Exploring New TechnologySolutions for the conditions of Eutric/ Haplic Vertisols and Gleyic-Chromic Luvisols

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Summary: *Determining the sustainability of agricultural production are agro-technical activities, as the main units in any technology. A study has been carried out to evaluate the impact of crop treatment systems, mineral fertilization and integrated weed control on soil and climatic conditions in the Sofia region.*

It has been found that less intensive weeding with annual and perennial weeds is observed when using a more intensive treatment system compared to the reduced treatment option. The number of weeds per unit area is increasing in the non-fertilizing variants, but their mass is lower than the fertilizers. Deeper soil tillage contributes to maintaining the values of the physical parameters (humidity, bulk density and soil hardness) in a more favorable range. Fertilization has the most significant effect on yields during the three years of the experiment.

KEYWORDS: *CULTIVATION, TILLAGE SYSTEMS, FERTILIZATION, WEEDS, REDUCED TILLAGE, TECHNOLOGY, TWO-FACTOR EXPERIMENT, RAINFALL, WHEAT, MAIZE*

The problem of improving technology in agriculture, in particular in field growisng, is long-term and socially significant. Technological solutions that meet the performance criteria: increase productivity, reduce investment, rational use of resources, preserve and increase soil fertility are prerequisites for successful economic activity [1, 6, 7, 11]. This requires adapting them to the agro-environmental and technological conditions [2,8,9,10, 12, 13].

Agro-technical activities are crucial for sustainability of agricultural production, as the main units in any technology [3, 4, 5, 11,14].

The aim of the study is to test and evaluate systems of agrotechnical measures in field agriculture, to maintain and improve soil fertility, namely - a system for cultivation in crop rotation, mineral fertilization and integrated weed control for soil and climatic conditions in the Sofia region.

Material and methods

In order to accomplish this goal, in the period 2014-2016, two field experiments, based on the block method in pilot fields, were derived - the Bozhurishte of ISSAPP N. Pushkarov" and the IPBG- BAS in G. Lozen village, Sofia region.

The soil in the Bozhurishte Experimental Field is a Eutric/ Haplic Vertisol with a powerful (about 1 m), heavy clay - humic horizon. The content of physical clay for the Ap 0–26 cm horizon is high (74.1%). The relative density of the soil is 2,68. The bulk density in the dry state is 1.95 - 2.0 g / cm3 (Stoynev, 1973), and for optimum moisture content (OMC) - 1.23 - 1.25 g / cm3. Total nitrogen ranges from 0.093% to 0.134% and total phosphorus ranges from 0.095% to 0.117%. The soil solution was neutral 5.3-5.9 in KCl. The saturation with bases is above 95%. The humic content is on average — from 2.50 to 3.70%.

The soil in the experimental field of the IPBG is Gleyic-Chromic Luvisols. The mechanical composition is medium to heavy sandy-clay, the silt content in the humic horizon is about 35%, and of the physical clay - 47,8-57,6%. Phosphorus stocks range from weak to low. The absorbable forms of the macronutrients are unsatisfactory. These soils have good moisture content, low filtration rate, which may make the profile more moist.

For the 2014-2016 survey period, the highest total rainfall was in 2014, respectively for the two bases 958.4 mm and 1013 mm, which is almost twice the average annual amount for the 80-year period. The amount of precipitation in Bozhurishte in 2015 is close to the average perennials - 584,2mm, with the highest rainfall in March - 113,7mm and in October - 110,2mm.2016 characterized by precipitation below the average - 539.5 mm. For G. Lozen, the years 2015 and 2016 are below average for the multiannual period - 506.8mm and 476.8 mm respectively.

The experiments are based on a two-factor scheme of type 2x3 with four blocks (repetitions), each of which is divided into two sub-blocks corresponding to the two tillage systems (Table 1). Three variants of fertilization were tested in each sub-block (Table 2). Field trials include a three-crop "maize-wheat-maize" crop rotation.

