Effects of tillage and crop rotation on yield and quality parameters of durum wheat in Tunisia

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1 ABSTRACT

Conservation agriculture has been proposed as an alternative to conventional agriculture to mitigate the climate change impact and ensure food security. This study examined the effect of three tillage systems, ((conventional tillage (CT), chisel tillage (ChT) and no tillage (NT)) and two crop-rotation systems ((two year crop rotation (2-yr) and three year crop rotation (3-yr)) on some yield and quality parameters of two winter durum wheat genotypes. The results showed that biological yield (BY) and thousand kernel weight (TKW) were neither significantly affected by tillage, crop rotation nor genotype. Only the genotype significantly affected grain yield (GY). Grain protein content (GPC %) showed higher values than straw protein content (SPC %) and NT negatively affected GPC%. Some significant differences of mineral elements were observed according to tillage system applied and NT showed the lowest values of grain N, straw K, straw Ca and straw Na. Tillage system, crop-rotation system and genotype had no effect on total phenolic content (TPC) and total flavonoid content (TFC). Highly significant negative correlation (-0,378**) was recorded between GY and grain N, and accordingly GPC%. The two winter durum wheat genotypes demonstrated that with the two crop-rotation systems, yields and most of quality parameters under NT and ChT were similar to those under CT. This study expands our knowledge on durum wheat chemistry variation in relation to agricultural system adopted and provides a basis for selecting the adequate crop-rotation system and genotype following the NT adoption in Tunisian semi-arid areas.

2 INTRODUCTION

Durum wheat (*Triticum turgidum* subsp. *durum* (Desf.) Husn.) is one of the main crops cultivated and consumed in the Mediterranean. Its wealth in energy, proteins, mineral elements and fibre makes it contributes to human diet as a main staple food. The aleurone layer of wheat grains contains the largest part of mineral

elements (Buri *et al.*, 2004). Nevertheless, the mineral elements concentration may be differentially affected by the environment factors. In fact, management practices such as tillage systems could affect nutrient concentration and distribution (Lavado *et al.*, 2001). Since phytochemicals are a key factor in

evaluating quality, efforts have been made to determine the content of polyphenols and flavonoid of durum wheat. The antioxidants content of cereal grain could vary according to the genotype, the environment and possibly genotype-environment interactions (Yu *et al.*, 2003; Beta *et al.*, 2005). In Tunisia, winter durum wheat is grown on about 50 % of cereal area and accounts for 60% of cereals production (ONAGRI, 2015). Production is concentrated in northern Tunisia and satisfies 30% of country demand. However, the sustainability of production is threatened due to climate changes, unstable socio-economic conditions and problems of cultivar adaptation to agro-ecological zones. In semi-arid areas, soils are prone to erosion. Such conditions are aggravated by inappropriate agricultural practices. In fact, farmers are accustomed to till their soils more than twice a year before cereal sowing. In conventional tillage (CT), these tillage operations are necessary for weed control, seedbed preparation and to prevent crust formation. Accordingly, CT coupled with monoculture and overgrazing result loss of soil moisture, destruction of soil physical properties, and reduction of soil organic matter (Ben-Hammouda *et al.*, 2005). In such situations, conservation agriculture has potential as an alternative to conventional agriculture. Conservation agriculture permits soil and water conservation and improvement of soil biological processes (Ben-Hammouda *et al.*, 2005). In Tunisia, conservation agriculture

based on NT was introduced in 1999 under rainfed conditions (Ben-Hammouda *et al.*, 2005). Recently, Bahri *et al.* (2019) mapped 260 000 ha of agricultural area in two Tunisian contrasting climatic locations (semiarid and sub-humid) as priority for conservation agriculture adoption. Since the worldwide adoption of conservation agriculture, several studies have reported its effect on crop yield, soil physical properties, soil moisture and organic matter (Alvarez and Steinbach, 2009). The effects on grain yield have ranged from an increase, a decrease or no change (Hao *et al.*, 2001). This effect depends on weather conditions and crop sequence used, rainfall during crop establishment and on the interaction between many others parameters (Brennan *et al.*, 2014; Ercoli *et al.*, 2017). Furthermore, no tillage is recognized to improve soil physico-chemical properties, soil moisture, soil organic matter and biological processes (Ben-Hammouda *et al.*, 2005; Alvarez and Steinbach, 2009). In contrast, few research activities have been conducted on the tillage effects on grain quality. This is despite the fact that tillage can influence hormone activity (Liu *et al.*, 2013), sucrose content (Hao *et al.*, 2001), protein and gluten content (Šíp *et al.*, 2013). The main objective of this study was to determine the effect of tillage and crop rotation systems on some yield and quality parameters of two Tunisian durum wheat genotypes in semi-arid conditions.

