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RESPONSE OF TEN WINTER WHEAT (*TRITICUM AESTIVUM* L.) CULTIVARS DEVELOPED AT NARDI FUNDULEA, TO BASIC CONSERVATION AGRICULTURE PRACTICES

Alexandru I. Cociu and Eliana Alionte

National Agricultural Research and Development Institute Fundulea, 915200 Fundulea, Călăraşi County, Romania
E-mail: acociu2000@yahoo.com

ABSTRACT

Soil tillage is an essential factor of winter wheat (*Triticum aestivum* L.) crop management. Genotypes well adapted to different agricultural practices could be identified by either conducting the breeding and selection process in the respective conditions, or just testing the response of selected cultivars to such conditions. The objectives of this study were: (a) to test the influence of seeding in no-tillage (NT) and chisel-tillage (CT) systems, within conservation agriculture conditions, on winter wheat grain yield and its components, as well as on grain protein, in the South-East Plain of Romania; (b) to estimate the response of 10 cultivars, released by NARDI Fundulea, to these cropping practices and conditions. The field experiment was conducted over two growing seasons: 2010-2011 and 2011-2012. Comparisons were done among the two tillage systems and the 10 tested varieties. Grain yield, its components, and grain protein content were not significantly affected by tillage system within conservation agriculture, but were significantly influenced by the cultivar. The cultivars under study performed well when seeded directly in no-tillage (NT) or chisel-tillage (CT) systems, producing yields of over 5000 kg ha^{-1}, regardless of the fact that they were developed within a breeding program which was based on conventional (traditional) agricultural practices.

Key words: Winter wheat, grain yield, yield components, grain protein content, conservation agriculture, tillage system.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the essential crops in the world, being cultivated on the largest acreage, of 200 million hectares, in comparison with the other cereals (http://www.fao.org). Its grains, due to their high content and quality of carbohydrates and proteins, constitute the raw material for bread-making industry, producing basic food for 35-40% of world population. In Romania wheat crop covers around 2.35 million hectares, which represent 25% of the total arable acreage and 40% of the total cereals acreage.

Considering that wheat is less exigent to soil tillage, many farmers have adopted more economic cropping practices, reducing or even eliminating soil work and also keeping the previous crop vegetal residue on soil surface. In this case, a judicious crop rotation has to be followed, in order to stabilize and improve soil quality and to maintain high yield levels (Bradford & Peterson, 2000). Presently, this cropping way has become known as Conservation Agriculture (AC). A series of experimental results, as those obtained by Sayre et al. (2005), demonstrated clearly its advantages and how it can contribute to productivity, poverty alleviation, food security, and environmental protection and improvement.

Genotypes with good response to conservation agriculture practices could be obtained by either conducting the breeding process in CA conditions or just testing old and new cultivars in such conditions. Cultivars adapted to these practices should be able to emerge better from non-ploughed soil and to grow quickly through the vegetal residue of the previous crop, penetrating the layer of surface organic matter, which influences positively the nutrition dynamic and the increase of soil fauna and micro-

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organisms (Watt et al., 2005). In addition, Trethowan et al. (2005) showed that there is a strong genotype x tillage interactions that affect the development of conservation agriculture practices for wheat and other crops.

Plant breeders need to continue to improve wheat for CA systems, especially zero- and minimum-tillage. Traits of interest include: better water utilization, improved root health and development, and resistance to pests that emerge in residues or result from adoption of CA practices (Ortiz et al., 2008).

Conservation agriculture strives for sustainable productivity, quality and economic viability while leaving a minimal foot print on the environment.

Preservation of soil and its water content is the core of this approach, and zero or minimum tillage is techniques used extensively for this purpose in CA. Most crop breeding programs are conducted on complete tillage regimes, thus limiting the identification of crop genotypes responsive to CA (Mahmood et al., 2009).