Table 1. Soil tillage systems in three-pole crop rotation

Crop	Variant O_1	Variant O_2
Maze	tillage 25-30 cm Loosening 40-45 cm	disking 10-12 cm plowing 25–30 cm
wheat	plowing 15-18 cm	disking 10-12 cm
maze	disking 10-12 cm plowing 28 – 30cm	plowing 23 -25 cm

Due to the mechanical composition of the soils and the more dense layer therein, more intensive tillage is included in the O1 system. Deep loosening as the main maize crop for the first year and plow as a pre-sowing crop for wheat.

Table 2 *Variants of fertilization*

Култура	Variants of fertilization		
	T_0	T_1	T_2
maze	Withount fertilization	$N_{16}P_{10}K_6$ potassium sulfate superphosphate ammonium nitrate	$N_{16}P_{10}K_6$ Eurobio Patent K Ca - ammonium nitrate leaf fertilizer
wheat	Withount fertilization	$N_{14}P_{10}$ superphosphate ammonium nitrate	$N_{14}P_{10}$ ammophos Ca - ammonium nitrate leaf fertilizer
maze	Withount fertilization	$N_{16}P_{10}K_6$ potassium sulfate superphosphate ammonium nitrate	$N_{16}P_{10}K_6$ Eurobio Patent K Ca - ammonium nitrate leaf fertilizer

For maize, phosphorus fertilizer with a slightly alkaline reaction and increased content of easily digestible forms (Eurobio - P_2O_5 27%) was used as an alternative to traditional fertilizer (superphosphate), and for wheat with a high phosphorus content - Ammophos ($N_{10}P_{50}$) and rapidly absorbed phosphates (Table 2).

In the T_2 fertilization variant, part of the soil nitrogen fertilizer is replaced with leaf fertilizer - Agroleaf (containing 30% nitrogen) at a dose of 400 g / da, carried out in the “9-10 leaf” phase of maize and the wheat germination phase.

Variants of integrated weed control have been implemented. Mechanical control includes the specified soil tillage systems. For chemical control, broad-spectrum herbicides were used: maize - mesotrione (75 g / l) + nicosulfuron (30,0 g / l), product Elumis OD - dose 200 ml / da; wheat - tribenuron-methyl (250 g) / kg) + tifen-sulfuron-methyl (250 g / kg) and phenoxaprop-P-ethyl (69 g / l) + antidote.

The species composition of weeds and degrees of weeding were determined by the quantitative-weight method of measuring 0.25 m2 in four repetitions, in phases:

- "3-5 leaves", "dumping" and "harvesting" for maize;
- "breeding", "breeding" and "waxy maturity" for wheat.

Phenological observations were carried out - growth rate and biomass accumulation as well as biometric measurements.

Measured soil indicators affecting plant development:

-water-physical - moisture content by weight % and bulk density in g / cm3 layer by layer 10 cm deep to 60 cm with rings of 100 cm3 volume;

- hardness - layer by layer through 5 cm to a depth of 40 cm;

-agrochemical: mobile forms: nitrogen - by the method of Bremner and Kiney; phosphorus - by the method of P. Ivanov; potassium by the method of P. Ivanov;

-reaction of soil solution (pH) - potentiometrically in water and potassium chloride; soil organic matter content - the Tyurin method;

The effect of the implementation of agro-technical measures is determined by the productivity - the main and additional production of the cultivated crops, calculated in kg/da.

Results and discussion

The degree of influence of the same fertilizer norms has been established: nitrogen, phosphorus and potassium (but imported with different types of fertilizers), applied tillage and soil-climate systems, on the productivity of maize and wheat under the conditions of Gleyic-Chromic Luvisols soil. Gorni Lozen and the eutric vertisol of Bozhurishte.

The variance analysis of the maize yield data for both bases shows that in the first experimental year, the influence of the two fertilizer and tillage factors tested is statistically significant. As a result of the loosening (O_1 variant), the productivity is higher than in O_2, in eutric vertisols and as well as for Gleyic-Chromic Luvisols (Fig. 1). Higher yields were also obtained in the application of foliar application.

In 2014/2015, it was found that both fertilization and the applied processing system had a significant influence in the Bozhurishte field (at $p < 0.1\%$). The wheat yields from the fertilization variants are more than twice as high as the control variants for both treatment systems. There was no statistically proven difference between the yields obtained by applying different types of fertilizer.

