THE INFLUENCE OF THE CROP ROTATION, THE NUTRITION REGIME AND THE HERBICIDES ON PRODUCTION AND SEVERAL PRODUCTIVITY ELEMENTS IN WINTER WHEAT (*Triticum aestivum* L.) CULTIVATED ON ACID SOILS IN THE WESTERN PLAIN OF ROMANIA

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Abstract. The crop rotation plant is a decisive factor influencing the growth and development of wheat .The choice of an appropriate crop rotation of plants, for instance, maintains a normal C/N ratio of 40-70 (assimilative C versus assimilative N). Bacterial N fixation in the soil and a normal C/N ratio are conditions that offer the forerunner plant ameliorative properties [11].

The influence of plant cultivation technologies is expressed in the yield obtained per ha. The economic efficiency is quantified by the cost per ha or product unit.

At present, this quantification is irrelevant due to the fact that products' prices oscillate dramatically as a consequence of the inflation which is a characterisic of the present period. Thus, the most recommended method is to express the efficiency of the applied agrotechnical measures throught a different indicator, more stable and synthetic: KWh. This indicator is more realistic in respect to the investments and benefits of a cultivated crop and also makes possible the application of adequate measures leading to production increase per surface unit [1].

Keywords: crop rotation, fertilisation level, herbicides, productivity elements, winter wheat, brown luvic soils (acid soils), spike, grains.

INTRODUCTION

Cultivated in a rotation of 4-6 years and securing a density of 600 spike/m^2 it does not present significant problems like weeding plants. However, in Romania, in wheat cultures grow different species of weeds, that, without proper control, produce damages between 10 şi 20 % and even 60-80 % of the yield [14]. The largest number of weeds in wheat cultures are annual and perennial dycotiledons [7, 8]. Not all of them are similarly damaging, some being grown higher by wheat plants. But some of them are extremely damaging, leading to the reduction of the production, quality and bringing great damages at harvest and grain keeping. Very damaging are the species: *Agrostemma githago, Centaurea cyanus, Cirsium arvense, Convolvulus arvensis, Galium aparine, Matricaria inodora, Papaver rhoeas, Polygonum convolvuls, Sinapis arvensis, Sonchus arvensis,* etc. [4, 5].

Every technological stage is characterised by specific energetical coefficients. The goal is to reflect the rentability of the taken measures. Until now, few experiments regarding energetic efficiency in wheat and corn in the Western Romanian Plain were reported. The conclusions show that applied technological measures, especially in wheat (minimal processing and deep break up of the soil) are more energetically efficient in wheat than in corn, on acid soils with a temporary humidity excess [15].

Data presentation on production and energetic efficiency of the studied factors was separated in two groups corresponding to research years: the first group – displays the obtained production differences and their significance; the second – energetic efficiencies transformed in several energetic index as efficiency and energetic report also expressed in a synthetic coefficient, KWh/ha [12].

The crop rotation together with other appropriate agricultural practices contribute to the favourableness of growth and development conditions of wheat root system, to an improved synthesis of specific organic compounds and their improved translocation to plant's organs [3, 10].

Productivity elements permit the justification of yield differences between the average of the researched years. Thus, the main productivity element was the number of spike/m^2 that significantly influenced the yield level and at a lesser extent the rest of the studied productivity elements [6, 13].

MATERIALS AND METHODS

During 2006-2008, at the Agricultural Research-Development Station Oradea (Bihor county, Romania), was set up a multifactorial experiment (the subdivided stand's method) on a substrate of acid soil. Climatic conditions were favourable during 2006 and marked by drought during 2008. Productivity elements were assessed differentially for the crop rotation plant under different climatic conditions. On ploughing depth, the soil is low acid (pH=6.8), low humus content (1.75%), phosphorus (22.0 ppm) and potassium (845.4 ppm) have average values; the hydrostability of macroaggregates is high and the bulk density (1.44 g/cm^3) is high, too [9].

Investigated factors:

A. Crop rotation

a_1= Wheat (*Triticum aestivum* L., 'Delia' cultivar) monocrop

a_2 = Wheat (*Triticum aestivum*, L.) – Corn (*Zea mays* L.)

a_3 = Pea (*Pisum sativum* L., 'Corina' cultivar) – Wheat (*Triticum aestivum* L. 'Delia' cultivar) – Corn (*Zea mays* L. HT - Elan)

a_4 = Pea (*Pisum sativum* L.) – Wheat (*Triticum aestivum* L.) – Corn (*Zea mays* L.)

