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RESEARCH ARTICLE

SILAGE CORN PRODUCTION UNDER DIFFERENT PLANTING METHODS IN RAINFED AGRICULTURE SYSTEM: AN ENERGY ANALYSIS

Rana Shahzad Noor[a,b], Fiaz Hussain[b], Muhammad Umair[b], Muhammad Umar Farooq[c], Abu Saad[b], Yong Sun[a*]

[a]Department of Agriculture, Biological, Environment and Energy Engineering, College of Engineering, Northeast Agricultural University, Harbin 150030, China
[b]Faculty of Agricultural Engineering & Technology, PMAS-Arid Agriculture University, Rawalpindi 46300, Pakistan
[c]College of Hydraulic Engineering, Yunnan Agricultural University, Kunming Yunnan, 650204, China
Corresponding Author e-mail:* **sunyong@neau.edu.cn

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ABSTRACT

Energy management in crop production system is an essential component in sustainable agricultural production systems. The aim of study was to evaluate the impact of flat planting (FP), ridge planting (RP) and direct planting (DP) methods under reduced tillage system (RTS) on the energy balances used in silage corn production, planted after winter wheat crop in Potohar region. The study was carried out under complete randomized design (CRD) with three replications at Koont research farm Chakwal, PMAS-Arid Agriculture University, Rawalpindi during 2018 and 2019 crop seasons. Results of this study indicated that the specific energy value of reduced tillage flat planting was calculated as 0.44 MJ-kg^{-1}, ridge planting as 0.40 MJ-kg^{-1}, and direct drilling was calculated as 0.46 MJ-kg^{-1}. Comparing the energy output/input rates, this rate was determined as 9.34 in reduced tillage flat planting, as 10.36 in ridge planting, and as 9.06 in direct drilling. In all methods, it was shown that fertilizer energy had the maximum rate of application among the total input energies. Corn cultivation with ridge sowing is more energy efficient and profitable production technique under rainfed agriculture in Potohar region.

KEYWORDS

silage corn, rainfed-agriculture, planting methods, energy balance.

1. INTRODUCTION

Sustainable agricultural practices have been brought to the agenda in order to protect the natural ecosystem and especially the more sensitive agroecosystem in order to protect soil and increase soil fertility. Sustainable and economical agriculture in the world has started to make radical changes in soil tillage in agriculture in recent years. Depending on these thoughts and changes, protective soil processing, which is an alternative to traditional soil processing, is particularly common in direct cultivation method is becoming widespread (Noor et al., 2019). Protective soil processing is an agricultural practice in which enough vegetation and increments are left in the field to protect water and soil in which energy use and cost are minimized (Mikanová et al., 2009; Noor et al., 2020a). Reduced soil processing, back planting and direct cultivation methods are also included in protective soil processing systems. With the application of back-to-back planting, which is one of the reduced soils processing systems, depending on the product and climate; Benefits such as reduction in labor consumption, increasing soil efficiency, efficient use of water and wind erosion control, increasing plant root depth (Balesdent et al., 2000). Energy analysis related to agricultural production is an important approach in defining and grouping agricultural systems in terms of energy consumption (Dorrell and Vick, 1997).

In the evaluation of an agricultural production project in line with the principles of sustainable agriculture in recent years, the trio of economy, energy and environment are examined together (Noor et al., 2020b). With another opening, the ratio between the energy equivalent of the product in the unit area in any agricultural production arm and the amount of energy spent for production can be used as an indicator and a benchmark value for successful and profitable production, as well as an important value for the effective use of energy today, where environmental sensitivity is rapidly increasing. In addition, the difference between alternative production techniques is an important approach to consider in value-resurrecting, together with the cost per unit area (Erdogan, 2009).

Energy analysis is done to examine whether the production of the product or service, which will be presented to the market, is possible for energy usage effectiveness, although it requires the fulfillment of many economic and technical comprehensive studies (Aslam et al., 2020). In energy analysis, the engineering dimension of the production system comes to the fore. Comparison between input and output energy values in agricultural activities is a more realistic way to asses energy efficient crop production (Devasenapathy et al., 2009).

The energy efficiency values recorded in previous studies for silage corn are 12.6 to 17.5 (Hetz, 1992). Abbas et al., (2020) determined the energy output/input ratio in cotton production in Anatolia region as 2.38, the specific energy value as 10.52 MJ-kg^{-1} while energy productivity values as 0.095 khMJ^{-1}. In our study, the maximum energy inputs were determined in fuel-oil energy with 41.24%, followed by fertilizer energy with a value of 34.63%. Aslam et al. (2020) obtained as 8.26 in back-to-back and 7.90 in direct cultivation. Velmurugan et al. (2020) calculated energy efficiency, specific energy, energy productivity and net energy production as 11.38, 1.63 MJkg^{-1}, 0.61 kgMJ^{-1} and 154391.27 MJha^{-1}, respectively, to produce