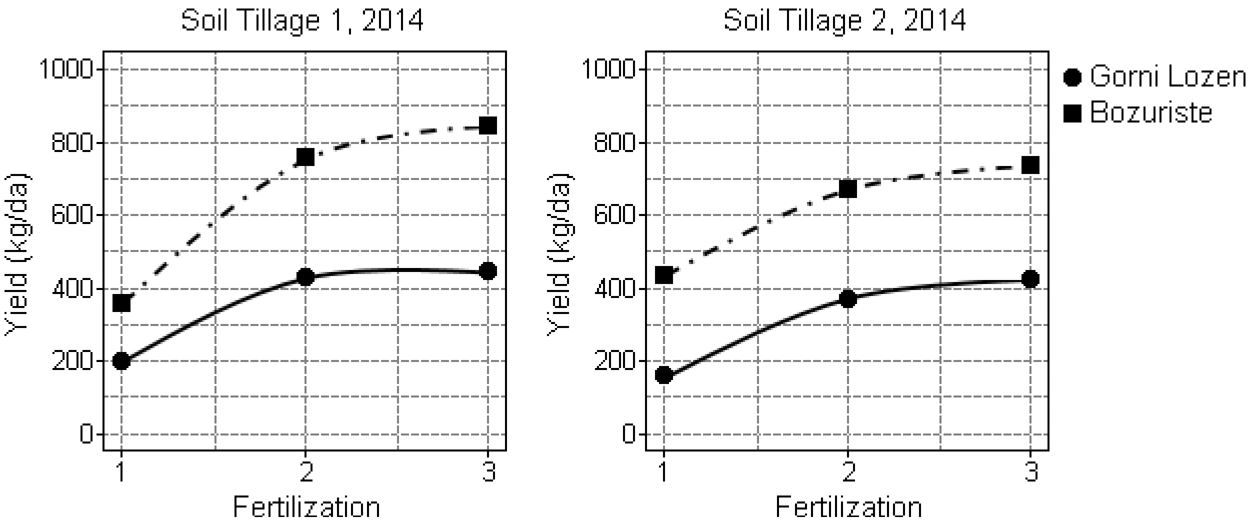

Fig. 1. *Maize yields depending on soil and climatic conditions and soil tillage – 2014*

Of the factors studied in the wheat for the Gorni Lozen base, only fertilization had a major impact on the yields (Fig. 2). The processing system applied has no proven influence. Due to the drought in the period April - May, during the spraying with liquid fertilizer, the leaf fertilization also did not affect the yields.

In the third experimental year, it was found that only fertilization had an impact on both maize yields for both bases. No stimulating effect of the applied foliage applied due to soil moisture deficiency. The applied tillage systems, under the climatic conditions of the year, did not affect the yields (Fig. 3).

In general, fertilization (with a probability of error $p < 0.1\%$) had the greatest impact on crop productivity during the study period. 96.84% of the total variation in the data from Bozhurishte and 73.00 % - from Gorni Lozen are due to different fertilization variants (Table 3).

For the Bozhurishte base, the differences in yields between the control and the two fertilizer variants are statistically proven at 0.1%, with the yields obtained by traditional fertilization being 90.25% higher than those for fertilizers and for fertilizing with alternative fertilizers. and liquid fertilizer added - 92.92% higher. For Gorni Lozen base - are 22.70% and 29.05% respectively, with yields from variants with added liquid fertilizer proved higher (at 1% difference) than those obtained in traditional fertilization.

For both experimental bases, the influence of the applied processing system is proven. The differences between the tillage system variants (O_1 and O_2) for eutric vertisols and as well as for Gleyic-Chromic Luvisols are respectively 154.57 and 93 units in favor of the first system.

