THE BEHAVIOR OF MAIZE IN SANDY SOIL CONDITIONS DEPENDING ON THE PRECEDING PLANT IN THE ROTATION

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Abstract

The aim of this study was to monitor the development of the maize plant depending on the preceding plant (rye; alfalfa for forage), with the objective of promoting crop rotation with alfalfa jumping plots within the agricultural system practiced on sandy soils. The results obtained showed that alfalfa incorporated into the soil after five years had a positive effect on soil fertility and implicitly on the behavior and productivity of maize. Thus, the content of organic matter, left in the soil after incorporating alfalfa, was 4.3 times higher than that recorded in the soil with the preceding plant rye. The beneficial role of the alfalfa precursor plant was highlighted on the stress behavior of the maize plant, which best regulated its resistance mechanism to stress conditions by binding at the cellular level a percentage of water bound to 3.03%, higher by 0.43% compared to maize sown after rye. Also, the maize sown after alfalfa showed better character stability, the coefficients of variability having lower values compared to the maize grown after rye, and at harvest the grain production was 27.9% higher, compared to the sown after rye, the difference in production being statistically significant.

Key words: preceding plant, maize, phenology, stress, productivity

INTRODUCTION

Maize (*Zea mays* L.) is the most important annual cereal crop for food and industry, occupying the first place in the world, with an annual production estimated at 1,148 billion tons obtained on 197 million hectares. In Romania, the maize is one of the strategic cereals for the internal and external market (Popescu, 2018, Haș et al., 2019), and according to the National Institute of Statistics (https://insse.ro), at the level of the European Union, Romania was located in the year 2023, in first place in the area cultivated with grain maize (2,373,000 ha), and in third place in terms of production (8,522,000 t) after France and Poland. Maize production depends on the genetic potential of the variety used, management practices, soil and agroclimatic factors (Tandzi, et al., 2020). From a climatic point of view, according to the Köppen climate classification, based on the natural distribution of plants native to an area, on annual and specific temperatures, on the rainfall regime, on local fluctuations and on seasonality, the area of psammosols in southern Oltenia is included in the climatic province Cfa, having a pronounced temperate continental character, with a slight Mediterranean influence, characterized by a pronounced dryness in the months of July - September and a surplus of precipitation in the months of May and June (Paraschiv, 2023). Many factors contribute to low maize yields, including drought and heat (Soare et al., 2019; Bonea&Dunăreanu, 2021) and pests (Szőke et al., 2002; Draghici et al., 2010; Urechean&Bonea, 2018a). Also, worldwide research has emphasized the negative impact of global warming on maize production, showing that at temperatures above 30-33 ºC the photosynthesis process in the plant is significantly reduced, thus reducing the assimilation rate of organic carbon (Rotundo and et al., 2019, Liu et al, 2022). The deficient pedoclimatic conditions in areas with sandy soils, as a result of reduced natural fertility and the increase in the drought phenomenon, require finding solutions for efficient utilization by plants (Parichi&Oancea, 1984; Drăghici et al., 2022). Therefore, the aim of our study was to monitor the development of the maize plant depending on the preceding plant (rye; alfalfa for forage), with the objective of promoting crop rotation with alfalfa jumping soil within the agricultural system practiced on sandy soils.

MATERIALS AND METHODS

The research was carried out on the grain maize culture studied in 2024 at the Research Development Station for Plant Culture on Sands Dăbuleni, located on the sandy soils of southern Oltenia (North latitude: 43°48′, East longitude: 24°5′), under irrigation conditions. The influence of two precursor plants (rye and alfalfa for fodder) on the growth and development of the maize plant under the conditions of climate change in the area of sandy soils was studied In this sense, the *Olt* maize hybrid was sown, in two experimental plots with an area of 3000 m², after the precursor plant of rye and alfalfa for fodder. According to specialized literature (Davidescu et al., 1981), the soil on which the experiment was located was poorly supplied in nitrogen and exchangeable potassium and well supplied in extractable phosphorus (Table 1).

