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RESEARCH REGARDING THE ENERGY EFFICIENCY OF MAIZE CROP CULTIVATED IN ECOLOGICAL AND CONVENTIONAL SYSTEMS IN ROMANIAN PLAIN

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Abstract

Agriculture involves complex activities, which require the updating of farmers' knowledge and the adaptation of their strategies in order to have economic efficiency. Producers must make decisions regarding the structure of crops adapted so as to cultivate species that bring material satisfaction, but last but not least, adapted to current climate changes and new culture technologies. Corn is one of the crops that bring significant financial results, but the irrigation factor and the genetic material must be taken into account. The aim of this research is to analyze the energy and economic efficiency of a corn hybrid grown without irrigation conditions in the southern part of Romania, in a conventional and ecological technology system. The results highlighted the higher productivity of the conventional variant, 8,200 kg/ha, a higher fuel consumption of 93.4 l/ha compared to the ecological system where 89.9 l/ha were consumed. The energy consumption for obtaining a ton of corn was 0.126 kwh, in conventional culture system and 0.143 kwh for the ecological system. The energy efficiency is influenced by the productions obtained, the conventional system being superior from this point of view, for the P9241 hybrid, for the applied technology and for the pedoclimatic conditions of the respective area.

Key words**:** *maize, conventional system, ecological system, , economic efficiency, energy efficiency*

INTRODUCTION

Agriculture is a complex field of activity where farmers are focused every year on what kind of crops to cultivate on their land and what surface to allot to each plant. The decisions are always linked to economic efficiency of each cultivate hectare, more exactly on net returns level [4,11]. Besides wheat and rice, maize is an important human food resource, accounting for 94% of all cereal consumption at world level [5].

Maize is an important cereal proving high nutritional value food products for human and animal consumption.

Maize has a high production potential, by 50 % higher than the other cereals. It is able to produce constant harvests, it is good in monoculture for many years, a good prior plant for most of crops, and its cultivation is mecanisable 100 %, it has a good feed-back to fertilization and irrigation, it has a good resistance to drought, it could be cultivated on various soil types, and could be used for many purposes [25, 26]. In Romania was being

cultivate on 47.1 % of the agricultural land cultivated with cereals [18]. Romania is placed in the top in the EU-28 and among the top producers in the EU and in the world for its maize cultivated area [13, 26].

Also, maize is an agro-food product required for export, Romania's trade balance being a positive one [23].

Most of the corn production in the world is used for animal feed. Average productions can reach 10 t/ha in some countries. In the vast majority of cases, corn is harvested at full maturity when it is used in fodder rations. corn is the food with the highest caloric content, which contains more oil than wheat and has a lower protein content than other cereals [28].

In the traditional system, the maize crop had the largest cultivated area (2,605,165 ha), and the smallest cultivated area in the organic farming system 23,136 ha, which represents a percentage of 0.88 % of the total area [3]. During the years (1992, 1993, 1995, 1996,1997, 1998, 1999, 2000, 2003, 2004), the area was greater than 3 million hectares, the absolute record being recorded in 1992, when there were cultivated 3.3 million ha with grain corn [19].

In the last ten years, the productivity performances were the result of the farmers' efforts regarding the modernization of production technologies and the increase of the economic efficiency of wheat, corn or sunflower crops. Productive performances would have been superior if climate changes had not intensified, environmental factors being the main elements that influence plant development and, finally, the productivity [21]. The deviations of temperature and precipitations from climatological norms are considered a high risk for agriculture.[2]. A study carried out and published by the European Commission concluded the comparison made between the two agricultural models - organic and conventional - to see which is more profitable [17, 30, 31]. Following research, it has been proven that organic farming brings slightly higher incomes in some cases [17, 31].

The European Parliament has made the recent assessments which confirm a diminished cereals production in the EU main producing countries due to the extreme meteorological phenomena, mainly concerning high temperatures, heat waves and long and serious droughts [5, 6].