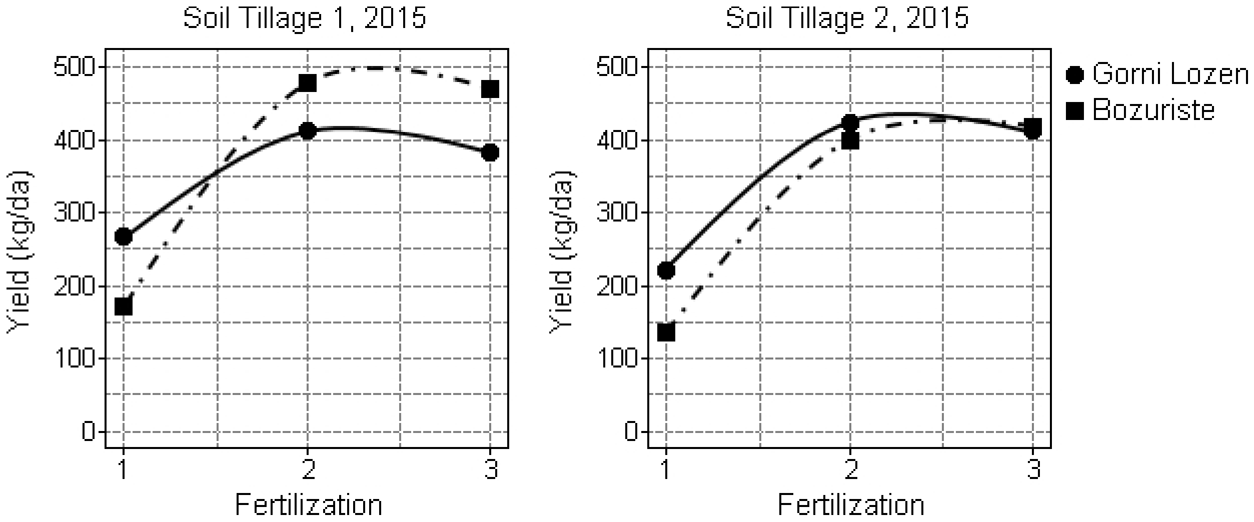

Fig. 2. Wheat yields depending on soil and climatic conditions and tillage

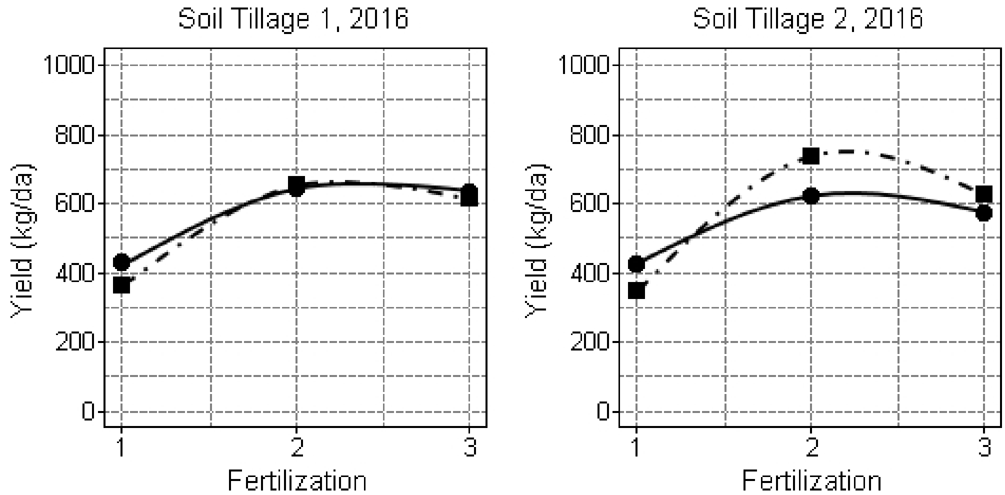

Fig. 3. Maize yields depending on soil and climatic conditions and soil tillage – 2016

Table 3. *Impact of test factors and interaction between them on total productivity*

Source of variation	Sum of squares	Sum of squares, %	Degrees of freedom	Average square	F-relat.	Level of sign.
fertilization (F)	11776244,565	64,060	2	5888122,282	578,702	,000***
Processing (O)	183845,884	1,000	1	183845,884	18,069	,000***
Punct (P)	2558551,044	13,918	1	2558551,044	251,462	,000***
F*O	325334,203	1,770	2	162667,101	15,987	,000***
F*P	3070565,245	16,703	2	1535282,623	150,892	,000***
O*P	11377,953	0,062	1	11377,953	1,118	,297 -
F*O*P	91053,055	0,495	2	45526,527	4,474	,018 **
mistake	366289,206	1,992	36	10174,700		
Total sum	18383261,156		47			

