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ORIGINAL ARTICLE

Tillage and Residue Management Effect on Durum Wheat [*Triticum turgidum* (L.) Thell. ssp. *turgidum* conv. *durum* (Desf.) MacKey] Growth and Yield Under Semi Arid Climate

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Houria Chennafi, Abderrahmane Hannachi, Omar Touahria, Zine El Abiddine Fellahi, Mahfoud Makhlouf, and Hamenna Bouzerzour: Tillage and Residue Management Effect on Durum Wheat [*Triticum turgidum* (L.) Thell. ssp. *turgidum* conv. *durum* (Desf.) MacKey] Growth and Yield Under Semi Arid Climate

ABSTRACT

A field study was conducted during two cropping seasons (2009/10 and 2010/11) at the Institute of Field Crop- Agricultural Research Station of Setif (eastern Algeria) to compared the effect of tillage (no till and conventional tillage) and residue management (0, 30 and 60% soil cover) on the growth and grain yield of durum wheat. The cumulative growing season precipitations were 427.7 and 312.1 mm. Soil water storage to a depth of 0.4 m was higher under CT in the first year and no significant differences existed between NT and CT during the second year. Above-ground biomass was higher under CT, while grain yield, spikes m^{-2} and number of kernels m^{-2} were higher under NT. Residue rate affected positively all measured traits, suggesting the necessity to maintain residue cover to avoid reducing yield under NT management system. Averaged over residue rates, Transpiration was higher under CT than under NT, in 2009/10, but not significant difference was noted in 2010/11. The opposite was noted for evaporation. Transpiration increased as residue rates increased during both seasons. CT showed higher WUE_{BIO} and WUE_{GY} in the first year, while during the second year, NT expressed higher WUE_{BIO} and WUE_{GY}. WUE_{BIO} and WUE_{GY} increased as residue rate increased, during both cropping seasons. The results of the present study indicated that with adequate residue cover, no-till did not decreased grain yield, which suggested that durum wheat can be grown under NT with the expectation that gain yield will be higher or at least equal to CT grain yield.

Key words: Tillage, wheat, residue, growth, soil water content, water use efficiency, semi- arid.

Introduction

Two third of Algerian small grain cereals sown area are located on the high plateaus region, which is characterized by a wide year to year fluctuation in precipitation and temperature regimes [1]. Under such growing conditions, grain yields are low and irregular [2,3,4]. In the Setif region, the main cropping system adopted is black fallow-wheat. This management system, inspired from the dry farming techniques promoted by Campbell for the US Great Plains in the early 1900's, was introduced, during the French colonization, by the Geneva Company, as an alternative to boost cereal production in this semi-arid region [5]. Black fallow aimed to enhance soil water storage in order to secure a high wheat crop yield the following season [6]. This agronomic practice was encouraged by the development of powered machinery and the advent of steel- made tillage tools, mainly the moldboard plow [5]. Tilled fallow, which consists of a primary inverting tillage, followed by repeated secondary shallow tillage to create dust mulch, is actually largely adopted by state farms [7].In small private farms, with a traditional mixed farming system integrating livestock and cereal production, weedy fallow is practiced and used for grazing. After harvest of the main crop, straw is balled, stocked and fed to livestock during the winter months while crop residues are over grazed during the summer, returning little organic matter to the soil [8].

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Unable to raise crop yield ceiling in this region, which has been cropped for centuries, and which shows soil erosion and fertility decline problems, farmers are looking for alternatives to reduce input costs without penalties on grain yield [9,10]. In Morocco and under similar semiarid conditions, no till and reduced tillage production systems showed potential to improve soil conservation and to reduce input costs without jeopardizing grain yield [11,12]. In [13] reported higher grain yield under reduced tillage. [14] noted that zero tillage with residue retention, combined to crop rotation, resulted in a soil with good physical, chemical and biological qualities, and stable crop yields. [15] mentioned that no-till and reduced-tillage improved soil water content and reduced soil erosion without always resulting in increased grain yield. Benefits of no till and reduced tillage arise partly from crop residue maintenance. According to several researches, besides protecting soil from wind and water erosion, crop residue influences favorably most determinants of soil productivity and all mechanisms by which water storage and crop growth are enhanced [12,16, 17,18,19,37,38,39,40]. Since crop growth and yield are the integrated evaluators of the efficiency of a given management system, the objective set to this study was to investigate the effect of tillage and residue management on wheat crop growth and yield under semi- arid environment of the eastern high plateaus of Algeria.