In Romania, the consumption of ecological products is starting to gain ground, according to some studies. However, it remains quite low, approx. 2%, of the total food, compared to a consumption between 3-5% in Western Europe. According to the Association of operators of Organic Agriculture "Bio Romania", approximately 80% of the annual bio products arrive on export, the value of their being of about 200 million euros, these being exported, particularly in Germany, Austria and Belgium [24, 29]. Green products have undergone significant development in the past two decades [10]. The application of mineral fertilizers determines higher yields and significant increases in production. The unbalanced application of chemical fertilizers can produce imbalances in the plant and the crop increases recorded are increasingly lower as the amount administered increases beyond the useful limit for the plants, which causes higher expenses that are not found in the increases achieved.

This analysis followed the reaction of hybrid to the applied technology and choose for the future the one that brought us the best results without generating large expenses [15].New technologies with fewer inputs have to be delivered to farmers helping them to optimize costs, sustain production and obtain high quality products and their business to be economically viable [20].The International Federation of Organic Agriculture Movements (IFOAM) defines organic agriculture as "a production system that supports the health of soils, ecosystems and people" [1]. Organic agriculture differs from conventional agriculture in two aspects: in the concept of plant nutrition and fertilization, as well as in the nature of the means used to protect plants against the attack of diseases and pests [27]. The main advantage of organic farming is that it does not use the dangerous chemicals of conventional agriculture [1]. Conventional agriculture has determined the decrease in the content of organic matter in the soil and the

accumulation of toxic compounds through the use of pesticides. By using organic fertilizers in ecological agriculture, the percentage of organic matter in the soil is increased and maintained [9].

In the area of Transylvania, it was possible to achieve an optimal combination between fertilization and plant protection in the ecological agriculture system, which could be an alternative to the conventional system, for corn and wheat. [8]. The concept of "reduced inputs" in organic farming leads to the reduction of transport and other inputs. Organic farming is a management system of agricultural production that favors renewable resources and recycling and does not harm the environment [14]. Minimum tillage in winter crop results in equal or slightly higher yields than those resulted from conventional soil tillage; in maize, yield was 5-11% lower, as it was a less favourable year for this crop. The energy consumed for the crop decreased in minimum tillage, resulting from lower fuel consumption/ha [12].

Energy types can be converted into each other, and energies can be stored and transferred by various methods. Measuring the energy consumed in agricultural production is a process of considerable complexity.

The purpose of the observations was to compare the results from the point of view of the production achieved in the non-irrigated maize culture, the expenses incurred, the incomes obtained and the profit achieved in the two variants, ecological and conventional. Another aspect followed was the determination of the energy consumption and efficiency of these two culture systems.

MATERIALS AND METHODS

The study carried out in the Experimental Field of the Research and Development Station for Pomiculture Băneasa, Moara Domneasca, during the period 2021-2022. It was interpreted the average data of this period.

Moara Domnească is located at 30' north latitude, 260 13' east longitude, at an altitude of 90 m, N-E of the city of Bucharest.

To the west and north, the Experimental Base where the experiments were located, is bordered by the Afumati commune, to the east by the village of Moara Domneasca and to the south by the Bucharest city belt.

The territory of the locality is included in the relief of the Romanian Plain, the subdivision of the Vlăsia Plain, in the transition zone from the forest-steppe to the forest area. In order to highlight the impact of climatic conditions on the productions achieved, Table 1 shows the amounts of precipitation recorded during the period in which the experiments were carried out.

In 2020, the amount of accumulated precipitation was 378 mm, in 2021 ,539.4 mm and in 2022, 494.8 mm. All values are below the 50-year multiannual average of 548.0 mm. but above the average of the three years studied, 477.4 mm, in the years 2021 and 2022 (Figure 1).

Regarding the year 2022, the amounts of precipitation recorded had satisfactory values in the months of May, June and July, totaling 175.4 mm, an amount that favored the development of corn plants in optimal parameters, which was reflected in obtaining a relatively good harvest, in the absence of irrigation.

