Bulgarian Journal of Agricultural Science, 19 (No 5) 2013, 1056-1060
Agricultural Academy

ENERGY ASSESSMENT OF NEW BROCCOLI VARIETY

M. MIHOV [1*], G. ANTONOVA [1] and K. MIHOV [2]
[1] *Maritsa Vegetable Crops Research Institute, BG – 4003 Plovdiv, Bulgaria*
[2] *Agricultural University, BG – 4000 Plovdiv, Bulgaria*

Abstract

MIHOV, M., G. ANTONOVA and K. MIHOV, 2013. Energy assessment of new broccoli variety. *Bulg. J. Agric. Sci.,* 19: 1056-1060

The energy budgets in crop production could be used as a key indicator that helps to assess the productivity and profitability that are dependent on energy use. Therefore, it is essential to conduct an energy assessment of crop varieties, as they are a major component of production. Tests were carried out in three consecutive years (2010-2012) under standard technology for late field production in order to determine the energy costs involved in the production of two varieties of broccoli as well as to assess the energy parameters. Standard fertilization and plant protection with pesticide chemical origin were applied. The total energy consumption in Coronado F_1 and IZK Iskra varieties productions was 3570.31 MJ.da^{-1} and 3511.68 MJ.da^{-1}, respectively. Variety IZK Iskra is more energy efficient because of reduced energy costs for diesel oil, machinery, some insecticides, human power and higher energy output. The higher energy output in IZK Iskra variety leads to a 22.50% increase in energy productivity and energy use efficiency in comparison with Coronado F_1 variety. The shares of non-renewable energy for Coronado F_1 and IZK Iskra varieties production were almost equal and were up to 89.30%. There is a heavy reliance on the use of chemical fertilizers, diesel oil and machinery. Consumption of these non-renewable energies can be reduced using bioproducts for fertilization and plant protection, and biofuel. It is essential for the creation and use of modern energy efficient varieties and hybrids.

Key words: energy use, energy efficiency, broccoli, yield

Introduction

The focus of modern agriculture in recent years in increasingly on the effective use of energy as important criterion for sustainable production. High-energy efficiency is a prerequisite for reducing environmental problems, preventing the destruction of natural resources and promoting sustainable development of agriculture as an economic production system (Uhlin, 1998; Jonge, 2004; Ghorbani et al., 2011).

The energy consumption per unit area is directly related to the development of technology, systems and production level in agriculture (Turhan et al., 2008; Mihov and Antonova, 2009; Moore, 2010; Hamedani et al., 2011). Therefore, the choice of variety as a fundamental component of production is of major importance. The biological potential of the variety along with desirable economic indicators determines the choice of the variety. Increasingly more attention is being paid to the energy assessment of varieties as a real opportunity to reduce energy inputs in the production in the aspect of modern environmentally efficient agriculture (Moore, 2010; Tabatabaie et al., 2012; Mihov et al., 2012).

The purpose of this research is to analyze the use of energy and determine the energy parameters in late field production of a new Bulgarian broccoli variety.

Materials and Methods

The object of the study is the new Bulgarian variety IZK Iskra. IZK Iskra and Coronado F_1 varieties were tested under standard technology for early field production with the spring planting on sandy-clay soil at Maritsa Vegetable Crops Research Institute (MVCRI) in Plovdiv, Bulgaria in the period from 2010 to 2012. MVCRI is located at 42°10' N latitude 24°45' E longitude and 160 m above the sea level. The seedlings were produced in an open field, with dates of sowing and transplanting from 16th to 18th June and from 27th July to

E-mail: mihovm@gmail.com

1st August respectively. Planting of seedlings was done manually. The experiment was conducted using the block method with two variants in four replications with 22 plants per replication. The experimental plot size was 9.60 m^2. Crops were grown on high flat bed based on 90+70/60 cm transplanting scheme.

Conventional fertilization and plant protection with pesticide chemical origin were applied. Mineral fertilizer in quantities of P_2O_5 23.0 kg.da^{-1} active ingredient (a.i.) and K_2O 24.4 kg.da^{-1} a.i. (determined by soil fertility analysis) were broadcast homogeneously and incorporated prior to planting on the soil surface. A quantity of 0.60 kg a.i. herbicide was incorporated in the soil for the purposes of weed control. Plants were nourished with 9.9 kg da^{-1} a.i. nitrogen during the hoeing. The results obtained for the total yield of the central flower heads and for the total yield of the lateral flower heads were processed statistically using dispersion analysis (Lakin, 1990).

The total energy inputs were given as a sum of all costs converted into energy values through their energy equivalent. The energy analysis parameters were determined using the following formulas: Energy productivity (kg.MJ^{-1}) = Broccoli yield (kg.da^{-1}) / Energy inputs (MJ.da^{-1}); Energy intensity (MJ.kg^{-1}) = Energy inputs (MJ.da^{-1})/ Broccoli yield (kg.da^{-1}) and Output-inputs ratio [R] = Energy output (MJ.da^{-1}) / Energy inputs (MJ.da^{-1}).