3 METHODOLOGY

3.1 Trials description: This study was conducted at the experimental station of the National Institute of Agricultural Research of Tunisia at Kef situated in north western Tunisia (36°12' N, 8°42' E, elevation of 518 m). The climate is semi-arid with an average of annual precipitation of about 450 mm. The annual mean maximum and minimum temperatures and the rainfall of the experimental site are shown in Fig. 1. The soil was a silty clay (50% of clay, 30% of silt and 20% of sand), with a pH of 7.5. The trial was established during the

2010-2011 growing season, the sowing date was November 15th, 2014 and the sampling was performed at the harvest July 10th, 2015. The experimental design was a split-split plot. The elementary plot was 120 m² size (20 m × 6 m). Two crop-rotation systems (biannual/2-yr and triennial/3-yr) combined three tillage systems: conventional tillage (CT), chisel tillage (ChT) and no tillage (NT) were tested. CT consisted of reversible moldboard ploughing to 30-40 cm depth followed by secondary tillage with offset 15-20 cm for seedbed preparation, for ChT

chisel was used to 40-50 cm depth followed by cultivator 10-15 cm depth and NT plots were seeded by a direct driller. For NT, weeds were controlled with glyphosate at a rate of 3 L.ha⁻¹. Two winter durum wheat genotypes, 'Maali' a modern genotype and 'Chili' an old genotype, were tested. The biannual crop rotation was faba bean (*Vicia faba* L. minor) and durum wheat, and the triennial crop-rotation was faba bean, durum wheat and barley (*Hordeum vulgare*

L.). The seeding rates were 160 kg.ha⁻¹ for durum wheat, 130 kg.ha⁻¹ for barley and 120 kg/ha for faba bean. Fertilizers were surface broadcasted, durum wheat and barley received 100 kg.ha⁻¹ of Di-Ammonium Phosphate at sowing and 300 kg.ha⁻¹ of ammonium nitrate half at early tillering and half at stem elongation stages. Faba bean received at sowing 33 kg.ha⁻¹ of ammonium nitrate.

Figure 1: Minimum and maximum temperatures (°C) and rainfall (mm) recorded in Kef from November to June during the 2014-2015 growing season.

3.2 Sampling and measurements: At durum wheat maturity, yield parameters (biomass yield or biological yield (BY), grain yield (GY), and thousand-kernel weight (TKW)) were determined in quadruplicate. Then samples of grain and straw were ground, sieved and then stored until analysed. These samples were used to determine mineral elements, total phenolic content and total flavonoid content.

3.3 Mineral elements and total protein content determination: For mineral elements, about 1 g of dry sample were ashed in a muffle furnace at 600 °C for 6h, and

mineralized with HCl. Mineral elements measurements were made in quadruplicate. Potassium, calcium and sodium were estimated by flame photometry. Phosphorus concentrations were determined by spectrophotometry (Murphy and Riley, 1962). Kjeldahl method was used to determinate N (Kjeldahl, 1883) then protein content after multiplying Kjeldahl nitrogen by 5.7 (De Vita *et al.*, 2007) and expressed on a dry weight basis (%).

3.4 Biochemical analysis

3.4.1 Extraction: Samples of the ground plant material (0.5 g) were shaken with 25 ml of

methanol (80%) for 2 h and filtrated through a Whatman filter paper to discard the solid phase. The extracts were prepared in quadruplicate and then stored until TPC and TFC analysis.

3.4.2 Determination of total phenolic content (TPC): The TPC of the two durum wheat genotypes were quantified using the Folin–Ciocalteu reagent according to Singleton and Rossi (1965). The absorbance of the reaction mixtures was measured at 720 nm against a blank after 1 h. Gallic acid (GA) was used to obtain the standard curve (0–1000 ppm) and TPC was expressed as milligram of gallic acid equivalent (GAE) per gram of dry weight.

