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EFFECTS OF STABILIZATION PERIOD OF CONSERVATION AGRICULTURE PRACTICES ON WINTER WHEAT, MAIZE AND SOYBEAN CROPS, IN ROTATION

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ABSTRACT

The main field crops, such as cereals and forages, are mostly produced on rainfed conditions all over the world. In this case, about the most important aspect is the efficiency of utilization of water from precipitation. Cropping systems based on conservation agriculture are closely linked to the management of this water source. They involve significant reduction of tillage, surface retention of adequate crop residues, and diversified, economically viable crop rotations. A long term field experiment (from 2007 to 2012), with winter wheat (*Triticum aestivum* L.), maize (*Zea mays* L.) and soybean [*Glycine* max. (L) Merr.], all in rotation, was conducted at the National Agricultural Research and Development Institute of Fundulea, which is located on a typical soil of the South – Eastern part of Romania. The main objective of this experiment was to evaluate the advantages of conservation agriculture (CA), in comparison to traditional agriculture (TA), in the period of stabilization of the effects of "direct seeding". The factors under study were: water use efficiency (WUE), grain yield, and the economic benefit of these three crops. The WUE of winter wheat was not significantly influenced by the agriculture system, but varied due to precipitations received in vegetation period and accumulated in fall. The WUE of maize was significantly influenced by the agriculture system, and for soybean this influence was not significant, but both varied in dependence to the precipitation during vegetation period and the water reserve at seeding time. The yields of winter wheat and maize were significantly higher when conservation agriculture was practiced than in the case of traditional agriculture. In this study, soybean yields were not significantly affected by the agriculture system. Economic benefits of conservation agriculture in comparison with traditional agriculture were with 1011 lei ha^{-1}, 1153 lei ha^{-1}, and 457 lei ha^{-1} higher then within traditional agriculture, for winter wheat, maize, and soybean, respectively. The output / input ratio evaluated for all three crops were superior when conservation agriculture was applied. Considering all results of this research, we can state that conservation agriculture is an optimum cropping system for increasing grain yields, enhancing water use efficiency and saving energy.

Key words: conservation agriculture (CA), winter wheat – maize – soybean rotation, water use efficiency (WUE), grain yield, economic benefits.

INTRODUCTION

Water supply has been a major limiting factor in most agriculture systems or practices, especially where the water supply or its distribution during the year are unsure. The large scale use of fertilizers, herbicides and pesticides, as well as of genetically superior varieties and hybrids, was expected to assure much higher outputs, but this has not always happened, mainly due to the use of not adequate agriculture (cropping) systems. Additionally, there has been an increasing concern regarding intensive agriculture activities, which contribute more than the extensive practices to the gas emission, this being one of the main causes of climate change. Intensive tillage conducts to quicker organic matter decomposition, so to more intense CO_2 release in the atmosphere, as well as it is done by burning the vegetal residues (Reicosky, 2001). Additionally, greater use of fossil fuels for field machineries makes this matter even worse. Montgomery (2007) pointed out that yield losses of different crops have increased where intensive agriculture was continuously practiced many years, due to soil erosion and its quality degradation. On

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large areas, soil degradation has reached the critical point of important physical, chemical, and biological parameters, which are essential for obtaining high, stable and durable yield levels. Inefficient application of high nitrogen fertilizer rates results in a greater NO and NO_2 emission in the atmosphere. These two gases are considered more noxious than CO_2, and contaminate also the underground water.

Intensive agriculture characterizes the traditional (conventional) agriculture (TA) practices, widely adopted in the past, including intense soil loosening by ploughing with furrow overturning, vegetal residues removal, a series of secondary soil works for preparing the seeding bed and for crop maintenance. Monoculture or two year rotation, as well as application of heavy doses of chemical fertilizers, herbicides, insecticides and fungicides are very common.

Economically, traditional agriculture practiced many years in a row has an important negative result: a rapid increase of production cost associated with gradually growing input inefficiency. Consequently, agronomists and farmers, realizing all these drawbacks of TA, required scientific research to identify new, less aggressive cropping managements, which may contribute in long term to amelioration of already depreciated agriculture resources and their quality conservation. So, a new agronomy approach has been recently extended, named conservation agriculture (CA).

Conservation agriculture (CA) has been the term used in the last, let say, ten years, for its differentiation from conservation tillage (CT), in order to move the accent from the only soil tillage to a more integrated cropping concept, aimed to improve the agriculture durability and over all its quality.

Conservative agriculture (CA) is characterized by the application in certain combinations of the following basic principles: (i) dramatic reduction of soil tillage; (ii) rational retention - in a practical layer - of vegetal residues on soil surface; (iii) adequate crop rotation; (iv) making the farmers aware of the benefits of this new technology.