Researchers studying genotype x tillage practice interaction have generally reported a lack of interaction in field crops (Cox, 1991; Ullrich and Muir, 1986; Francis et al., 1984). Thus the probability of finding a significant genotype x tillage practice interaction in improved crop germplasm may be limited and the inclusion of greater genetic diversity in applied breeding may be necessary if better adapted cultivars are to be developed (Trethowan et al., 2012).

Winter wheat breeding program within the National Agricultural Research and Development Institute Fundulea is well known as very proficient in developing superior and high quality varieties (Săulescu et al., 2007).

Before being released, these varieties have been tested on a large scale under traditional (conventional) cropping conditions, but their behaviour to conservation soil practices has not yet been evaluated.

The main objectives of this research were the following: (a) to evaluate the influence of seeding in no-tillage (NT) and chisel-tillage (CT) systems of conservation agriculture on winter wheat grain yield and its components, as well as on grain quality, in the South-East Plain of Romania environment; (b) to estimate the response to these cropping practices and conditions of 10 varieties, developed at NARDI Fundulea.

MATERIAL AND METHODS

Winter wheat cultivars chosen for this research were as follows: Boema 1, Miranda, Dropia, Gruia, Litera, Delabrad 2, Flamura 85, Faur F, Glosa, Izvor. Field experiments were conducted during two growing seasons (2010-2011 and 2011-2012) at NARDI Fundulea, which is located at 44º27'45" latitude and 26º31'35" longitude, East of Romanian Danube Plain, and East of Fundulea town.

Soil and Climatic Description

Soil on which this experimentation was carried out is a cambic cernozem formed on loessoide deposits, which is typical for a large area of this plain. Its surface is flat, at 68 m altitude, and with the underground water at 10-12 m depth. Morphologically, the soil presents an Ap 0-27 cm horizon, dusty – argillaceous, with 36.5% clay, and with a compaction of 1.41g/cm^3. It contains good – very good levels of potassium (soluble K=175 ppm), phosphorus (70 ppm), and humus (2.2). Total nitrogen is around 0.194 and pH=6.7.

The respective region is characterized by a temperate continental climate. The average temperatures and rainfall of both the 2010-2011 and 2011-2012 growing seasons, as well as the long-term (1960-2012) averages for the region, are presented in Table 1.

Precipitations fallen in fall-winter period are considered very important for remaking soil water reserve. In both experimental seasons these precipitations were significantly lower than the multi-annual mean, with 7% and 23%, respectively. In both periods, heading (blooming) took place at the beginning of May, which is a month with higher amount of precipitations.

Table 1. Climatic data for Fundulea Region from – 2010-2011, 2011-2012, long-term (LT) averages

Month	Temperature (ºC)			Rainfall (mm)		
	2010-2011	2011-2012	LT	2010-2011	2011-2012	LT
October	8.9	10.3	11.2	47.0	27.0	40.4
November	10.7	3.3	5.1	9.0	1.5	42.3
December	-0.7	2.8	-0.2	92.5	28.1	44.7
January	-3.2	-1.4	-2.5	43.7	73.5	34.1
February	-2.5	-7.3	-0.5	16.5	42.2	31.9
March	5.0	5.5	4.7	5.1	4.8	36.8
April	10.3	14.2	11.2	28.9	35.1	44.3
May	16.3	18.0	17.0	76.8	159.5	60.2
June	27.3	23.3	20.8	102.4	20.7	71.9
Total				421.9	92.4	406.6

Field management

The field experiments were set after soybean in both growing seasons, within a long term, multi-disciplinary research platform based on conservation agriculture, initiated in 2009. The scheme used comprised 20 un-replicated plots for observation, divided in two tillage systems: no-tillage (NT) and chisel-tillage (CT). The 20 plots were seeded on Oct. 25 in 2010, and Oct. 21 in 2011. Seeding rate for all plots was 500 germinal grains/m². The combined drill used for seeding and fertilizing was of the type of TUME Nova Combi 3000 (Noka-Tume Oy, Turenky, Finland). This drill can be adjusted for seeding in prepared soil or directly in no tilled land. It is provided with wheals to control precisely the depth of seeding, which in this case was of 4 cm.

