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STUDY ON THE INFLUENCE OF LONG-TERM MONOCULTURE AND OF THREE TYPES OF CROP ROTATIONS ON WHEAT YIELD IN BURNAS PLAIN (ROMANIA)

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Abstract

In sylvo-steppe conditions, on a leached chernozem with around 3.5% humus, 10 years experiments (2005-2014) were carried out on the yield of Josef premium wheat variety in monoculture (W-W-W-W), in crop rotation with two plants (W-W-M-M), in crop rotation with four different plants, but without ameliorative plant (W-R-M-SF) and crop rotation with peas as an ameliorative plant (P-W-R-W). After 10 years, wheat monoculture reduced production by 22 q/ha, i.e. 35% compared to the starting year. In the W-W-M-M crop rotation system, the yield loss was reduced by half (18.6%), while in the case of W-R-M-SF, wheat production remained constant throughout the entire experimentation period. The crop rotation system with peas (P-W-R-W) brought a very significant harvest increase after 10 years – 8.58 q/ha (12.1%). It is especially recommended the crop rotation system with the ameliorative plant, which obtains the highest yield (70.38 q/ha), followed by the one with different plants, which doesn't reduce the production, but doesn't raise it either. Under no circumstances, wheat monoculture mustn't exceed 2-3 years.

Key words: *wheat, monoculture, crop rotation system, yield, Burnas Plain*

INTRODUCTION

The papers presented at the Global Forum on Food and Agriculture 2020, held in Berlin (January 16-18, 2020), have debated a perpetual problem, that of ensuring food safety and security under sustainable conditions for all inhabitants of the planet (Berca, 2020) [2]. The goal is noble, but difficult to achieve as long as over 800 million people die of hunger each year and over one billion are overweight (FAO, 2019) [6], causing huge costs to the planet. A third billion inhabitants of the planet suffer from chronic hunger. Under such conditions, the World Health Organization (WHO), the European Union, but also other institutions believe that any innovations, any solutions that bring quantity and quality enhancements to the main food products will be taken over by the international heritage of science.

Modern agricultural science has created an agriculture very close to the goals of sustainability, but this is not the case all over the world. In many agricultural areas, the technologies still have large gaps, which influence both the quantity and the quality of yields, as well as the quality of the environment. A deficient factor of agricultural technologies that is still practiced due to the conjuncture of the agricultural product markets is monoculture and rotation, that is, isolation (Strauss, 2017) [15]. Monoculture, especially in cereals, had been developed in the decades 6-7 of the last century, when by obtaining and using large quantities of fertilizers (especially with nitrogen) and pesticides it was thought that the negative effects could be blurred, especially to wheat (Berca and Horoiaș, 2019) [1].

Research and observations in the field have shown that after 3-4 years of monoculture, the obtained yields dropped out almost exponentially, the losses over a period of 10 years reaching about 40% in Romania (Ionescu-Șișești and Staicu, 1958; Staicu, 1969; Sin, 2007; Popescu, 2017 and others) [9, 14, 13, 11], as well as in many other countries (Boguslawski, 1981; Charles et al., 2011; Christen, 2001; Félix, 2015; Hennessy, 2006; Marais et al., 2012; Schneider et al., 2010; Wahbi et al., 2016; Zimmer et al., 2016, etc.) [3, 4, 5, 7, 8, 10, 12, 16, 17].

The presented results intended to demonstrate how a relatively new wheat variety (Josef), a premium one, reacts under 10-year monoculture conditions, compared with three crop rotations of 4 years each, consisting of 2, 3 or 4 crops. The research aims to cover an information gap for the specialists, who continue to excessively use wheat monoculture, but also to highlight the role of the improving plants (peas) in increasing the yield level and the quality of the environment.

MATERIALS AND METHODS

The researches were carried out in the east of the Burnas Plain, on a chernozem type soil with 3.3-3.5% humus (medium to normal supply) and on a loam-clay texture.