The application of cropping systems based on CA is greatly associated to the ways of water management. Its effectiveness on water use efficiency (WUE), and, in the end, on yield level, depends on soil type, specific crop requirements, precipitation probability, and soil capacity of water storage (Boone, 1988). There are some controversies on this mater. Oleary and Connor (1997) consider that replacement of TA with CA improves soil capacity of water storage and yield levels, beside the economic advantages. On the other hand, Tan et al. (2002) did not find significant differences of humidity volumetric contents between the two systems, and Lampurlanes et al. (2002) reported no differences of humidity volumetric contents, neither of WUE, which varied greatly from one year to the other.

Seeding system adopted as part of CA implies a stabilization period, which may extend over more vegetation cycles before full advantages of it can be seen. In many cases, the grain yields obtained during the stabilization period, in rain-fed conditions, may be lower, even over a period of 5 years (Govaerts et al., 2005). Baumhardta and Jonesb (2002) obtained various results comparing the efficiency of TA with CA, reaching the conclusion that it is important to adjust the CA practices at the local level before their extension on a large scale.

The present research was intended to evaluate the advantages of CA in comparison with TA, during the stabilization period of the effects of "direct seeding", regarding water use efficiency (WUE), yield performances of winter wheat, maize and soybean, in rotation, as well as the economic benefits of these crops. The results presented and discussed in this paper can be well used by agronomists and farmers for achieving high and durable yields of these three crops, along with a higher degree of water conservation.

MATERIAL AND METHODS

Study site and meteorological conditions

This research was carried out in the period of 2007-2012, at NARDI Fundulea, which is located at 44º27'45" latitude and

26º31'35" longitude, East of Romanian Danube Plain, and East of Fundulea town.

The soil 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/cm³. 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. Multiannual mean temperature is 10.7ºC, and precipitations over the last 52 years averaged 578.7 mm per year.

The temperature and precipitation data were registered at the meteorological station of NARDI Fundulea, which is located at 400 m from the respective experimental plot. Table 1 presents the monthly and annual temperature means recorded in the period of this research (2007-2012), as well as the multiannual means of 1960-2012 period, and Table 2 includes the respective precipitation data.

Table 1. Monthly and annual temperature means (2007-2012), and multiannual mean of the last 52 years

Month	Temperature means (°C)					
	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	1960-2012
X	11.7	12.6	12.1	8.9	10.3	11.2
XI	3.3	5.8	7.5	10.7	3.3	5.1
XII	-0.6	2.5	0.5	-0.7	2.8	-0.2
I	-3.1	-0.9	-3.9	-3.2	-1.4	-2.5
II	2.4	2.4	-0.8	-2.5	-7.3	-0.5
III	8.2	5.9	5.0	5.0	5.5	4.7
IV	12.7	11.5	11.9	10.3	14.2	11.2
V	16.6	17.6	17.4	16.3	18.0	17.0
VI	21.9	21.8	21.7	27.3	23.3	20.8
VII	23.3	24.0	23.5	23.7	27.3	22.7
VIII	25.0	23.3	25.4	23.2	25.0	22.1
IX	16.6	18.5	18.2	20.8	19.5	17.3
Mean	11.5	12.1	11.5	11.7	11.7	10.7

Table 2. Monthly and annual precipitation (2007-2012) and multiannual mean of the last 52 years

Month	Precipitation means (mm)					
	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	1960-2012
X	46.2	25.9	60.1	47.0	27.0	40.4
XI	52.7	27.5	19.1	9.0	1.5	42.3
XII	62.4	33.2	54.9	92.5	28.1	44.7
I	15.0	69.2	45.4	43.7	73.5	34.1
II	2.3	25.5	69.8	16.5	42.2	31.9
III	21.4	32.3	38.3	5.1	4.8	36.8
IV	61.6	22.1	41.8	28.9	35.1	44.3
V	59.9	35.8	31.2	76.8	159.5	60.2
VI	30.6	103.6	104.5	102.4	20.7	71.9
VII	57.5	119.5	95.0	59.0	2.0	71.8
VIII	1.6	24.6	34.4	29.7	47.8	50.7
IX	59.2	43.2	28.6	13.8	49.1	49.6
Sum	470.4	562.4	623.1	524.4	491.3	578.7

Experimental design, seeding and harvest

The scheme used was a randomized complete bloc design, with 3 replications and 18 experimental plots of 6 x 10 m size.