Nitrogen and phosphor fertilizers, 30 kg a.i. ha^{-1} and 80 kg a.i. ha^{-1} respectively, were applied simultaneously with seeding, and a dose of 90 kg a.i. ha^{-1} nitrogen fertilizer was added by spreading in spring. Before first inter-node formation, 0.6 kg/ha of 2,4 D herbicide was applied. No disease, insects or pests infestations were noticed. Harvests was performed on July 15 in 2011 and July 04 in 2012, with a small plot combine of the type of Delta (Wintersteiger AG, Ried, Austria) with 2 m work width, and was performed in the middle of the plot, on a length of 50 m.

Sampling and methods

Grain yield results are reported at the 14% standard moisture. The yield components, as grain weight per spike, number of spikes per m², number of grain per spike, aerial biomass, harvest index, thousand grain weight, and test weight were measured analyzing 50 plants, sampled from each experimental plot, following the method described by Gómez-Macpherson et al. (2003). Grain protein concentration was determined by direct chemical analyses, utilizing the grain analyzer Foss Infratec 1225 (Foss Tecator AB, Höganas, Sweden), which was calibrated on the basis of the results making use the traditional Kjeldhal procedure for protein content evaluation.

Statistical analysis

Analysis of variance (ANOVA) was performed using the MSTAT-C statistical package to determine the significance of differences in grain yield, biomass yield components and protein content, with cultivars and tillage system as main factors, for both growing seasons. “Duncan's New Multiple Range Test“, at 5% probability level, was used to compare the mean differences. Correlation analysis (Steel and Torrie, 1980) was also run on grain yield, yield components, and grain protein for each tillage system.

RESULTS AND DISCUSSION

Plant height was not significantly influenced by soil tillage, but varied significantly among cultivars, as an expression of their genetic diversity. Interaction between the two factors was non-significant (Table 2).

Plant height mean within NT system, over the two growing seasons, was 3.6 cm lower than that calculated for CT of which value was 68.6 cm.

The highest value of plant height was recorded in CT system for variety Miranda (86.0cm), and the shortest height for variety Flamura 85, in NT system (59.7 cm). In this context, it is worth to mention that the correlation analysis revealed a strong positive relationship between the grain yield and height plant (Table 7).

Table 2. Influence of seeding methods, within two conservation agriculture tillage systems, on plant height and grain weight spike^{-1} of 10 winter wheat varieties, Fundulea (2010/2011 and 2011/2012 season means)

Variety	Plant height (cm)			Grain weight spike^{-1} (g)		
	NT	CT	Mean	NT	CT	Mean
Boema 1	63.1 bc	63.4 bc	63.2 B	1.42abc	1.42 abc	1.42 AB
Litera	68.8 bc	70.6 bc	69.7 B	1.35 abcd	1.21 cde	1.28 BCD
Flamura 85	59.7 c	65.2 bc	62.4 B	1.30 abcde	1.19 cde	1.24 CD
Dropia	62.2 bc	66.2 bc	64.2 B	1.23 bcde	1.21 cde	1.22 D
Glosa	64.3 bc	64.3 bc	64.3 B	1.42 abc	1.37abcd	1.40 ABC
Gruia	64.3 bc	66.7 bc	65.5 B	1.43 abc	1.19 cde	1.31 ABCD
Izvor	69.6 bc	69.1 bc	69.3 B	1.07e	1.31 abcd	1.19 D
Miranda	75.5 ab	86.0 a	80.7 A	1.51 a	1.42 abc	1.46 A
Delabrad 2	62.1 bc	68.0 bc	65.0 B	1.28 abcde	1.16 de	1.22 D
Faur F	60.5 c	66.9 bc	63.7 B	1.22 bcde	1.48 ab	1.35 ABCD
Mean	65.0 A	68.6 A		1.32 A	1.29 A	

Means within the same column, followed by the same letter(s) are not significantly different at the 5% level.

