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Science and Technology

Meri-Rastilantie 3 B, FI-00980
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Journal of Food, Agriculture & Environment Vol.5 (3&4) : 349-353. 2007

www.world-food.net

Soil fertility management in North-East Romania

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Received 12 May 2007, accepted 5 August 2007.

Abstract

The effect of different soil tillage systems on crop yield and soil chemical and physical characteristics were studied during 1985-2006. Experiments were established in split-split plots on a typical cambic chernozem of clay-loam texture, a mean humus content of 3.3%, a weakly acid reaction and a moderate level of mineral nutrients. Twenty-two years of ploughing to a depth of 20 cm resulted in settling of the soil at a depth of 19-27 cm; causing high bulk density (1.52 g/cm^3), low porosity (43.3%) and a high degree of settling (16.4% of volume). In the case of chisel tillage, bulk density decreased from 1.41 to 1.33 g/cm^3, settling degree was lower at 0.8% and hydraulic conductivity increased from 6.4 to 21.5 mm/hour at a depth of 40 cm. The mean wheat yield over the period, using 20 cm ploughing was 3690 kg/ha. Compared to 20 cm ploughing, using chisel ploughing and disks and also by repeated disking produced lower yields by 5.0% (-170 kg/ha) and 11.0% (-423 kg/ha), respectively. In maize, fertilizers were better utilized under conditions of deeper soil tillage (30 cm ploughing; chisel ploughing and disks) where yield increases varied with fertilizer rates from 98 to 131% (3940-5260 kg/ha). In soybean, mean yields using 20 cm ploughing and chisel ploughing and disk tillage were similar; in the case of chisel ploughing and disks, yield was higher by 12.0% (260 kg/ha) and with disks alone, yields were lower by 15.0% (336 kg/ha). The results indicate that soil tillage systems must be adjusted to plant requirements for crop rotation and to the pedoclimatic conditions of the area.

Key words: Soil tillage, crop rotation, mineral fertilizers, humus, nutrients, soil fertility, yield.

Introduction

Establishing soil tillage systems that are economically efficient and ensure high yields with added fertilizer is a special concern for farmers across many climatic areas. In recent times, there has been a trend of diminishing soil tillage and increased retention of residues on the soil surface for reducing erosion losses of mineral elements and soil and for reductions in energy use. This system requires weed control, seedbed preparation and no-tillage sowing and removes the need for the moldboard plow and other intensive treatments that disturb soil. Reduced tillage for soil conservation has been found to lower crop yields at low nitrogen rates. At high nitrogen rates, yields can be equal or higher with no-tillage [4]. In the case of reduced tillage, crop residues and organic matter can accumulate in soil surface layers. For a period of time this can immobilize nitrogen fertilizers and diminish their availability for crops.

Long-term use of a chisel plough and no-tillage increased the organic carbon content in the uppermost soil layer (0-10 cm) compared with the plough treatment. A tillage system based on a chisel plough or a no-till system compared with traditional ploughing increased the organic carbon in the soil 9 percent (4.1 t/ha) [7]. The different responses to nitrogen of the two soil tillage systems are caused by differences in immobilization, mineralization and denitrification processes which are influenced by different water conservation conditions and leaching. Many studies have shown a tendency to apply more nitrogen fertilizer for no-tillage, compared to conventional tillage.

The conventional system of annual ploughing at the same depth and the repeated use of disk-harrows for seedbed preparation have negative consequences on some soil physical characteristics, e.g., mechanical and water stability of aggregates, porosity, infiltration capacity, hydraulic conductivity, water holding capacity, stratification of organic matter and nutrients, activity and diversity of soil flora and fauna, carbon biomass, soil water and temperature regime [2, 7]. Major environmental deterioration can be caused by soil erosion, soil compaction, soil structural damage due to human activities, loss of organic matter as well as due to extreme climatic conditions influenced by human activity. Because conventional farming systems have caused soil degradation in many countries, the technologies of agricultural mechanization must be adapted to the needs of soil and water conservation. In areas with soil sensitive to degradation, soil conservation practices are necessary[1, 3]. Soil tillage according to crop rotation requirements and climatic conditions contributes to the improvement of soil physical and chemical characteristics [6]. This can reduce infestation and allow manure and crop residue incorporation [5]. The aim of the study was to examine the effect of different soil tillage systems and fertilization on crop yield and soil chemical and physical characteristics of a cambic chernozem in Romania.