A field experience has been organized under yield conditions on plots of 24 x 200 m, in order to work with production equipment. The dimensions of the plots were 24 x 200 m = 4,800 sqm. Observations and harvests have been made on 100 sqm plots obtained randomly, by cutting from the large plot, in 4 repetitions. The harvesting has been done with a special mini-combine for experimental plots.

The experimental variants have been the following:

(1)Wheat monoculture for 10 years (autumn 2004 - autumn 2013);

(2)Wheat - wheat - maize - maize (W-W-M-M) crop rotation system;

(3)Wheat - rapeseed - maize - sunflower (W-R-M-SF) crop rotation system;

(4)Peas - wheat - rapeseed - wheat (P-W-R-W) - with the ameliorative plant interspersed between the wheat crops.

The soil works and the preparation of the germinal bed have been carried out according to the farm technology.

All variants have been evenly fertilized, with $N_{100}P_{70}K_{40}$, phosphorus and potassium being applied in the autumn, before sowing. Nitrogen has been applied 20% in autumn and the rest in two stages in spring-summer. The treatments performed have been those specific to the farm for weeds, as well as for diseases and pests. Harvesting has been done at 13% humidity. The analysis of variance, regressions and correlations in 2D and 3D has been used. The results have been interpreted in the form of tables and graphs.

RESULTS AND DISCUSSIONS

The climatic zone corresponds to a modified sylvo-steppe, characterized by the following parameters for the period 1997-2006:

- the average annual temperature, which was 11.65°C;
- the average annual rainfall, which were 549 mm.

For the years of experimentation, the climatic parameters are presented in Figure 1 and Figure 2. In Figure 1 is shown the evolution of the average monthly temperatures for the 10 agricultural years of the study, including the scheme with the evolution of the heat regime, expressed through the annual averages. It turns out that the warmest year have been 2006-2007, with an average of almost 14°C, followed by 2012-2013, 2013-2014, 2011-2012 and 2008-2009, with average temperatures around 12°C, higher than the multiannual standard average. Less warm years have been 2010-2011 and 2005-2006, slightly below average.

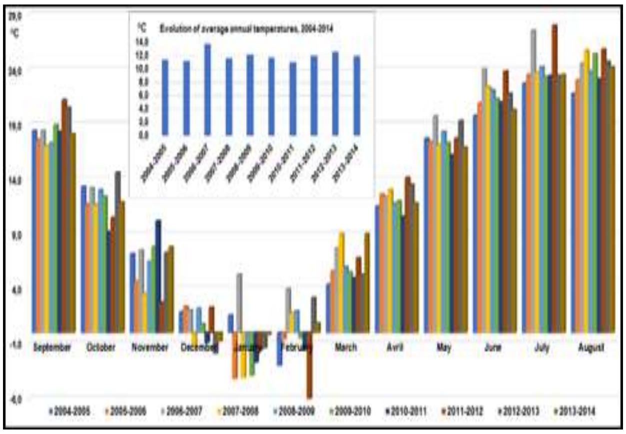

Fig. 1. Graphs of the evolution of monthly and annual temperatures for the period 2004-2014 (Alexandria area)
Source: own data.

The warmest month was July, especially in 2011-2012 and 2006-2007, when the average monthly temperatures approached 28-29°C, followed by August and June. January was the coldest, but extremely cold was February 2011-2012 (-6.1°C). September, as the month before sowing, was warm and dry during almost all the years of experimentation, except for 2011-2012 and 2012-2013.

The rainiest months of the analyzed period were July 2013, September and May 2005 (with values between 160 and 225 mm). On the other hand, there were months when the rains were almost completely absent. As annual amounts, the rainiest year was 2004-2005, with over 900 mm of rainfall, followed by 2010-2011, 2013-2014 and 2005-2006, with 650-680 mm each (Figure 2). Very dry, with precipitation below 400 mm, were the years 2011-2012 and 2006-2007. Drought was also 2012-2013, with about 460 mm of rainfall.

