

Effect of Conservation Agriculture on Maize Yield in the Transilvanian Plain, Romania

M.A.Grigoras, A.Popescu, D.Pamfil, I.Has and L.C.Cota

Abstract—An experimental study is presented on the effect of Conservation Agriculture (CA) compared to Conventional Agriculture (ConvA) upon Maize Yield based on split-plot model. Two factors have been considered: A Factor-Fertilization with two variants: A1- $N_{40}P_{40}$ kg/ha and A2- $N_{90}P_{70}$ kg/ha; B Factor- Crop protection with 4 variants : B1- 4 treatments, B2-3 treatments, B3- 2 treatments and B4- 1 treatment. In comparison with conventional agriculture, CA determined lower maize yields. Fertilization is the key factor determining a yield gain of 973.58 kg/ha in ConvA and 1,123.33 kg/ha in CA. A reduced number of treatments determined a yield decline. The A-B interaction had a positive effect on maize yield when a larger amount of fertilizer and 4 or 3 treatments were applied in ConvA and a benefic in CA for highest fertilization level and 2 treatments. The B2A2 ConvA variant was the most efficient leading to 302.67 kg/ha gain while B3A2 CA variant brought 181.33 kg production gain.

Keywords—conservation agriculture, conventional agriculture, maize, yield

I. INTRODUCTION

AS an alternative to traditional agriculture, during the last 30 years, new technologies have been developed within the so called “Conservation Agriculture (CA)”. The new concept of Conservation Agriculture is based on three principles : minimum soil disturbance, optimum crop rotation and minimum 30 % vegetal residue retention [1].

Conservation agriculture includes Resource Conserving Technologies-RCTs such as Zero-tillage, whose aim is to reduce fuel consumption, to improve water use and soil health and quality. For this reason, new equipments adapted to no-tillage and crop residue conditions have been designed and produced [2]. Applying the CA principles in wheat and maize bed

M.A. Grigoras is with University of Agricultural Sciences and Veterinary Medicine, 400372 Cluj Napoca , Romania (Phone:+40 264596384, Fax:+40, Email: sustenabil.grigoras@gmail.com).

A. Popescu is with University of Agricultural Sciences and Veterinary Medicine, 011464 Bucharest, Romania, (Phone: +40 213182564/232, Fax: +40 21 3182888, Email:agatha_popescu@yahoo.com).

D. Pamfil is with University of Agricultural Sciences and Veterinary Medicine, 400372 Cluj Napoca , Romania (Phone:+40 264596384, Fax:+40 0264593792, Email: dpamfil@usamvcluj.ro).

I. Has is with Agricultural Research and Development Station. 40100 Turda, Cluj County, Romania, (Phone: +40 264311680, Fax:+40 264311792, Email: ioanhas@yahoo.com).

L.C. Cota is with University of Agricultural Sciences and Veterinary Medicine, 400372 Cluj Napoca , Romania (Phone:+40 264596384, Fax:+40 0264 593792, Email: lccota@gmail.com).

cropping in Mexico, CIMMYT researchers obtained a higher efficiency in water use and reduced soil erosion [3]. Under no-tillage system, if vegetal residue are not kept on the soil, production could be diminished by 37 % in wheat and by 51 % in maize compared to the same conservation agriculture system where crop residue were preserved. Experiments carried out in Mexico have pointed out the positive impact of CA on crop performance, soil quality and potential C emission reduction and C sequestration in contrasting environment.

In order to develop the sustainable wheat and maize based systems, CIMMYT operates an unique set of long-term experiments in order to compare different CA-based systems with traditional farming system [4].

CA is a challenge and opportunity to improve soil and water conservation [5]. Sustainable agriculture practices are also used for increasing productivity, environment quality and financial gains [6]. CA increases yields and reduces labor requirement, improve soil fertility and reduce erosion [7].

CA, based on minimum soil disturbance, crop residue retention and crop rotation offers potential solutions to mitigate effects of seasonal drought. In Africa, experiments have proved a 3-5 times water infiltration on direct seeding plots compared to conventional ploughed control plots [8].

