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THE IMPACT OF NPK FERTILIZERS ON THE YIELD AND ENERGY EFFICIENCY OF SUGAR BEET AND SOYBEAN PRODUCTION

Bozic Marija[1], Dimitrijevic Aleksandra[1], Mileusnic Zoran[1], Miodragovic Rajko[1]

[1]University of Belgrade, Faculty of Agriculture, Nemanjina 6, 11080 Belgrade, Serbia
marija_bozic15@yahoo.com

Abstract*. Agricultural production is of a great importance for the human population being the major source of food for the population of the planet, whose number is increasing daily. The objectives of this study are the evaluation of the energy embodied in the process of fertilizer application in the sugar beet and soybean production and identification of the energy input – output relation. Data from three production season were collected and analysed. In the case of both cultures results show that the highest share in total energy consumption has the energy input through the application of fertilizers. The nitrogen content in total energy consumption in sugar beet production was 51.89%, 38.44% and 31.83%; phosphorus was 1.77%, 3.66% and 4.18%; potassium was 3.09%, 5.24% and 2.87%. In soybean production the nitrogen content in the energy balance through the seasons was 37.86%, 39.55% and 39.38%; phosphorus was used in first and last season, with content of 4.69% and 3.46%; potassium was used in second agricultural year with the content of 2.30%.*

Based on the data obtained, it was concluded that the use of fertilizers is very important for the sustainability of agricultural production and that it must be balanced concerning the negative impact of excessive amounts on the both production economy and ecology.

Key words: *soybean, sugar beet, fertilizer, energy input, energy output, energy efficiency*

1. INTRODUCTION

Production of sufficient quantities of food and industrial raw materials, both for the existing population and for generations to come, is one of the most important tasks of the society [11]. Therefore, the development of agriculture, its sustainability and continuous improvement is crucial for humanity [7, 14, 27]. Modern agricultural production can not be imagined without the use of fertilizers, particularly in terms of better utilization of plant biological yield [7, 8, 9, 26, 28]. Otherwise, the yield of crops would be significantly reduced regardless the application of all other cultural practices carried such as tillage, crop protection and care.

In current agricultural practice nutritive value of fertilizers was evaluated on the basis of their impact on crop yield increase and possibility of yield quality improvement [16, 17]. However, with the advancement of all sectors, including agriculture, more and more analyzes are dedicated to the energy flow in fertilizer production and application analysing the processes such as transport, storage and handling of fertilizers. All these analysis show that the share of energy consumed in agriculture is very high ranging in some countries up to 5% of total energy consumption in the country. Energy inputs can be divided into the following groups [2, 18]: direct energy inputs (human power, diesel fuel, water and electricity), indirect energy inputs (chemicals, fertilizers, seeds and machinery); renewable energy inputs (human power, seeds and manure fertilizers) and non-renewable energy inputs (diesel fuel, electricity, chemicals, water, fertilizers and machinery).

In the total energy consumption, the share of the built-in fertilizers goes up to 50% [5]. This is one of the key reasons for devoting the additional research and to pursue its rationalization with the aim of not only economically viable [6], but also environmentally effective production [3, 20, 23, 24].

The aim of this paper is the analysis of energy consumption in the production of sugar beet and soybean since they are considered to be energy demanding crops. Special attention was given to the energy consumption via mineral fertilizers. Based on the final results it could be possible to achieve a sustainable agricultural production, with focus on the environmental sustainable crop production.

2. MATERIALS AND METHOD

Tests were conducted on the property of PKB Corporation "7 July" in Jakovo (Vojvodina region, Serbia). The aim was to determine the energy parameters of sugar-beet and soybean production in the conventional tillage production system. Data were collected for the 2009/10, 2010/11 and 2011/12 seasons.

In order to determine the energy efficiency of crop production energy input (direct, indirect) and energy output were identified.