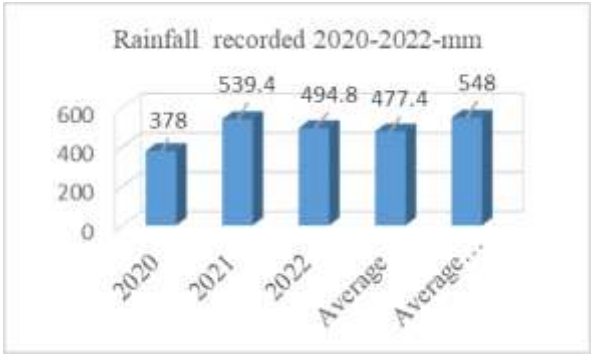

Fig. 1. Rainfall recorded during 2020-2022 (mm)
Source : own representation based on the data from Meteo Station Moara Domneasca [17].

The soil. The type of soil is reddish preluvosoil, having loam-clay texture [16].

This type of soil has the following physical-chemical characteristics:

the texture is loamy-clay throughout the profile, the main hydro-physical indices have medium to high values (CH Around 9% in A

and up to almost 10% in B; CO over 13% in A and over 14% in B; CC 26-25% in A and 24-21% in B; the humus content is medium in A (2.77-2.16%) and remains relatively high in A/B (around 1.2%). The sum of exchange bases has high values, generally over 21 me/100 g of soil, on the entire profile; exchangeable hydrogen has small and very small values (2-5 me);the degree of saturation in bases usually presents high values (79-89%);the reaction is weakly acid-neutral (in A, pH=6.2-6.6 and in B, pH=6.0-6.5);

Table 1. Recorded precipitation during period2020-2022

Luna	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**mm**
2020	31.8	3.0	16.4	30.0	73.4	31.0	52.2	8.4	40.0	32.8	29.6	29.4	**378.0**
2021	58.4	20.4	26.4	5.4	44.2	96.4	163.2	22.4	31.4	33.8	10.8	46.6	**539.4**
2022	28.4	31.4	31.2	29.8	49.6	67.4	58.4	27.6	21.8	37.6	10.2	101.4	**494.8**
Mean													**477.4**
Mean 50 years													**548.0**

Source: Meteo Station Moara Domneasca [17].

The nitrogen indices are medium in A (above 2) and low in B (below 2), which shows a medium and weak nitrogen supply, respectively; at a depth of 20 cm from the surface (the active start of roots), the soil is moderately supplied in mobile phosphorus (17 ppm PAL) and well supplied in mobile potassium (184 ppm KAL) [17].

To achieve the objectives, a monofactorial experience was carried out where

a1: Conventional agriculture

a2: Organic farming

The size of the experimental plot was 480 m^2 (16x30) and that of the harvestable plot was 176 m^2 (8x22), following the elimination of the edges.

The hybrid sown was Pioneer P9241 Aquamax, semi-early hybrid, with excellent production capacity, it has a very well developed root system, the height of the plant is medium-tall. It has a good ability to adapt to thermal and water stress. As elements of productivity, the hybrid has a number of rows per cob of 14-16, a number of seeds per row of 44-47 and MMB of 350-396 g. These elements ensure high productions. The favorable culture areas for this hybrid are the semi-arid and semi-humid ones in the west and southeast of the country. The recommended density for non-irrigated is 66,000 - 75,000 harvestable plants/ha.

RESULTS AND DISCUSSIONS

To obtain agricultural production (Ec), a whole series of energy costs are included:

- direct active energy or direct external energy (human energy, mechanical energy, etc.);
- indirect active energy, necessary for the production of consumable goods in a single production process (seeds, pesticides, chemical fertilizers, etc.);
- passive energy, necessary for the production of fixed means (machines, constructions, etc.) used in agriculture [17, 22]. Active energy, especially direct active energy, has the largest share of energy from the total energy consumed to obtain agricultural plant production, mainly determined by the consumption of fuel for the movement of agricultural aggregates during the technological links. From the total amount of agricultural work, the highest consumption is realized during the execution of soil works [15, 22]. Mechanized land use consumes a lot of energy, with the highest energy consumption observed in basic soil work (ploughing), and this parameter is significantly influenced by soil characteristics (texture, structure and moisture). Plowing consumes the largest amount of mechanical energy, representing about 35% of the total energy consumed for the mechanized execution of works in plant production [15,

22]. The consumption of indirect active energy is largely determined by the consumption of chemical fertilizers [22].