Grain weight spike^{-1} was not significantly affected by the tillage system, but it was significantly influenced by the cultivar. The interaction between the two factors was not significant. The highest value was recorded within NT system for variety Miranda (1.51 g), and the lowest one for Izvor (1.07g). Looking again at Table 7 data, it is quite surprising to see that the linear relationship between grain yield ha^{-1} and grain weight spike^{-1} was not significant in both tillage systems under this study.

Another important trait in view of wheat breeding programs is the number of spikes m^{-2}. The results presented in Table 3 show that this trait was also not influenced significantly by the tillage system, but it was affected significantly by the cultivar. The interaction between the two factors was again non-significant.

Table 3. Influence of seeding methods, within two conservation agriculture tillage systems, on number of spikes m^{-2} and number of grain spike^{-1} of 10 winter wheat cultivars, Fundulea (2010/2011 and 2011/2012 season means)

Variety	Number of spikes m^{-2}			Number of grains spike^{-1}		
	NT	CT	Mean	NT	CT	Mean
Boema 1	336.0 c	362.5 bc	349.25 B	34.0 ab	34.0 ab	34.0 A
Litera	397.0 bc	447.5 bc	422.25 AB	32.5 abc	30.0 abc	31.25 ABC
Flamura 85	388.5 bc	408.0 bc	398.25 B	27.5 abc	25.5 c	26.5 C
Dropia	396.5 bc	424.5 bc	410.50 B	28.0 abc	26.0 bc	27.0 BC
Glosa	414.0 bc	394.5 bc	404.25 B	35.5 a	29.5 abc	32.5 AB
Gruia	365.5 bc	478.0 b	421.75 AB	34.0 ab	32.0 abc	33.0 A
Izvor	588.0 a	416.5 bc	502.25 A	33.0 abc	31.5 abc	32.25 AB
Miranda	375.0 bc	416.0 bc	395.50 B	33.0 abc	33.5 abc	33.25 A
Delabrad 2	408.0 bc	466.5 b	437.25 AB	31.0 abc	27.5 abc	29.25 ABC
Faur F	478.5 b	375.0 bc	426.75 AB	32.5 abc	35.0 a	33.75 A
Mean	414.7 A	418.9 A		32.1 A	30.45 A	

Means within the same column, followed by the same letter(s) are not significantly different at the 5% level

The highest number of spikes m^{-2} was recorded for the variety Izvor (588 spikes m^{-2}) and the lowest one for the variety Boema 1 (336 spikes m^{-2}), in both systems. Correlation analysis presented in Table 7 put in evidence that the relation between grain yield and the number of spikes m^{-2} was fairly strong, within both tillage systems.

The varieties Glosa, in NT system, and Faur F, in CT system, performed the best in regards to the number of grains spike^{-1}, with values of 35.5 and 35.0, respectively (Table 3). Comparing the mean values of this trait, calculated for each tillage system, the difference of 5.4% in favour of CT was not statistically significant.

The factor cultivar had an influence on this trait at the limit of significance, but the interaction of it with the two tillage systems was non-significant. Correlation analysis, presented in Table 7, showed that the relationship between grain yield and number of grain spike^{-1} was not significant, within both tillage systems.

Another trait taken into consideration in this study was biomass (Table 4). The NT and CT systems did not affect significantly this trait, but it varied greatly among cultivars. The interaction between the two factors was not significant. The highest biomass quantity was recorded for variety Izvor (1359.5 g m-²), and the lowest one for Boema 1 (930 g m-²). Correlation analysis (Table 7) made evident a very close relationship between grain yield and plant biomass, within both tillage systems.