The 6 plots with winter wheat (*Triticum aestivum* L.) were seeded as follows: Oct. 17 in 2007, Oct. 16 in 2008, Oct. 12 in 2009, Oct. 25 in 2010, and Oct. 21 in 2011. Seeding rate for all plots was 500 viable grains m^{-2}. The combined planter for seeding and fertilizing used was of the type TUME Nova Combi 3000 (Noka-Tume Oy, Turenky, Finland). This planter can be adjusted for seeding in prepared soil or directly in no tilled land. It has wheals to control precisely the depth of seeding; in this case it was of 4 cm. Harvest was performed on: July 21 in 2008, July 08 in 2009, July 15 in 2010, July 15 in 2011, and July 04 in 2012.

The maize (*Zea mays* L.) 6 plots were seeded as follows: April 21 in 2008, April 21 in 2009, April 28 in 2010, April 19 in 2011, and April 11 in 2012. Seeding rate was set to ensure 65,000 plants ha^{-1}. A combined planter for seeding and fertilizing of the type REGINA (Gaspardo Seminatrici S.p.A., Morsano al Tagliamento, PN, Italy), which can be also adapted for seeding in prepared soil for planting or directly in no worked land, was used. Its control wheals were set for 6 cm depth. Harvest was done on: Sept. 11 in 2008, Sept. 15 in 2009, Sept. 14 in 2010, Sept. 15 in 2011, and Aug. 27 in 2012.

The soybean [*Glycine max*. (L.) Merr.] 6 plots were seeded on: May 08 in 2008, April 27 in 2009, April 30 in 2010, April 28 in 2011, and April 27 in 2012. The seeding rate on all plots was 480,000 viable grains/ha, using a combined planter for seeding and fertilizing of the type REGINA (Gaspardo Seminatrici S.p.A., Morsano al Tagliamento, PN, Italy). It has also seeding depth control wheals; the depth used being of 3-4 cm. Harvest was carried out on: Sept. 25 in 2008, Sept. 17 in 2009, Sept. 15 in 2010, Sept. 21 in 2011, and Aug. 28 in 2012. The differences in seeding and harvest times among years were due to the temperature and precipitation differences from one year to the other.

Experimental treatments

The management of agriculture systems and their sequence within each system are presented for each crop under study in Tables 3, 4, and 5.

Table 3. Agriculture systems tested for winter wheat crop NARDI Fundulea, in the period of 2007-2012

Agriculture system	Characteristic operations
Traditional agriculture (TA)	FALL: freeing the land from vegetal residues, P_{80} fertilization, ploughing with mouldboard plough, disc work, preparing the seeding bed with combinator, seeding. SPRING: N_{120} fertilization, herbicide and pesticide applications.
Conservation agriculture (CA)	FALL: chopping vegetal residues and uniform spreading, pre-emergent application of total herbicides, seeding + $N_{30}P_{80}$ fertilization. SPRING: N_{90} fertilization, herbicide and pesticide applications.

Table 4. Agriculture systems tested for maize crop at NARDI Fundulea, in the period of 2007-2012

Agriculture system	Characteristic operations
Traditional agriculture (TA)	FALL: freeing the land from vegetal residues, P_{80} fertilization, ploughing with mouldboard plough. SPRING: disc work, pre-emergent herbicide application, preparing the seeding bed with combinator, seeding. VEGETATION PERIOD: N_{180} fertilization, post-emergent herbicide application,weeding.
Conservation agriculture (CA)	FALL: chopping vegetal residues and their uniform spreading. SPRING: pre-emergent application of total herbicides, seeding + $N_{30}P_{80}$ fertilization. VEGETATION PERIOD: N_{150} fertilization, post-emergent herbicide application.

Table 5. Agriculture systems tested for soybean crop at NARDI Fundulea, in the period of 2007-2012

Agriculture system	Characteristic operations
Traditional agriculture (TA)	FALL: freeing the land from vegetal residues, P_{60} fertilization, ploughing with mouldboard plough. SPRING: disc work, pre-emergent herbicide application, preparing the seeding bed with combinator, seeding. VEGETATION PERIOD: post-emergent herbicide and pesticide application, weeding.
Conservation agriculture (CA)	FALL: chopping vegetal residues and their uniform spreading. SPRING: pre-emergent application of total herbicides, seeding + P_{60} fertilization. VEGETATION PERIOD: post-emergent herbicide and pesticide application.

Measurements and statistical analysis

Soil humidity was measured using the gravimetric method (oven dry), in 3 field replications for each variant, at seeding as well as harvest times, from the depth of 0-90 cm. Evapotranspiration (water consumption) in vegetation period, which consists of plant transpiration and soil water evaporation, was determined using the relation:

$$ET = U_{seeding} + P - U_{harvest},$$

in which: ET is evapotranspiration, $U_{seeding}$ and $U_{harvest}$ are soil humidity at seeding and harvest times respectively, at 0-90 cm profile, and P (mm) are the precipitations fallen in vegetation period. The other components of water balance, as surface leakage and drainage, were considered insignificant in these experimental conditions. Water use efficiency (WUE) was calculated using the following relation: WUE = GY/ET, in which GY is grain yield (kg ha^{-1}) and ET is evapotranspiration in vegetation period (mm).