Materials and Methods

The effect of soil tillage systems and fertilization on wheat, maize and soybean yields was studied during 1985-2006 on a cambic chernozem at the Agricultural Research and Development Station of Podu-Iloaiei, Iasi County, Romania. The crops were in a soybean-wheat-maize-barley four-year rotation with irrigation (1980-1996) and without irrigation (1997-2006). The typical cambic chernozem of Podu-Iloaiei formed on a loess loam, has mean humus content of 3.1-3.4%, is supplied well with mobile potassium (235 ppm) and moderately with phosphorus (28-35 ppm) and nitrogen (0.160-0.165%). The soil has high clay content (38-40%) and is difficult to till when soil moisture is close to the wilting point (12.2%).

Experimental design was split-split plot with 4 replicates. In maize crop, the manure was applied every 3rd year since 1999. The wheat varieties used were Fundulea 29 (1986-1991), Fundulea 4 (1992-2000) and Gabriela, the maize varietes were hybrids F-308 (1986-1989), PI-101 (1990-1995) and Oana (2000-2006) and the soybean varieties used were Evans (1986-1990) and Atlas (1991-2006). Physical and chemical analyses of soil samples were done according to the methods of the Research Institute of Bucharest, commonly used by all agrochemistry laboratories in Romania.

Results and Discussion

The climate of the Moldavian Plain is characterized by long-term (over 79 years) annual mean temperature of 9.6ºC and mean rainfall of 547 mm, of which 160 mm falls during September-December and 387 mm during January-August. Over the last 22 years, there have been 9 years with rainfall under the long-term mean, the lowest value in 1986 was 237 mm below the long-term average. In these years, the reduced rainfall was associated with higher soil and air temperatures. During 9 years of the period 1985-2006 wheat was affected by drought in September-December. Rainfall during January-June (1985-2006) ensured normal conditions for wheat growing in 13 years. The rest of 9 years were droughty with a rainfall deficit between 43 and 119 mm.

The climatic conditions during 1985-2006 were favorable for maize for 13 years and unfavorable, due to low rainfall, in the other 9 years. In the last 22 years, the rainfall during January-August was between 71 and 126 mm below the long-term average (385 mm). The lack of rainfall in that period was associated, in most of cases, with mean and maximum temperatures which exceeded the normal temperatures of the area. The drought in autumn and during January-August required a change in soil preparation practices to conserve soil water.

The analyses carried out on soil profiles, which had different tillage systems for 22 years, showed changes in soil physical and chemical characteristics, both in the ploughed layer and in the lower soil profile. In the chisel ploughed soil profile the clay mean content was low near the surface and increased in the Am and A/B horizons (22-55 cm; Table 1). However, the coarse fraction content near soil surface was also high for both soil tillage methods. The process of slight clay migration due to leaching did not cause degradation of texture and structure at the soil surface.

Compared to the conventional system of soil tillage (ploughing at 20 cm and disks) equipment that loosens soil to depth (paraplough, chisel) increased the available soil water at a depth of 0-40 cm by 7.2% and increased aeration porosity from 12.8 to 17.2% (Table 2). Conventional tillage led to the settling of soil at a depth of 19-27 cm, where bulk density was high (1.52 g/cm^3), total porosity low (43.3%) and settling degree 16.4% of volume.