No-tillage system has a positive long-term effect on soil organic carbon compared to conventional tillage system [9]. Highest maize yields were obtained under zero tillage with retained residues where the CropSyst-soil-simulation model was applied in order to assess the performance of conservation tillage in comparison to conventional agriculture in maize cropping in Mexico [10]. Also, CA has a benefic effect on salted-affected irrigated lands as noticed in maize cropping in Uzbekistan [11].

Compared to conventional agriculture, CA offer the potential to increase wheat and maize productivity [12], reduce production costs and increase soil organic carbon [13] and decrease soil salinity [14].

Under the Mediterranean conditions, experiments in wheat [15] and maize in the sub-humid tropical highlands [16], CA has had a benefic impact on production.

CA is suitable to smallholder farming and has to be adapted to local conditions [17], [18]. In this respect, FAO promotes a package of soil conserving practices under the banner of CA.

For its advantages, CA has been rapidly extended to many countries and continents. In 2008, zero-tillage was practiced on 95 million ha at world level, of which 50 % are in non-

OCDE countries. About 70 million ha are in 4 countries; USA, Brazil, Argentina and Australia. Ca is also applied in the Indo-Gangetic area, South Asia [19].

In Europe, direct sowing is achieved on 10 % of agricultural surface in Finland and Greece and 5 % in Czech Republic, Slovakia, Spain and United Kingdom. Reduced tillage system is practice on 50 % of agricultural land in Finland, United Kingdom and on 25 % in Portugal, Germany and France [20].

In Romania, CA advantages have been assessed under different experiments. The CA effects on crop protection have been approached under present climate change [21]. Also, the impact of CA on wheat technology was evaluated [22]. The impact of minimum and no-tillage on soil and water management and wheat, maize and soy bean on productivity and product quality was also researched in the Transilvanian Plain [23], [24], [25].

II. MATERIAL AND METHODS

The experiments were carried out in maize crop using Turda 165 hybrid cultivated in the Transilvanian Plain on a brown reddish soil within Agricultural Research and Development Station Turda, Cluj County, Romania, during the years 2008-2010. The assessment of the impact of agriculture system on maize yield was based on a bifactorial experiment organized according to a split-plot model and variance analysis. Two factors have been taken into account as follows: A Factor – Fertilization with 2 variants: A1-N₄₀P₄₀ kg/ha applied at sowing and A2 – N₉₀P₇₀ kg/ha applied at vegetation recover in Spring season and B Factor-Crop protection with four variants: B1- 4 treatments, B2-3 treatments, B3-2 treatments and B4-1 treatment.

The data were collected from the field concerning maize yield and were processed according to the well known modern statistical methods (split-plot model, variance analysis, comparison method).

The purpose of the paper was to make a comparison between conservation agriculture system (minimum tillage) and conventional tillage was made. Turda 165 maize hybrid used in this experiment is the earliest hybrid created at Turda Research and Development Station and it is characterized by a high resistance to extreme temperature and rainfalls conditions and also high production performance.

Conventional agriculture system applied was characterized by sowing after plowing in Autumn 2009, land preparation with John Deer 6620 SE+ Grubber HRB 403 D, with 4 m operating width. The maize seeds were sowed in April 30, 2010 using John Deere 6620 SE +Sowing Machine in a semi prepared land and prepared MT-6 on 6 rows at 70 cm distance. The treatments were manually done, digging was also manually done and harvesting as well.

Conservation agriculture was characterized by the following aspects: the agricultural land was prepared by scarification, using John Deere 6620 SE + Pinochio 2.5 which assures a deep refining at 30-35 cm. This operation was imposed by practice as an adaptation of CA to local conditions. Maize

seeds were sowed in April 30, 2010, using John Deere 6620 SE + sowing machine in a semi prepared land and prepared MT-6 on 6 rows at 70 cm distance. The treatments were manually done .