Table 4.Yield(fodder units) – FT Bozhuriste and GorniLozen

Fertilizing	Processing	Punct	Average yield
0	1	1	1766,412
		2	1866,149
	2	1	1691,672
		2	2096,229
1	1	1	3344,677
		2	2499,208
	2	1	3234,363
		2	2362,827
2	1	1	3474,913
		2	2743,020
	2	1	3196,263
		2	2370,371

НМДР 5%=144,648 ; НМДР 1%=193,934; НМДР 0,1%=255,417

The dispersion analysis of the data for the two bases shows that the total productivity for the eutric vertisols from Bozhurishte under both the applied fertilization and the two treatment systems is higher than the Gleyic-Chromic Luvisols soil from the experience in Gorni Lozen (Table 3). In most cases, yields are higher than alternative fertilizer applications (chemically neutral and slightly alkaline fertilizers with increased digestible content) and added leaf fertilizer. In the non-fertilized variant, the productivity of the crop rotation in the test area on the Gleyic-Chromic Luvisols soil is higher.

During the first year of the experiment (2014), the soil moisture content was influenced by both the applied agrotechnics and the heavy rainfall during the growing season for both experimental bases (Fig. 4).

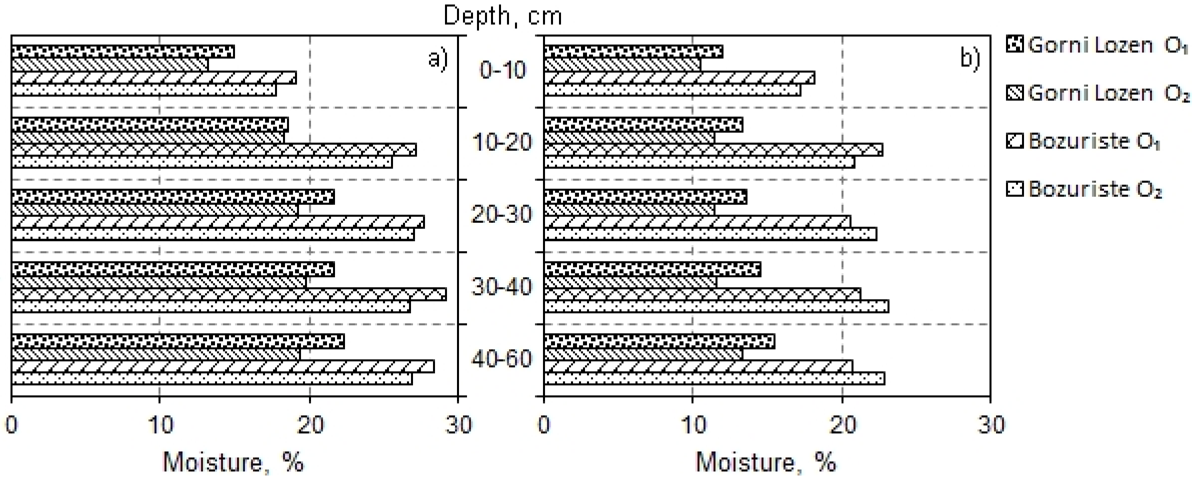

Fig.4.*Soil moisture content (%), maize - 2016*

In 2014/2015 wheat was grown on both test fields. During the growing season, soil and climatic conditions were found to have a significant effect on soil moisture (at p <0.1%) during all three phases of measurement, while the applied treatment system - only during the “emergence” phase.

The moment moisture content of the soil, established at the beginning of the growing season and in the phase of "tasseling" of the maize in the harvest 2016, is strongly influenced by the applied treatment (with a probability of error p <0.1%), whereas at the end of the growing season its influence was statistically proven only at p <5%. In the "tasseling" phase, the humidity in the surface 20 cm soil layer of the eutric vertisol is higher in the case of deeper tillage (O1), while in the 20 - 60 cm layer the higher humidity is observed in the shallower plowed (O2). The same tendency is observed for the “wax maturity” phase (Fig. 5).