B. Nutrition regime

b 1 = unfertilised
b 2 = $N_{120}P_{80}$
b 3 = $N_{100}P_{80}$ + 10 t/ha manure

C. Treatment with herbicides
c 1 = No herbicides
c 2 = Arelon super 2 l /ha
c 3 = Assert 2.5 l/ha + Icedin super 1 l/ha
c 4 = Puma super 1 l/ha + Icedin super1 l/ha

For autumn wheat (*Triticum aestivum* L.) we worked with the 'Delia' cultivar. The 'Delia' cultivar has a production potential with excellent panification qualities [2]. It has an average vegetation period, revaluating in a superior degree the created agrofunds. It has a great resistance to falling (due to the relatively short straw) and rust, being more sensitive to harsh winters without snow but also to drought in the years with long periods without rain and intense heat [4].

For the maize (*Zea mays* L.) that entered the rotation it was used *HT - Elan* and for pea (*Pisum sativum* L.) the Corina cultivar. The experiemental results regarding the obtained production were interpreted using the method of the "analysis of the variation" and expressed in appropriate units (q/ha with 14 % moisture).

The energetic efficiency was calculated on the quantification of the consumed energy (soil preparation, fertilization, sowing, herbicides, harvesting, yield transportation) the resulted energy (main production).

The moisture of the grains at harvesting was determined using the moisture meter.

The main production was calculated at the STAS moisture of 14.5%.

RESULTS

Tables 1 – 6 reflect average production results as function of the investigated factors (2006-2008).

Table 1. The influence of the crop rotation, the nutrition regime and the treatment with herbicides on winter wheat (*Triticum aestivum* L.) production, cultivated on acid soils, Oradea 2006-2008.

Investigated factor	Production		± difference	Significance of difference
	q/ha	%	Difference	
a. Crop rotation				
Monocrop Wheat	29.2	100	-	-
Wheat-Corn	35.3	120.9	+ 6.1	***
Pea-Wheat-Corn	45.5	155.8	+ 16.3	***
Pea- Wheat - Corn - Corn	45.9	157.2	+ 16.7	***
DL 5% DL 1% DL 0,1 %	-	-	2.5 3.6 5.3	-
b. Nutrition regime				
Unfertilised	26.1	100	-	-
$N_{120}P_{80}$	43.9	168.2	+ 17.8	***
$N_{100}P_{80}$+ 10 t/ha manure	46.9	179.7	+ 20.8	***
DL 5% DL 1% DL 0,1 %	-	-	1.8 2.5 3.3	-
c. Treatment with herbicides				
No herbicides (Mt)	35.9	100	-	-
Arelon super 2 l/ha	38.4	106.9	+ 2.5	**
Assert 2.5 l/ha + Icedin super 1 l / ha	35.3	98.3	- 0.6	-
Puma super 1 l/ ha +Icedin super 1 l / ha	38.2	106.4	+ 2.3	**
DL 5% DL 1% DL 0,1 %	-	-	1.6 2.1 2.7	-

Note: 1.– unsignificant = under 1.60; * significant =1.60-2.10; ** significantly different =2.10-2.70; *** very significant =over 2.70.

DISCUSSION

The influence of the investigated factors (crop rotation, nutrition regime, treatment with weeding) on wheat yield is presented in Table 1.

The analysis of the crop rotation shows that, compared to wheat monoculture with an average of yield of 29.2 q/ha wheat cultivated after corn or pea reaches an average increment of the yield of about 6.1-16.7 q/ha, which represents a significant value. It is remarkable that the highest yield increments were obtained after pea (16.3-16.7 q/ha) and the lowest after corn (6.1 q/ha) (Table 1).

Concerning the created agrofund, Table 1 shows that mineral fertilisation (N_{120} P_{80}) and mixed fertilisation (N_{120} P_{80} + 10 t/ha manure) determined significant yield raises that oscillated between 17.8-20.8 q/ha as compared to the unfertilized alternative of an average yield around 26.1 q/ha. Remarkably, the highest yield increments were obtained under complex fertilisation (20.8 q/ha) which surpassed mineral fertilisation alternative with 3.0 q/ha.

Concerning the treatment with herbicides, the average of the researched years (2006-2008), shows distinctively significant yield increments in alternatives treated with herbicides (Puma super 1 l/ha + Icedin super 1 l/ha and Arelon super 2 l/ha) as compared to untreated alternatives. The obtained yield was of 35.9 q/ha in the case of untreated alternatives and yield increments in treated alternatives raised the yield with 2.3-2.5 q/ha.