Table 1. Chemical quality of the soil in the experimental maize field according to the preceding plant

The preceding plant for maize	Depth (cm)	Nitogen total (%)	Extractable phosphorus (ppm)	Exchangeable potassium (ppm)	Organic carbon (%)	pH_{H2O}
Rye	0-20	0.04	85.63	51.2	0.22	7.60
	20-40	0.03	73.57	25.6	0.27	7.34
Alfalfa	0-20	0.05	67.66	35.20	1.10	6.92
	20-40	0.05	65.89	27.20	1.00	6.96
Supply domain (Davidescu D. et. al, 1981)	Poorly supplied	<0.10	8.1 - 18	<66	<0.58	5.01-5.80 Weak acid
	Means supplied	0.11- 0.15	18.1 - 36	66.1 - 132	0.59 - 1.16	5.81-6.8 Moderately acidic
	Well stocked	0.16 - 0.20	36.1 - 72	132.1 - 200	1.17 - 2.32	6.81-7.20 Neutral

From the point of view of the content of organic matter of the soil, the positive influence of alfalfa incorporated into the soil is observed after 5 years, the percentage of organic carbon being 1-1.1%, compared to the quality of the soil after rye, where the organic carbon content it was much lower (0.22-0.27%). The soil reaction revealed a neutral pH after the alfalfa crop and slightly alkaline after the rye crop. The maize cultivation technology was followed on sandy soils, ensuring a fertilization system of N150P80K80, a good cultural condition by weeding the pre-emergence crop with *Dual 960 EC* (1.5 l/ha) and post-emergence, in the 5-6 phase leaves, with *Mustang* (0.6 l/ha) + *Novapower* (1.2 l/ha) and an optimal supply of the plant with water, through irrigation by applying 6 waterings with a rate of 250 m³ water/ha.

During the vegetation of the maize plant, observations and determinations were made regarding:

- development of vegetation phenophases and recording of daily climatic conditions during the vegetation period;
- the biometry characteristics of the plant in the silking phase: plant height, stem diameter, cob insertion height
- the leaf surface determined in the silking phase by the following methodology: number of leaves/plant x the surface of a leaf, measured in the laboratory with the *AM 300* device x 6.5 plants/ m².
- the dry matter and the forms of water in the plant (total water, free water and bound water) by the following method: during the silking phase, the fresh leaves were taken and weighed immediately, after which they were allowed to dry at room temperature room until they reached a constant weight by repeated weighing, then they were dried in an oven at a temperature of 105 ºC for 3-4 hours and weighed at the end.

At maturity were determined the number of cobs/plant, grain production and its quality (Weight of a thousand grains-WTG; weight hectoliter of grains-WH; Total protein, Fats). The protein and fats content were determined by the spectrophotometric method, with the NIR analyzer, model INFRAMATIC 9200 from Perten.

RESULTS AND DISCUSSIONS

The evolution of meteorological conditions

The climatic conditions recorded in 2024, during the vegetation period of the maize crop (April-August) showed an increase in the phenomenon of thermohydric stress, compared to the multi-year average (Table 2). With the exception of May, which recorded a precipitation surplus of 51.33 mm and a deficit of thermal resource in the air of -0.25 ºC, compared to the multiannual average, the other calendar months (April, June, July and August) exceeded the multiannual average with 3.16-3.56 ºC in the air and recorded precipitation deficit values in the range: -11.13...-47.41 mm, which led to the application of a number of 6 waterings, with a watering rate of 250 m³ water/ha, to ensure the water needs of the maize plants. Creating a favorable microclimate through irrigation is essential on sandy soils, because both the high temperature in the air and soil drought can seriously affect the yield of maize, and the growth and development processes of the plant can even be blocked under the conditions of the combination of the two environmental factors (Bonea&Urechean, 2020; Yan et al., 2023).