Table 4. Influence of seeding methods, within two conservation agriculture tillage systems, on biomass and harvest index of 10 winter wheat varieties, Fundulea (2010/2011 and 2011/2012 season means)

Variety	Biomass (g m^{-2})			Harvest index		
	NT	CT	Mean	NT	CT	Mean
Boema 1	930.0 d	982.0 cd	956.0 D	0.520 ab	0.525 a	0.523 A
Litera	1123.0 bc	1101.5 bcd	1112.25 BC	0.490 abcde	0.490 abcde	0.490 BC
Flamura 85	1037.5 cd	1081.0 bcd	1059.25 CD	0.490 abcde	0.460 de	0.475 BC
Dropia	1023.5 cd	1103.0 bc	1063.25 CD	0.475 bcde	0.455 e	0.465 C
Glosa	1151.0 bc	1137.0 bc	1144.0ABC	0.515 abc	0.490 abcde	0.503 AB
Gruia	1062.5 bcd	1142.5 bc	1102.5 BC	0.505 abcd	0.485 abcde	0.495 AB
Izvor	1359.5 a	1124.0 bc	1241.75 A	0.455 e	0.495 abcde	0.475 BC
Miranda	1161.0 bc	1220.0 abc	1190.5 AB	0.495 abcde	0.495 abcde	0.495 AB
Delabrad 2	1124.5 bc	1162.0 bc	1143.25 ABC	0.470 cde	0.460 de	0.465 C
Faur F	1227.0 ab	1090.5 bcd	1158.75 ABC	0.485 abcde	0.510 abc	0.497 AB
Mean	1119.95 A	1114.35 A		0.490 A	0.486 A	

Means within the same column, followed by the same letter are not significantly different at the 5% level.

Table 4 comprises also the values calculated for harvest index. This characteristic was not affected by tillage system, but strongly influenced by cultivar. The interaction between the two factors was not significant. The highest values were registered for variety Boema 1, in both NT and CT systems (0.520 and 0.525, respectively), and the lowest, of 0.455, was found in varieties Izvor in NT system, and Dropia in CT system. The correlation analysis, presented in Table 7, reveals a strong negative linear relationship between grain yield and harvest index, in both tillage systems.

The trait thousand grain weights were not affected by tillage system, but it was again strongly influenced by cultivars (Table 5). The interaction between the two factors was not significant in this case. The highest value was recorded for variety Dropia (49 g) within in CT system, and the lowest one for variety Izvor (40 g), in both CT and NT systems. There were significant differences among varieties. Correlation analysis of Table 7 shows that the relationship between grain yield and thousand grain weight was not significant, within both tillage systems.

Grain test weight was not significantly affected by soil tillage (Table 5). Few significant differences among varieties were registered.

The interaction between the two factors was again not significant. The highest test weight values were recorded for the variety Dropia (81.8 kg hl^{-1}) in NT system and for Flamura 85 (81.75 kg hl^{-1}) in CT system. The lowest test weight was shown by variety

Miranda (74.9 kg hl^{-1}) in CT system. Correlation analysis (Table 7) proves that grain yield was positively influenced by the test weight trait at the limit of significance, within NT system, and not significantly affected within CT system.

Protein content, which is one of the important grain quality characteristic of this crop, was not influenced by the tillage system, over all, but varied significantly between cultivars (Table 6). The interaction between the two factors was not significant. The highest value was determined for variety Flamura 85 (14%) and the lowest for Miranda (12.4%), both in NT system. Data from Table 7 show that there was a very strong negative relationship between grain yield and protein content, in both tillage systems. These results are well in line with the most published research on this subject (Metzger, 1935; Schlehuber and Tucker, 1959; Terman et al., 1969).