3.4.3 Estimation of total flavonoid content (TFC): For the TFC the colorimetric assay

reported by Zhishen *et al.* (1999) with minor modification (Chaieb *et al.*, 2011) was used. Absorbance of the mixture was measured at 510 nm with methanol 80% used as the blank. Rutin was used to run the calibration curve and the flavonoid content was expressed as milligram of rutin equivalents (RE) per gram of dry weight.

3.5 Statistical Analysis: The Statistical Package for the Social Sciences software (SPSS 20.0, SPSS Inc., Chicago, IL, USA) was used for all statistical analysis to identify treatment effects and interactions (Two-way MANOVA and PEARSON correlation). If significant effects were found ($p < 0.05$), differences between variables were checked by DUNCAN post hoc test.

4 RESULTS

4.1 Yield parameters: ANOVA results of durum wheat yield parameters are recorded in Table 1. Effects of tillage (T), crop rotation (R), and genotype (G) were not significant on BY and TKW. However, genotype significantly

affected the grain yield (GY) and straw yield (SY). “Maali” had higher GY and lower SY than “Chili”. No significant effects of the interactions ($T \times R$, $T \times G$, $R \times G$, and $T \times R \times G$) on yield parameters were noted.

Table 1: Effect of tillage, crop rotation and genotype on yield parameters of two durum wheat genotypes in Kef during 2014-2015 growing season.

Treatment	BY* (t ha ⁻¹)	GY (t ha ⁻¹)	TKW (g)
Tillage			
CT	10,2381±1,5359 a ¹	2,5746±0,7562 a	36,846±4,859 a
ChT	11,3225±2,1585 a	2,9348±0,9156 a	36,532±5,083 a
NT	11,2894±1,4567 a	2,6962±0,9574 a	34,829±4,838 a
Crop-rotation			
2-yr	11,4004±1,9559 a	2,8749±0,9663 a	36,877±4,397 a
3-yr	10,4996±1,4971 a	2,5955±0,7679 a	35,261±5,334 a
Genotype			
Chili	11,0246±1,7327 a	2,0752±0,4011 b	35,291±4,691 a
Maali	10,8754±1,8645 a	3,3951±0,7032 a	36,847±5,088 a

¹ In each column, values not followed by the same letters for the same treatment are significantly different ($p < 0.05$).

* 2-yr, two year crop-rotation; 3-yr, three year crop-rotation; BY, biological yield; ChT, chisel tillage; CT, conventional tillage; GY, grain yield; NT, no tillage; TKW, thousand kernel weight.

4.2 Mineral elements concentration: The concentrations of nitrogen, phosphorus and potassium of durum wheat grains and straw are presented in Table 2. Analysis of variance showed that the tillage (T) had significant effect

on grain N (GN) and straw K (SK) concentrations. In fact, no tillage (NT) had the lowest GN and straw K (SK) concentrations. Only GK was significantly affected by crop rotation with the 3-yr rotation showing the

highest GK. In addition, genotype revealed no significant effect on N, P, and K concentrations, except for the SK. $T \times R$ interaction significantly affected the SK. It must be also noted that straw presented significant variability for Ca and Na content and 'Maali' showed higher SCa and lower SNa than "Chili". Analysis of variance of grain Ca (GCa) and grain Na (GNa) showed no significant effect of T and G. $R \times G$ interaction had a significant effect on GCa. Tillage had significant effect on

straw Ca (SCa) and straw Na (SNa) with NT having the lowest contents.

4.3 Protein content (%): Protein content of durum wheat is a quality parameter to take into consideration for industrial processing. In general, grain showed significantly higher protein content than straw (Table 3). Only tillage (T) had significant effect on protein content, as NT showed significantly the lowest value for grain protein content was noted.

Table 2: Effect of tillage, crop-rotation and genotype on nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and sodium (Na) concentrations of two durum wheat genotypes grains and straw in Kef during 2014-2015 growing season.