Material and Methods

Trial management:

A field trial was carried out during the 2009/10 and 2010/11 cropping seasons at the Institute of Field Crop Agricultural Research Station of Setif (ITGC-ARS Setif, 36°08'N, 05°20'E and 963 masl).The experiment was conducted under rainfed conditions in an experimental design made up of four unreplicated strips, 9 m wide by 50 m long each. The soil of the experimental site is a shallow brown calcareous soil, classified as a steppic brown soil, with a pH of 8.2 and 1.35% organic matter [13].The four treatments were conventional tillage and no till with zero, 30 and 60% residue cover rates. Conventional tillage consisted of moldboard plowing to a 25 cm depth in the winter and two spring cultivations with an offset disc harrow. Seed bed was prepared with an offset disc harrow, followed by a spike tooth harrow, after application of 100 kg ha^{-1} of super phosphate 46%. Sowing was done on November 12th, the first year and on December 10th, the second year, with a commercial 3 m- wide drill, at a 300 seeds m^{-2} seeding rate. The exponential relation between percent residue cover and residue mass was utilized to convert residue mass available at seeding time to percent cover which was also approximated by the line- transect method [20,21]. Bar soil treatment was left uncovered by removing all flat and standing residues present on the soil surface, while 0.25 and 2.2 t ha^{-1} residues equivalent were uniformly scattered over the entire strip surface of the 30 and 60% treatments, respectively. No till treatments were spread with 2 l ha^{-1} glyphosate herbicide [*N-(phosphonométhyl) glycine*] to control any standing vegetation prior to sowing. Seeding and phosphate fertilization, 100 kg ha^{-1} of super phosphate 46% placed beneath the seed, were done with a commercial 3 m wide Semeato drill. Durum wheat [*Triticum turgidum* (L.) Thell. ssp. *turgidum* conv. *durum* (Desf.) MacKey] cultivar Mohammed Ben Bachir was utilized as a plant materiel. Nitrogen deficiency was prevented by an application of 100 kg ha^{-1} of urea 36%, at the jointing growth stage (Zadock's growth scale = ZGS 31) [22]. Post emergence weeds were controlled chemically with *Gran Star* [Methyl Tribenuron] at 12 g ha^{-1} rate and Zoom [4.1% Triasulfuron + 65.9% Dicamba, 3,6-dichloro-2-methoxybenzoic acid] at 150 g ha^{-1} rate.

Data collection:

The number of plants per unit area was determined by counting seedlings in 2-row segments, 1 m long, at three sampling sites located diagonally across each strip, at the two-leaf growth stage (ZGS 12). Wheat above ground biomass was sampled from 2-row segments, 1 m long, at three sampling sites located diagonally across each strip, at the following growth stages: jointing (ZGS 31, 34), booting (ZGS 49), heading (ZGS 55), Anthesis (ZGS 65), soft dough (ZGS 85) and at harvest (ZGS 95). Vegetative samples were oven dried at 70°C during 48 hours. The last sampling, done at maturity, was used for the determination of the number of spikes, grain yield, above ground biomass, harvest index, straw yield and thousand-kernel weight. Straw yield was determined as the difference between above ground biomass and grain yield. Economical yield was estimated as grain yield plus 0.30 straw yield [23]. Thousand- kernel weight was determined from the count and weight of 250 kernels. Seed number produced per square meter was derived from grain yield and 1000-seed weight. Seed per spike was calculated as seed number divided by spike number, per square meter. Plant height was measured from ground level to the tip of the terminal spikelet.

Grain yield was also determined from the harvest of three plots 1.2 m x 40 m per strip, with an experimental wintersteiger plot combine. Because of the presence of a hard pan at less than 0.4 m from the soil surface, samples for soil water content determination, measured gravimetrically, were taken to that depth by a 0.10 m increment. Plant available soil water (ASW, mm), at a given sampling date, was deduced by the following formulae: ASW (mm) = $[(H\%\text{-}WP) \times h \times \rho_b]/100$, where H% = 100(wet soil weight-dry soil weight)/dry soil weight, WP =

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wilting point =11%, average of the soil of the experimental site, h = soil profile depth in mm, and ρ_b = bulk density = 1.3. Seasonal crop water use (CWU), assumed to be the sum of the crop transpiration (T) and soil evaporation (E), was estimated according to Chen *et al*., [24]: CWU = R + $ASW_{seeding}$ $-ASW_{Harvest}$, where R = rainfall (mm), $ASW_{seeding}$ = available soil water at seeding (mm) and $ASW_{Harvest}$ = available soil water at harvest (mm). Crop transpiration (T, mm) was deduced from the accumulated above-ground biomass (BIO, kg m²), the vapor pressure deficit (Δe, Pa) and the wheat crop-specific coefficient k = 4.5 Pa, as follows: $T = BIO(\Delta e)/\ k$ [25, 26]. Δe is the average of the daily measurements during the active growth period from jointing to soft drought stage, which roughly extended from mid-March to mid-June. Soil water evaporation (E) component of seasonal crop water use was derived as: E = CWU-T. Above ground biomass (BIO, kg ha^{-1}) and grain yield (GY, kg ha^{-1}) water use efficiency (WUE) was determined as: WUE_{BIO} (kg ha^{-1} mm^{-1}) = BIO/CWU and WUE_{GY} (kg ha^{-1} mm^{-1}) = GY/CWU.