Chisel ploughing decreased bulk density from 1.41 to 1.33 g/cm^3, the settling degree diminished to 0.8% and hydraulic conductivity at 0-40 cm depth increased from 6.4 to 21.5 mm/hour. Under wheat, bulk soil weights varied between 1.33 and 1.41 g/cm^3, according to tillage system and applied fertilizer (Table 3). The highest values were for 20 cm ploughing, where in the 20-30 cm layer there was a sudden increase in bulk density (1.41 g/cm^3), indicating a low settling degree (8.3% of volume). In maize, the greatest values of bulk density (1.45 g/cm^3) were for 20 cm ploughing with no added fertilizer, and the settling degree was moderate at 11% of volume (Tables 2 and 3). Under these conditions, total porosity was 45.47% compared to a minimum necessary porosity of 51.5%, causing a decrease in permeability and available water for plants. Results indicate that the main limiting factors were weak settling of soil at 18-27 cm depth (i.e., hardpan formation) and structural degradation of the surface soil from repeated disk tillage.

In wheat, the percentage of water-stable aggregates was less influenced by soil tillage (47.6-53.0%) and more by applied fertilizers (38.6-56.2%) (Table 4). The highest percentage of water-stable aggregates was found for fertilizer treatment N 80 kg/ha + P_2O_5 80 kg/ha (48.3-50.7%) and for organo-mineral fertilization (52.6-53.2%). For maize, the percentage of water-stable aggregates varied according to applied fertilizer rates, 41.1-52.0% at 20 cm ploughing, 44.2-53.1% at 30 cm ploughing and 41.7-51.2% for chisel ploughing.

The water stability of structure for chisel ploughing had lower values at the soil surface (46.1-46.7%), compared to 20 cm ploughing. However, at a depth of 10-30 cm it was 2.3% higher in wheat and 37% higher in maize, than for 20 cm ploughing. Under soil loosening without inverting, there were increases in clay, humus and nutrient contents to the depth of 40 cm in comparison to ploughing at 20 cm + disk (Table 5). Chemical analyses show that the typical cambic chernozem from Podu-Iloaiei has clay loam texture, weak acid reaction in ploughed layer and moderate humus content and nutrient supply (Table 5).

By comparing the results of analyses from soil tilled by chisel plough and disk to 20 cm ploughing (Table 5, Profile 2) it was found that in chisel-ploughed soil profile humus content, pH and mobile potassium supply were slightly improved. In deep-tilled soil profiles without inverting, there was a slight clay and humus migration down the profile. In the 20 cm ploughed soil profile, at the depth of 19-27 cm, an Ap_2 horizon appeared (hardpan) with degraded physical and hydrophysical characteristics due to soil compaction.

Table 1. Granulometric composition of typical cambic chernozem from the Agricultural Research and Development Station of Podu-Iloaiei, Iasi County.

Horizon	Depth, cm	Granulometric composition			
		< 0.002 mm	0.002-0.02 mm	0.02-0.2 mm	0.2-2.0 mm
Profile 1 - Typical cambic chernozem - Chisel + disk					
Ap	0-21	39.3	30.8	27.7	2.2
Am	22-40	41.7	30.1	28.2	0.0
A/B	41-55	41.2	29.5	29.3	0.0
Bv	56-73	39.8	30.2	30.0	0.0
C_1	74-94	36.7	27.2	36.1	0.0
Profile 2 - Typical cambic chernozem - Ploughing at 20 cm + disk					
Ap_1	0-18	40.3	30.0	28.1	1.6
Ap_2	19-27	39.9	31.4	28.7	0.0
Am	28-38	40.5	31.6	27.9	0.0
A/B	39-55	42.1	30.8	27.1	0.0
Bv	56-73	41.7	30.2	28.1	0.0
C_1	74-94	31.3	26.9	40.3	1.5

Table 2. Physical and hydrophysical characteristics of typical cambic chernozem at different soil tillage systems.