The influence of factors' interaction, crop rotation x nutrition regime on wheat yield is displayed in the data in Table 2. The averages obtained during the investigation period show that regardless the crop rotation, mineral or mixed fertilisation, very significant yield increments were obtained, between 14.2-27.9 q/ha. It is worth remarking that average yield increments were higher in the case of weaker crop rotation plants. In wheat cultivated after wheat or after corn increments oscillated between 18.2-27.9 q/ha as compared to the unfertilized alternative . In wheat cultivated after pea, increments were lower, between 14.2-20.1 q/ha. Regardless the crop rotation plant, yield maximal levels were obtained in the mixed fertilization alternative.

Table 2. The interaction of factors: crop rotation x nutrition regime on winter wheat (*Triticum aestivum* L.) production cultivated on acid soils, Oradea 2006-2008.

Investigated factors	Production		± Difference	Significance of difference
	q/ha	%	q/ha	
a. Monocrop- wheat				
Unfertilised	17.0	100	-	-
$N_{120}P_{80}$	35.3	207.6	+ 18.3	***
$N_{100}P_{80}$ + 10 t/ha manure*	35.2	207.0	+ 18.2	***
b. Crop rotation- 2 years (Wheat-Corn)				
N_0P_0 (Mt)	18.9	100	-	-
$N_{120}P_{80}$	40.3	213.2	+ 21.4	***
$N_{100}P_{80}$ + 20 t/ha manure*	46.8	247.6	+ 27.9	***
c. Crop rotation- 3 years (Pea-Wheat-Corn)				
Unfertilised	35.1	100	-	-
$N_{120}P_{80}$	49.3	140.4	+ 14.2	***
$N_{100}P_{80}$+ 30 t/ha manure*	52.0	148.1	+ 16.9	***
d. Crop rotation- 4 years (Pea-Wheat-Corn-Corn)				
Unfertilised	33.5	100	-	-
$N_{120}P_{80}$	50.7	151.3	+ 17.2	***
$N_{100}P_{80}$+ 40 t/ha manure*	53.6	160.0	+ 20.1	***
DL 5% DL 1% DL 0,1 %	-	-	3.6 4.9 6.6	-

Note: *) manure was administrated in corn culture crop rotations; 1.– unsignificant = under 3.60; * significant =3.60-4.90; ** significantly different =4.90-6.60; *** very significant =over 6.60.

Tabelul 3. The influence of the investigated factors on production and energetic efficiency in wheat (*Triticum aestivum* L.) cultivated in different crop rotations and agrofunds on acid soils, Oradea 2006-2008.

Investigated factors	Production q/ha	Energy (Kwh/ha)		Energetic efficiency	Energetic ratio
		consumed	produced		
a. Crop rotation plant					
Monocrop Wheat	29.2	4.160	13.023	3.13	0.32
Crop rotation- 2 years (Wheat-Corn)	35.3	4.160	15.744	3.78	0.26
Crop rotation- 3 years (Pea-Wheat-Corn)	45.5	4.160	20.293	4.88	0.21
Crop rotation- 2 years (Pea- Wheat - Corn – Corn)	45.9	4.160	20.471	4.92	0.21
DL 5% DL 1% DL 0,1%	2.5 3.6 5.3	-	-	-	-
b. Nutrition regime					
Unfertilised	26.1	1.341	11.641	8.68	0.12
$N_{120}P_{80}$	43.9	4.976	19.579	4.01	0.25
$N_{100}P_{80}$+ 10 t/ha manure	46.9	6.262	20.917	3.34	0.31
DL 5% DL 1% DL 0,1%	1.8 2.5 3.3	-	-	-	-
c. Treatment with herbicides					
No herbicides (Mt)	35.9	4.160	16.011	3.85	0.27
Arelon super 2 l/ha	38.4	4.306	17.126	3.98	0.26
Assert 2.5 l/ha + Icedin super + 1 l/ha	34.6	4.417	15.432	3.49	0.29
Puma super 1 l/ha +Icedin super 1 l/ha	38.1	4.306	16.993	3.95	0.26
DL 5% DL 1% DL 0,1%	1.5 2.1 2.7	-	-	-	-

Note: 1 kg of wheat = 4.46 kWh1kWh= 0.325 l oil

The treatment with herbicides (Table 3) displays a similar pattern in investigated alternatives concerning quantities of produced energy and calculated energetic indices.