Data analysis:

Data were analyzed using a factorial design with three replications, in which years were random, and tillage-residue managements were considered fixed effects. Single degree of freedom contrasts were used to test the various effects and there interaction with year. [27] software was used to analyze the data.

Results and Discussion

Seasonal rainfall and temperature:

Accumulated rainfall from September to June was 382.4, 502.6 and 409.4 mm for the 12-year period and the 2009/10 and 2010/11 growing seasons, respectively (Figure 1). The 12-year period exhibited a monotone distribution of rainfall with an average varying from 30 to 40 mm for most of the months excepted for September and June. The former exhibited a higher rainfall average while the second had a lower average. Compared to the 12-year period, 2009/10 and 2010/11 growing seasons showed a contrasted pattern of rainfall distribution. Both cropping seasons had 31% (120.0 mm) and 6% (22.2 mm) more rainfall than the 12-year period average, respectively. Winter and spring months were rainy, accumulating 81% and 73% of the season total. This suggested that growing conditions were relatively favorable during both seasons, even though 2009/10 season showing a better rainfall distribution compared to the rainfall distribution of the 2010/11 season which was more variable. January and June 2011 received 13.2 and 18.2 mm, respectively, while February and April 2011 accumulated 97.5 and 81.0 mm, respectively (Figure 1). The cumulative rainfall recorded from crop sowing to harvest during the 2009/10 and 2010/11 cropping seasons were 427.7 and 312.1 mm, respectively. Air temperatures followed a similar pattern each year, with the lowest monthly temperatures recorded during January-February period, and the highest during the summer months. Monthly mean temperatures were below 10°C during most of the growing season, and rose sharply above this threshold by early April, restricting the active crop growth to the spring-early summer months.

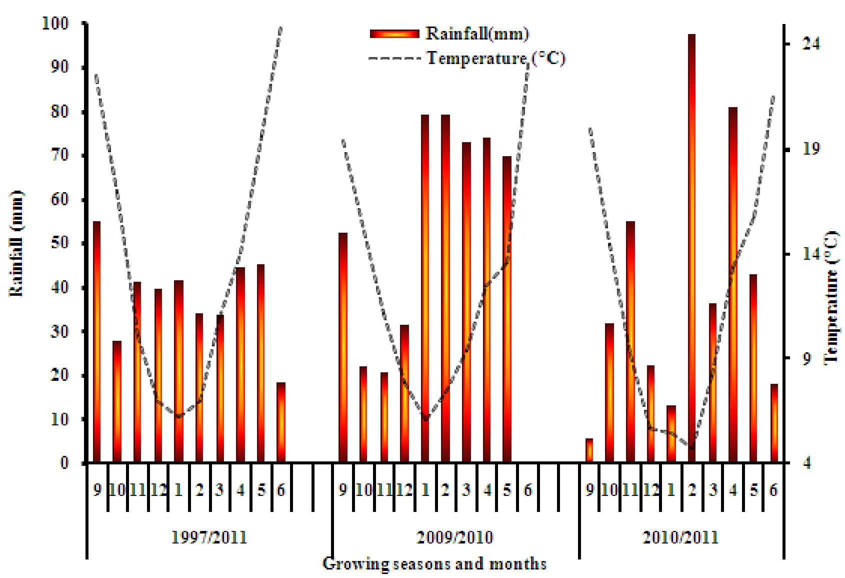

Fig. 1: Monthly rainfall and mean temperature of the two growing seasons (2009/10 and 2010/11) and the 12- year average recorded at the Setif ITGC ARS experimental site.

Variation in soil water content:

In 2009/2010, soil water content, in the 0-0.40 m soil profile, was always greater under CT than under NT, even though the differences declined towards the end of the crop cycle. The difference between CT and NT varied from 10 mm at 75 days after sowing (DAS) to 29 mm at 156 DAS and then returned back to zero at maturity (Figure 2). At seeding time CT had 7.2 mm more stored water than NT. This difference seems to stem partially from the preceding crop which was tilled fallow for CT and weedy fallow for NT. It is also hypothesizing that less available soil water was stored under NT treatments because of higher evaporation. $NT_{60\%}$ had more available soil water than $NT_{30\%}$ and $NT_{0\%}$, from 75 to 132 DAS, but differences declined toward the end of the crop cycle. $NT_{30\%}$ showed similar pattern of water use as $NT_{0\%}$ (Figure 2). NT used up all the soil moisture and goes through a drought stress period from 167 to 183 DAS (Figure 2). The last rainfall events of late May recharged partially the sol profile of NT crop which seems unable to use up this available soil moisture, while CT crop does, as the difference in the available sol water between both treatments becomes smaller (Figure 2). It is hypothesizing that the drought stress period experienced by NT hasten the physiological maturity of the crop which was unable to use the available water brought by the late rainfall events while crop under CT management avoided this stress and was still growing, making best use of the available moisture. The results indicated also that higher residue rate treatment tended to have more available water than bare or low residue rate treatment. Soil water content variation during the 2010/11 crop season suggested no significant differences among the treatments, even though at the beginning of the cycle CT and $NT_{60\%}$ treatments tended to exhibit higher soil water content (Figure 2).