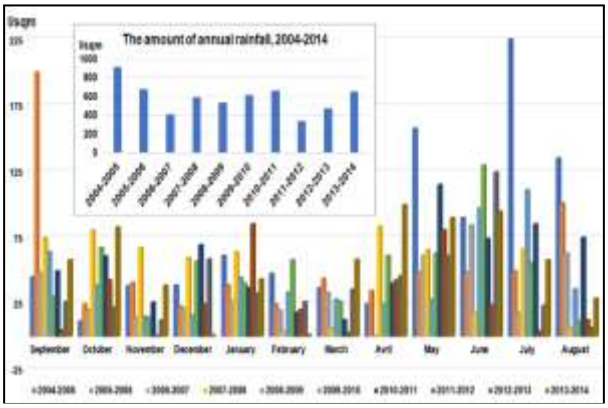

Fig. 2. Graphs of the evolution of monthly and annual rainfall for the period 2004-2014 (Alexandria area)
Source: own data.

This analysis shows us that for the wheat crop, of the Josef variety in particular, the climatic conditions were favourable to the culture, there being favourable trade-offs between the autumn and the spring-summer months, which allowed a good vegetation of the culture, without shock-like stresses.

The evolution of yields during the 10 years, according to the four suns, is shown in Fig. 3. We emphasize that in the first year of measurements all the production starts at 61.8 q/ha. In monoculture, during the first 3 years, we do not see significant decreases in production. Starting with year 4, production decreases progressively and very significantly, from –7.22 q/ha (year 5), to –21,7 q/ha (year 10). During the whole experimental period we have a loss of 35% compared to the starting year (the red line in the graph in Fig. 3).

In the second crop rotation system (W-W-M-M) there are losses, but they are insignificant. In the 5th year we have a significant decrease, so that a year later it will be three times higher, i.e. very significant. In the last year of research, the loss reaches 12 q/ha, more than half compared to monoculture (about –19%).

In the third crop rotation system (W-R-M-SF), made up of different crops, but without an improvement plant, the yield variation is smaller. It manifests itself within the limits of the errors, a very significant negative deviation registering in the 6th year (–5.7 q/ha = 10%). We can say that this is a constant crop rotation, which maintains the yield durability throughout the studied decade.

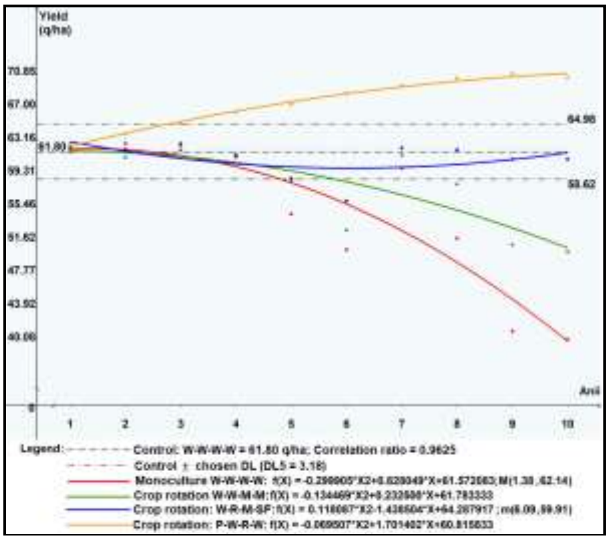

Fig. 3. Evolution of Josef wheat variety yields according to monoculture and three crop rotation systems, over a period of 10 years (2005-2014)
Source: own data.

The fourth crop rotation system (P-W-R-W), which include a leguminous crop, an ameliorative one, represented by peas, has been offered the best crop structure, the yields being ordered in continuous growth, from significantly positive in the 3rd year (+5.3%) to very significant over the last three years, with increases of 8.5-9.0 q/ha, i.e. over 12%. It is the ideal variant recommended for agricultural practice in the area (yellow line in Fig. 3).