The energy equivalents used in the research are presented in Table 1. Mihov (2009) calculated the energy equivalents of the seedlings (kg) and the broccoli flower heads. The researchers Helsel (1992), Yaldiz et al. (1993) and Singh et al. (2002) previously used the energy equivalents of the remaining costs for estimating the energy inputs in agricultural production.

Results and Discussion

Energy requirements of broccoli production

The structure of the energy inputs for both varieties is presented in Table 2. Total energy costs are 3 570.31 MJ.da^{-1} for the Coronado F_1 variety and 3 511.68 MJ.da^{-1} for the IZK Iskra variety. Energy outputs based on the variety amounted to 2 674.10 MJ.da^{-1} and 3 235.10 MJ.da^{-1} respectively.

Data in Table 2 shows that the largest share of total energy consumption for growing these varieties are fertilizer, diesel oil and machinery. The share of each energy input as a percentage of the total energy inputs for both broccoli varieties are shown in Figure 1. It appears that the largest share of the total energy costs for growing these varieties are fertilizers (30.46%), diesel oil (26.12%), machinery (13.34%), etc. Plastic wrapping also represents a relatively large share (11.34%) of the total energy costs. The share of pesticides (7.67%) is

Table 1
Energy equivalents

Parameters	Unit	Energy equivalent, MJ.unit^{-1}	References
Inputs			
Pesticides, active ingredient (a.i.)			
herbicides	kg	238.00	Helsel, 1992
fungicides	kg	92.00	Helsel, 1992
insecticides	kg	238.00	Helsel, 1992
Fertilizers (a.i.)			
N	kg	64.40	Singh et al., 2002
P_2O_5	kg	11.96	Singh et al., 2002
K_2O	kg	6.70	Singh et al., 2002
Diesel oil	L	56.30	Singh et al., 2002
Machinery	h	62.70	Singh et al., 2002
Human power			
technicians	h	2.30	Yaldiz et al., 1993
farm-workers	h	1.96	Yaldiz et al., 1993
Seedlings	kg	2.36	Mihov, 2009
Plastic wrapping	kg	88.50	Alkon, 1997
Water for irrigation	m^3	0.63	Yaldiz et al., 1993
Output			
Broccoli	kg	1.87	Mihov, 2009

in acceptable limits, however these as well as fertilizers can be replaced with organic products because organic products have a lower energy equivalent, reduce energy costs and achieve environmental effect.

The differences in energy costs observed in the production of both broccoli varieties are determined by the expression of some of the main features of their economic characteristics. The new variety of broccoli IZK Iskra is with a shorter duration of the period from planting to harvesting the central flower heads. Because of the shorter vegetation, the number of treatments reduces (five mechanized and seven manual vs six and eight for Coronado F_1 variety). Thus the consumption of human power and diesel old decreases by 12.52% and 16.69% respectively.

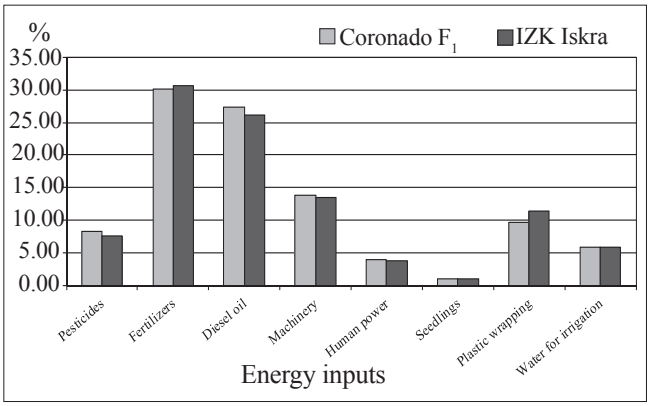

Fig. 1. Energy use pattern in production of both broccoli varieties

This genotype has a higher level of tolerance when under attack from economically important pests, which results in reducing the number of insecticide treatment. The number of spraying can be reduced from 8 to 6 in the production of IZK Iskra variety which leads to energy savings for insecticides and human power of 20.18% and 3.57 percent.

In this experimental setting, both varieties of broccoli achieve almost the same yield of central flower heads. Energy return on them is 2094.40 MJ.da^{-1} and 2019.60 MJ.da^{-1} for Coronado F_1 and the new variety respectively. The greater energy output amounting to 1215.50 MJ.da^{-1} for IZK Iskra variety is due to the productivity of lateral flower heads, which is 209.68% in comparison to the control variety Coronado F_1.