In what concerns the energetic efficiency of the investigated factors, this is displayed in Table 3. Data show: between yield and the produced quantity of energy as function of the investigated forerunner plant there is a positive, direct correlation: as yield increases in wheat monoculture (22.2 q/ha) toward 4 yiears crop rotation (45.9 q/ha), the produced energy quantity increases as well from 13,023 to 20,071 kWh/ha. The same positive correlation is observed in the case of the energetic efficiency that increases from 3.14 kWh/ha in wheat monoculture to 4.92 kWh/ha in 4 years crop rotation. Concerning the energetic report, this is indirectly related to the realised yield, decreasing from 0.32 kWh/ha in monoculture to 0.21 kWh/ha in 4 years crop rotation.

Table 3 shows that in the case of the nutrition regime, there is a proportional increase of the produced quantity of energy with increment of created agrofund from 11,641 kWh/ha in unfertilised alternative to 20,971 kWh/ha in mixed fertilisation alternative. There is a decrease of energetic efficiencies from 8.68 kWh/ha to 3.34 kWh/ha followed by a raise of the energetic report from 0.12 kWh/ha to 0.31 kWh/ha (in unfertilised alternative and mixed fertilisation alternative, correspondingly).

Table. 4. The influence of factors' interaction: crop rotation x nutrition regime on production and energetic efficiency in wheat (*Triticum aestivum* L.) cultivated on acid soils, Oradea 2006-2008.

Investigated factors	Production [q/ha]	Energy - Kwh/ha		Energetic efficiency	Energetic report
		consumed	produced		
a. Monocrop- wheat					
Unfertilised	17.0	1.341	7.582	5.65	0.18
$N_{120}P_{80}$	35.3	4.874	15.744	3.23	0.32
$N_{100}P_{80}$+ 10 t/ha manure*	35.2	6.262	16.699	2.51	0.41
b. Crop rotation- 2 years (Wheat-Corn)					
Unfertilised	18.9	1.341	8.429	6.28	0.17
$N_{120}P_{80}$	40.3	4.874	17.974	3.69	0.27
$N_{100}P_{80}$+ 20 t/ha manure*	46.8	8.162	20.873	2.56	0.40
c. Crop rotation- 3 years (Pea-Wheat-Corn)					
Unfertilised	35.1	1.341	15.655	11.67	0.09
$N_{120}P_{80}$	49.3	4.874	21.988	4.51	0.23
$N_{100}P_{80}$+ 30 t/ha manure*	52.0	10.062	23.192	2.30	0.45
d. Crop rotation- 4 years (Pea-Wheat-Corn-Corn)					
Unfertilised	33.5	1.341	14.941	11.14	0.09
$N_{120}P_{80}$	50.7	4.874	22.612	4.64	0.22
$N_{100}P_{80}$+ 40 t/ha manure*	53.6	11.962	23.906	2.00	0.53
DL 5% DL 1% DL 0,1%	3.6 4.9 6.6	-	-	-	-

*) manure was administrated in corn culture crop rotations.

Table 5. The influence of factors: crop rotation, nutrition regime and herbicides on several productivity elements in winter wheat (*Triticum aestivum* L.) cultivated on acid soils, Oradea 2006-2008.

Investigated factor	Productivity elements							
	spike/ m^2		grains / spike		MMB		M.H.	
	no.	%	no.	%	g	%	kg	%
a.Crop rotation								
Wheat monoculture	260	100	37	100	33.9	100	71.5	100
2 years crop rotation (Wheat-Corn)	358	137.6	36	97.3	35.2	103.8	72.4	101.2
3 years crop rotation (Pea-Wheat-Corn)	473	181.9	37	100	35.2	103.8	72.7	101.7
4 years crop rotation (Pea-Wheat-Corn-Corn)	491	188.8	36	97.3	34.4	101.5	72.6	101.5
b. Nutrition regime								
Unfertilised	354	100	31	100	38.2	100	72.8	100
$N_{120}P_{80}$	401	113.3	40	129	34.3	89.8	72.1	99.0
$N_{100}P_{80}$ + 10 t/ha manure	425	120.0	40	129	34.8	91.1	71.8	98.6
c. Treatment with herbicides								
No herbicides (Mt.)	438	100	36	100	33.8	100	71.9	100
Arelon super 2l/ha	395	90.2	38	105.5	35.4	104.7	72.3	100.5
Assert2.5 l/ha + Icedin super 1 l/ha	364	83.1	36	100	34.8	102.9	72.0	100.1
Puma super 1 l /ha + Icedin super 1 l/ha	376	85.8	36	100	34.9	103.2	72.7	101.1

The influence of factors, interaction x nutrition regime on wheat energetic efficiency is presented in Table 4.