In the “tasseling” phase, the moisture content of the Gleyic-Chromic luvisols soil gradually increases in profile depth, such as higher at plowing at 28-30 cm depth. A similar tendency is observed for the waxy maturity phase, with no difference in humidity in the 0 - 20 cm layer for the two treatment systems.

The soil moisture content is mainly influenced by the weather conditions and the treatment applied, with loosening as the main and inter-row treatment contributing most to its increase.

The bulk density is highly dependent on the soil moisture content. In 2014, the reported values are in the range optimal for the development of the plant root mass. The applied processing system has a significant influence on this indicator in all three phases of reporting (Fig. 5), whereas in 2014/2015 it had an impact only during the first two phases - “emergence” and “twisting”. In the third year, the applied treatment had a significant influence on the values of the bulk density for all three phases of measurement (Fig. 5). In the "tasseling " phase, both densities were reported for both soils, and for Gorni Lozen it was about above the critical. The highest values were observed in the 20–30 cm layer (1.48 g / cm3 for the eutric vertisol and 1.62 g / cm3 for the Gleyic luvisols).

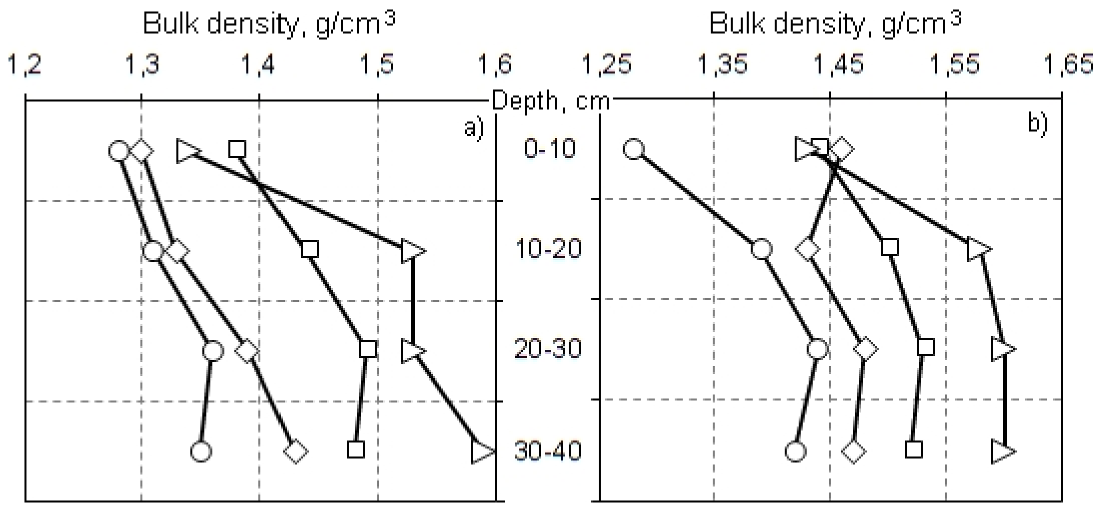

Fig. 5.*Bulk density (g / cm^3), maize - 2016*

The bulk density values are in the range of 1.07 to 1.73 g / cm3 for the eutric vertisol and from 1.33 to 1.74 g / cm3 for Gleyic luvisols.

From the analysis of the data it was found that the rigidity is mainly influenced by the applied processing system. At all stages of wheat and maize development, its values are lower in the $O_{1.}$ processing system. Therefore, loosening at a depth of 40-45 cm and a plowing of 28-30 cm are more effective.

For the studied physical parameters, humidity, bulk density and soil hardness, it was found that deeper tillages contribute to maintaining their values in a more favorable range.

During the short period of the study no decrease in the assimilated nitrogen content was found in the eutric vertisol, while in the Gleyic-Chromic Luvisols there was a slight decrease at the end of the experiment, with fertilized variants ranging from 2.9 to 5.6 mg / kg soil (Table 4).

There was a tendency of slight increase in the content of digestible forms of phosphorus in Gleyic-Chromic Luvisols , in variants with fertilization it was 2.4-3.6 mg / 100 g. In the eutric vertisol, the increase was from 1.1 to 2.3 mg / 100 g of soil (Tables 3 and 4).