The method used for energy efficiency analysis [19] is based on the energy input analysis (definition of direct and indirect energy inputs), calculation of the energy consumption for a given plant production and the energy efficiency. On the basis of sugar beet and soybean production output and the energy input, specific energy input, energy output-input ratio and energy productivity were estimated. The energy inputs were calculated by multiplying the material input with the referent energy equivalent [12, 15]. The quantities of material input were obtained directly from the farm managers.

3. RESULTS AND DISCUSSION

3.1 Energy consumption and energy output in sugar beet production

Energy inputs and output in sugar beet production are presented in Table 1 and Table 2. Data presented in Table 1 represent average values from the three years trials.

Table 1 Energy consumption for sugar beet production

Input	Quantity per unit area (unit ha^{-1})	Energy ($MJha^{-1}$)	%
Direct			
Diesel fuel (l)	158.26	7564.86	27.10
Kerosene (l)	5.45	200.13	0.82
Total	163.71	7764.99	27.93
Indirect			
Labor (h)	9.84	19.29	0.07
Tractor (h)	9.10	833.91	3.11
Combine (h)	0.72	63.43	0.55
Transport (h)	3.78	112.63	0.38
Machinery (h)	6.07	380.54	1.53
Nitrogen (kg)	179.10	11845.28	40.72
Phosphorus (kg)	62.6	778.72	3.20
Potassium (kg)	89.44	997.24	3.73
Insecticides (kg)	6.82	690.01	2.80
Fungicides (kg)	0.99	212.35	0.59
Herbicides (kg)	13.99	3321.49	12.04
Water (m^3)	1.70	1.73	0.01
Seeds (kg)	16.70	835.15	3.52
Total indirect	400.52	20020.99	72.07
Total input		27785.99	

Table 2 Energy output for sugar beet production

	Season		
	09/10	10/11	11/12
Yield (kg/ha)	78323.43	56128.78	10020.00
Output (MJ/ha)	1315833.60	942963.50	168336.00

Table 1 shows specific energy consumption per ha and the share of the specific energy input in total energy consumption. Data showed that the highest amount of energy in the production is consumed thorough the fertilizers. Its share in total energy consumption was 47.56% in average, for the three years trial. Energy input through water is the water consumed in plant protection and therefore its share is proportionally lower. Irrigation was not performed. The second most intensive energy input was fuel and had 27.10% share in the total energy consumption.

Energy parameters from three production seasons are given in Table 3.

Table 3 Energy parameters for sugar beet production

Energy parameters	Season		
	2009/10	2010/11	2011/12
EI, MJ/kg	0.51	0.45	1.82
ER	33.11	37.20	9.21

EP, kg/MJ	1.97	2.21	0.55

Asgharipour et al. (2012) [4] carried an economic analysis of sugar beet production system in Iran, in Khorasan Razavi province. The total energy input was 42231.9 MJ/ha, and approximately 29% and 22% were from chemical fertilizers and irrigation water, respectively. Econometric assessment indicated that energy inputs of human labor, machinery, diesel fuel, total chemical fertilizers, farmyard manure, electricity, and irrigation water made significant contribution. Total energy output of sugar beet production was 563645.4 MJ/ha. The specific energy, energy productivity and net energy of the sugar beet production were 1.3 MJ/kg, 521413.7 MJ/ha and 0.8 kg/MJ, respectively. The energy input is approximately the same in this study and in season 2009/10. It is significantly higher here than in the seasons 2010/11 and 2011/12 in the Sava region in Serbia. Lower quantities of fertilizer were used in Iran, but irrigation was applied. Yields are higher in the Sava region in Serbia for the first two seasons, but not in the third, because of the reduced amount of fertilizer used.

Gulistan et al. (2007) [12] carried an economical analysis of sugar beet production in Tokat province of Turkey. The results revealed that total energy consumption in sugar beet production was 39685.51 MJ/ha, where fertilizer had a share of 49.33% and diesel fuel 24.16%. The output/input energy ratio was 25.75 and energy productivity was 1.53 MJ/ha. Compared with the results which are presented, it is obvious that the energy input is higher, but the output is lower, which shows the ratio of output / input. The percentage share of mineral fertilizer and diesel fuel is about the same.