Maize harvest was done manually from two adjoining rows from the middle of the plot. Winter wheat and soybean harvests were mechanically performed taking the middle of the plot with a combine of the type Delta (Wintersteiger AG, Ried, Austria), with 2 m work width. The length of all plots was 10 m.

The yields were reported at the standard moisture of 14%, 15.5%, and 12% for winter wheat, maize and soybean, respectively.

Economic benefits of the two agriculture systems under study were estimated based on technical – economic parameters of the field equipment used, and the mean yields of the three crops recorded in all five experimental years (Cociu, 2010).

The results were analyzed using the analysis of variance ANOVA, and comparison of variants was performed based on the multiple comparison test "Duncan's New Multiple Range Test" at 5% probability level (Steel and Torrie, 1980). Correlations between water consumption and yields of the three crops in both agriculture systems were also estimated.

RESULTS AND DISCUSSION

Temperatures and precipitation characteristics

All 5 experimental years were warmer than the multiannual mean of the last 51 years, with 0.8°C in 2008, 1.4°C in 2009, 0.8°C in 2010, 1°C in 2011 and 2012 (Table 1). From data presented in Table 2 we can see that the years 2008 and 2012 were very dry, with 18.7% and 15.1% lower precipitations than the multiannual mean. The year 2011 was less dry, with only 9.4% under the mean. The year 2009 can be considered normal, with 2.8% under the mean, and 2010 was quite humid, with 7.7% precipitations over the mean.

Yield, evapotranspiration (ET), and water use efficiency (WUE)

Table 6 presents the winter wheat yields, ET and WUE results, obtained within the traditional agriculture (TA) and conservation agriculture (CA) systems, under study, in the period of 2007-2012. The ET and WUE values varied each year in function of the land management in the period between the previous crop and seeding time. The yields ranged between 4440 and 6180 kg ha^{-1} within TA and between 4764 and 6943 kg ha^{-1} within CA. WUE, varied between 11.57 and 14.27 kg ha^{-1} mm^{-1} and between 12.03 and 15.43 kg ha^{-1} mm^{-1}, respectively. These variations can be attributed mainly to the precipitations received in vegetative period and also to the soil water reserve at seeding time.

Agriculture system had a significant influence on winter wheat crop. The mean yield obtained within CA over the 5 experimental years was with 6.7% higher than within TA, but this difference was not significant. This value was well reduced by the yield recorded in 2007-2008 season (8.5% lower in CA than in TA), when we switched from ploughed to non tilled land. The yields obtained in the other 4 seasons were higher within CA than TA with 7.5%, 12.3%, 15.5% and 5.6%.

Table 6. Winter wheat evapotranspiration (ET), grain yield, and water-use efficiency (WUE) using traditional and conservation agriculture systems, 2007-2012

Year	Treatment	$U_{seeding}$* (mm)	Growing season precipitation (mm)	$U_{harvest}$* (mm)	ET (mm)	Yield (kg ha^{-1})	WUE (kg ha^{-1} mm^{-1})
2007-2008	TA CA	228.9 223.3	356.3	190.0 201.0	395 379	5367a 4910a	13.58a 13.01a
2008-2009	TA CA	197.7 217.3	365.8	179.7 186.2	384 397	4440a 4773a	11.57a 12.03a
2009-2010	TA CA	237.9 246.3	487.9	209.4 194.9	516 539	6180b 6943a	11.98a 12.89a
2010-2011	TA CA	211.3 225.4	389.8	210.4 195.6	391 420	5602b 6470a	14.27a 15.43a
2011-2012	TA CA	194.3 214.2	365.4	186.1 193.4	374 386	4513a 4764a	12.07a 12.34a
5-Year average	TA CA	214.0 225.3	393.0	195.1 194.2	412 424	5220b 5572a	12.69a 13.14a

Values with the same letter within a column and year are not significantly different at p=0.05.

* $U_{seeding}$ and $U_{harvest}$ are soil humidity at seeding and harvest times, respectively, at 0-90 cm profile.