For the three-year study period a decrease in the content of digestible forms of potassium was found. For the eutric vertisol in variants T_2 using physiologically neutral and alkaline fertilizers in the 0-30 cm layer, the values depend on the processing system: 5.3 for O_1 and 5.5 for O_2. In variant T_1, there are 4.9 and 4.8 respectively. In Gleyic – chromic luvisols soil there is also a tendency to improve the response of the soil solution after the use of alternative fertilizers - variant T_2, with soil pH values being 5.3 for both tillage systems and 5.0 for T_1 respectively. O_1 and 4.9 for O. Therefore, by using physiologically neutral and alkaline fertilizers, it only prevents the development of acidification processes, but also improves the soil response.

The conducted research revealed that both agrotechnical factors tested - soil tillage and fertilization - influence the quantitative weeding of the experimental areas. When using a more intensive tillage system (O_1 variant), less weeding with annual and perennial weeds was observed compared to the reduced tillage (O_2) variant in both soil differences (Tables 5 and 6).

Fertilization provides good nutrition and conditions for the dominance of cultivated plants in the competitive control of weeds. The amount of weeds per unit area increases in the non-fertilized variants, but their mass is lower than the fertilizers. The weeding in the test area on Gleyic-Chromic Luvisols soil differs in greater density than the experience on the eutric vertisol, which is as a result of a long-lasting cereal monoculture that led to a large stock of weed seeds in the soil.

Table 4. Agrochemical analysis of samples - maize wax maturity, 2016

№	Variants	Depth of test, cm	pH(KCl)	Σ N-NH_4+NO_3 (mg/kg)	P_2O_5 (mg/100g)	K_2O (mg/100g)	Хумус (%)	pH(KCl)	Σ N-NH_4+NO_3 (mg/kg)	P_2O_5 (mg/100g)	K_2O (mg/100g)	Хумус (%)
			Field test Bozhurishte					Field test Gorni Lozen				
1	T_0O_1	0-30	5,3	8,2	1,1	29,4	2,80	5,0	12,7	1,3	27,6	1,92
2	T_0O_1	30-60	5,7	9,8	0,2	24,1	2,55	5,4	10,9	0,4	24,0	1,46
3	T_0O_2	0-30	5,3	13,8	0,3	31,1	2,82	4,9	19,6	1,4	29,8	1,68
4	T_0O_2	30-60	5,7	5,7	0,2	25,5	2,34	5,1	16,7	0,2	23,4	1,28
5	T_1O_1	0-30	5,4	24,8	4,0	38,1	2,96	5,1	18,6	1,2	31,5	2,00
6	T_1O_1	30-60	5,8	20,3	0,2	22,8	2,51	5,4	13,6	0,2	23,1	1,30
7	T_1O_2	0-30	5,0	33,2	4,7	36,0	3,30	4,7	14,1	0,9	28,9	1,85
8	T_1O_2	30-60	5,5	28,2	0,6	27,6	2,53	5,0	11,0	0,4	23,7	1,36
9	T_2O_1	0-30	5,0	35,7	1,6	39,0	2,71	4,8	13,6	2,3	28,8	1,72
10	T_2O_1	30-60	5,3	28,8	0,2	28,4	2,69	5,0	11,9	0,6	24,2	1,38
11	T_2O_2	0-30	5,2	30,6	1,9	35,8	3,04	4,7	16,1	1,0	29,5	1,79
12	T_2O_2	30-60	5,3	31,7	0,7	25,6	2,74	5,1	12,4	0,4	23,1	1,35

For both bases in the later stages of vegetation, the main weed species are representatives of late-spring bi-weekly and perennial root and root shoots. The difference is with the dominant representatives of these groups. In the experience in Bozhurishte, these are three-lobe beggartick (Bidens tripartitus L.) and field bindweed (Convovulus arvensis L.), and in Gorni Lozen - gray foxtail (Setaria glauca PB), barnyard grass (Echinochloa crus galli L.) and quackgrass (Agropyrum arvensis L.

In wheat cultivation, it was found that the field of cultivation in Bozhurishte contains fewer typical weed species, whereas in Gorni Lozen the species composition is larger due to the increase in the seed bank as a result of previously practiced long-term cereal monoculture and application of shallow processing.