Horizon	Depth, cm	Bulk density, g/cm^3	Total porosity % v/v	Air porosity, % v/v	Settling degree, %	Hygroscopic coefficient, % g/g	Wilting point % g/g	Field capacity % g/g	Available moisture capacity % g/g	Hydraulic conductivity mm/h
Profile 1 - Typical cambic chernozem - Chisel + disk										
Ap	0-21	1.31	51.3	17.0	0.8	8.4	12.3	26.2	13.9	8.99
Am	22-40	1.30	51.5	17.3	0.1	8.9	13.4	26.3	12.9	34.15
A/B	41-55	1.37	49.1	14.2	4.5	8.9	13.4	25.5	12.1	13.43
Bv	56-73	1.41	47.6	13.1	6.7	8.7	13.1	24.5	11.4	12.66
C_1	74-94	1.34	50.0	16.5	2.0	7.4	11.1	25.0	13.9	22.64
Profile 2 - Typical cambic chernozem - Ploughing at 20 cm + disk										
Ap_1	0-18	1.28	52.2	18.9	4	8.2	12.3	26.0	13.7	7.50
Ap_2	19-27	1.52	43.3	6.8	16.4	8.0	12.0	24.0	12.0	4.50
Am	28-38	1.29	52.2	18.3	0.2	9.5	14.3	26.3	12.0	45.02
A/B	39-55	1.31	51.1	16.6	1.7	9.0	13.5	26.3	12.8	80.66
Bv	56-73	1.37	48.9	13.8	5.6	9.4	14.4	25.6	11.2	28.51
C_1	74-94	-	-	-	-	7.0	10.5	-	-	-

Table 3. Soil bulk density at wheat and maize harvesting placed under different variants of soil tillage.

Soil tillage	Fertilization rate	Depth (cm)							
		Wheat				Maize			
		0-10	10-20	20-30	0-30	0-10	10-20	20-30	0-30
Ploughing at 20 cm + disk	N_0P_0	1.35	1.38	1.41	1.38	1.35	1.39	1.45	1.40
	N 80 kg/ha + P_2O_5 80 kg/ha	1.34	1.36	1.37	1.36	1.35	1.38	1.42	1.38
	N 80 kg/ha + P_2O_5 80 kg/ha + 30 t/ha manure	1.33	1.34	1.36	1.34	1.32	1.39	1.40	1.37
	Average	1.34	1.36	1.38	1.36	1.34	1.39	1.42	1.38
Ploughing at 30 cm + disk	N_0P_0	1.35	1.36	1.38	1.36	1.34	1.38	1.39	1.37
	N 80 kg/ha +P_2O_5 80 kg/ha	1.33	1.34	1.36	1.34	1.34	1.36	1.39	1.36
	N 80 kg/ha + P_2O_5 80 kg/ha + 30 t/ha manure	1.32	1.34	1.35	1.34	1.34	1.36	1.38	1.36
	Average	1.33	1.34	1.36	1.35	1.34	1.37	1.39	1.36
Chisel + disk	N_0P_0	1.34	1.35	1.36	1.35	1.34	1.38	1.37	1.36
	N 80 kg/ha + P_2O_5 80 kg/ha	1.35	1.36	1.38	1.36	1.33	1.37	1.38	1.36
	N 80 kg/ha + P_2O_5 80 kg/ha + 30 t/ha manure	1.33	1.36	1.37	1.35	1.33	1.37	1.37	1.35
	Average	1.34	1.36	1.37	1.36	1.33	1.37	1.37	1.36

Table 4. Influence of soil tillage and fertilization on hydrostability of soil aggregates (%) of > 0.25 mm.