The synthesis Table 1 it presents the basis of the functions showed in Fig. 3, which are

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assured by a correlation ratio of R = 0.9625 (very significant) and, consequently, are reproducible for every situation.

Table 1. Josef variety yields in four crop rotation systems, in our study (2005-2014)

Crop rotation	Years	Average yields (q/ha)	Control ratio (%)	Control difference (q/ha)	Sign
W-W-W-W	2005	61.80	100.00	–	Martor
	2006	62.75	101.54	0.95	
	2007	62.00	100.32	0.20	
	2008	61.48	99.47	-0.32	
	2009	54.58	88.31	-7.22	o o o
	2010	50.45	81.63	-11.34	o o o
	2011	59.90	96.93	-1.89	
	2012	51.75	83.74	-10.04	o o o
	2013	41.02	66.38	-20.77	o o o
	2014	40.08	64.85	**-21.72**	o o o
W-W-M-M	2005	61.98	100.28	0.18	
	2006	61.15	98.95	-0.65	
	2007	62.80	101.62	1.00	
	2008	61.17	98.99	-0.62	
	2009	58.40	94.50	-3.39	o
	2010	52.70	85.28	-9.09	o o o
	2011	61.38	99.31	-0.42	
	2012	58.05	93.93	-3.75	o
	2013	51.03	82.56	-10.77	o o o
	2014	50.20	81.23	**-11.59**	o o o
W-R-M-SF	2005	62.33	100.85	0.53	
	2006	62.08	100.44	0.28	
	2007	62.58	101.25	0.78	
	2008	61.30	99.19	-0.50	
	2009	58.72	95.02	-3.07	
	2010	56.10	90.78	-5.70	o o o
	2011	62.23	100.69	0.43	
	2012	62.02	100.36	0.23	
	2013	60.92	98.58	-0.87	
	2014	60.95	98.62	-0.84	
P-W-R-W	2005	62.75	101.54	0.95	
	2006	63.85	103.32	2.05	
	2007	65.07	105.30	3.27	*
	2008	66.38	107.40	4.58	* *
	2009	67.27	108.86	5.47	* * *
	2010	68.63	111.04	6.83	* * *
	2011	69.45	112.38	7.65	* * *
	2012	70.35	113.83	8.55	* * *
	2013	70.85	114.64	9.05	* * *
	2014	70.38	113.88	8.58	* * *
DL5% = 3.18		DL1% = 4.20		DL0,1% = 5.41	

Source: own data.

In relation to the yields average obtained in these ten years, the behavioral top is presented in Table 2. It clearly indicates the priority in which their use in the local agricultural production would be necessary. The respective data can also be found in Fig. 4.

Table 2. Crop rotations behaviors (average for 10 years) in our experience in Teleorman County (2005-2014)

Crop rotation	Average yields (q/ha)	Control ratio (%)	Control difference (q/ha)	Sign
W-W-W-W	54,58	100,00	–	Martor
W-W-M-M	57,88	106,06	3,30	* *
W-R-M-SF	60,92	111,62	6,34	* * *
P-W-R-W	67,50	123,67	12,92	* * *
			DL5% = 2,23	
			DL1% = 2,94	
			DL0,1% = 3,79	

Source: own data.

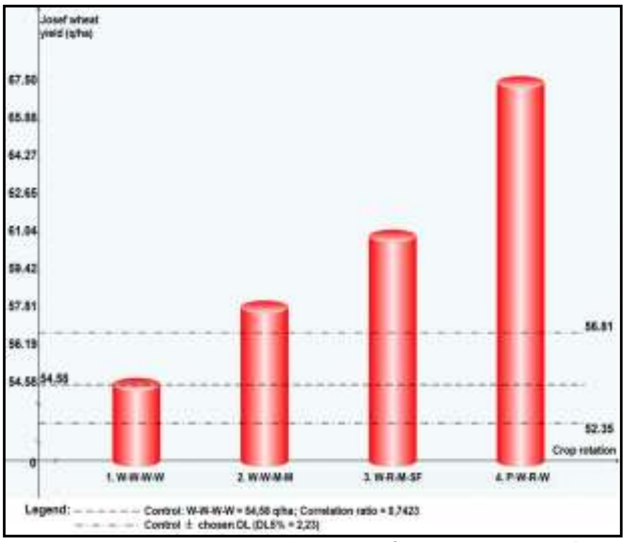

Fig. 4. Crop rotations top (average for 10 years) in the research from Teleorman County (2005-2014)
Source: own data.