Agriculture system did not influence significantly WUE values of winter wheat crop. The average calculated for CA over the 5 experimental years was with only 0.44 kg ha^{-1} mm^{-1} higher than for TA (13.14 kg ha^{-1} mm^{-1}). With the exception of 2007-2008 season in which WUE was with 0.60 kg ha^{-1} mm^{-1} lower, in all the other four season its values within CA were, 0.47 kg ha^{-1} mm^{-1}, 0.90 kg ha^{-1} mm^{-1}, 1.08 kg ha^{-1} mm^{-1}, and 0.25 kg ha^{-1} mm^{-1}, higher than within TA, where WUE values were: 11.57 kg ha^{-1} mm^{-1}, 11.98 kg ha^{-1} mm^{-1}, 14.27 kg ha^{-1} mm^{-1}, and 12.07 kg ha^{-1} mm^{-1}.

Under rainfed conditions, soil moisture reserve comes partially from precipitations during vegetation period and the rest from the water accumulated in the period before seeding time. The contribution of these two components (estimated as percentage of soil water reserve consumed by the respective crop and reported to ET) showed a non significant variation due the precipitations during vegetative period and the two agriculture systems. In seasons with rainy falls, such as 2007-2008, 2008-2009, and 2009-2010, up to 8% from the total water consumption of winter wheat crop was sourced from the water accumulated in the period before seeding. In seasons like 2010-2011 and 2011-2012, with lack of fall precipitations, only 3.8% of the total crop consumption came from the water accumulated in the period before seeding.

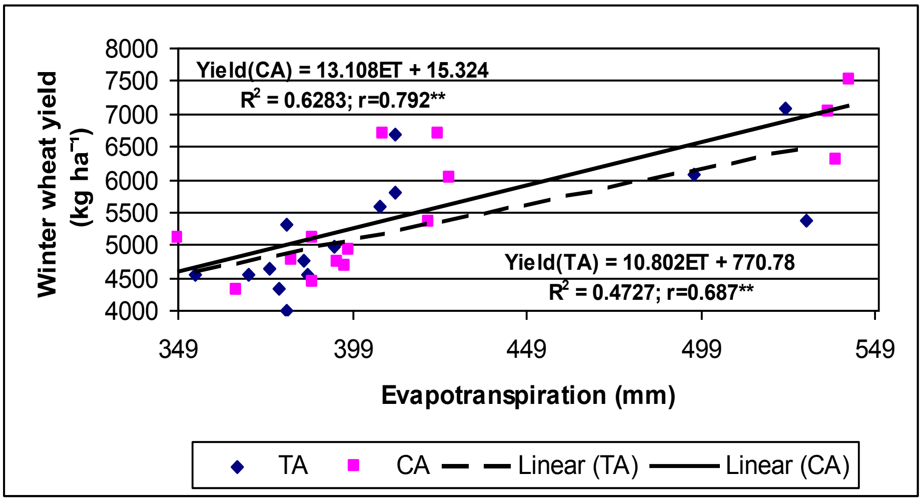

Figure 1. Correlations between winter wheat yield and evapotranspiration (ET) within traditional agriculture (TA) and conservation agriculture (CA) systems (Fundulea, 2007-2012)

The regressions presented in Figure 1, make evident the significant correlations between winter wheat yield and ET, in both agriculture systems (TA and CA). The estimated equation for TA is:

Yield= 0.802ET+770.78, with r=0.687**, and for CA:

Yield=13.108ET+15.324, with r=0.792**.

The values of ET, grain yield, and WUE for maize, within the two agriculture systems under study, are presented in Table 7. ET and WUE varied from one year to the other, depending on the land management in the period without vegetation and on environmental conditions. The maize yields within TA ranged between 4333 kg ha^{-1} and 10987 kg ha^{-1} and within CA between 4627 kg ha^{-1} and 11883 kg ha^{-1}, and the WUE values were comprised between 12.00 kg ha^{-1} mm^{-1} and 29.30 kg ha^{-1} mm^{-1} and respectively between 13.77 kg ha^{-1} mm^{-1} and 32.97 kg ha^{-1} mm^{-1}. These large variations may be mainly due to the precipitations fallen during vegetative period and soil water reserve at seeding time.

Table 7. Maize evapotranspiration (ET), grain yield, and water-use efficiency (WUE) using traditional and conservation agriculture systems, durring 2007-2012

Year	Treatment	$U_{seeding}$* (mm)	Growing season precipitation (mm)	$U_{harvest}$* (mm)	ET (mm)	Yield (kg ha^{-1})	WUE (kg ha^{-1} mm^{-1})
2008	TA CA	281.2 276.2	164.8	158.4 156.0	287 285	6277a 6023a	21.88a 21.17a
2009	TA CA	236.7 228.6	333.9	195.7 201.5	375 361	10987a 11883a	29.30b 32.97a
2010	TA CA	287.9 284.7	270.2	185.2 199.9	373 355	9966b 11528a	26.73b 32.57a
2011	TA CA	294.9 294.2	283.6	175.3 174.8	403 403	8190b 9275a	20.33a 23.03a
2012	TA CA	277.3 267.3	261.1	177.9 191.5	361 337	4333a 4627a	12.00a 13.77a
5-Year average	TA CA	275.6 270.2	262.7	178.5 184.7	360 348	7950b 8667a	22.05b 24.70a

Values with the same letter within a column and year are not significantly different at p=0.05.