III. RESULTS AND DISCUSSIONS

A. Influence of A Factor –Fertilization on Maize Yield Conventional agriculture

Fertilization determined an increased maize yield. The higher the amount of fertilizer, the higher the maize yield. In case of conventional agriculture, maize yield registered 6,221.08 kg/ha for A1- N₄₀P₄₀ kg/ha and 7,194.67 kg /ha for A2- N₉₀P₇₀ kg/ha. This yield is by 973.59 kg/ha, that is by 15.6 % higher than the one recorded by control variant (Table I).

TABLE I
 CONVENTIONAL AGRICULTURE- INFLUENCE OF A-FACTOR-FERTILIZATION ON MAIZE YIELD

Variant	Maize Yield Kg/ha	Difference kg/ha	%	Significance
A1	6,221.08	0	100.0	-
A2	7,194.67	+973.59	115.6	x
	DL (P 5%)	+ 1,100.13		
	DL (P 1%)	+ 2,540.54		
	DL (P 0.1%)	+ 8,084.69		

Conservation agriculture

The maize yield was lower compared to the one registered on the plots where conventional agriculture was practiced. But the application of the increased amount of fertilizer on the experimental plot A2 determined a production of 6,495.33 kg/ha, by 1,123.33 kg/ha (20.9 %) higher compared to A1-control variant (Table II).

TABLE II
 CONSERVATION AGRICULTURE- INFLUENCE OF A-FACTOR-FERTILIZATION ON MAIZE YIELD

Variant	Maize Yield Kg/ha	Difference kg/ha	%	Significance
A1	5,372.0	0	100.0	-
A2	6,495.33	+1,123.33	120.9	x
	DL (P 5%)	+1,663.21		
	DL (P 1%)	+2,540.54		
	DL (P 0.1%)	+8,084.69		

Therefore, conventional agriculture assured superior maize yields by 849.08 kg/ha (15.80 %) in case of A1 and 1,107.66 kg/ha (10.76 %) in case of A2 (Table III).

B. Influence of B Factor –Crop protection on Maize Yield Conventional agriculture

The reduced number of treatments from B1 (4 treatments) to B4 (1 treatment) had not a benefic effect on maize yield, on the contrary, the less number of treatments, the lower maize yield. The highest maize production was performed by B1, 6,923 kg/ha and the lowest one was achieved by B4 variant,

6,423.5 kg/ha. The loss of production accounted for 499.5 kg/ha, meaning 7.2 % less than in case of control variant B1 (Table IV).

TABLE III
YIELD GAIN IN CONVENTIONAL AGRICULTURE COMPARED TO CONSERVATION AGRICULTURE DUE TO FERTILIZATION

Variant	Maize Yield Gain Kg/ha	%
A1	+849.08	115.80
A2	+1,107.66	110.76

TABLE IV
CONVENTIONAL AGRICULTURE- INFLUENCE OF B-FACTOR-CROP PROTECTION

Variant	Maize Yield Kg/ha	Difference kg/ha	%	Significance
B1	6,221.08	0	100.0	-
B2	7,194.67	-23.0	99.7	x
B3	6,585.0	-338.0	95.1	-
B4	6,423.5	-499.5	92.8	-
	DL (P 5%)	+ 1,134.16		
	DL (P 1%)	+ 1,591.98		
	DL (P 0.1%)	+ 2,247.50		

Conservation agriculture

The reduced number of treatments had a different impact on maize yield from a variant to another. Despite that, the general trend was a decreasing one from B1 to B4. The highest production level was 6,379.67 kg/ha registered by B1- control variant where 4 treatments were applied. The lowest maize yield was 5,557.67 kg/ha belonging to B4 variant where just 1 treatment was practiced. The difference between the highest and the lowest yield is 882 kg/ha, that is 12.9 % (Table V).

TABLE V
CONSERVATION AGRICULTURE- INFLUENCE OF B-FACTOR-CROP PROTECTION

Variant	Maize Yield Kg/ha	Difference kg/ha	%	Significance
B1	6,379.67	0	100.0	-
B2	5,585.67	-794.0	87.6	-
B3	6,211.67	-168.0	97.4	-
B4	5,557.67	-822.0	87.1	-
	DL (P 5%)	+ 821.40		
	DL (P 1%)	+1,152.97		
	DL (P 0.1%)	+1,627.72		

Therefore, conservation agriculture in its variant minimum tillage had a negative impact on maize yield.