Table 5. Influence of seeding methods, within two conservation agriculture tillage systems, on thousand grain weight and test weight of 10 winter wheat varieties, Fundulea (2010/2011 and 2011/2012 season means)

Variety	Thousand grain weight (g)			Test weight (kg hl^{-1})		
	NT	CT	Mean	NT	CT	Mean
Boema 1	43.0 efgh	44.0 cdefgh	43.5 B	80.85 ab	79.70 ab	80.275 A
Litera	43.5 defgh	43.0 efgh	43.25 B	80.50 ab	80.20 ab	80.350 A
Flamura 85	47.5 abcd	48.5 ab	48.0 A	81.55 a	81.75 a	81.650 A
Dropia	47.0 abcde	49.0 a	48.0 A	81.80 a	81.25 a	81.525 A
Glosa	45.5 abcdef	48.0 abc	46.75 A	80.85 ab	80.60 ab	80.725 A
Gruia	42.5 fgh	42.5 fgh	42.5 BC	80.60 ab	80.30 ab	80.450 A
Izvor	40.0 h	40.0 h	40.0 C	81.0 ab	80.70 ab	80.850 A
Miranda	43.0 efgh	42.0 fgh	42.5 BC	76.45 bc	74.90 c	75.675 B
Delabrad 2	40.5 gh	44.5 bcdefg	42.5 BC	79.10 abc	78.65 abc	78.875 A
Faur F	40.0 h	43 efgh	41.5 BC	80.55 ab	79.60 ab	80.075 A
Mean	43.25 A	44.45 A		80.325 A	79.765 A	

Means within the same column, followed by the same letter are not significantly different at the 5% level.

Table 6. Influence of seeding methods, within two conservation agriculture tillage systems, on protein content and grain yield of 10 winter wheat varieties, Fundulea (2010/2011 and 2011/2012 season means)

Variety	Protein content (%)			Grain yield (t ha^{-1})		
	NT	CT	Mean	NT	CT	Mean
Boema 1	13.95 ab	13.95 ab	13.95 AB	5.15 e	5.505 cde	5.328 BC
Litera	14.0 ab	13.80 abc	13.90 AB	5.72 bcde	5.65 bcde	5.685 B
Flamura 85	14.60 a	14.45 a	14.525 A	5.385 de	5.13 e	5.257 BC
Dropia	14,35 a	14.35 a	14.35 A	5.105 e	5.19 e	5.148 C
Glosa	13.20 abc	13.35 abc	13.275 BC	6.325 ab	5.865 bcde	6.095 AB
Gruia	13.55 abc	13.65 abc	13.60 AB	5.71 bcde	5,76 bcde	5.735 B
Izvor	13,45 abc	13.65 abc	13.55 ABC	6.665 a	5.89 abcde	6.277 A
Miranda	12.40 c	12.80 bc	12.60 C	6.205 abc	6.38 ab	6.293 A
Delabrad 2	14.05 ab	14.20 ab	14.125 AB	5.71 bcde	5.64 bcde	5.675 B
Faur F	14.20 ab	13.80 abc	14.0 AB	6.35 ab	6.0 abcd	6.175 AB
Mean	13.775 A	13.80 A		5.832 A	5.701 A	

Means within the same column, followed by the same letter are not significantly different at the 5% level.

Data presented in the second part of Table 6 reveal that the two tillage systems did not affect significantly the grain yield per hectare. The average value calculated for NT system, over the two experimental growing seasons, was higher only with 2.3% than that for CT system. In exchange, cultivars had a very significant influence on this trait, proving again a large genetic diversity of the genotypes included in this study. The highest grain yield per hectare was registered for variety Miranda (6,293 t ha^{-1}), and the most reduced one for Dropia (5,148 t ha^{-1}).

Soil tillage x variety interaction (data presented in Table 6) makes evident that the influence of the two conservation agriculture tillage systems on average yield performance of all varieties under study was not significant.

Table 7. Correlation analysis regarding the response of winter wheat yield per hectare to the yield components and grain protein content, within two conservation agriculture tillage systems

Yield components and grain protein content	Correlation coefficient (r)	
	NT	CT
Plant height	0.923***	0.949***
Grain weight spike^{-1}	Correlation coefficient was not found significant	
Number of spikes m^{-2}	0.893***	0.853***
Number of grains spike^{-1}	Correlation coefficient was not found significant	
Biomass	0.986***	0.959***
Harvest index	-0.714***	-0.759***
Thousand grain weight	Correlation coefficient was not found significant	
Test weight	0.539*	not found significant
Protein content	-0.824***	-0.774***

Varieties reacted differently to the respective tillage systems (Figure 1). Some of them, such as Gruia, Dropia, Miranda and Boema 1 had a slightly higher yield in CT
system, in comparison to NT system. The others, such as Litera, Delabrad 2, Flamura 85, Faur F, Glosa, and Izvor performed better in NT systems, with yield differences raging between 70 kg ha^{-1} and 775 kg ha^{-1}.