The behavioral function of Josef wheat yield in relation to the crop rotation system and the years of experimentation is represented in 3D in Fig. 5. It is confirmed by a correlation ratio close to the determination, being a complex polynomial function. The largest productions are obtained, after 10 years, with the fourth crop rotation system (P-W-R-W), and the smallest ones with monoculture, almost from single to double.

Numerous researches carried out all over the world show that wheat monoculture brings significant losses everywhere. The losses can't be compensated by chemical or even organic fertilizers (see the results in the literature). The causes are various, some of them being studied in our own experiences.

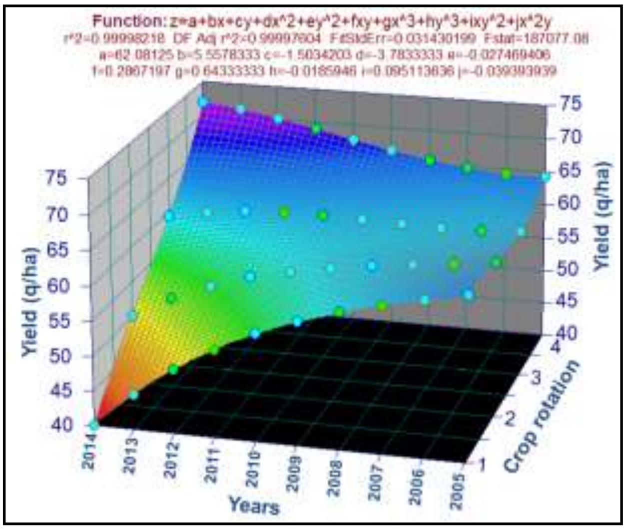

Fig. 5. Dynamics of Josef wheat yield according to the crop rotation, Teleorman County, 2005-2014 (synthesis)
Source: own data.

We emphasize the monoculture effects on the growth of soil infestation with weeds and spores of the numerous foliar and spike diseases. There has also been a reduction in humus content, as well as other nutrients and, thus, a general decrease in soil fertility. There have been reported and determined negative changes in soil biology and microbiology, the disappearance of mycorrhizae, of useful bacteria and rhizomes. The soil gets tired and loses its ability to give the wheat crop the vital force which it needs in order to produce efficiently and sustainably. Monoculture induces the lack of sustainability of the agricultural system and is very necessary to be avoided. Combating the harmful effects of monoculture has only proved to be partially effective (50%) and is also more expensive. The efficiency and durability of wheat cultivation can be obtained by practicing crop rotation systems with 2-4 plants and especially by using leguminous ameliorative plants. In the researched area, peas proved to be the most suitable.

CONCLUSIONS

In the conditions of the research area, after 10 years of experiments with monoculture and various crop rotation systems including wheat, the following conclusions have been reached:

(1)Josef wheat doesn't support monoculture more than 2-4 years, after which the harvest losses are exponentially negative, reaching -22 q/ha = 35% after 10 years, compared to the starting year.

(2)W-W-M-M crop rotation system had also proved to be inefficient, even though the crop loss has been reduced to half compared to monoculture (–18.6%).

(3)In the case of crop rotation system with four plants (W-R-M-SF), wheat yield has remained constant throughout the entire experimentation period.

(4)The crop rotation system with improvement plant (P-W-R-W) interspersed between the wheat crops, after 10 years brought a very significant harvest increase, namely 8.58 q/ha (+12.1%). It is the culture variant that ensures the highest durability, satisfying the requirements of European Commission.

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