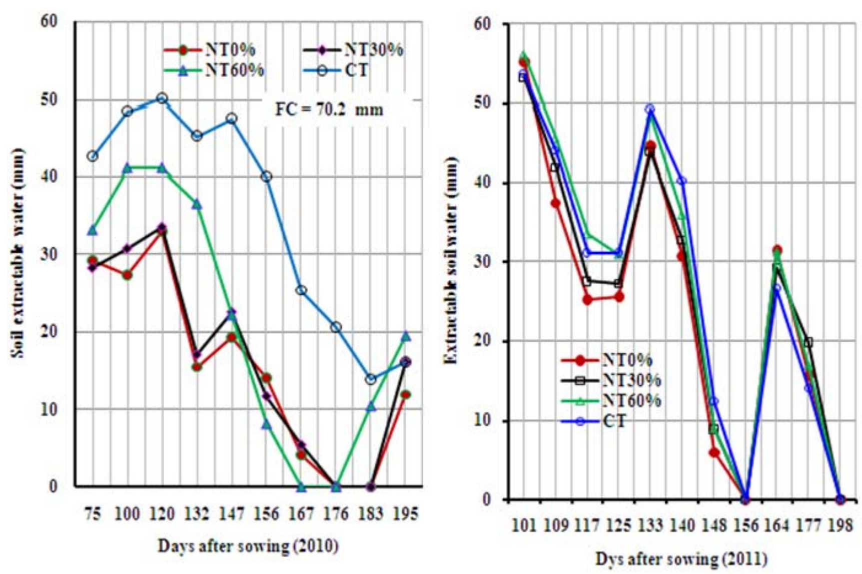

Fig. 2: Soil water content variation under CT and NT treatments during the 2009/10 (left) and 2010/11 (right) cropping seasons.

Rising air temperatures during April and May allowed a rapid growth which consumed most of the available water in the top 40-cm of the soil profile, leading the crop to experience a drought stress period at 156 DAS and ending up at maturity with a soil profile reaching the wilting point. These results contrasted with those of [28][29][30] who found that NT stored significantly more water than CT, because residues shade the soil surface and reduce evaporation. But they are in agreement with those of [31] who found less water stored in the NT soil profile compared with CT, resulting in grain yield reduction. The results of the second year were in agreement partially with those of Pala *et al*. [32] who reported that the general trends in soil water change were the same for NT and CT tillage practices, but NT treatment left more water at harvest for the following crop compared with CT practices. The results of this study indicated no significant difference between tillage practices in terms of stored water left at harvest.

Above ground biomass accumulation:

During both cropping seasons, the pattern of above ground biomass accumulation was affected by tillage and residue managements. Under CT, the rate of biomass accumulation was relatively higher than under no till. The coefficients of regression of the linear growth phase of both treatments were 0.08968 and 0.0669, in 2009/10; and 0.12624 and 0.08487 t day^{-1} ha^{-1} in 2010/11growing seasons (Figure 3). This resulted at harvest in a higher above ground biomass accumulated under CT compared to NT. The regression coefficients of $NT_{0\%}$, $NT_{30\%}$ and $NT_{60\%}$ were 0.0484, 0.0619 and 0.0907 t day^{-1} ha^{-1}, in 2009/10; and 0.0690, 0.0903 and 0.0950 t day^{-1} ha^{-1}, in 2010/11 suggesting a positive residue effect on the rate of biomass accumulation (Figure 3). $NT_{0\%}$ exhibited the lowest above ground biomass production, corresponding to a higher soil water loss. This suggested that under $NT_{0\%}$ treatment soil evaporation was high and crop transpiration was low. The results of the present study contrasted with those reported by [12] who found that maximum total dry matter was produced under NT compared to CT.