Haciseferogullari et al. (2013) [13] calculated energy balance of the sugar beet production for middle Anatolia conditions (Konya region). According to the obtained results, the total energy input, energy output, output/input ratio and net energy ratio were found to be 19760.65 MJ/ha, 378491.2 MJ/ha, 19.15 and 18.15, respectively (for 6.9 t/ha yield). Compared with the results presented in previous section, lower input and output were obtained compared to 2009/10 and 2010/11 seasons. Even with the drought periods in these seasons, energy output in Serbia region was higher. The results indicate the higher benefit for sugar beet growing in the Vojvodina region near river Sava. This could also be concluded based on the higher yields. However, in the absence of rainfall and irrigation, there was an obvious reduction of yields in 2011/12 season.

Reineke et al. (2013) [22] calculated energy balance parameters for sugar beet cultivation in commercial farms in Germany. Authors collected data from 285 fields. Total energy input (median) was 17.3 GJ/ha, energy output 261.7 GJ/ha, energy gain (energy output less input) 244.6 GJ/ha, output/input ratio 15.4 and energy intensity (energy input versus natural yield measured in Grain Equivalents) was 87.4 MJ/GE. The energy input is lower than in all three seasons in the Vojvodina region, but the output is higher when compared with last season in Serbia. There was not enough rainfall in that season. Farmers in Germany have used lower quantities of nitrogen fertilizers. The increased use of organic fertilizers in these farms also reduced the energy inputs.

3.2 Energy consumption and energy output in soybean production

Energy inputs and output in soybean production are given in the Table 4 and Table 5. The values represent in the table 4 are the average values of three years trials.

Table 4 Energy consumption for soybean production

Input	Quantity per unit area (unit ha^{-1})	Energy (MJ/ha)	Share, %
Direct			
Diesel fuel (l)	86.71	4144.99	36.72
Total	86.71	4144.99	36.72
Indirect			
Labor (h)	5.88	11.51	0.10
Tractor (h)	5.36	493.11	4.38
Combine (h)	0.48	31.61	0.29
Transport (h)	1.11	33.00	0.29
Machinery (h)	3.42	298.32	2.65
Nitrogen (kg)	66.32	4393.04	38.93
Phosphorus (kg)	37.60	467.69	4.08
Potassium (kg)	22.92	255.5	2.30
Insecticides (kg)	1.00	101.52	0.90
Herbicides (kg)	4.65	1105.76	9.74
Water (m^3)	1.13	1.16	0.01
Seeds (kg)	94.11	338.80	2.51
Total indirect	216.16	7204.82	63.28
Total input		11349.81	

The data show that the highest average share in the total energy consumption had fertilizer (45.31%) followed by fuel (36.72%) and herbicide usage (9.74%). Water was used only in the operation of plant protection. The soybean yield per hectare significantly decreased from season to season (Table 5).

Table 5 Energy output for soybean production

	Quantity per unit area (unit ha^{-1})			%		
	09/10	10/11	11/12	09/10	10/11	11/12
Yield (kg/ha)	3300.00	2350.00	1351.26			
Output (MJ/ha)	82500.00	58750.00	33781.58	77.34	77.35	59.04
Straw (kg/ha)	1208.77	860.00	1172.00			
Output straw(MJ/ha)	24175.38	17200.00	23440.00	22.66	22.65	40.96
Total output	106675.38	75950.00	57221.58	100.00	100.00	100.00

Energy parameters from three production seasons are given in Table 6.