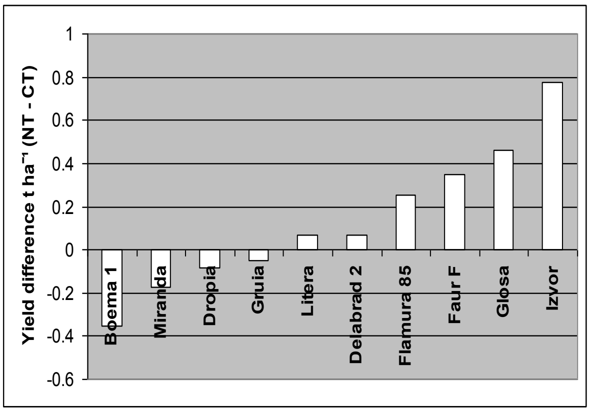

Figure 1. Yield differences between no-tillage (NT) and chisel -tillage (CT) systems, within conservation agriculture, of 10 winter wheat cultivars,based on means of 2 years

Yield differences between no-tillage (NT) and chisel tillage (CT) systems correlated positively and significantly with the number of spikes m^{-2}, and significantly with the biomass (Figures 2 and 3). Yield relationships with all the yield components and grain protein content were statistically not significant.

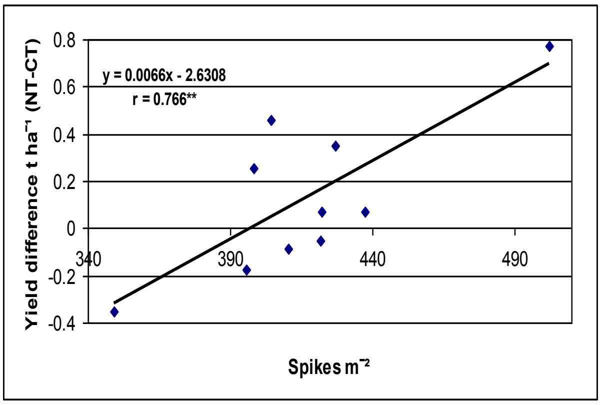

Figure 2. Relationship of yield differences between no-tillage (NT) and chisel tillage (CT) systems, within conservation agriculture, and number of spikes per m², based on means of 2 years

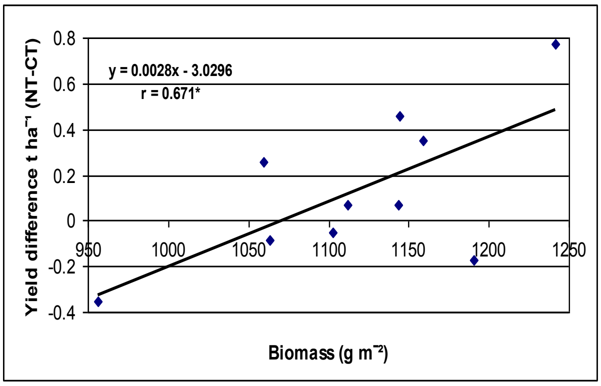

Figure 3. Relationship of yield difference between no-tillage (NT) and chisel tillage (CT) systems, within conservation agriculture and biomass, based on means of 2 years

CONCLUSIONS

The results of this research indicate that many winter wheat cultivars developed by the breeding program of NARDI Fundulea, under conventional (traditional) agricultural practices, perform well, with yields over 5000 kg/ha, when they are seeded in conservation agriculture no-tillage (NT) or chisel-tillage (CT) systems.