Table 2. Climatic conditions recorded at the weather station of SCDCPN Dăbuleni recorded in 2024, compared to the multi-year average 1956-2023

Specificare		April	May	June	July	August	April-August
Air temperature in 2024 (ºC)	decade I average	16.7	16.1	24.0	25.1	24.49	
	decade II average	15.8	15.8	24.4	29.1	27.72	
	decade III average	12.9	18.1	26.7	25.4	25.41	
	monthly average	15.2	16.7	25.1	26.5	25.86	21.87
	absolute monthly minimum	2.7	7.4	11.3	11.87	10.51	2.7
	absolute monthly maximum	34.1	28.6	37.9	40.97	40.32	40.97
Rainfall in 2024 (mm)		36	114	22.6	22.6	1.4	196.6
Number of days with rainfall in 2024		7	15	6	7	3	38
The relative humidity of the air - 2024 (%)	average	58	71.2	61.5	56.42	52.99	60.05
	minimal	10.2	22.7	17.7	14.14	13.65	10.2
	maximum	99.6	100	100	100	100	100
Multiannual average temperature (ºC)		11.87	16.95	21.54	23.32	22.7	19.28
Multiannual rainfall (mm)		47.13	62.67	70.01	54.29	36.55	270.65
Deviation from the multiannual temperature (ºC)		3.33	-0.25	3.56	3.19	3.16	2.59
Deviation from multiannual rainfall (mm)		-11.13	51.33	-47.41	-31.69	-35.15	74.05

Monitoring the development stages of the maize plant

To evaluate the behavior of maize under sandy soil conditions, the date of registration of the main vegetation phenophases was monitored (Table 3).

Under the climatic conditions of 2024, maize emerged after 10 days in the plot sown after rye (Table 4) and after 11 days in the plot sown after alfalfa Table 5).

Table 3. Evolution of the vegetation phenophases of the maize plant according to the preceding plant

The preceding plant for maize	Calendar date of the registration of vegetation phenophases in maize								
	Sowing	Emergence	2-3 leaves	5-6 leaves	10-12 leaves	Panicle	Silking	Milk	Maturity
Rye	10 April	19 April	1 May	11 May	3 June	15 June	20 June	5 July	7 August
Alfalfa	12 April	22 April	4 May	13 May	6 June	18 June	25 June	10 July	15. August

The emergence of the maize crop was achieved under the conditions of recording an average air temperature of 15-16.4 ºC, which was optimal for the germination of the seed under conditions where the minimum germination is 8-10 ºC (Matei Gh., 2013). The amount of precipitation recorded, of 11.4-18.4 mm, was insufficient to ensure a uniform emergence of the plants, necessitating the application of an emergence irrigation with 250 m³ water/ha. The analysis of the duration of time, in days, required for the initiation of the vegetation phenophases showed similar values, minor differences of 1-2 days were recorded between the two batches of maize (Tables 4, 5).

Table 4. Climatic resources recorded in 2024 for the development of the vegetation cycle of the maize crop sown after rye

Climatic conditions		Sowing - Emergence	Emergence 2-3 leaves	2-3 leaves - 5-6 leaves	5-6 leaves - 10-12 leaves	10-12 leaves - Panicle	Panicle - Silking	Silking - Milk	Milk - Maturity	Total vegetation period (emergence-maturity)
Number of days		10	13	10	22	12	6	15	34	112
Total thermal resources (ºC)		148.1	172.8	157.9	396.9	287.82	127.58	383.8	877.12	2403.92
Air temperature (ºC)	Average	16.4	13.3	15.8	18	24	25.51	25.59	26.58	21.25
	Minimum	3.1	2.7	7.4	7.8	12.81	11.34	11.87	10.51	2.7
	Maximum	34.2	25.1	27.8	32.6	36.29	37.92	37.26	40.97	40.97
No rainy days		2	5	7	8	4	0	4	6	34
Rainfall (mm)		11.4	24.4	86.2	27.8	13.6	0	20.6	11.2	183.8
The relative humidity of the air (%)	Average	54.3	68.7	74.9	70.1	62.6	62.3	59.74	54.25	64.66
	Minimum	10.2	23.5	29.8	22.7	18.4	22.82	17.73	13.65	13.65
	Maximum	96.1	99.6	100	100	100	100	100	100	100

Table 5. Climatic resources recorded in 2024 for the development of the vegetation cycle of the maize crop sown after alfalfa