Table 6 Energy parameters for soybean production

Energy parameters	Season		
	2009/10	2010/11	2011/12
EI, MJ/kg	3.65	4.75	8.01
ER	8.85	6.80	5.29
EP, kg/MJ	0.27	0.21	0.12

Abbas and Majid (2012) [1] calculated energy input-output ratio and have carried an economic analysis of soybean production in the main agricultural production areas in Iran. The results revealed that soybean production consumed a total of 29895.49 MJ/ha, of which the share of diesel fuel and chemical fertilizer energy consumption were 67.47 and 9.5%, respectively. About 68.4% of the total energy inputs used in soybean production were direct (human labor, diesel) and the rest (31.6%) were indirect (seeds, fertilizers, manure, chemicals, machinery). Mean grain yield which was in rain-fed farming system was about 1850 kg/ha. In the current study, total energy output and net energy was estimated to be 54131 and 24235,5 MJ/ha, respectively. Also, energy productivity and energy use efficiency (EUE) were determined to be 0.06 kg/MJ and 1.81 respectively. When these results are compared with previously presented, it can be concluded that significantly less fertilizer was used but these lower quantities were compensated with the irrigation which had a positive effect on yield even with the lower quantities of fertilizer. However, the output is approximately equal to the output of the season with the lowest productivity in addition to Sava region in Serbia. Results show that optimal quantities of fertilizer should be used. Quantities higher that optimal will not provide higher yield and on the other side will lead to higher energy consumption and lower energy productivity.

Kordkheili et al. (2013) [15] calculated the energy input-output ratio and they have also carried an economic analysis for soybean production in Mazandaran province of Iran. The results indicated that total energy input for soybean was about 38756.32 MJ/ha. Among all energy inputs electricity (49.42%) and fertilizer (20.82%) had the highest energy values per hectare. The values of specific energy consumption for soybean cultivation were 12.12 MJ/kg. Total energy output was 79902.21 MJ/ha. Compared to here presented results, the energy output shown here is lower only in the first season. In the second and especially in the third is higher, although the percentage of the fertilizer is lower. This confirms the importance of irrigation, which is omitted in the region of Sava in Serbia. Soybean yield was higher in the Sava region in 2009/10 season. In the next season output is approximately equal, while in the dry season 2011/12 is lower in study. The reason has already been mentioned

Ramedani et al. (2011) [21] determined the energy consumption and evaluation of inputs sensitivity for soybean production in Kordkuy county of Iran. The results showed that the total input was 18026.50MJ/ha, total output 71228.86 MJ/ha, and approximately 66.67%, 14.32% and 6.18% were from diesel fuel, chemical fertilizers and irrigation, respectively. Inputs in the Vojvodina region in all three seasons were lower. There was no irrigation and significantly lower quantities of diesel fuel were used. However, the use of mineral fertilizers was higher in the Sava region. This led to higher output in the first two seasons, while in the third it was lower, due to drought and lack of irrigation.

3.3 Energy consumption and yield

The need to improve agricultural production is growing day by day. World population is growing and the demand for food is increasing. For this reason the main objective of modern agricultural production is to increase the crop yields. Based on the results it is evident that reducing the quantity of the used mineral fertilizers with the lack of irrigation decreases the overall crop production productivity [25].

To establish the nature of a relationship between two quantitative variables regression analysis was used [10]. An interesting fact is related to the positive correlation between yield and energy consumption in the production of sugar beet, presented with r = 0.93 in Figure 1.

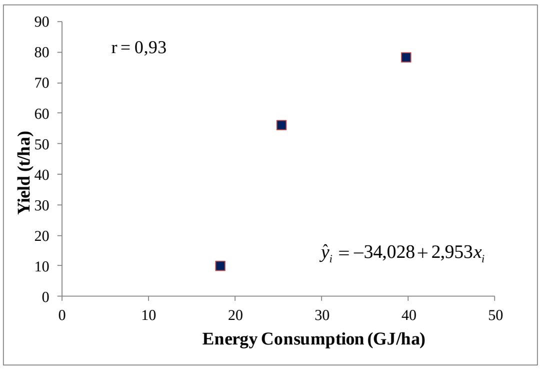

Fig. 1 Correlation between energy consumption (GJ/ha) and yield (t/ha) in sugar beet production