* $U_{seeding}$ and $U_{harvest}$ are soil humidity at seeding and harvest times, respectively, at 0-90 cm profile.

Agriculture system had a distinct significant influence on maize grain yield. The average yield over the 5 experimental years was with 9% higher within CA than TA, with which a mean of 7950 kg ha^{-1} was obtained. Only in 2008, when we changed from seeding in ploughed soil to direct seeding in non worked soil, the yield recorded for CA was inferior, with 4%, to that of TA (6277 kg ha^{-1}). In the other 4 years, the yields registered for CA were superior to those of TA (10987 kg ha^{-1} , 9966 kg ha^{-1}, 8190 kg ha^{-1}, and 4333 kg ha^{-1}), in order with: 8.2%, 15.7%, 13.2% and 6.8%.

WUE of maize crop was also influenced significantly by the agriculture system. Its mean value over the 5 experimental years within CA was with 2.65 kg ha^{-1} mm^{-1} higher than of TA, with which 22.05 kg ha^{-1} per 1 mm precipitation was obtained. With the exception of 2008, in which WUE was with 0.70 kg $ha^{-1}mm^{-1}$ inferior, in all the other four years its values within CA were higher than within TA, with 3.67 kg $ha^{-1}mm^{-1}$, 5.84 kg $ha^{-1}mm^{-1}$, 2.70 kg $ha^{-1}mm^{-1}$, and 2.65 kg $ha^{-1}mm^{-1}$.

In years with lack of precipitations during vegetation period, such as 2008, over 40% of maize water consumption (ET) came from soil water reserve registered at seeding time. In wet years, such as 2009, this percentage decreased up to 10%. In the other 3 experimental years, characterized by moderate precipitations in vegetative period, less than 30% of ET was sourced from soil water reserve at seeding time.

The regressions presented in Figure 2 show a positive correlation, but not statistically significant, between maize grain yield and ET, within both agricultural systems (TA and CA). The estimated equation for TA is:

Yield=26.033ET-1.418, with r=0.417,

and for CA:

Yield = 36.824ET-4.154.9, with r=0.503.

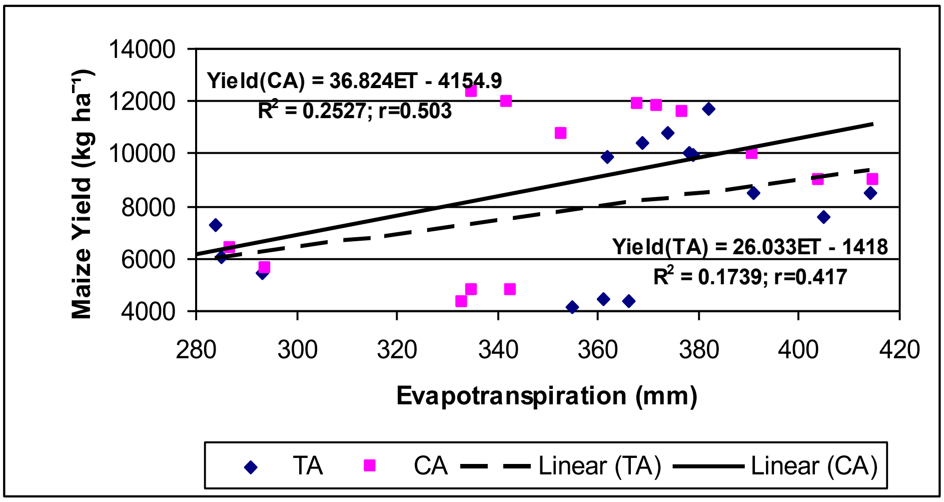

Figure 2. Correlations between maize yield and evapotranspiration (ET) within traditional agriculture (TA) and conservation agriculture (CA) systems (Fundulea, 2007-2012)

In soybean, the values of ET, grain yield, and WUE, within the two agriculture systems under study, are presented in Table 8. ET and WUE varied from one year to the other in function of the land management in non vegetation period and the environmental conditions. The yields within TA ranged between 767 kg ha^{-1} and 3460 kg ha^{-1} and within CA between 917 kg ha^{-1} and 3330 kg ha^{-1}. WUE data varied between 2.38 kg $ha^{-1}mm^{-1}$ and 9.73 kg $ha^{-1}mm^{-1}$ for TA and between 2.90 kg ha^{-1} mm^{-1} and 9.27 kg ha^{-1} mm^{-1} for CA. These variations may be mainly attributed to the precipitations received during the vegetative period and soil water reserve at seeding time.