Treatment	N (g kg ⁻¹)		P (g kg ⁻¹)		K (g kg ⁻¹)		Ca (g kg ⁻¹)		Na (g kg ⁻¹)	
	GN*	SN	GP	SP	GK	SK	GCa	SCa	GNa	SNa
Tillage										
CT	29,54±2,77 a ¹ A ²	5,88±1,02 a B	21,19±6,63 a A ₁	2,30±0,64 a B ₁	7,70±0,66 a B ₂	12,99±1,89 b A ₂	0,13±0,02 a B ₃	1,59±0,46 a A ₃	0,21±0,12 a B ₄	2,21±0,80 a A ₄
ChT	28,57±3,47 a A	5,63±0,75 a B	22,75±4,58 a A ₁	2,67±0,84 a B ₁	7,53±0,58 a B ₂	14,25±2,34 a A ₂	0,13±0,02 a B ₃	1,60±0,39 a A ₃	0,18±0,12 a B ₄	1,66±0,34 b A ₄
NT	26,83±3,80 b A	5,40±1,40 a B	23,05±5,81 a A ₁	2,03±0,82 a B ₁	7,59±0,87 a B ₂	12,57±2,26 b A ₂	0,13±0,03 a B ₃	1,35±0,48 b A ₃	0,21±0,18 a B ₄	1,55±0,68 b A ₄
Crop-rotation										
2-yr	27,44±3,93 a A	5,44±0,97 a B	21,41±6,24 a A ₁	2,46±0,82 a B ₁	7,33±0,65 b B ₂	13,32±2,31 a A ₂	0,13±0,03 a B ₃	1,52±0,39 a A ₃	0,20±0,15 a B ₄	1,81±0,76 a A ₄
3-yr	29,19±2,79 a A	5,82±1,23 a B	23,19±5,10 a A ₁	2,22±0,77 a B ₁	7,88±0,65 a B ₂	13,24±2,21 a A ₂	0,13±0,02 a B ₃	1,51±0,51 a A ₃	0,20±0,13 a B ₄	1,81±0,62 a A ₄
Genotype										
Chili	29,25±3,37 a A	5,77±0,93 a B	23,11±5,48 a A ₁	2,52±0,89 a B ₁	7,52±0,77 a B ₂	12,45±1,83 b A ₂	0,13±0,02 a B ₃	1,34±0,43 b A ₃	0,21±0,13 a B ₄	2,04±0,73 a A ₄
Maali	27,38±3,42 a A	5,50±1,24 a B	21,57±5,91 a A ₁	2,15±0,66 a B ₁	7,69±0,63 a B ₂	14,16±2,33 a A ₂	0,12±0,02 a B ₃	1,70±0,40 a A ₃	0,19±0,15 a B ₄	1,57±0,56 b A ₄

¹ In each column, values not followed by the same minuscule letters for the same treatment are significantly different ($p < 0.05$).

² In each line, values of the same mineral element not followed by the same majuscule letters for the same parameter are significantly different ($p < 0.05$).

* 2-yr, two year crop-rotation; 3-yr, three year crop-rotation; ChT, chisel tillage; CT, conventional tillage; GCa, grain calcium; GK, grain potassium; GN, grain nitrogen; GNa, grain sodium; GP, grain phosphorous; NT, no tillage; SCa, straw calcium; SK, straw potassium; SN, straw nitrogen; SNa, straw sodium; SP, straw phosphorous.

Table 3: Effect of tillage, crop-rotation and genotype on total phenolics content, total flavonoids content and protein content of two durum wheat genotypes grains and straw in Kef during 2014-2015 growing season.

Treatment	Total phenolics content (mg GAE/g of DW)		Total flavonoids content (mg RE/g of DW)		Protein content (%)	
	GTPC	STPC	GTFC	STFC	GPC	SPC
Tillage						
CT	4,868±2,890 a ¹ A ²	6,502±3,640 a A	0,495±0,147 a B1	1,010±0,166 a A1	16,837 ±1,579 a A2	3,141 ± 1,008 a B2
ChT	4,850±4,077 a A	4,531±2,735 a A	0,495±0,296 a B1	1,026±0,254 a A1	16,287 ±1,977 a A2	3,011 ± 0,903 a B2
NT	4,942±3,186 a A	7,878±4,510 a A	0,484±0,106 a B1	1,031±0,139 a A1	15,296 ±2,168 b A2	3,078 ± 0,797 a B2
Crop-rotation						
2-yr	4,701±3,678 a A	5,966±2,926 a A	0,469±0,253 a B1	1,045±0,238 a A1	15,641 ±2,243 a A2	2,974 ± 0,814 a B2
3-yr	5,073±3,052 a A	6,638±4,681 a A	0,514±0,117 a B1'	1,000±0,123 a A1	16,639 ±1,593 a A2	3,180 ± 0,965 a B2
Genotype						
Chili	4,580±2,787 a A	6,163±3,557 a A	0,500±0,168 a B1	1,042±0,168 a A1	16,672 ±1,922 a A2	3,150 ± 0,848 a B2
Maali	5,193±3,867 a A	6,440±4,245 a A	0,483±0,224 a B1	1,003±0,209 a A1	15,608 ±1,951 a A2	3,004 ± 0,941 a B2

¹ In each column, values not followed by the same minuscule letters for the same treatment are significantly different ($p < 0.05$).