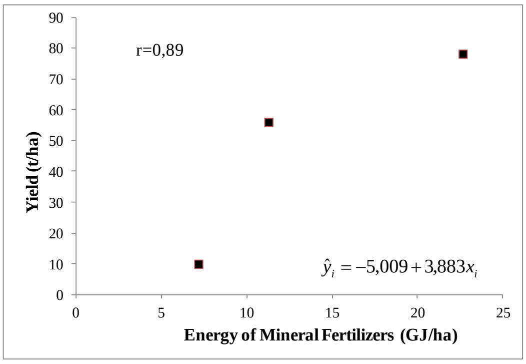

Fig. 2 Correlation between energy of mineral fertilizers (GJ/ha) and yield (t/ha) in sugar beet production

With the increase of energy input yields are increased and thus, the energy output. Major role in this certainly have mineral fertilizers, as shown in Figure 2, where r = 0.89. The correlation is in this case is positive and shows that the adequate use of mineral fertilizers is of great importance in obtaining higher yields. Application has to be well balanced in order to meet the requirements of rational energy use and economic feasibility, but also the impact on the environment.

Concerning the soybean production, Figure 3 shows a very significant correlation between the yield and the energy consumption (r = 0.99).

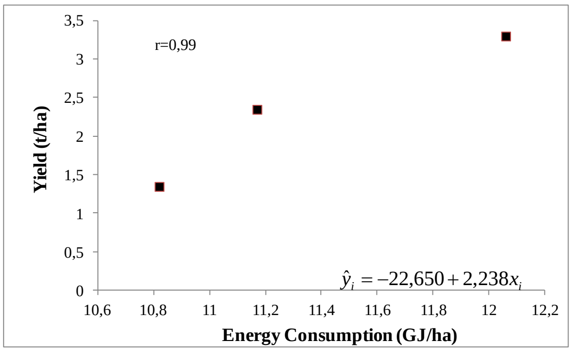

Fig. 3 Correlation between energy consumption (GJ/ha) and yield (t/ha) in soybean production

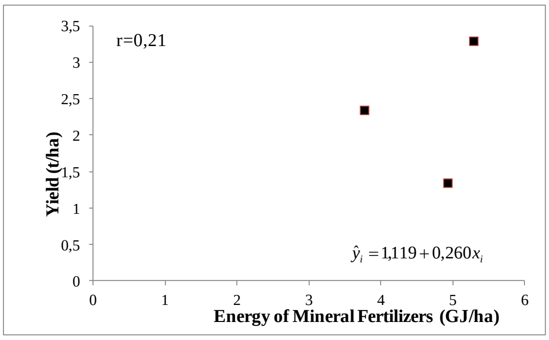

Fig. 4 Correlation between energy of mineral fertilizers (GJ/ha) and yield (t/ha) in soybean production

Comments are like those in the case of sugar beet, with special emphasis on the optimum amount of fertilizer and irrigation in the critical months (June, July and August), particular in the case of low precipitation. Based on the Figure 4, it is evident that the correlation between yield and energy input through mineral fertilizers is not significant (r = 0.21). There is a linear relationship between the two specified parameters, which gives room for continued research and monitoring of the impact of the use of mineral fertilizers on yields and their energy value in the coming seasons.

CONCLUSIONS

Task of agricultural production is not just to produce food. It must above all be a cost-effective, profitable and must meet certain environmental standards. On the basis of the above research results through three seasons of sugar beet and soybean, it can be concluded that with the reduction of mineral fertilizer use from year to year yield decreases. Lack of irrigation can also significantly affect the yield, which is best shown in the 2011/12 season, when in the summer months rainfall was minimal. This is also reflected on the decrease in output, especially in sugar beet. The fact that the intensive agricultural production can not be imagined without the use of fertilizers requires a balanced fertilization, with the optimum amount of fertilizer applied at the right place and the right time. This is not much to lose in production if smaller quantities of fertilizer are used. It will be cost-effective and will have a positive impact on energy efficiency of the productions systems in region and on environmental sustainability. The economical difference in having lower quantities of fertilizer can be used in investments in irrigation which can, as results have shown, lead to the higher yields, better energy utilisation, better energy efficiency and positive effect on the agro-ecological condition in the region.

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