Table 2
Structure of energy inputs and output in broccoli production

Consumption	Varieties					
	Coronado F_1			IZK Iskra		
	Quantity, unit. da^{-1}	Total energy equivalent, MJ.da^{-1}	%	Quantity, unit. da^{-1}	Total energy equivalent, MJ.da^{-1}	%
Pesticides, active ingredient (a.i.), kg	1.40	295.51	8.28	1.29	269.33	7.67
herbicides	0.60	142.80	4.00	0.60	142.80	4.07
fungicides	0.25	23.00	0.64	0.25	23.00	0.65
insecticides	0.55	129.71	3.63	0.44	103.53	2.95
Fertilizers (a.i.), kg	57.30	1076.12	30.14	57.30	1076.12	30.64
nitrogen	9.90	637.56	17.86	9.90	637.56	18.16
phosphorus	23.00	275.08	7.70	23.00	275.08	7.83
potassium	24.40	163.48	4.58	24.40	163.48	4.66
Diesel oil, L	17.30	973.99	27.28	16.29	917.13	26.12
Machinery, h	7.92	496.58	13.91	7.58	475.27	13.53
Human power, h	70.48	139.49	3.91	66.75	132.12	3.76
technicians	3.96	9.11	0.26	3.79	8.72	0.25
farm-workers	66.52	130.38	3.65	62.96	123.40	3.51
Seedlings, kg	15.07	35.57	1.00	15.07	35.57	1.01
Plastic wrapping, kg	3.90	345.15	9.67	4.50	398.25	11.34
Water for irrigation, m^3	330.00	207.90	5.82	330.00	207.90	5.92
Total inputs, MJ.da^{-1}		3570.31	100.00		3511.68	100.00
Output, MJ.da^{-1}	1430.00	2674.10		1730.00	3235.10	
central flower heads	1120.00	2094.40		1080.00	2019.60	
lateral flower heads	310.00	579.70		650.00	1215.50	

Seven harvests are obtained with variety IZK Iskra (two more than variety Coronado F_1) which increased the energy inputs for human power and for diesel oil by 20.98% and 21.28% respectively.

Parameters of energy analysis

The parameters of energy analysis are presented in Table 3. The data shows that in terms of energy parameters better results are obtained with the cultivation of the new variety. The obtained data defines an output-inputs ratio R=0.75 for variety Coronado F_1 and R=0.92 for variety IZK Iskra.

The output-inputs ratio and the energy productivity of both investigated varieties are higher than the typical vegetable crops production values: for tomatoes 0.21 and 0.25 kg.MJ^{-1} respectively (Turhan, 2008), for potatoes – 1.25 and 0.35 kg.MJ^{-1} (Mohammadi, 2008), for green pepper – 0.21 and 0.09 kg MJ^{-1} (El-Helepi, 1997 p.93), for onion – 0.20 and 0.25 kg.MJ^{-1} (Ibrahim, 2011), etc.

Distribution of energy inputs by type

The total energy inputs, grouped as direct and indirect, renewable and non-renewable are shown in Table 4. The direct energy includes human power, diesel oil, and water for irrigation and indirect include chemicals: pesticides and fertilizers, seedlings, plastic wrapping and machinery. Renewable energy includes human power, seedlings and water for irrigation. Non-renewable energy includes other energy costs.

The direct and indirect energy for growing the new energy efficient variety IZK Iskra constitute 35.80% and 64.20% respectively. Direct energy costs are dominated by fuel costs and indirect costs are formed mainly of fertilizers, machinery and energy plastic wrapping. Like other crops, growing broccoli is based on non-renewable energy that constitutes 89.30% of the total energy used.

The results show a weak dependence of broccoli production on the use of pesticides, but a heavy reliance on the use of chemical fertilizers, diesel oil and machinery. A new approach aiming to optimize the conventional fertilization, application of bioproducts with low energy equivalents and the use of modern agricultural machinery is needed. It is essential for the creation and use of modern energy efficient varieties and hybrids.

Conclusions

The total energy consumption in the production of varieties Coronado F_1 and IZK Iskra was 3570.31 MJ.da^{-1} and 3511.68 MJ.da^{-1} respectively. The largest share of the total energy costs are for diesel oil and machinery (39.65-41.19%), fertilizers (30.14-30.64%), plastic wrapping (9.67-11.34%) and pesticides (7.67-8.28%).

The investigated varieties realize almost the same yield of central flower heads 2094.40 MJ.da^{-1} and 2019.60 MJ.da^{-1} for Coronado F_1 and IZK Iskra respectively. The new variety IZK Iskra realized 1215.50 MJ.da^{-1} higher energy output with the yield of lateral flower heads, which is 209.68% in comparison to the control variety Coronado F_1.

The variety IZK Iskra demonstrates resistance to attack by pests and shorter vegetation period. These qualities allow the energy cost of insecticides and diesel oil to decrease by 20.18% and 12.52% respectively.