Soil tillage	Fertilization rate	Depth (cm)							
		Wheat				Maize			
		0-10	10-20	20-30	0-30	0-10	10-20	20-30	0-30
Ploughing at 20 cm + disk	N_0P_0	38.6	40.4	46.8	41.9	38.4	40.2	44.6	41.1
	N 80 kg/ha + P_2O_5 80 kg/ha	44.2	48.5	52.3	48.3	42.6	45.8	48.2	45.5
	N 80 kg/ha + P_2O_5 80 kg/ha + 30 t/ha manure	51.2	52.8	53.9	52.6	48.8	52.3	54.8	52.0
	Average	44.7	47.2	51.0	47.6	43.3	46.1	49.2	46.2
Ploughing at 30 cm + disk	N_0P_0	39.6	44.3	49.7	44.5	40.1	45.2	47.2	44.2
	N 80 kg/ha + P_2O_5 80 kg/ha	46.5	49.3	56.2	50.7	47.2	51.2	55.1	51.2
	N 80 kg/ha + P_2O_5 80 kg/ha + 30 t/ha manure	52.1	53.2	54.2	53.2	52.8	52.6	53.8	53.1
	Average	46.1	48.9	53.4	49.5	46.7	49.7	52.0	49.5
Chisel + disk	N_0P_0	37.4	41.3	48.7	42.5	38.2	42.6	44.2	41.7
	N 80 kg/ha + P_2O_5 80 kg/ha	43.2	49.2	53.6	48.7	41.5	44.5	53.8	46.6
	N 80 kg/ha + P_2O_5 80 kg/ha + 30 t/ha manure	50.4	54.3	54.2	53.0	50.2	48.2	55.1	51.2
	Average	43.7	48.3	52.2	48.0	43.3	45.1	51.0	46.5

Table 5. Chemical characteristics of typical chernozem at different soil tillage variants.

Horizon	Depth cm	pH (H_2O)	Humus %	Effective cation exchange capacity me/100 g soil	Degree of base saturation %	Total N %	Mobile P ppm	Mobile K ppm
Profile 1 - Typical cambic chernozem - Chisel + disk								
Ap	0-21	6.9	3.24	27.0	89.2	0.182	46	286
Am	22-40	6.9	2.98	26.3	88.6	0.163	42	218
A/B	41-55	7.1	2.74	25.9	91.7	0.134	-	87
Bv	56-73	-	-	-	-	-	-	-
C_1	74-94	-	-	-	-	-	-	-
Profile 2 - Typical cambic chernozem - Ploughing at 20 cm + disk								
Ap_1	0-18	6.4	3.25	31.2	79.1	0.159	45	234
Ap_2	19-27	6.3	2.94	31.2	87.6	0.151	43	139
Am	28-38	6.9	2.36	28.2	91.1	0.143	4	90
A/B	39-55	6.9	2.52	26.6	92.7	0.143	-	-
Bv	56-73	-	-	47.8	94.1	-	-	-
C_1	74-94	-	-	-	-	-	-	-

The mean wheat yield during 1985-2006 using 20 cm ploughing was 3690 kg/ha, and in the case of chisel ploughing and disk and also by repeated disking yields were lower by 5.0% (-170 kg/ha) and 11.0% (-423 kg/ha) respectively (Table 6). In the same period, the wheat mean yield obtained with no added fertilizer was 2010 kg/ha, and fertilizer applied at rates of N 80 kg/ha + P_2O_5 80 kg/ha or N 120 kg/ha + P_2O_5 80 kg/ha resulted in relative yields of 87% (1758 kg/ha) and 116% (2333 kg/ha), respectively.

In dry years, 30 cm ploughing resulted in higher wheat yields, compared to 20 cm ploughing, by 14.0% (385 kg/ha). In the case of disk tillage, the yields were lower by 6.0% (-171 kg/ha) (Table 6). Under drought, applied fertilizer determined yield increases of 63% (1055 kg/ha) at the rate of N 80 kg/ha + P_2O_5 80 kg/ha and 105% (1770 kg/ha) at N 120 kg/ha + P_2O_5 80 kg/ha.