The positive differences in yield gains performed by conventional cropping system reflects its superiority comparatively to minimum tillage system (Table VI).

TABLE VI
YIELD GAIN IN CONVENTIONAL AGRICULTURE COMPARED TO CONSERVATION AGRICULTURE DUE TO CROP PROTECTION

Variant	Maize Yield Gain Kg/ha	%
B1	+543.33	108.51
B2	+1,314.33	123.53
B3	+373.33	106.01
B4	+865.83	115.57

The highest difference was noticed in case of the application of B2- 3 treatments, where maize yield gain accounted for 1,314.33 kg/ha and the lowest one in case of B3- 2 treatments.

C. The influence of A-B Factors Interaction on maize yield

Conventional agriculture

This combination of factors determined the following three situations:(a)the increased amount of fertilizer combined with 4 treatments and even 3 treatments assured an increased maize yield by 1,450 kg/ha in case of A2B1 variant and by 2,101.33 kg/ha in case of A2B2 variant compared to A1B1-control variant; (b)on the contrary, an increased fertilization level and a reduced number of treatments to 2 treatments determined a maize yield for A2B3 by 302.67 kg/ha lower than the one performed by control variant;(c) an increased fertilization level and only 1 treatment applied at blooming determined, in case of A2B4, a yield by 645.67 kg/ha higher than the one performed by control variant.

Therefore, the general trend is an increasing maize production performance if agricultural land is better fertilized and the number of treatments is less.

As a result, fertilization could be considered the main factor influencing production while the number of treatments has a positive impact on maize yield only if 4 or 3 treatments are applied (Table VII).

The highest yield gain was registered by A2B2 variant where the highest amount of fertilizer and 3 treatments were applied, +2,101.33 kg/ha compared to control variant.

Conservation agriculture

The combined influence of A-B factors, fertilization-crop protection, showed that the higher amount of fertilizer and number of treatments practiced, the higher maize yield. Onlu one exception was noticed: it is about A2B3 variant, recording the highest maize yield, 6,959.33 kg/ha by 1,495.33 kg/ha higher than the one performed by control variant, 5,464 kg/ha (Table VIII).

TABLE VII
CONVENTIONAL AGRICULTURE-THE COMBINED INFLUENCE OF A AND B –
FACTORS INTERACTION ON MAIZE YIELD

Variant	Maize Yield Kg/ha	Difference kg/ha	%	Significance
A1B1	6,198.00	0	100.00	-
A2B1	7,648.00	+1,450.00	123.39	-
A1B2	5,849.33	0	100.00	-
A2B2	7,950.67	+2,101.33	135.92	x
A1B3	6,736.33	0	100.00	-
A2B3	6,433.67	-302.67	95.50	-
A1B4	6,100.67	0	100.00	-
A2B4	6,746.33	+645.67	110.58	-
DL (P 5%)		+ 1,467.05		
DL (P 1%)		+ 2,153.58		
DL (P 0.1%)		+ 3,466.19		

TABLE VIII
CONSERVATION AGRICULTURE-THE COMBINED INFLUENCE OF A AND B –
FACTORS INTERACTION ON MAIZE YIELD

Variant	Maize Yield Kg/ha	Difference kg/ha	%	Significance
A1B1	5,981.33	0	100.00	-
A2B1	6,778.00	+796.67	113.30	-
A1B2	5,038.67	0	100.00	-
A2B2	6,132.67	+1,094.00	121.70	-
A1B3	5,464.00	0	100.00	-
A2B3	6,959.33	+1,495.33	127.40	x
A1B4	5,004.00	0	100.00	-
A2B4	6,111.33	+1,107.33	122.10	-
DL (P 5%)		+ 1,839.39		
DL (P 1%)		+ 3,549.47		
DL (P 0.1%)		+ 9,379.32		

D. The influence of B-A Factors Interaction on maize yield

Conventional agriculture

The reduced number of treatments combined with the lowest amount of fertilizer determined a large variation of production between the highest record 6,736.33 kg/ha in case of 2 treatments and the lowest one 5,849.33 kg/ha when 3 treatments were applied. In case of B3A1 variant, production gain was 538.33 kg/ga and in case of B4A1, the yield loss was 97.33 kg/ha. When the number of treatments was reduced to 2 and fertilization was at the highest level, maize yield recorded the highest performance: 7,950.67 kg/ha in case of B2A2.