² In each line, values of the same mineral element not followed by the same majuscule letters for the same parameter are significantly different ($p = 0.05$).

*2-yr, two year crop-rotation; 3-yr, three year crop-rotation; ChT, chisel tillage; CT, conventional tillage; GPC, grain protein content; GTFC, grain total flavonoids content; GTPC, grain total phenolics content; NT, no tillage; SPC, straw protein content; STFC, straw flavonoids content; STPC, straw phenolics content; TKW, thousand of kernel weight.

4.4 Total phenolic content (TPC) and Total flavonoid content (TFC): Analysis of variance of TPC and TFC showed that the effects of tillage (T), crop rotation (R) and genotype (G) were not significant (Table 3). There were significant $T \times R$ and $R \times G$ interactions effects on TPC. Straw TFC was significantly higher than grain TFC.

4.5 Parameters relationships: As shown in Table 4, GY showed significant positive correlations with BY and TKW. Even if the correlations were not significant for most of them, GY was negatively correlated to mineral elements concentrations (N, P, K, Ca and Na)

of grain. In addition, some negative correlation coefficients, linking grain yield and grain composition, were noted. Some highly significant negative correlations were recorded between GY and GN, and accordingly GPC. Similarly, TKW presented highly significant negative correlation with GN and GPC, and a significant negative correlation with GP%. For the straw, positive significant correlation related K to Ca, when it was negatively correlated to Na. Besides, the correlations between grain and straw parameters indicated positive correlations between SN, GN and consequently SPC and GPC.

Table 4: Correlation coefficients among yield and quality parameters of two durum wheat genotypes in 3 different tillage systems and 2 crop-rotations systems in Kef during 2014-2015 growing season.

	GY ^a	BY	TKW	GN	GP	GK	GCa	GNa	SN	SP	SK	SCa	SNa	GPC	SPC	GTPC	GTFC	STPC	STFC
GY	1																		
BY	0,358*	1																	
TKW	0,341*	0,051	1																
GN	0,378**	0,004	0,534**	1															
GP	-0,202	-0,041	-0,312*	0,213	1														
GK	-0,154	0,314*	-0,191	0,120	0,200	1													
GCa	-0,277	-0,118	-0,109	0,110	0,266	0,063	1												
GNa	-0,114	-0,189	-0,060	-0,036	0,015	0,187	0,149	1											
SN	-0,348*	-0,184	-0,141	0,401**	0,082	0,306*	0,023	0,422**	1										
SP	-0,116	0,292*	0,117	-0,023	0,080	0,384**	0,123	-0,213	-0,145	1									
SK	0,343*	0,027	-0,223	0,292*	0,196	-0,084	0,033	-0,034	0,147	-0,029	1								
SCa	0,401**	0,079	0,058	0,151	0,168	-0,123	0,114	-0,224	-0,251	0,095	0,537**	1							
SNa	-0,305*	-0,217	0,138	0,125	0,024	0,091	0,222	0,046	-0,122	0,014	-0,303*	0,150	1						
GPC	0,378**	0,004	0,534**	1,000**	0,213	0,120	0,110	-0,036	0,401**	-0,023	0,292*	0,151	0,125	1					
SPC	-0,189	-0,011	-0,096	0,331*	0,072	0,208	0,130	0,271	1,000**	-0,145	0,234	0,125	-0,263	0,331*	1				
GTPC	0,137	0,246	-0,197	0,137	0,193	-0,091	0,091	-0,305*	-0,170	0,135	0,366*	0,223	-0,197	0,137	-0,016	1			
GTFC	0,019	0,029	0,142	-0,185	0,168	0,108	0,108	0,273	-0,048	0,113	-0,186	0,046	0,348*	-0,185	0,328*	-0,077	1		
STPC	-0,057	-0,039	0,083	-0,011	0,042	0,195	0,196	-0,039	-0,063	0,312*	-0,091	0,059	-0,191	-0,011	0,107	0,088	-0,154	1	
STFC	0,052	0,178	0,0196	-0,040	0,060	-0,006	0,025	-0,039	-0,084	-0,061	0,024	0,083	-0,044	-0,040	-0,005	0,275	0,017	0,235	1

* Significant correlation $p < 0.05$.

