), wheat/ triticale/ pea/ wheat (W/T/P/W). The experiment was designed as a strip-plot organized in randomized complete block with three blocks.

Wheat was seeded (120 Kg/ ha) with an experimental seeder under the conventional tillage system and the direct seeding (no tillage) was carried out using a specialized tine seeder (in rows) of the John Shearer type from Australia, the spacing between seed rows is 0.23 m.

Background fertilization was applied at sowing with 100 kg/ha of TSP 46% (0.46.0). Nitrogen fertilization was applied in two applications of 46% urea, the first was applied at the three-leaf stage at a rate of 35 kg/ha and the second at the ear 1cm stage at a rate of 65 kg/ha.

Weeds were controlled with glyphosate [N-(phosphonomethyl) glycine] (3 L/ha) before sowing. Post-emergence chemical weed control was carried out with pallas+adjiv li 700 (1 L/ha).

Measurements

At the heading stage, leaf relative water content (LRWC)was determined on samples of five leaves in each plot using the method of Barrs and Weartherly (1962) described by Pask *et al.,* (2012) and leaf chlorophyll content (LCHC) of five fully expanded flag leaves per plot was measured using SPAD chlorophyll meter (Minolta SPAD-502 meter, Tokyo, Japan).

Yield and yield components of wheat including plant height, spike length, spike number, seed number, 1000-seed weight, seed yield and biological yield were measured at crop maturity.

Data analysis

The results obtained were developed statistically with the the analysis of variance (ANOVA) using XLSTAT 2019. The significance of differences between mean values was determined with the *Newman-Keuls (SNK)* test at *P*<0.05 and the correlations between the different pairs of variables were also calculated.

Table 1: General soil characteristics.

Parameters	First horizon 0-20 cm (H1)	Second horizon› 20 cm (H2)
Particle size distribution		
<0.002 mm (clay) (%)	26%	
0.002-0.05 mm (silt) (%)	32%	
>0.05 mm (sand) (%)	42%	
Organic matter (OM) (%)	0.42	01.17
Nitrogen (N) (%)	0.22	0.12
Phosphorus (P) (p.p.m.)	42.00	13.80
Potassium (K) (meq/100 g)	0.55	0.50
C/N ratio	12.21	05.67
pH water	07.80	07.84
CEC (ms/cm)	0.21	0.19
CaC_{O3} (%)	05.64	06.69

RESULTS AND DISCUSSION

Weather conditions in the study area

During the growing season of wheat (September-June), the average air temperature in the years of study was higher than the long-term average (2006/07-2015/16). Throughout the duration of the experiment, the highest total precipitation (419.40 mm) was recorded in the second growing season (2017/18) of wheat cultivation. Nevertheless, the precipitation in this year of study was not distributed evenly. The lowest precipitation level occurred in the 2016/17 season, when the total was lower by 176.49 mm than the

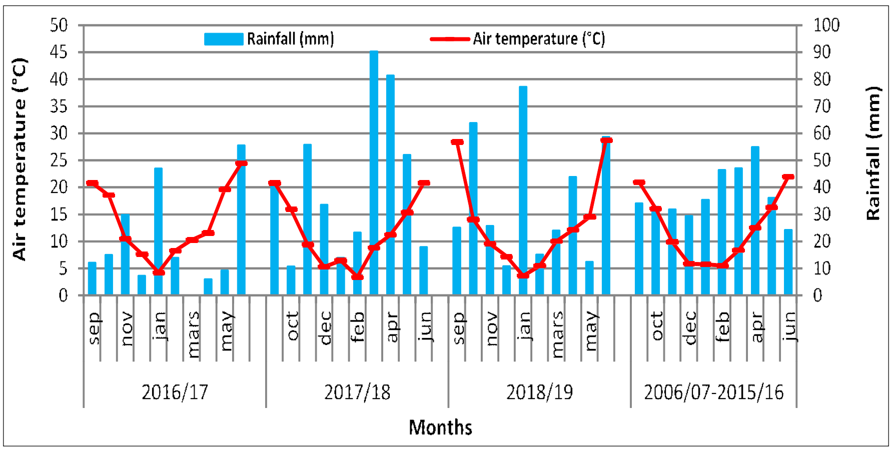

Fig 1: Rainfall (mm) and air temperature (°C) in the region of Sétif (Algeria).

long-term average for this period (Fig 1). According to Rouabhi *et al.* (2019), Algeria will experience a decrease in precipitation and an increase in temperatures which will have a direct impact on agricultural productivity and food security.