For the highest amount of fertilizer applied combined with 2 treatments, maize yield registered the lowest performance for B3A2, that is 6,433.67 kg/ha meaning by 1,214.33 kg less per surface unit than in case of B1A1 Control variant (Table IX).

TABLE IX
CONVENTIONAL AGRICULTURE-THE COMBINED INFLUENCE OF B AND A –
FACTORS INTERACTION ON MAIZE YIELD

Variant	Maize Yield Kg/ha	Difference kg/ha	%	Significance
B1A1	6,198.00	0	100.00	-
B2A1	5,849.33	-348.67	94.40	-
B3A1	6,736.33	+538.33	100.00	-
B4A1	6,100.67	-97.33	98.40	-
B1A2	7,648.00	0	100.00	-
B2A2	7,950.67	+302.67	104.00	-
B3A2	6,433.67	0	84.10	-
B4A2	6,746.33	-901.67	88.20	-
DL (P 5%)		+ 1,603.94		
DL (P 1%)		+ 2,251.40		
DL (P 0.1%)		+ 3,178.43		

Therefore, the interaction between the number of treatments and fertilization level had a positive impact on maize yield only if 3 or 4 treatments were practiced in tillage system.

Conservation agriculture

The interaction between the number of treatments and the amount of applied fertilizer had a negative impact on maize production performance. The major yield loss was -942.67 kg/ha, registered by B2A1 variant (3 treatments and lowest fertilization level) and the minimum loss - 517.33 kg/ha, noticed in case of B3A1 variant, where 2 treatments and the lowest fertilization level were practiced.

However, B3A2 variant record was 6,959.33 kg/ha, the highest yield, by 181.33 kg higher than the one registered by control variant. In this case, the two treatments combined with the highest amount of fertilizer had a positive effect on production (Table X).

TABLE X
CONSERVATION AGRICULTURE-THE COMBINED INFLUENCE OF B AND A –
FACTORS INTERACTION ON MAIZE YIELD

Variant	Maize Yield Kg/ha	Difference kg/ha	%	Significance
B1A1	5,981.33	0	100.00	-
B2A1	5,038.67	-942.67	84.20	-
B3A1	5,464.00	-517.33	100.00	-
B4A1	5,004.00	-997.33	83.70	-
B1A2	6,778.00	0	100.00	-
B2A2	6,132.67	-645.33	90.50	-
B3A2	6,959.33	+181.33	102.70	-
B4A2	6,111.33	-666.67	90.20	-
DL (P 5%)		+ 1,161.63		
DL (P 1%)		+ 1,630.55		
DL (P 0.1%)		+ 2,301.95		

IV. CONCLUSIONS

Fertilization is the major actor influencing yield in maize cropping both in tillage and minimum tillage system. The number of applied treatments for crop protection is less important, because its impact on determined a variation in maize yield. But, if one treatment is practiced, maize yield reached the lowest performance. In case of conservation agriculture, the combination between fertilization and the number of treatments had a benefic effect on maize yield only if the amount of fertilizer was at the top level and at least 2 treatments were applied. The comparison between conventional agriculture and conservation agriculture in its variant-minimum tillage system has lead to the conclusion that conventional agriculture assures maximum maize yield in the Transilvanian Plain. Conservation agriculture could be recommended for farmers who own brown reddish soil, use Turda 165 maize hybrid, apply a fertilization level of $N_{90}P_{70}$ kg/ha and 2 treatments for crop protection. Because in case of A2B3 and B3A2 variants, production is similar and equal to 6,959.33 ka/ha, fertilization is the key factor for increasing maize yield in conservation agriculture system under the conditions of the Transilvanian Plain..

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