** High significant correlation $p < 0.01$.

^a BY, biological yield; GCa, grain calcium; GK, grain potassium; GN, grain nitrogen; GNa, grain sodium; GP, grain phosphorous; GPC, grain protein content; GTFC, grain total flavonoids content; GTPC, grain total phenolics content; GY, grain yield; SCa, straw calcium; SK, straw potassium; SN, straw nitrogen; SNa, straw sodium; SP, straw phosphorous; SPC, straw protein content; STFC, straw flavonoids content; STPC, straw phenolics content; TKW, thousand of kernel weight.

5 DISCUSSION

5.1 Effect of Tillage: Crop production in the semi-arid regions is highly dependent on rainfall, and frequent droughts are a limiting factor of yields. In such regions NT, has been suggested as a way of improving water availability in the soil profile, soil organic matter and soil nutrients. In this study, yield parameters did not vary under different tillage methods. These results are similar to those of Montemurro & Maiorana (2014) who determined the responses of durum wheat to soil tillage and found no significant effect of tillage on grain yield. In similar, Hao *et al.* (2001) studied the effect of conventional and minimum tillage on crop yield for soft wheat (*Triticum aestivum* L.) and noted no significant effects on grain yield for three successive cropping seasons. Otherwise, Woźniak *et al.* (2014) obtained higher durum wheat grain yield under conventional tillage compared to reduced tillage. However, De Vita *et al.* (2007) studied the effect of tillage on durum wheat yield in two Italian regions for three years and higher yields were observed under NT in dry years compared to CT when this difference was not remarkable in wet years. They concluded that the resultant effects were dependant on the region and the year. In addition, Alvarez and Steinbach (2009) reported that the effect of tillage on yield parameters depends on the crop. In a cool Atlantic climate, the variability of winter wheat grain yield under different tillage system was dependent on the rainfall and temperature of the year (Brennan *et al.*, 2014). Minerals in plants play a major role for the maintenance of certain physicochemical processes, which are essential to life. Regarding macronutrients, nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca) have specific functions in plant. They are components of nucleic acids, proteins, hormones, coenzymes and chlorophylls, phospholipids, adenosine triphosphate (ATP), etc. Our results showed that the effect of tillage on mineral composition of grain and straw is dependent on mineral elements considered. In our case, NT showed the lowest GN. López-Bellido & López-Bellido

(2001), who found that wheat under NT presented lowest N uptake compared to CT for three successive cropping seasons, report similar results. As stated by Woźniak *et al.* (2014), reduced tillage showed higher mineral elements (P, K, Ca) concentrations than conventional tillage. In contrary, Ercoli *et al.* (2017) found that conventional tillage had lower GN concentration than reduced tillage during the transition phase from conventional to reduced tillage. The low values of nitrogen recorded for NT could be explained by the fact that it may alter the availability of plant nutrients and may necessitate reconsidering the fertilizer management. Due to fertilizer management, crop residue and nutrients move shallower into the soil; NT permits the accumulation and concentration of nutrients in the top few inches of soil. Thus, stratification and accumulation of nutrients can limit the crop nutrient availability (Shipitalo *et al.*, 2013). As protein content is directly related to N concentration, NT showed the lowest GPC. These results are in accordance with those of Šíp *et al.* (2013) who found that conventional tillage presented higher protein yield in winter wheat compared to reduced tillage. In contrast, Rakszegi *et al.* (2016) reported that the management system, organic and conventional, had not significant effect on protein content. For grain and straw, no effects of tillage were noted on TPC and TFC. As reported by Stracke *et al.* (2009) management practices such as conventional and organic practices had no effect on wheat phytochemicals concentrations. As management practices could affect TPC and TFC (Asami *et al.*, 2003), the invariabilities observed between different tillage systems were probably due to the time elapsed time between different tillage practices and sampling.