Comparisons between fuels

Historically, mankind has generally obtained energy by consuming fossil fuels, so comparing fuel sources in terms of the amount of unit energy they contain helps with this calculation.

1 kg of anthracite (4% moisture) = 36MJ = 10 kWh

1 m3 natural gas = 39 MJ = 10.8 kWh

1 liter of petrol = 34 MJ = 9.4 kWh

1 liter of diesel = 40 MJ = 11.1 kWh

1 liter of liquefied petroleum gas = 41 MJ = 11.4 kWh

1 liter of fuel oil = 44 MJ = 12.2 kWh

By comparison, 1kg of renewable fuel such as woody biomass typically contains 4.2 kWh. 1 liter of diesel contains approximately 18% more energy than 1 liter of petrol [17, 22].

The sowing was carried out on April 27. The predecessor plant was wheat. The production achieved in the non-irrigated culture was 8,200 kg/ha in the conventional system and 7,000 kg/ha in the ecological system.

Table 2. Technological sheet of the maize crop cultivated in conventional system

Indicator	Diesel consumption Liters/ha	Expenses Lei/ha
Stubble-turning 8-12cm	6.0	42.0
Disk 15cm	5.6	88.5
Fertilize	1.2	33.8
Plowgh	25	400.0
Disk 15cm	5.6	88.5
Combinator	4.0	56.3
Treat the seed with insecto-fungicides	1.0	
Seed transport	2.6	3.75
Sowing	5.0	119.3
Serviced seeders	-	-
Fertilized with solid fertilizers	1.5	33.8
Foliar fertilizer + phytosanitary treatment	1.5	27.8
Herbicide X 2	1.5	71.5
Insecticide treatment	1.7	41.9
Fungicide treatment	1.7	41.9
Harvesting	11.0	500.0
Transportation 5 km away	5.0	60.0
TOTAL GENERAL	**93.4**	**1,609.0**

Source: Own calculation.

Following the performance of various soil works, maintenance works (phytosanitary treatments), harvesting, 93.4 liters of diesel were consumed, representing an expenditure of 1,609.0 lei per hectare.

Table 2 shows the fuel consumption for each technological link, technology applied in the conventional system.

In order to ensure the prevention of some diseases and pests, seed treatments were carried out for sowing with the product Nuprid 600 FS. Over time, such treatments applied by other researchers have led to positive results such as an increase in biomass, dry matter and a proper development of the plant. Application of bio-stimulator treatments resulted in improvement of all biometric indicators of maize plants. Treatments applied determined increases of MMB, MH, starch, U% and protein but those were not statistically assured [7]. The materials used in the corn culture were: for sowing - seed from the P9241 hybrid, for fertilizing - DAP 18:46 fertilizers in a dose of 250 kg/ha, urea and nitrolime, to fight diseases and pests, products such as Retengo, Coragen, to fight weeds, the Rekord Max product.

Table 3 shows that the application of these products generated expenses of 2,816.5 lei/ha.

In conclusion, the expenditure on inputs exceeded the expenditure on fuel. Taken together, these expenses reached the value of 4,425.5 lei.

To this value, 10% indirect expenses were added, resulting in a sum of 4,868.05 lei total expenses related to the establishment of a hectare of corn in a conventional, non-irrigated system.

Table 3. Products applied for fertilization and phytosanitary treatments

Indicator	Materials	U.M.	Doses	Expenses- lei
Fertilizer	DAP 18:46	Kg	250	875
Treat the seed with insecticide	Nuprid 600 FS	l	0.2	74
Sowing	Hybrid P9241	sac	0.83	705
Herbicide	Rekord Max(Callam+Samson Extra+ Dash)	l	0.2	255
Tratament for biostimulation	Maize top	Kg	2	70
Fertilize	Uree	Kg	100	190
Fertilize	Nitrocalcar	l	100	140
Foliar fertilizer + biostimulant treatment	Blacjack	l	1	60
	Azospeed amino	l	5	125
Insecticide + fungicide treatment	Retengo	l	1	150
	Coragen	l	0.125	172.5
TOTAL				**2,816.5**

Source: Own Calculation.