Agriculture system did not have a significant influence on soybean yield in most cases. The average yield over the 5 experimental years was 1.12% lower within CA than TA, with which a mean of 2166 kg ha^{-1} was obtained. In the first 3 years (2008, 2009 and 2010), the yields registered within CA were 14.6%, 7.0% and respectively 3.9% lower than within TA, for which the following yields were obtained: 1550 kg ha^{-1}, 2590 kg ha^{-1} and 3460 kg ha^{-1}. In 2011 and 2012, however, the practice of CA resulted in positive differences (but also non significant), of 9.2% and respectively 19.6%, in comparison with TA, where yields were 2465 kg ha^{-1} and 767 kg ha^{-1}.

WUE of soybean crop was not significantly influenced by the agriculture system. The average WUE over the 5 experimental years was 0.05% lower within CA than TA, where a mean of 6.24 kg $ha^{-1}mm^{-1}$ was obtained. In the first 3 years, WUE values for TA were with 0.70 kg $ha^{-1}mm^{-1}$, 0.27 kg $ha^{-1}mm^{-1}$ and 0.76 kg $ha^{-1}mm^{-1}$, respectively, higher than for CA, but in the last 2 years the differences were 0.66 kg $ha^{-1}mm^{-1}$ and 0.52 kg $ha^{-1}mm^{-1}$ in favour of CA.

All these differences were not statistically significant. In years with abundant precipitations, such as 2009, less than 16% from the water consumption (ET) for soybean crop was coming from soil water reserve at seeding time. In years characterized by moderate precipitations in vegetation period this percentage was between 24% and 28%.

Table 8. Soybean evapotranspiration (ET), grain yield, and water-use efficiency (WUE), using traditional and conservation agriculture systems, in the period 2007-2012

Year	Treatment	$U_{seeding}$* (mm)	Growing season precipitation (mm)	$U_{harvest}$* (mm)	ET (mm)	Yield (kg ha^{-1})	WUE (kg $ha^{-1}mm^{-1}$)
2008	TA CA	262.0 261.5	184.5	199.6 202.6	247 243	1550a 1353a	6.27a 5.57b
2009	TA CA	261.1 255.3	328.4	194.6 199.1	395 385	2590a 2420a	6.57a 6.30a
2010	TA CA	275.9 279.7	270.2	191.5 190.6	355 359	3460a 3330a	9.73a 9.27a
2011	TA CA	277.7 278.7	283.6	168.6 173.5	393 389	2465a 2691a	6.27a 6.93a
2012	TA CA	267.1 261.6	230.0	170.4 174.8	327 317	767a 917a	2.38a 2.90a
5-Year average	TA CA	268.8 267.4	259.3	184.9 188.1	343 339	2166a 2142a	6.24a 6.19a

Values with the same letter within a column and year are not significantly different at p=0.05.
* $U_{seeding}$ and $U_{harvest}$ are soil humidity at seeding and harvest times, respectively, at 0-90 cm profile.

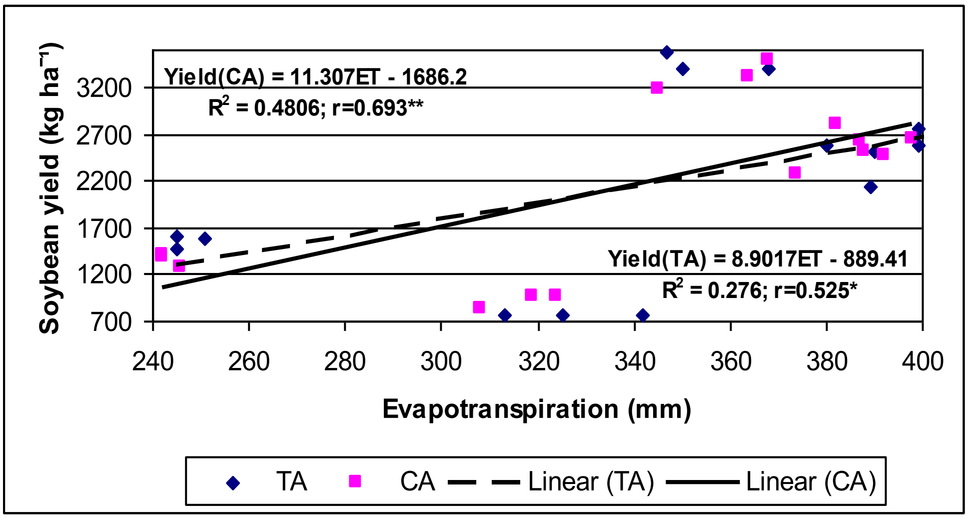

Figure 3. Correlations between soybean yield and evapotranspiration (ET) within traditional agriculture (TA) and conservative agriculture (CA) systems (Fundulea, 2007-2012)

The regressions presented in Figure 3 make evident positive, significant correlations between soybean yield and ET when either TA or CA was applied. The estimated equation for TA was: Yield=8.9017ET-889.41, with r=0.525, and for CA was: Yield=11.307ET-1.686.2, with r=0.693.