REFERENCES

Bradford, J. M. & Peterson, G. A., 2000. *Conservation tillage*. In: Handbook of Soil Science (Ed. M. E. Summer): 247-270. Boca Raton: CRC Press.

Cox, D.J., 1991. *Performance of hard red winter wheat cultivars under conventional-till and no-till systems*. North Dakota Farm Research, 48: 17-20.

Francisc, C.A., Saeed, M., Nelson, L.A., Moomaw, R., 1984. *Yield stability of sorghum hybrids and random-mating populations in early and late planting dates.* Crop Sci., 24, 1109-1112.

Mahmood, T., Ahmad, A., Ali, Z., Trethowan, R., 2009. *Genotype x tillage interactions in broad acre crops and their implications for cultivar improvement*. Paper presented at 14th Australasian Plant Breeding & 11th SABRAO Conference, 10-14 August 2009, Cairns, Australia.

Metzger, W.H., 1935. *The residual effect of alfalfa cropping periods of various lengths upon the yield and protein content of succeding wheat crops*. J. Amer. Soc. Agron., 27: 653-659.

Gomez Macpherson, H., van Herwaarden, A.F., and Rawson, H.M., 2003. *Constraints to cereal based rainfed cropping in Mediterranean environments and methods to measure and minimise their effects.* In: Explore On-farm trials for adapting and adopting good agricultural practices. FAO, Roma: 1-18. (www.fao.org/DOCREP/006/Y5146E/ Y5146E00.htm).

Ortiz, R., Sayre, K. D., Govaerts, B., Gupta, R., Subbarao, G. V., Ban, T., Hodson, D., Dixon, J. M., Ortiz-Monasterio, J.I., & Reynolds, M., 2008. *Climate change: Can wheat beat the heat?* Agriculture, Ecosystems and Environment, 126: 46-58.

Sayre, K.D., Limon-Ortega, A., Govaerts, B., Martinez, A. & Cruz Cano, M., 2005. *Effects following twelve years of irrigated permanent raised bed planting systems in Northwest Mexico (Mex).* In: Proceedings of International Conference, Soil – Agriculture, Environment, Landscape: 99-106. Brno, Czech Republic. 29 June – 1 July, 2005, ISTRO.

Săulescu, N.N., Ittu, Gh. Ittu, M., Mustățea, P., 2007. *Five decades of wheat breeding at Fundulea – Romania*. Anale INCDA, LXXV: 55-72.

Schlehuber, A.M., and B.B.Tucker., 1959. *Factors affecting the protein content of wheat*. Cereal Sci. Today, 4: 240-242.

Steel, R.G.D., and Torrie, J.H., 1980. *Principles and procedures of statistics*. McGraw-Hill Publishing Company, New York.

Terman, G.L., Ramig, R.E., Dreier, A.F.& Olson, R.A., 1969. *Yield-protein relationships in wheat grain, as affected by nitrogen and water.* Agron. J., 61: 755-759.

Trethowan, R.M., Reynolds, M., Sayre, K.D., Ortiz-Monasterio, J.I., 2005. *Adapting new wheat cultivars to resource conserving farming practices and human nutritional needs*. Ann. Appl. Biol., 146: 405-413.

Trethowan, R.M., Mahmood, T., Ali, Z., Oldach, K. & Garcia, A.G., 2012. *Breeding wheat cultivars better adapted to conservation agricultura*. Crops Res., 132: 76-83.

Ullrich, S.E., Muir, C.E., 1986. *Progress in the evaluation, use in breeding, and genetic analysis of semi-dwarf mutants of barley.* Semi-dwarf cereal mutants and their use in cross-breeding, II: 31-38.

Watt, M., Kirkegaard, J.A. & Rebetzke, G.J., 2005. *A wheat genotype developed for rapid leaf growth copes well with the physical and biological constraints of unploughed soil*. Functional Plant Biology, 32: 695-706.