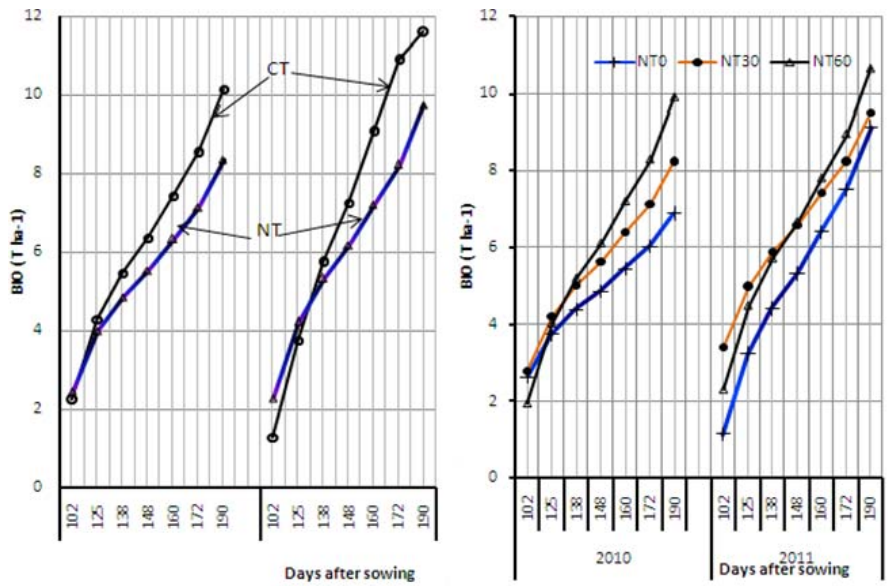

Fig. 3: Pattern of aboveground biomass accumulation, from tillering stage till maturity, under tillage (left) and residue managements (right) during the cropping seasons.

Grain yield, yield components and morphological traits:

Treatment effect was significant for all studied traits, as indicated by the results of the analysis of variance (Table 1). Differences among years were not significant for the seedling population emerged and above ground biomass, measured at maturity. Tillage effect as well as the interaction tillage x years were significant for all traits studied. Averaged over tillage management, 2009/10 cropping season had significantly more spikes m^{-2}, higher plant height and straw yield. 2010/11 cropping season had significantly higher thousand-kernel weight, grain yield, seed per spike, seed per m², harvest index and economical yield (Table 2). Averaged over years, no till (NT) exhibited significantly more emerged seedlings, spikes, number of kernels per m^2, grain yield and harvest index; while conventional tillage(CT) showed significantly higher thousand-kernel weight, kernels per spike, plant height, above ground biomass, straw yield and economical yield (Table 2). Averaged over residue treatments, NT had higher seedlings emerged m^{-2} during both years even though the difference between tillage treatments was smaller during the 2010/11 cropping season. Similar pattern of response was noted for the number of spikes and kernels m^{-2}, whose expression was favoured under NT conditions, and which corroborated findings of Kumudini *et al.,* [33] who reported an increased number of fertile tillers under NT. During both years, CT had higher 1000-seed weight (Table 3). This contrasted with findings of De [29] who found that 1000-seed weight was higher under NT in each of the three-year tests. A compensating effect between number of kernels per m² and 1000-seed weight may explain partially the observed difference between tillage treatments. Qualitative interactions appeared between years and tillage management for grain yield, number of kernels per spike, plant height, above ground biomass, straw and economical yields. The mean values of those traits were higher under CT during the 2009/10 growing season and under NT during the 2010/11 cropping year (Table 3).

Table 1: Mean squares of the combined analysis of variance of the studied traits affected by year and tillage-residue management at Setif (Algeria) during the 2009/10 and 2010/11 cropping seasons.

Source	DF	SDL	PHT	BIO	STR	HI
Treatments	7	6561.4*	435.9*	82818.3*	57982.8*	104.4*
Year (Y)	1	44.8^{ns}	612.2*	276.1^{ns}	39256.0*	519.4*
tillage (T)	3	9644.8*	317.7*	83370.0*	48404.2*	29.0*
Y x T	3	5650.1*	495.5*	109779.7*	73801.3*	41.0*
Y * NT vs CT	1	16094.3*	1250.2*	255481.9*	189890.5*	110.7*
Y* Residue lin	1	70.0^{ns}	235.9*	19154.6*	6416.0*	11.8*
Y* Residue quad	1	783.1^{ns}	0.0ns	54675.0*	25116.8*	0.5ns
Error	24	303.4	5.42	1366.1	1235.7	5.3

Source	DF	SN	TKW	KN	KNS	GY	ECY
Treatments	7	31015.5*	216.3*	5.0*	93.03*	10532.3*	20039.1*
Year (Y)	1	126177.8*	1155.0*	4.3*	353.8*	32921.8*	14895.4*
tillage (T)	3	22320.6*	96.4*	7.9*	26.3*	8953.4*	21112.6*
Y x T	3	7989.6*	23.1*	3.8*	72.8*	4643.7*	20680.7*
Y * NT vs CT	1	22509.4*	18.1*	9.0*	183.7*	4850.7*	40180.2*
Y* Residue lin	1	1391.3*	31.0*	2.7*	1.9ns	3340.8*	6756.8*
Y* Residue quad	1	55.5^{ns}	45.1*	0.6ns	32.9*	5529.8*	15094.6*
Error	24	230.7	0.99	0.24	2.55	346.4	392.4

SDL = number of seedlings per m², PHT = plant height, BIO = above ground biomass, STR = straw yield, HI= harvest index, SN= spikes number, TKW = thousand-seed weight; KN = number of kernels per m², KNS= number of kernels per spike, GY = grain yield, ECY = economical yield

[29] reported greater grain yield under NT during two consecutive years and no significant difference existed between NT and CT yields, the third year. [11] mentioned that wheat grain yields were higher under NT than CT because of better utilization of growing season precipitation. [15][34]. reported that grain yield was higher under NT in the dry year and under CT in the wet year. In the present study, both years were characterized by a rainy end of the growing season and a cumulative rainfall of 502.4 and 404.6 mm from September to June (Figure 1). The apparent advantage of the CT was due to the low yield achieved under NT with 0 and 30% residue cover (Figure 4).