Climatic conditions		Sowing - Emergence	Emergence - 2-3 leaves	2-3 leaves - 5-6 leaves	5-6 leaves - 10-12 leaves	10-12 leaves - Panicle	Panicle - Silking	Silking - Milk	Milk - Maturity	Total vegetation period (emergence -maturity)
Number of days		11	12	9	24	12	7	15	36	115
Total thermal resources (ºC)		167.7	141.6	144.5	451.8	292.2	195.33	377.24	957.75	2560.42
Air temperature (ºC)	Average	15	14	16.1	18.8	24.4	27.9	25.15	26.6	21.85
	Minimum	2.7	3.1	7.4	7.8	11.34	15.68	11.87	10.51	3.1
	Maximum	34.1	25.1	27.8	32.6	36.29	37.92	38.15	40.97	40.97
No rainy days		4	3	5	9	3	0	4	7	31
Rainfall (mm)		18.4	36.4	67.2	28	13.4	0	20.6	12	177.6
The relative humidity of the air (%)	Average	58	69.3	72.1	69.5	62.29	51.95	60.47	54.75	62.91
	Minimum	10.2	23.5	29.8	22.7	18.1	17.73	18.88	13.65	13.65
	Maximum	99.6	100	100	100	100	99.67	100	100	100

Monitoring the physiological indices of the maize plant

From emergence to physiological maturity, 112-115 days were recorded. From the recorded data regarding the time interval between the phenophases of vegetation, a 2-day extension of the periods 5-6 leaves to 10-12 leaves and of the period between the formation of the grain in the leaf-ripening period, during which also the sowing period, was noted for maize after alfalfa - emergence was higher by 3 days, compared to the maize lot sown after rye. This longer duration was due to the quality of the soil, which, thanks to the alfalfa crop, recorded a higher content of organic carbon, better conserving soil moisture. The thermal resources that were recorded during the emergence-physiological maturity of the plant were 2403.92 ºC, in the maize lot after rye and 2560.42 ºC in the maize lot after alfalfa. From this thermal resource, the largest percentage accumulated between the formation of the grain in the milk and the physiological maturity, representing approximately 36.5-37.4%. In terms of the plant's requirement for moisture, the water requirement of maize increases as the plants advance in vegetation, the maximum consumption being recorded starting with the appearance of the panicle until the beginning of the ripening phase in the wax (Ploae et al., 2001; Marinică et al., 2003). Soil moisture during this period ensures the fertilization and formation of the grain. In the climatic conditions recorded this year, when during the appearance of panicle-grain in milk, a small amount of precipitation was recorded, of 26 mm, recorded over a period of 21 days, which corroborated with maximum temperatures of 37.26-38.15 ºC in air, which had a high frequency and a minimum relative humidity in the air of 17.76-18.88%, there was an increase in thermohydric stress, which affected the viability of the pollen, even if the two crops were irrigated, so the hybrid of *OLT* maize, did not realize the full biological potential of the plant.

Analyzing the behavior of the maize plant from a physiological point of view (Table 6), the determinations made during the silking phase of the cob, revealed a percentage of dry matter from the leaves between 27.9%, in the maize sown after rye and 27.2%, in maize sown after alfalfa. Leaf water content revealed better hydration of maize leaves sown after alfalfa, which recorded 72.83% total water, 69.8% free water and 3.03% bound water. It was revealed that maize sown after alfalfa best adjusted its resistance mechanism to the stress conditions of 2024, by binding a high percentage of water at the cellular level. When the vital activity of plants is greatly reduced, the amount of bound water increases, which determines a greater resistance of plants to stress (Burzo, 2014). The ability of crops to maintain adequate water status and efficiently use available resources is crucial for their growth and survival in water-scarce environments (Shao et al., 2008). The results obtained recommend alfalfa as a predecessor plant, because it improves the quality of the soil, leaving in the soil an amount of organic matter 4.3 times greater than that recorded in the soil with the predecessor plant rye.