Table 5.Number and weight of weeds per m^2, maize waxy maturity phase - 2016, FT Bozhuriste,tillage system O_1

Groups of weeds	Variant - T_0O_1			Variant - T_1O_1			Variant - T_2O_1		
	№/m²	Fresh w.,g	Dry w.,g	№/m²	Fresh w.,g	Dry w.,g	№/m²	Fresh w.,g	Dry w.,g
I. Annuals	16	90,64	19,02	10,0	63,72	19,16	7,0	27,14	5,99
1.Ephemeral	0,33	1,26	0,12	-	-	-	1,0	1,05	0,59
2.Early Spring weed	-	-	-	0,66	1,89	0,37	-	-	-
3.Late Spring weed	15,67	89,38	18,90	9,33	61,83	18,79	6,0	26,09	5,40
4.spring weed	-	-	-	-	-	-	-	-	-
II.Perennial	19	40,25	14,82	10	30,73	12,10	5,33	28,17	10,87
1.Rhizomes/ rootstock weed	1	2,10	0,61	0,33	2,02	0,24	-	-	-
2.root-sprouting	18	38,15	14,21	9,67	28,71	11,86	5,33	28,17	10,87

Table 6.Number and weight of weeds per m2, maize waxy maturity phase - 2016, FT Gorni Lozen, tillage system O1

Групи плевели	Variant - T0O1			Variant - T1O1			Variant - T2O1		
	№/m²	Fresh w.,g	Dry w.,g	№/m²	Fresh w.,g	Dry w.,g	№/m²	Fresh w.,g	Dry w.,g
I. Annuals	36,0	82,34	29,00	18	45,80	20,10	20	52,62	20,99
1.Ephemeral	-	-	-	1,0	6,56	1,83	2,0	3,34	0,75
2.Early Spring weed	4,0	10,51	2,63	-	-	-	-	-	-
3.Late Spring weed	32,0	71,83	26,37	17,0	39,24	18,27	18	49,28	20,24
4.Spring weed	-	-	-	-	-	-	-	-	-
II.Perennial	10	15,24	7,40	6	13,35	3,31	3,0	9,17	1,97
1.Rhizomes/ rootstock weed	2,0	4,51	1,00	0,67	1,27	0,16	-	-	-
2.Root-sprouting	8,0	10,73	6,40	5,33	12,08	3,15	3,0	9,17	1,97

Conclusions

The most significant impact on maize and wheat yields during the three years of the experiment was fertilization, with the variation in the data due to this factor (relative to the total variation) being as follows: in 2014 for Gorni Lozen OB - 96.83 % and for Bozhurishte OB - 92.57%; for 2015 - 78.55% and 94.05% respectively and for 2016 - 73.47% and 89.97%. The effect of the added leaf fertilizer on the yields of wheat and maize is negligible.

The treatment systems applied have a statistically significant effect on maize yields for both bases only in the first year of the experiment (1.49% for Gorni Lozen and 2.97% for Bozhurishte) and on wheat production in Bozhurishte OB in the second year (2 , 65%). For them, higher yields are observed in the system with more intensive processing;

At the end of the rotation, there was a slight increase in the content of digestible forms of phosphorus, such as in gleyic – chromic luvisols soil from traces at the beginning of the experiment, in fertilization variants it was 2.4-3.6 mg / 100 g, and in eutric verstisol is approaching medium storage; There is a slight decrease in the content of digestible forms of potassium, which is more sensitive in the meadow-cinnamon soil; An increase in the pH of the Gleyic-Chromic Luvisols was found, changing from 4.7-4.9 values to 5.0-5.5, which is explained by the use of calcium-ammonium nitrate and ammophos instead of ammonium for a three-year period. nitrate and superphosphate.

When using a more intensive tillage system (O_1 variant), weeding with annuals and perennial weeds is lower than the reduced tillage (O_2) variants for both soil differences. The number of weeds per unit area is increasing in the non-fertilizing variants, but their mass is lower than the fertilizers.

Deeper soil tillage contributes to maintaining the values of the physical parameters (humidity, bulk density and soil hardness) in a more favorable range.

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