In maize, 30 cm ploughing resulted in higher yields by 8% (535 kg/ha) compared to 20 cm ploughing and disk tillage reduced yield by 8% (556 kg/ha) (Table 7). Fertilizers applied at rates of N 80 kg/ha + P_2O_5 80 kg/ha or N 140 kg/ha + P_2O_5 80 kg/ha increased yield by 112% (3960 kg/ha) and 148% (5240 kg/ha), respectively. In maize grown during drought, 30 cm ploughing gave 12% higher yield (602 kg/ha) compared to 20 cm ploughing, and in the case of chisel ploughing and disk by 5.0% (240 kg/ha). Disk ploughing resulted in a yield reduction of 5.0% (226 kg/ha) compared to 20 cm ploughing (Table 7).

In soybean, the yields with chisel ploughing and disk were 12% higher (260 kg/ha) than those with 20 cm ploughing. In the case of soil treatment with disks, yields were 15.0% (336 kg/ha) lower than those with 20 cm ploughing (Table 8). Yield increases due to fertilizer applications were between 27% (460 kg/ha) at the rate of N 30 kg/ha + P_2O_5 60 kg/ha and 51% (888 kg/ha) at N 90 kg/ha + P_2O_5 60 kg/ha. In drought the soybean yield with 20 cm ploughing was 1735 kg/ha (100%), and with disk tillage it diminished by 20% (-280 kg/ha) (Table 8). In soybean, fertilizer applications increased yield, compared to no fertilizer, by between 21% (280 kg/ha) at the rate of N 30 kg/ha + P_2O_5 60 kg/ha and 55% (730 kg/ha) at N 90kg/ha + P_2O_5 60 kg/ha.

Conclusions

Soil preparation without inverting resulted in improved soil physical and hydrophysical characteristics and allowed a better utilization of technological factors and especially fertilizers , which increased yields in comparison to 20 cm ploughing by 8% (353 kg/ha) in maize (N 140 kg/ha + P_2O_5 80 kg/ha). Under these conditions there was an increase in clay, humus and mineral element content in the soil profile down to a depth of 40 cm. Soil tillage by chisel ploughing and disks allowed soil treatment under better conditions for wheat in the dry autumns frequently experienced in the area.

Twenty-two years of the conventional tillage system settled soil at a depth of 19-27 cm, where bulk density was high at 1.52 g/cm^3, total porosity low at 43.3% and settling degree high at 16.4%. Water stability of structure using the chisel plough was lower, compared to 20 cm ploughing, only at the soil surface (46.1-46.7%). However, at a depth of 10-30 cm, it was higher by 2.3% in wheat and 3.7% in maize.

The mean wheat yield during 1985-2006 with 20 cm ploughing was 3690 kg/ha; in the case of chisel ploughing and disk and repeated disking, yields were lower compared to 20 cm ploughing, by 5.0% (-170 kg/ha) and 11.0% (-423 kg/ha), respectively. In maize, fertilizers were better utilized under conditions of deeper soil tillage (30 cm ploughing; chisel ploughing and disk) where yield increases varied with fertilizer rates from 98-131% (3940-5260 kg/ha).

The results indicate that soil tillage systems must be adjusted to plant requirements for crop rotation and to the pedoclimatic conditions of the area. Establishing systems of soil tillage for all components of the crop rotation sequence (disking or chisel ploughing and disk tillage in wheat, 20 cm ploughing for soybean, 20 cm ploughing for maize) resulted in a better utilization of the other technological factors, soil water conservation, maintaining soil physical conditions and reduction in fuel consumption.

Table 6. Influence of soil tillage system and mineral fertilization on wheat yield (kg/ha).