Table 6. Monitoring of some physiological indices in the maize plant, depending on the preceding plant

The preceding plant of maize	Dry matter (%)	Total water (%)	Free water (%)	Bound water (%)
Rye	27.9	72.1	69.5	2.6
Alfalfa	27.2	72.83	69.8	3.03

Evaluation of the biometric properties of the maize plant

From the point of view of the development of maize plants, it was revealed that the maize sown on a more fertile land, with a higher input of nitrogen left in the soil by the alfalfa crop, presented higher values of plant growth components (Table 7). Thus, the height of the plants recorded 228.83 cm, for maize sown after rye and 230.83 cm, for maize sown after alfalfa, but the difference was insignificant. The preceding crop and implicitly soil fertility positively influenced the leaf surface of the maize plant. Thus, the leaf surface index showed values of 4.46 for maize after rye and 5.18 for maize after alfalfa, the surface of the leaves having a special role on the intensity of physiological processes in the plant and on productive accumulations. The differentiation of the two maize lots is also observed in terms of stem diameter, the number of cobs per plant and the height of cob insertion per plant. Regarding the statistical analysis of the determinations of plant biometrics, it is observed that maize, in both cropping systems, presented a good stability of plant height, leaf index and cob insertion height (s%=4.83-14.2), a medium variability in cob diameter (s%=17.9-19.13) and a very high variability in the number of cobs per plant (s%>30%). If we analyze the influence of the preceding plant on the variability of the plant characters, a better stability is highlighted in the maize grown after alfalfa, the coefficients of variability having lower values compared to the maize grown after rye.

Table 7. Variability of maize plant biometry characters according to the preceding plant

The preceding plant of maize	Statistical indices	Plant height (cm)	Leaf area index (LAI)	Stem diameter (cm)	No cobs/ plant	Cob insertion height on the plant (cm)
Rye	Average	228.83	4.46	1.99	1.23	111.33
	Standard deviation (σ)	14.43	0.37	0.38	0.43	15.81
	Coefficient of variability (s%)	6.30	8.28	19.13	34.88	14.2
Alfalfa	Average	230.83	5.18	2.20	1.37	100.00
	Standard deviation (σ)	13.78	0.25	0.40	0.49	11.22
	Coefficient of variability (s%)	5.96	4.83	17.99	35.86	11.22

Significance of the coefficient of variability (s%): 0-15% = very little variability; 15-30 % = medium variability; >30% = very high variability (inhomogeneous population)

Analysis of grain production obtained from maize

The analysis of the elements of maize productivity (Table 8) highlighted the best results for maize sown after alfalfa, which recorded a grain production of 7222 kg/ha, with a difference of 1575.67 kg/ha, statistically ensured of growing maize after rye. The results regarding the quality of the harvest showed that, from a physical point of view, there were average values of 157.33-187 g for the weight of a thousand grains (WTG) and 62.27-65.85 kg/hl weight hectoliter of grains (WH), the values being higher in the maize crop established after alfalfa. The chemical quality of the production revealed a protein content in the maize grain of 14.8-15.47% and a fats content between 4.43-4.63%. The statistical analysis of the quality indices underlines a significant differentiation only at the weight of a thousand grains, the other indicators being within the limits of the experimental error. It was noted that total protein correlated negatively with grain yield and positively with plant dry matter shown in Table 6.

Table 8. Statistical analysis of maize grain production according to the preceding plant

The preceding plant of maize	Grain production (kg/ha)	WTG (g)	WH (kg/hl)	Total protein (%)	Fats (%)
Rye	5646.33	157.33	62.27	15.47	4.43
Alfalfa	7222.00*	187.00*	65.83	14.80	4.63
LSD 5%	973.65	20.21	3.89	0.79	2.03

CONCLUSIONS

The results obtained recommend alfalfa as a predecessor plant for maize, because it improves the quality of the soil, leaving in the soil an amount of organic matter 4.3 times greater than that recorded in the soil with the predecessor plant rye.

The maize vegetation period was 112-115 days, under the conditions of achieving a total thermal resource of 2403.92 ºC, in the maize lot after rye and 2560.42 ºC after alfalfa.

It was revealed that maize sown after alfalfa best adjusted its resistance mechanism to stress conditions of 2024, by binding at the cellular level a percentage of bound water of 3.03%, higher than 0.43%, compared to maize sown after rye.

From the point of view of the development of maize plants, the maize sown after alfalfa stood out, which showed better stability of characters, the coefficients of variability having lower values compared to the maize grown after rye.

Grain production obtained at harvest was 5646.3-7222 kg/ha, the maximum being recorded for the maize crop established after alfalfa, which achieved an increase of 27.9%, compared to sowing after rye, the difference of production being statistically significant.

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