Measurements variability

The analysis of variance showed a significant effect of tillage system, year and the interaction (tillage system × year) at (P<0.01) on the number of plants/ m² (NPM) and the number of tillers/ m² (NTM). The NMP and the NTM recorded under NT system with all the three crop rotation, were successively 28% and 78% higher than in CT. The difference between the two systems was more important during the drought season (2016/17). Under CT, the soil disturbance is more or less homogeneous manner which affects the seed bed quality and therefore the seeds are not placed in the same depth resulting in non-homogeneous emergence and low emergence density which can affect the yield. While under direct seeding system, the regularity of the seeding depth, the better placement of fertilizers and the good adherence of the seed to the soil (Mekhlouf *et al*., 2011) increased significantly emergence rate.

The combined analysis of variance indicated significant effect of the tillage system and year on the plant height and beards length at (P<0.01). The 2017/18 cropping season was the most favorable environment to express the potential of plant height (62.73 cm) and the highest mean of length beards (10.99 cm) was expressed during the 2018/19 season. The longest plant and beard length mean value were recorded under CT system. The system tillage × year interaction was significant of plant height and non-significant of beards length.

The spike length was not significantly influenced by neither of the studied factors or their interaction. Nevertheless, the best mean value of spike length (6.11 cm) was obtained in 2018/19 cropping season and the spike length was higher under the NT system (6.15 cm). The same result obtained by Woźniak *et al.* (2019) on the barley crop where he observed the longest spike of barley in direct seeding.

The combined analysis of variance indicated that tillage system had no significant effect on LCHC and LRWC. On the other hand, the year effect was significant at (P<0.001) on the two measured physiological traits. The interaction (tillage system × year) effect was significant (P<0.01) only on LCHC and its mean values averaged over years from 28.13 (SCMR) in 2016/17 cropping season to 21.53 SCMR in 2018/19 cropping season. The rotations W/W and W/T/P/W recorded higher LCHC under CT, while the rotations W/L/W had higher result of LCHC under NT system. High LCHC maintains wheat yields especially under drought and high temperature at the end of the cycle (Shirvani *et al*., 2021). In our study, the LCHC mean under NT system (25.76 SCMR) was higher than the mean under the CT system (25.55 SCMR) indicating a positive effect of the NT system on wheat yield particularly under drought at the end of cycle, which is frequent in the study area.

Leaf relative water content that reflects the water status of the plant, averaged over year from 50.21% in the 2016/17 cropping season to 80.77% in 2018/19 cropping season. Leaf water content is closely to photosynthesis activity, as it can provide early warnings of drought (Song *et al*., 2021). The long period of drought during the spring season 2016/17 had a significant impact on LRWC. On the other hand, the LRWC mean value under NT was higher than CT. This better hydratation of the plants under the NT system indicates also a lower impact of drought on the wheat culture which is one of the main advantages of the NT system. Regarding rotations, the rotation W/ L/ W and W/ T/ P/ W had a higher LRWC under CT but the rotation W/ W had higher result under NT system (Table 3). These results indicate that the expression of the physiological traits was affected by the environment and to the lesser extent by the tillage system.

The analysis of variance of number of spikes/m² (NSM) indicated a significant effect of tillage system and the season (P<0.001), while the effect of their interaction was not significant (Table 3). The NSM under NT system (262.31 spike/m²) was 20% higher comparatively to CT (221.31 spike/m²) which, is in accordance with the findings of Benniou and Bahlouli (2015). As between the years, the

Table 2: Seed yield, straw and biometric traits of wheat under different tillage systems and crop rotations.

System tillage	NT			CT			Value	
Variables	W/W	W/L/W	W/T/P/W	W/W	W/L/W	W/T/P/W	F	P
Seed yield t/ha	1.308	2.678	1.503	0.771	2.442	1.215	11.14	0.01**
1000-seed weigh (g)	35.17	49.61	41.25	33.73	52.65	44.72	2.92	0.12 ns
Seed per spike	27.77	20.60	26.17	19.00	23.77	31.67	00.00	0.99 ns
Spike number/m²	309.66	297.09	180.19	229.47	282.30	152.16	5.49	0.04*
Straw yield (t/ha)	3.300	17.588	2.432	3.461	16.272	3.302	0.02	0.90 ns
Biological yield (t/ha)	4.609	20.266	3.936	4.232	18.714	4.517	0.36	0.56 ns
Harvest index	0.28	0.13	0.39	0.18	0.13	0.27	24.71	0.001***
Plant height (cm)	40.93	59.28	47.25	41.67	66.18	54.47	23.20	0.001***
Spike length (cm)	6.60	5.72	6.13	4.71	5.77	6.10	1.29	0.28 ns
Length beards (cm)	9.29	10.26	10.44	9.96	10.52	11.53	8.95	0.01**

*: Significant at 0.05, ** : Significant at 0.01, *** : Significant at 0.001, ns : Not significant.