The value of energy productivity for IZK Iskra variety is 0.49 kg.MJ^{-1} and leads to a 22.50% increase in comparison to Coronado F_1 variety.

Table 3
Energy parameters

Parameter	Varieties	
	Coronado F_1	IZK Iskra
Total inputs MJ.da^{-1}	3570.31	3511.68
Yield, kg.da^{-1}	1430.00	1730.00 ***
central flower heads	1120.00	1080 ^{ns}
lateral flower heads	310.00	650 ***
Outputs, MJ.da^{-1}	2674.10	3235.10
Energy productivity, kg.MJ^{-1}	0.40	0.49
Energy intensity, MJ.kg^{-1}	2.50	2.03
Output-inputs ratio, R	0.75	0.92

*** significant at $p \leq 0.001$, ns - not significant

Table 4
Energy forms in broccoli production

Varieties	Total energy consumption	Energy forms							
		Direct energy		Indirect energy		Renewable energy		Non-renewable energy	
	MJ.da^{-1}	MJ.da^{-1}	%	MJ.da^{-1}	%	MJ.da^{-1}	%	MJ.da^{-1}	%
Coronado F_1	3570.31	1321.38	37.01	2248.93	62.99	382.96	10.73	3187.35	89.27
IZK Iskra	3511.68	1257.15	35.80	2254.54	64.20	375.59	10.70	3136.10	89.30

References

El-Helepi, M. M., 1997. Energy and Economic Analysis of Pepper Production under Plasticulture and Conventional Systems. National Library of Canada, 124 pp.

Ghorbani, R., F. Mondani, S. Amirmoradi, H. Feizi, S. Khorramdel, M. Teimouri, S, Sanjani, S. Anvarkhah and H. Aghel, 2011. A case study of energy use and economical analysis of irrigated and dry land wheat production systems. *Applied Energy*, **88:** 283-288.

Hamedani, S. R., Z. Shabani and S. Rafiee, 2011. Energy inputs and crop yield relationship in potato production in Hamadan province of Iran. *Energy*, **36:** 2367-2371.

Helsel, Z. R., 1992. Energy and alternatives for fertilizer and pesticide use. In Fluck, R.C. (ed.). Energy in World Agriculture. vol. 6, *Elsevier Science Publishing,* pp. 177-210.

Ibrahim, Y. H., 2011. Energy Use Pattern in Vegetable Production Under Fadama in North Central Nigeria, *Tropical and Subtropical Agroecosystems*, **14** (3): 1019-1024.

Jonge A. M., 2004. Eco-efficiency improvement of a crop protection product: the perspective of the crop protection industry. *Crop Protection*, **23:** 1177-1186.

Lakin, G., 1990. Biometry. High school, Moscow, p. 345 (Ru).

Mihov, M. and G. Antonova, 2009 Energy assessment of monoculture and intercropping growing systems of broccoli. *Proceedings of International conference "Soil tillage and ecology"*, 1-5 September 2009, Albena, Bulgaria, pp. 190-195.

Mihov, M., G. Antonova, S. Masheva and V. Yankova, 2012. Energy Assessment of Conventional and Organic Production of Head Cabbage. *Bulg. J. Agric. Sci*., **18** (3): 320-324.

Mohammadi, A., A. Tabatabaeefar, S. Shahin, S. Rafiee and A. Keyhani, 2008. Energy use and economical analysis of potato production in Iran a case study: Ardabil province, *Energy Convers. Manage.,* **49** (12): 3566-3570.

Moore, S. R., 2010. Energy efficiency in small-scale biointensive organic onion production in Pennsylvania, USA. *Renewable Agriculture and Food Systems*, **25** (3): 181-188.

Singh, H., D. Mishra and N. M. Nahar, 2002. Energy use pattern in production agriculture of a typical village in Arid Zone India - Part I. *Energy Convers. Manage.,* **43** (16): 2275-2286.

Tabatabaie, S. M. H., S. Rafiee and A. Keyhani, 2012. Energy consumption flow and econometric models of two plum cultivars productions in Tehran province of Iran. *Energy*, **44:** 211-216.

Turhan, S., B. Canan and E. Rehber, 2008. A comparison of energy us in organic and conventional tomato production. *J. Food Agric. Environ.,* **6** (3-4): 318-321.

Uhlin, H., 1998. Why energy productivity is increasing: an I–O analysis of Swedish agriculture. *Agricultural Systems*, **56** (4): 443-465.

Yaldiz, O., H. Ozturk, Y. Zeren and A. Bascetincelik, 1993. Energy usage in production of field crops in Turkey. *5-th International Congress on Mechanization and Energy Use in Agriculture,* 11-14 Oct. 1993, Kusadasi, Turkey (Tr).

Received Febraury, 11, 2013; accepted for printing September, 2, 2013.