Table 2: Main effect of year and tillage management of the measured traits.

	SDL	SN	TKW	GY	KN	KNS	PHT	BIO	STR	HI	ECY
2009/10	262.5	381.5	39.1	225.8	5.7	15.5	76.9	778.6	552.8	29.5	391.6
2010/11	260.2	255.9	51.6	290.0	6.5	22.2	68.2	772.7	482.8	37.6	434.8
F test	ns	*	*	*	*	*	*	ns	*	*	*
NT	278.7	343.0	43.8	262.9	6.5	18.4	69.8	761.0	498.1	34.4	412.3
CT	209.4	245.9	50.0	242.9	5.0	20.1	80.8	819.7	576.9	31.1	415.9
F test	*	*	*	*	*	*	*	*	*	*	*

SDL = number of seedlings per m², PHT = plant height, BIO = above ground biomass, STR = straw yield, HI= harvest index, SN= spikes number, TKW = thousand-seed weight; KN = number of kernels per m², KNS= number of kernels per spike, GY = grain yield, ECY = economical yield.

Table 3: Mean values of the measured traits as affected by tillage management and year

		SDL	SN	TKW	GY	KN	KNS	PHT	BIO	STR	HI	ECY
2010	NT	292.8	421.1	37.9	223.7	5.8	13.7	70.6	712.3	488.6	31.4	370.3
	CT	171.7	262.7	42.5	232.1	5.5	20.9	96.0	977.4	745.3	23.8	455.7
2011	NT	264.6	264.9	49.6	302.1	7.2	23.1	69.0	809.6	507.5	37.3	454.3
	CT	247.1	229.0	57.6	253.6	4.4	19.3	65.6	662.0	408.4	38.3	376.1
	F test	*	*	*	*	*	*	*	*	*	*	*

SDL = number of seedlings per m², PHT = plant height, BIO = above ground biomass, STR = straw yield, HI= harvest index, SN= spikes number, TKW = thousand-seed weight; KN = number of kernels per m², KNS= number of kernels per spike, GY = grain yield, ECY = economical yield.

Under NT, residue management affected positively most of the studied traits which showed linear or quadratic responses (Table 4). In fact spikes m^{-2} increased from a mean value of 383.4, under bar soil to 446.3 spikes m^{-2} under 60% residue cover during the 2009/2010 cropping season, and from 243.7 to 289.5 spikes m^{-2} under the same residue treatments during the 2010/2011 season (Table 4). Similar pattern of response was observed for grain yield, kernel number, kernels per spike, plant height, above ground biomass, straw yield and economical yield. No clear trend was noted for thousand-kernel weight and harvest index, while the number of seedling emerged m^{-2} was not significantly affected by residue rate (Table 4). It is worth noting that during the 2009/10 cropping season CT had a grain yield significantly higher than NT (average over residue treatments), but when comparing this treatment with $NT_{60\%}$ (60% residue cover), the advantage was toward the $NT_{60\%}$ (Tables 3, 4, Figure

4). As growers are concerned about decreased crop yield with no-till practices, the results of the present study suggested that with adequate residue cover, no-till treatment did not decreased grain yield. These results corroborate findings of [30] who reported that the number of fertile tillers, the number of kernels per spike, 1000- kernel weight, grain yield, biological yield and harvest index increased with increased soil surface residue rate. These effects were related to higher soil water content and water use efficiency. [19] found that wheat yield increased with increased residue rate and were lowest under conventional tillage. [12] reported that during a 9-year period NT management either equaled or exceeded CT, in terms of grain yield. [35] reported that increased straw mulching rate decreased yield and water use efficiency of wheat. [36] reported no significant difference in grain yield among tillage systems, and a 50% saving in terms of labor time and fuel consumption was achieved with NT, in comparison with CT.

Table 4: Mean values of the measured traits as affected by residue management and year.