	Wheat yields obtained during 1985 - 2006						
	N0P0	N80P80	N100P80	N120P80	Average	%	Dif
Ploughing 20 cm + disk	2020	3890	4360	4490	3690	100	0
Ploughing 30 cm + disk	2240	4120	4530	4670	3890	105	200
Chisel + disk	1920	3640	4230	4290	3520	95	-170
Disk	1860	3420	3870	3920	3268	89	-423
Average	2010	3768	4248	4343	3592	x	x
LSD 5% = 250 kg/ha; LSD 1% = 350 kg/ha; LSD 0.1% = 470 kg/ha							
	Wheat yields obtained in dry years (1986, 1987, 1990, 1992, 1994, 1997, 2000, 2003, 2004)						
	N0P0	N80P80	N100P80	N120P80	Average	%	Dif
Ploughing 20 cm + disk	1640	2730	3260	3340	2743	100	0
Ploughing 30 cm + disk	1860	3250	3620	3780	3128	114	385
Chisel + disk	1650	2570	3240	3410	2718	99	-26
Disk	1560	2380	3090	3260	2573	94	-171
Average	1678	2733	3303	3448	2790	x	x
LSD 5% = 230 kg/ha; LSD 1% = 330 kg/ha; LSD 0.1% = 440 kg/ha							

Table 7. Influence of soil tillage system and mineral fertilization on maize yield (kg/ha).

	Maize yields obtained during 1985 - 2006						
	N0P0	N80P80	N120P80	N140P80	Average	%	Dif
Ploughing 20 cm + disk	3260	7620	8410	8720	7003	100	0
Ploughing 30 cm + disk	4020	7960	8890	9280	7538	108	535
Chisel + disk	3750	7560	8520	8850	7170	102	167
Disk	3120	6850	7560	8260	6448	92	-556
Average	3538	7498	8345	8778	7039	x	x
LSD 5% = 380 kg/ha; LSD 1% = 530 kg/ha; LSD 0.1% = 720 kg/ha							
	Maize yields obtained in dry years (1986, 1990, 1992, 1994, 2000, 2003)						
	N0P0	N80P80	N120P80	N140P80	Average	%	Dif
Ploughing 20 cm + disk	2130	5420	5930	6070	4888	100	0
Ploughing 30 cm + disk	2580	5910	6490	6980	5490	112	602
Chisel + disk	2250	5540	6240	6480	5128	105	240
Disk	2060	5100	5630	5860	4663	95	-226
Average	2260	5470	6070	6350	5038	x	x
LSD 5% = 290 kg/ha; LSD 1% = 415 kg/ha; LSD 0.1% = 645 kg/ha							

Table 8. Influence of soil tillage system and mineral fertilization on soybean yield (kg/ha).

	Soybean yields obtained during 1985-2006						
	N0P0	N30P60	N60P60	N90P60	Average	%	Dif.
Ploughing 20 cm + disk	1670	2210	2450	2640	2243	100	0
Ploughing 30 cm + disk	2030	2440	2670	2870	2503	112	260
Chisel + disk	1780	2310	2410	2670	2293	102	50
Disk	1460	1820	2040	2310	1908	85	-336
Average	1735	2195	2393	2623	2236	x	x
LSD 5% = 230 kg/ha; LSD 1% = 325 kg/ha; LSD 0.1% = 415 kg/ha							
Soybean yields obtained in dry years (1986, 1990, 1992, 1993, 1994, 1997, 2000, 2003, 2004)							
	N0P0	N80P80	N120P80	N140P80	Average	%	Dif
Ploughing 20 cm + disk	1340	1630	1840	2130	1735	100	0
Ploughing 30 cm + disk	1490	1830	2140	2450	1978	114	243
Chisel + disk	1330	1610	1950	2080	1743	100	8
Disk	1140	1350	1490	1560	1385	80	-350
Average	1325	1605	1855	2055	1710	x	x
LSD 5% = 225 kg/ha; LSD 1% = 310 kg/ha; LSD 0.1% = 390 kg/ha							

Acknowledgements

The authors would like to thank the National Authority for Scientific Research, Bucharest, for financing the Excellence Research Project CEEX 44/2005.

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