All data presented above indicate that CA can assure high and constant winter wheat, maize and soybean yields, in comparison with TA.

Economic benefits

Total costs (input values) when CA was applied at winter wheat, maize, and soybean crops were lower with 44.5%, 25.0%, and 28.2% than with TA, for which the input values were 1639 lei ha^{-1}, 2033 lei ha^{-1}, and 1808 lei ha^{-1}, respectively (Table 9). Fuel consumption for CA was much lower, with 55.6%, 65.5%, and respective 67.1% than for TA, for which the following fuel amounts were used: 57.79 l ha^{-1} for winter wheat, 67.33 l ha^{-1} for maize, and 66.37 l ha^{-1} for soybean. Another important advantage of CA, in comparison with TA, was the reduced labour, with: 50.3% for winter wheat, 57.2% for maize and 65.9% for soybean. The absolute labour time spent for TA was 4.59 h ha^{-1} for winter wheat, 8.11 h ha^{-1} for maize, and 7.28 h ha^{-1} for soybean.

Table 9. Output and input of winter wheat, maize and soybean under TA and AC cropping systems

TM	AY[1]	YT (%)	FC	LE	OV	IV	O/I	EB[2]	BFD[3]
Winter wheat									
TA	5220b	0	57.79	4.59	4176	1639	2.55:1	2537	0
CA	5572a	6.7	25.63	2.28	4457	909	4.9:1	3548	1011
Maize									
TA	7950b	0	67.33	8.11	7155	2033	3.52:1	5122	0
CA	8667a	9.0	23.22	3.47	7800	1525	5.11:1	6275	1153
Soybean									
TA	2166a	0	66.37	7.28	4765	1808	2.64:1	2957	0
CA	2142a	-1.1	21.81	2.48	4712	1298	3.63:1	3414	457

TM: treatment; AY: 5-year yield average (kg ha^{-1}); YT: yield advantage (%); FC: fuel consumption (l ha^{-1}); LE: labor expanditure (h ha^{-1}); OV: output value (lei ha^{-1}); IV: input value (lei ha^{-1}); O/I: output/input; EB: economic benefit (lei ha^{-1}); BFD: benefit diference (lei ha^{-1}).

[1]Values with the same letter within a column and year are not significantly different at p=0.005.

[2]Economic benefit = output value – total cost value (winter wheat grain price = 0.8 lei kg^{-1}, maize grain price = 0.9 lei kg^{-1}, soybean grain price = 2.2 lei kg^{-1}; the lei is the Romanian currency unit).

[3]Difference from the traditional agriculture.

CA system was also characterized by a better energetic efficiency, expressed by the output/input ratio, for all three crops, namely: 4.9, 5.11, and 3.63, when compared with 2.55, 3.52, and 2.64, calculated for TA. The benefit difference (BFD) was higher for CA with: 1001 lei ha^{-1} for winter wheat, 1153 lei ha^{-1} for maize, and 457 lei ha^{-1} for soybean.

CONCLUSIONS

One main conclusion of this research is that reaching the full advantages of CA takes time. In years of transition (stabilization) from TA, certain problems arise, that can make farmers to have doubts about practicing CA. Weeds represent a major difficulty within CA, requiring an integrated management to keep them under good control. The physical, chemical and biological soil properties improvement with CA takes place in longer or shorter time.

The switch from TA to CA influenced differently the WUE of the three crops under study. For winter wheat crop, this influence was not significant, varying mostly due to the annual precipitations in vegetative period and to the amount of water accumulated in fall – winter. WUE of maize was positively (significantly) enhanced by CA, but for soybean this influence was not significant. The economic benefit and output / input ratio were greater practicing CA than TA, for all three crops. Accordingly, in transition (stabilization) period from TA to CA, the farmer reduces the costs, mainly due to the direct seeding, as well as to lower amount of fuel and labour spent. Less land work is required and so less field machinery is used. Additionally, keeping the vegetal residues on soil surface, clearly increases WUE and productivity, due to better water infiltration and decreased soil water evaporation.

Despite problems which may arise in the transition (stabilization) years, the farmers have to be informed and encouraged by different means to adopt and continue CA application, emphasizing its clear long term advantages over TA.

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