5.2 Effect of crop rotation: Crop rotation is an encouraged practice due to climate change and erosion risks in semi-arid area. In this study, crop-rotation systems did not show any significant effect on yield parameters, minerals elements composition, PC, TPC and TFC. In another way, neither faba bean nor barley, the

two preceding crops, had an effect on durum wheat yield and quality parameters. These results are in contrast to those found by López-Bellido & López-Bellido (2001), Woźniak *et al.* (2014) and Montemurro & Maiorana (2014).

In fact, López-Bellido & López-Bellido (2001), when comparing faba bean and wheat as preceding crops, found that faba bean resulted higher durum wheat grain yield and N concentration. Similarly, Woźniak *et al.* (2014) noted that legumes as preceding crop presented the highest durum wheat yield parameters and mineral elements concentration. Montemurro & Maiorana (2014) found also that legume as preceding crop showed the most important yield parameters and N concentration.

5.3 Effect of genotype: The two studied genotypes “Chili” and “Maali” differed significantly for GY. Deghaïs *et al.* (2007) studied some Tunisian durum wheat genotypes and noted lower grain yield for ‘Chili’. In parallel, Arduini *et al.* (2006) found that genotype significantly affected grain yield and yield components in durum wheat. They found that modern genotypes had higher yield than the old ones. Similarly, some genotypes showed significant effects on wheat grain yield (Rozbicki *et al.*, 2015; Studnicki *et al.*, 2016). The obtained results in relation to mineral elements concentration, TPC, TFC and PC showed no significant differences between ‘Chili’ and ‘Maali’. In contrast, Guttieri *et al.* (2015) found that wheat genotype had a significant effect on mineral elements concentration. Additionally, Taghouti *et al.* (2010) reported a significant effect of durum wheat genotypes on some quality parameters such as PC. In parallel, Menga *et al.* (2010) studied some cereal species and noted that genotype had a significant effect on the phenolic content.

5.4 Effects of T, R and G interactions

In this study, most of interactions had no significant effects on the studied parameters. In fact, results did not present any significant effects on yield parameters. On the contrary,

Ercoli *et al.* (2017) studied the effect of tillage system, preceding crop and year of cultivation on grain yield of durum wheat. The 3-ways of interaction tillage system x preceding crop x year of cultivation significantly affected grain yield. The preceding crop effect varied according to the tillage system and the year of cultivation. They noted that in early transition period from conventional to minimum tillage; the effect of tillage on grain yield was dependent on preceding crops. Furthermore, significant effects of $T \times R$ and $R \times G$ interactions on TPC were noted. These results are in accordance with the outcomes of other experiments, which revealed that genotype, environment and genotype-environment interactions (Beta *et al.*, 2005) and growing conditions (Yu *et al.*, 2003) significantly affected wheat TPC. Some other interactions such as $T \times R$ and $R \times G$ that had significantly affected respectively SK and GCa. However, factors interactions did not show any significant effects on PC. In parallel, Rakszegi *et al.* (2016) reported that the management system, organic and conventional, had not significant effect on protein content. In contrary, Studnicki *et al.* (2016) affirmed that the genotype, the environment, the crop management and their interactions could influence grain protein content of wheat.

5.5 Correlation among yield and quality parameters: High significant negative correlations were recorded between some yield parameters and protein content. These results are in accordance to those found by Studnicki *et al.*, (2016) who noted significant negative correlations between yield components and GPC% and other grain quality parameters of spring wheat. The same correlations were noted between GY and GPC% of winter wheat (Šíp *et al.*, 2013). These negative correlations between GY and GPC% could be due to the dilution of protein by non-nitrogen compounds in the grain.

6 CONCLUSION

This study provides a contribution about the effect of tillage, crop rotation and genotype on some yield and quality parameters of durum wheat. The results showed that neither the tillage system nor the crop-rotation system had significantly affected the grain yield of two winter durum wheat genotypes. As expected, the modern genotype 'Maali' showed higher grain yield than 'Chili'. NT significantly decreased the grain nitrogen concentration and, the straw potassium and calcium concentrations. Against all odds, total phenolic content did not exhibit any significant

variability under different tillage systems and crop-rotation systems. The two winter durum wheat genotypes demonstrated that with the two crop-rotation systems, yields and most of quality parameters under NT and ChT were similar to those under CT. This study expands our knowledge on durum wheat chemistry variation in relation to agricultural system adopted and provides a basis for selecting the adequate crop-rotation system and genotype following the NT adoption in Tunisian semi-arid areas.

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