		SDL	SN	TKW	GY	KN	KNS	PHT	BIO	STR	HI	ECY
2010	$NT_{0\%}$	287.4	383.4	37.2	185.9	4.8	12.4	65.3	588.2	394.9	29.5	311.3
	$NT_{30\%}$	297.9	433.3	38.1	193.9	5.1	11.7	67.7	630.5	444.6	31.9	319.8
	$NT_{60\%}$	293.3	446.5	38.6	291.3	7.6	17.0	78.7	918.2	626.4	32.9	479.7
2011	$NT_{0\%}$	271.4	243.7	53.6	271.7	5.1	20.9	66.2	729.5	457.8	37.3	409.0
	$NT_{30\%}$	253.4	261.4	45.8	315.2	6.9	24.5	71.5	820.5	505.3	38.4	466.8
	$NT_{60\%}$	268.9	289.5	49.4	319.3	9.5	24.1	69.4	878.8	559.5	36.3	487.2
	F test	ns	*	*	*	*	*	*	*	*	*	*

SDL = number of seedlings per m², PHT = plant height, BIO = above ground biomass, STR = straw yield, HI= harvest index, SN= spikes number, TKW = thousand-seed weight; KN = number of kernels per m², KNS= number of kernels per spike, GY = grain yield, ECY = economical yield.

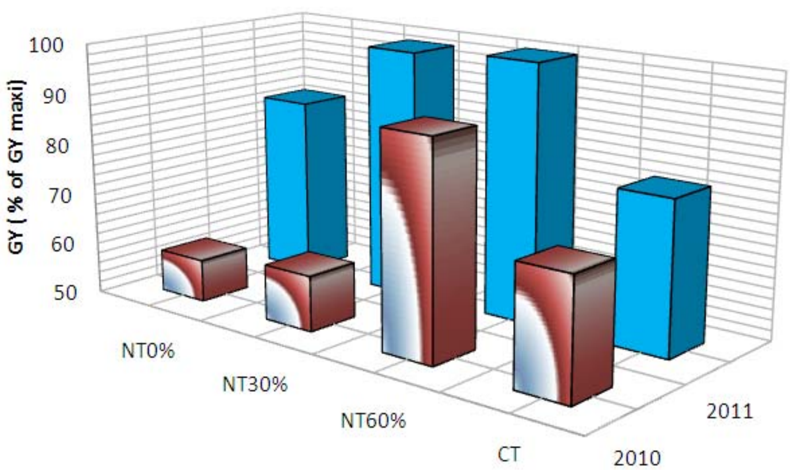

Fig. 4: Grain yield variation under tillage and residue management during the 2009/10 and 2010/11 cropping seasons at the ITGC-ARS of Setif (Algeria).

Crop water use and water use efficiency:

No sizeable differences existed between NT and CT for crop water use (CWU), whose average was 414.7 and 337.3 mm for 2009/10 and 2010/11 cropping seasons, respectively. CWU varied from 396.0 to 427.5, in 2009/10 and from 335.0 to 339.0 mm, in 2010/11. However differences do exited between NT and CT for transpiration (T) and evaporation (E) during 2009/10 cropping season. Averaged over residues rates, T value for NT was equal to 195.3 against 247.0 mm for CT. T values were 123.0 and 121.9 mm for the same treatments during the 2010/11growing season. Evaporation values were 220.7 vs 173.7, in 2009/10, and 213.7 vs 217.1 mm, in 2010/11, for NT and CT, respectively. T increased from 158.1 to 232.1 mm and from 117.8 to 134.5 as residue rates increased from 0% to 60%, during 2009/10 and 2010/11cropping seasons, respectively. CT achieved higher water use efficiency for above ground biomass production (WUE_{BIO}, 23.2 kg ha^{-1} mm^{-1}) than NT (17.2 kg ha^{-1} mm^{-1}) in 2009/10. But both treatments showed similar grain yield water use efficiency (WUE_{GY}), 5.5 and 5.4 kg ha^{-1} mm^{-1} for CT and NT, respectively. During the same season, WUE_{BIO} and

WUE_{GY} were 13.4, 15.2 and 23.1 kg ha^{-1} mm^{-1}; and 4.2, 4.6 and 7.3 kg ha^{-1} mm^{-1}, for $NT_{0\%}$, $NT_{30\%}$ and $NT_{60\%}$, respectively. In 2010/11, NT achieved higher water use efficiency for above ground biomass and grain yield with mean values equal to 24.0 and 8.9 kg ha^{-1} mm^{-1}, respectively. The corresponding values for CT were 19.5 and 7.4 kg ha^{-1} mm^{-1}. WUE_{BIO} changed from 21.7 to 26.0 kg ha^{-1} mm^{-1} and WUE_{GY} increased from 8.1 to 9.5 kg ha^{-1} mm^{-1}, as residue rate increased from 0 to 60%. These results indicated variation of T and E values between years and tillage management, but T increased and E decreased as residue rate increased. Variation between years was also noted for above ground biomass water use efficiency. Both tillage treatments had similar WUE_{GY} which increased as residue rate increased, too. WUE_{GY} found in this study were in the range reported in the literature. [11], grain yield water use efficiency ranged from as low as 2.5 to 10.7 kg ha^{-1} mm^{-1}. The same author observed a reduced evaporation under NT. [29] reported a greater WUE_{GY} of 6.1 1 kg ha^{-1} $mm^{-1}$for NT compared 3.7 kg ha^{-1} mm^{-1} for CT, in one season and no significant differences between tillage treatments in other two years. The same authors reported WUE_{BIO} values ranging between 6.1 and 32.2 kg $ha^{-1}mm^{-1}$.