Presented data show that, regardless the investigated crop rotation, both mineral and mixed fertilization determines a quantitative increase of the produced energy. There is a proportionality between the quantitative increase and the quality of the used crop rotation plant. It is understood that this increase is correlated to the level of the obtained productions. Thus, in wheat monoculture the quantity of produced energy varies between 7.582-16.699 kWh/ha as compared to 4 years crop rotation in which the quantity varies between 14.941-23.906 kWh/ha.

Concerning the calculated energetic indices, we can observe an increase of the energetic report regardless the crop rotation proportionally to the increment of the created agrofund.

Tables 5 and 6 present several productivity elements which permit the justification of yield differences between the average of the researched years. Thus, the main productivity element was the number of spike/m^2 that significantly influenced the yield level and at a lesser extent the rest of the studied productivity elements.

We present several data in order to illustrate later affirmations concerning the influence of the crop rotation and of the nutrition regime on yield level in spike'number/m^2 (Table 5).

Thus, in wheat monoculture this productivity element reached 260 spike/m^2 in wheat monoculture and between 358-491 spike/m^2 in crop rotations, in created agrofund as compared to the unfertilised alternative, 354 spike/m$^{2.}$ Mineral fertilization determined an increment between 401-425 spike/m^2.

An important contribution in the productivity level played the number of grains/spik that increased from 31 in wheat monoculture to 40 grains/spik in fertilised alternatives, both mineral and mixed. Concerning the treatment with herbicides, the most important role played MMB that influenced positively the yield level as depending on herbicide type and combination.

Table 6. The influence of factors: crop rotation, nutrition regime and herbicides on plant development, weeds' level and grains wilt in winter wheat (*Triticum aestivum* L.), cultivated on acid soils, Oradea 2006-2008.

Investigated factor	Plant'development				Wilting level (%) :				Weeds	
	height		spike'length		No. grains/spike		grains weight/ spike		No / m^2	%
	cm	%	cm	%	nr.	%	g	%		
a. Crop rotation										
Wheat monoculture	65.6	100	7.2	100	9.3	100	0.7	100	158	100
2 years crop rotation (Wheat-Corn)	67.1	102.3	6.9	95.8	9.3	100	0.7	100.0	36	22.8
3 years crop rotation (Pea-Wheat-Corn)	71.0	108.2	7.4	102.8	6.7	72.0	0.7	100.0	23	14.5
4 years crop rotation (Pea-Wheat-Corn-Corn	73.0	111.3	7.5	104.2	9.2	98.9	0.9	128.6	12	7.6
b. Nutrition regime										
unfertilised	61.0	100	6.6	100	6.0	100	0.6	100	44	100
$N_{120}P_{80}$	71.3	116.9	7.4	121.1	7.1	118.3	0.7	117.7	62	140.9
$N_{100}P_{80}$ + 10 t/ha manure	52.3	85.7	7.8	118.2	7.3	121.7	0.8	133.3	49	111.4
c. Treatment with herbicides										
No herbicides (Mt.)	72.0	100	7.1	100	1.4	100	0.5	100	119	100
Arelon super 2 l/ha	72.5	100.7	7.5	105.6	20.1	193.3	0.9	180.0	41	34.4
Assert 2.5 l/ha+ Icedin super 1 l/ha	72.5	100.7	7.4	104.2	15.3	147.1	0.6	120.0	56	47.0
Puma super 1 l/ha + Icedin super 1 l/ha	75.2	100.7	7.4	104.2	17.1	164.4	0.5	100.0	27	22.8

Table 6 shows the role of the investigated factors on the level of the treatment with herbicides of wheat crop, an important issue as referred to the biological or chemical control of weeds. Data from Table 6 show a great number of weeds in wheat monoculture, 158 weeds/m^2, and a significant decrease in 4 years crop rotation (12 weeds/m^2). Concerning the regime of nutrition we remark that compared to the unfertilized alternative, the number of weeds increases after fertilization reaches values that are superior to the blank alternative with 11.4-40.9%.

Certainly, if we consider only weeds' level, we may conclude that the regime of nutrition increases the treatment with herbicides and decreases crop level. The stimulation determined by fertilization in productivity elements induces a raise in yields.

Applied herbicides alone or in combinations of different ratios, under experimental conditions may reduce weeds' level from 100% in alternatives with no herbicides to 22.8-47.0% concerning weeds' level/m^2.

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