Regarding the ecological culture system, the material expenses generated the amount of 2,425.0 lei/ha, expenses consisting of fertilizers with Bio Ceres NOK, Aminotop, but also seed treatment products, Freya Seed, Germinoseed which ensured protection against plant diseases.

The Zapper product was applied to combat weeds. The doses and applied products are presented in Table 4.

Table 4. Products applied for fertilization and phytosanitary treatments

Indicator	Materials	U.M.	Doses	Expenses- lei
Fertilization	Bio SSP	Kg	200	400
Fertilize	Bio Ceres NOK	kg	200	400
Soil treatment	Pachet –Bacter, Country, Terra Clean+P-FIX+Roots	l	190	190
Treat the seed	Freya Seed	l	0.5	130
	Germinoseed	l	0.5	46
Sowing	Hybrid P9241	sac	0.83	705
Tratament for biostimulation	Aminotop Zinc	l	1	70
	Aminotop N	l	1	62
	Aminotop Ultra	l	1	62
Foliar fertilizer + biostimulant treatment	Aminotop Zn	l	1	70
	Alg Green	l	1	70
Insecticide treatment	Zapper	l	1	220
TOTAL				**2,425.0**

Source: Own Calculation.

From the data presented in Table 5, it appears that soil works such as plowing, tilling or preparing the germinal bed as well as sowing or phytosanitary treatments generated a consumption of 89.9 l diesel per hectare and an expense of 1,817.5 lei/ha.

Total material expenses + fuel = 4,242.5 lei. To this value, 10% indirect expenses were added, resulting in a sum of 4,666.75 lei total expenses related to the establishment of a hectare of corn in an ecological, non-irrigated system.

The economic efficiency is shown in Table 6, from which it appears that following the sale of the harvest at the price of 1.31 lei/kg, incomes in the conventional culture of 10,742 lei were obtained.

For the corn from the ecological system, sold at the price of 1.32 lei/kg, revenues of 9,240 lei/ha were recorded, with 1,502 lei less than the revenues obtained by capitalizing on the corn grown in the conventional system. The higher productions achieved in the culture using conventional technology (1,200 kg/ha) was generated this difference. For the establishment one hectare of corn, the expenses incurred were about 4,868.05 lei in the conventional system and 4,666.75 lei/ha, in the ecological system, the difference was coming from a reduce number of

phytosanitary treatments. The profit recorded was bigger (5,873.95 lei/ha) for the conventional system and smaller (4,573.25 lei/ha) for the ecological system, the difference of 1,300 lei/ha was the result of increased production. The profit rate was higher, 120%, for the conventional version and 98%, for the ecological version. A rate of profit of 120% means that the profit made is 120% of the initial investment or income generated. This indicates that for every unit of currency invested or earned, an additional 1.20 units of profit was earned. Nor is the rate of profit achieved in the ecological culture system low.

Table 5. The technological sheet of the maize crop grown in ecological system

Indicator	**Diesel consumption Liters**	**Expenses Lei**
Stubble-turning 8-12cm	6.0	88.5
Disk 15cm	5.6	88.5
Fertilized equipment serviced		
Fertilize	1.2	33.8
Plowgh	25.0	362.3
Disk 15cm	5.6	88.5
Combinator	4.0	56.3
Treat the seed with insecto-fungicides	1.0	-
Seed transport	2.6	3.75
Sowing	5.0	119.3
Serviced seeders	-	-
Fertilized with solid fertilizers	1.2	80.8
Foliar fertilizer + phytosanitary treatment	1.0	7.8
Transport	1.0	27.8
Herbicide	1.8	11.0
Serviced crop treated equipment	-	8.8
Transport	1.5	7.8
Insecticide treatment	1.7	41.9
Fungicide treatment	1.7	41.9
Harvesting	11.0	600.0
Transportation 5 km away	5.0	60.0
Chopping vegetable scraps	4.0	89.0
Straw balling	4.0	-
TOTAL GENERAL	**89.9**	**1,817.5**

Source: Own Calculation.