Discussion:

Durum wheat in Algeria is grown under rainfed conditions on the high plateaus region, and the yield observed is the lowest in the North African countries. Therefore, reduction of wheat production costs while maintaining yield level, through NT system is sought because it is of particular importance mainly for wheat growers of the region of Setif. NT is proposed as a promising strategy to improve soil and water conservation, to reduce input costs and to increase crop yield. In a number of studies, NT system has been reported to provide wheat yields equal to or even higher than those achieved under CT. However, other studies indicated lower wheat yields under NT compared to CT. NT management generally results in greater soil water content than CT system [11,12, 16,29]. NT promotes soil surface cover, reduces water loss via evaporation and increased water use efficiency [14,15,16,29,33,34]. A two-year field experiment was conducted at the ITGC-ARS experimental site to determine the potential of NT compared to CT. This study compared the effects of NT with and without soil residue cover to CT, on durum wheat [*Triticum turgidum* (L.) Thell. ssp. *turgidum* conv. *durum* (Desf.) MacKey] growth, yield, and water use efficiency. The cumulative rainfall recorded from crop sowing to harvest was 427.7 mm in 2009/10 and 312.1 mm in 2010/11. In 2009/10, soil water content was greater under CT than NT, because at seeding time CT had more stored water due to management difference of the preceding fallow: tilled vs weedy. Residue effect on water content was noted as $NT_{60\%}$ stored more soil water than $NT_{30\%}$ and $NT_{0\%}$. No significant differences in soil water content existed among treatments during the 2010/11 crop season. During both cropping seasons, the rate of biomass accumulation was relatively higher under CT than NT, resulting in a higher above ground biomass accumulated under CT at harvest time. Residue rate affected positively the rate of biomass accumulation with $NT_{0\%}$ exhibiting the lowest above ground biomass production. Significant tillage effect and interaction tillage x years were noted for all traits studied. Averaged over years, NT had more emerged seedlings, spikes, number of kernels per m^2, grain yield and harvest index; while CT showed significantly higher thousand-kernel weight, kernels per spike, plant height, above ground biomass, straw and economical yields. Under NT, residue management affected positively most of the studied traits, showing linear or quadratic responses. Increases were noted for spikes m^{-2}, grain yield, kernel number, kernels per spike, plant height, above ground biomass, straw yield and economical yield, as residue rates increased. Thousand-kernel weight, harvest index and seedling emerged m^{-2} were not affected by residue rate. During the 2009/10 cropping season CT showed higher grain yield than NT (average over residue treatments), but when comparing this treatment with $NT_{60\%}$, the advantage was toward the $NT_{60\%}$. Averaged over residue rates, T was higher under CT than under NT, in 2009/10, but not significant difference was noted in 2010/11. The opposite was noted for E which was higher under NT compared to CT and the difference between treatments was not significant during the second year. T values increased as residue rates increased during both seasons. In 2009/10, CT showed higher WUE_{BIO} than NT and similar WUE_{GY}. Both WUE_{BIO} and WUE_{GY} increased as residue rate increased. In 2010/11, NT achieved higher WUE_{BIO} and WUE_{GY} compared to CT. Both parameters increased as residue rate increased. As growers are concerned about decreased crop yield with no-till practices, the results of the present study suggested that with adequate residue cover, no-till did not decreased grain yield. However in the region concerned by this study straw had a high economical value, sometimes higher than the grain, which may incites farmers, adopting NT system, to over graze or to partially or entirely remove stubble for livestock feeding, this will likely have negative effect on grain yield. These findings indicate that wheat can be grown successfully under conservation tillage systems with yields equal or higher than those of conventional tillage.

Conclusions:

This study showed that with proper management no till yield can equal to those obtained under conventional tillage practices or even improved. The advantage of no-till originates from increased transpiration and reduced evaporation, because of the effect of residue remaining on the surface. The results indicated variation between years for soil water storage being higher under CT the first season and no difference exited the second year between tillage managements. Above-ground biomass was higher under CT, while grain yield, spikes m^{-2} and number of kernels m^{-2} were higher under NT. Residue rate affected positively the measured traits, suggesting the necessity to maintain residue cover to avoid reducing yield under NT management. CT showed higher WUE_{BIO} and WUE_{GY} in the first year; while NT expressed higher WUE_{BIO} and WUE_{GY} during the second year. WUE_{BIO} and WUE_{GY} increased as residue rate increased, during both cropping seasons. The results of the present study suggested that durum wheat can be grown under NT with the expectation that gain yield will be at least equal to CT grain yield.

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