Table 3: Physiological traits of wheat under system tillage and sequenced crop rotation.

ST	NT			CT			Value	
Traits	W/W	W/L/W	W/T/P/W	W/W	W/L/W	W/T/P/W	F	P
LRWC	52.24%	62.63%	80.57%	48.19%	64.99%	80.97%	0.08	0.78 ns
LCHC (SCMR)	28.11	30.42	18.74	28.15	24.19	24.31	0.03	0.87 ns

ns: Not significant.

Table 4: Coefficient of Pearson correlation between grain yield and its components.

Traits	Seed yield	Spike number/m²	Seed / spike	1000-seedweight	Spike length
Spike number/m²	0.46*				
Seed/spike	-0.21 ns	-0.28 ns			
1000-seedweight	0.83***	0.17 ns	-0.02 ns		
Spike length	0.04 ns	- 0.09ns	-0.07 ns	0.01 ns	
Plant height	0.82 ***	0.14 ns	0.01 ns	0.96 ***	0.00 ns

ns: Not significant, * : Significant at p<0.05, ** : Significant at p<0.01, *** : Significant at p<0.001.

NSM during 2019 was lower than the NSM during 2017 and 2018 (according to SNK test) which is mainly related to the important NPM during these years. This might be due to the most favorable climatic conditions, as well as the availability of nutrients (especially nitrogen) allowed to obtain the most important number of ears per m² (289.70) during this growing season (2017/18).

Seed yield was significantly influenced by the system tillage at (P<0.01) and the season at (P<0.001). In fact, the 2017/18 season, the wettest of three years under the study gave a much higher grain yield (2.56 t/ha) than the other two. The smaller differences (0.3 t/ha) in seed yield between 2018/19 and 2016/17 seasons can be ascribed to the rainfall distribution. Wheat grain yield following lens and pea exceeded the yield in the wheat monoculture. This result shows the importance of introducing legumes in a cropping system. Kumar and Roy Sharma (2000) and Sainju *et al.* (2017) proved that introducing legumes into the rotation can enrich the soil with N, break the cycle of diseases and weeds and conserve soil moisture which, resulted in a higher cereal yields after legumes. In our study, wheat grain yield under no-till system over the three rotations was 34% higher compared to CT. The presence of residues under NT system, increases soil moisture content and reduces water evaporation compared to CT system, especially during the dry season, can explain the increased wheat grain yield (López-Bellido *et al.*, 1996).

Tillage system had no significant effect on 1000-seed weight; straw yield and biological yield, in the opposite of the year effect that was significant at (P<0.001) on these measures. Nevertheless, Straw yield and biological yield were higher under NT system. Seed weight was higher in W/W on NT system, but in the rotation W/L/W and W/T/P/W seed weight was higher under CT system. The biological yield and straw yield were higher in NT system on the rotations W/W and W/L/W but the best expression in W/T/P/W was obtained in CT (Table 2).

The harvest index (HI) was influenced significantly (P<0.001) by the tillage system, year and their interaction. This trait had a direct effect on cereal yield (Kumar *et al.*, 2021), it reflects the efficiency of photosynthesis products translocation to the grain and it severely affected by drought particularly at the end of cycle that characterizes the Mediterranean climate. Between the seasons, the highest HI was fetched in 2018/19 (0.33%) where the climate was favorable for production and the lowest was obtained in the season 2017/18 (0.13%). The HI recorded under zero tillage (0.27%) was significantly higher than HI under the CT (0.19 %). NT is known to improve water storage in soil which limits the impact of drought on production and the higher yields under NT system indicates a better water use efficiency (Table 2).

In addition, the seed yield was significantly and positively correlated with its components spike number per m² and 1000 seed weight and both yield and 1000 seed weight were also positively related with the plant height which could be considered as an indicator of favorable conditions for production (Table 4).

CONCLUSION

Under Mediterranean rain-fed conditions, the amount of rainfall and its distribution during the growing season has a marked influence on wheat yield. The yield of wheat cultivated in CT in our study, was lower compared to the wheat grown in NT. The seed yield reduction was due to a lower number of spikes per m², lower 1000 seed weight and lower number of grain per spike, than in NT system. Differences were also demonstrated between LCHC and LRWC in NT and CT, the CT system was characterized by a lower LCHC and LRWC. Moreover, the results showed that the introduction of legumes as a preceding crop has a beneficial effect on wheat yield compared to wheat monoculture.

The positive relationship between wheat seed yield and direct seeding encourages the adaptation of this technique in semi-arid regions.

Conflict of interest: None.

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