A percentage of 98% highlights an efficient business strategy, which allows the company to control costs and maximize revenues, in conclusion to optimize the activity.

Table 6. The economic efficiency of the studied systems

Indicator	**Conventional System**	**Ecological System**
Yield-kg/ha	8,200	7,000
Price /kg-lei	1.31	1.32
Income- lei/ha	10,742	9,240
Expenses-lei/ha	4,868.05	4,666.75
Profit lei/ha(brut)	5,873.95	4,573.25
Profit rate %	120	98
Unit cost/ton-lei/to	600	670

Source: Own calculation.

The two values of the profit rate denote that the financial resources of the unit are sufficient to invest in development and improvement of the activity. The cost of obtaining a product unit (ton) was lower in the conventional system, 600 lei/ton, which is a positive aspect from an economic point of view, and 670 lei/ton in the ecological system.

Energy efficiency analysis - Maize conventional system

Total energy consumption

Diesel consumption (litres) xkw/l diesel

93.4x11.1=1,036.7 kw

Energy consumption/unit of harvested product

Total energy consumption: production (kg)

1,036.7:8,200=0.126 kwh

Energy efficiency analysis - Maize ecological system

Total energy consumption

Diesel consumption (litres) x kw/l diesel

89.9x11.1=997.9 kw

Energy consumption/unit of harvested product

Total energy consumption: production (kg)
997.9:7,000=0.143 kwh.
Regarding the energy efficiency of the two corn cultivation systems, we observe from Table 7 that in the conventional culture system 93.4 l of diesel per hectare were consumed compared with ecological culture system were only 89.9 l/ha were used, which means that the interventions performed on the culture were reduced as number.

Table 7. Energy efficiency of the analyzed systems

Indicator	**Conventional system**	**Ecological System**
Diesel consumption-l/ha	93.4	89.9
Diesel consumption-lei/ha	1,609.0	1,817.5
Total technological costs–lei/ha	4,868.05	4,666.75
Total energy consumption-kw/ha	1,036.7	997.9
Energy consumption/unit of harvested product kwh	0.126	0.143
Yield –kg/ha	8,200	7,000

Source: Own calculation.

Implicitly, the technological costs for each hectare were lower, 4,666.75 lei, for the ecological system and 4,868.05 lei, in the case of the conventional culture system. The consumption of diesel transformed into energy, is about 1,036.7 kw/ha for the conventional version and 997.9 kw/ha, for the ecological system. The transformation of this consumption into energy consumed to obtain a unit of product (ton) was carried out by dividing the total energy consumption by the realized production. In the conventional culture system, a consumption of 0.126 kwh was required compared to 0.143 kwh, in the ecological system. The recorded difference is generated by the larger productions made in the conventional system. High yields lead to lower energy consumption for obtaining them, implicitly, a lower cost price per product unit. Finally, they lead to energy and economic efficiency.

CONCLUSIONS

In the conventional culture system, fuel consumption was higher.

For obtaining a product unit (ton), the costs was lower in the conventional system, 600 lei/ton comparative with 670 lei/ton, in the ecological system.
This production cost influences the selling price, the profit, the profitability of the company and the strategy it will adopt in the future. In our case, the conventional technological system brought better results compared to the ecological system. The profit and the profit rate were higher. In the conventional technology system, for obtaining one ton of product was needed an energy consumption of 0.126 kwh and in the ecological system, 0.143 kwh. The difference between the values is the result of the higher productions obtained in the conventional system. Higher yields need lower energy consumption to obtain them, the lower energy consumption, lower cost price of the product unit, which means energy and economic efficiency. The energy efficiency is influenced by the productions obtained, the conventional system being superior from this point of view, for the P9241 hybrid, for the applied technology and for the respective pedoclimatic conditions.

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