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sweet sorgsays crop. Mikanová et al. (2009) measured the total energy in the production of winter rapeseed was 7662.4 $MJha^{-1}$ while total output energy was measured as 68332.1 $MJha^{-1}$ considering only seed yield. Maximum input was determined in fertilizer source with 38.2%, followed by fuel energy with 35.7%. Baran and Elm (2014) calculated the energy efficiency in sunflower production was observed as 3.21, the specific energy was 8.19 $MJkg^{-1}$, net energy production was calculated as 34404.90 $MJha^{-1}$. The irrigation energy with the biggest usage rate of 30.36% followed by fertilizer 28.78% and fuel-oil energy with 24.74% of the total inputs source in the production of sunflower. Baran and Gökdoğan (2014) performed energy analysis of barley production that presented the production energy input 16950.15 $MJha^{-1}$ and output energy 92233.60 $MJha^{-1}$. 59.33% of total inputs energy was chemical fertilizer source, 20.10% consist of diesel fuel, 15.80% seed, 3.67% machine, 0.96% chemical drug and 0.15% of labor power. Energy use efficiency, energy efficiency, specific energy and net energy in barley production were 5.44, 0.25 kg-MJ^{-1}, 2.79 MJ-kg^{-1}, and 75283.45 MJ-ha^{-1} respectively.

In this study, the energy use analysis for the three different planting methods under reduced tillage system in silage corn production was performed to evaluate the most profitable and energy efficient planting method with reduced tillage system under rainfed-agriculture in Potohar region.

2. Materials and Methods

2.1 Study Area Description

The field trails were conducted for two consecutive cultivation years 2018 and 2019 for corn production at the research field of Koont research station Chakwal, PMAS-Arid Agriculture University, Rawalpindi. Research area soil texture was sandy clay loam (56% sand, 22.8% silt, 21.2% clay) with a pH of 7.7.

2.2 Agricultural Machinery used in experiment

A pneumatic precision planting machine with 6 rows of disc legs was used as a transplantation machine planted directly in the parcels. A 4WD-85 hp Al-Ghazi tractor were used in all parcels of the trial. The specifications for the tools and machines utilized in different crop production activities were presented in Table 1.

Table 1: Technical specifications of agricultural machines used in the experiment.

Machine name	Working width (cm)	Working depth (cm)	Average operating speed (kmh^{-1})	Weight (kg)
Disc harrow	290	100-150	-	555
M.B. plow	90	25	-	355
Chisel plow	270	25-40	-	350
Rotavator	214	15	-	585
Pneumatic planter	420	-	5	1300
Direct seeder	420	-	5	1315
4WD Tractor	-	-	-	3011

2.3 Experimental layout

The experiments were conducted under complete randomized design (CRD) with three replications. The total area of 4.5 acres was divided into plots of 0.5 acre.

The soil tillage and planting methods used in this experiment were;

1. Reduced soil tillage flat planting (RT-FP) included M.B. plow (1 pass), disk harrow (2 pass) and planting.
2. Reduced soil tillage ridge planting (RT-RP) included disc harrow (2 pass) and sowing.
3. Direct Seeding (DS)

The trails were conducted at the beginning of May approximately and Pioneer 31 Y43 hybrid corn seed were selected for trail. The planting machine is set to 60 cm between the sequence and the seed range over the queue is 12 cm. During October, DAP fertilizer composing (18-46-0) was buried as base fertilizer, 150 $kgha^{-1}$ and 400 $kgha^{-1}$ urea fertilizer was applied when the plants reached a height of approximately 35-40 cm. A total of 4 irrigations were given to all the parcels in the trial. A total of 2 intermediate anchors were made in the experiment. Herbicide application was made to control weeds in silage corn. Since no harmful worm was seen in the field controls, no insecticide struggle was made. Time consumption (ha h^{-1}) in agricultural activities were measured and used to calculate effective field capacity (EFC) and effective time of work (Tef) (Vaheddoost et al., 2020).

$$A_{job} = 0.10 \times B_g \times V_g \times T_{ef} \quad (1)$$

$$T_{ef} = T_{es} / (T_{es} + T_d + T_k) \quad (2)$$

2.4 Determination of fuel consumption

Fuel consumption for each application was determined by full tank method. Before starting to work, the tractor's fuel tank is fully filled. At the end of the operation, using a scale duplet, the tank was filled again to its first level. The amount of fuel spent by application was determined by the amount of fuel processed (Moinfar et al., 2020; Astill et al., 2020).

2.5 Calculation of crop input-output energy sources

The seed energy input, pharmaceutical energy input, fertilizer energy input, fuel-oil energy input and manpower energy input were obtained through multiplication of equivalent value and input amounts used per unit area. Previous research has been taken to find equivalent values of energy sources. These resources were shown in Table 2. In human labor calculation, planting, spraying, fertilizing and harvesting operations used one driver + one assist, and only one driver in other tractor-driven works.

Machine Energy Input: Machine energy input was calculated by the formula given below (Khan et al., 2018).

$$ME = (W \times E) / (T \times EFC) \quad (3)$$

Here;

ME: Machine energy input ($MJha^{-1}$), W: machine weight (kg), E: Agricultural machine or tool production energy ($MJkg^{-1}$) and T: Economic life span of the tool (h), EFC: Effective field capacity (hah^{-1}).

The output energy per unit area was obtained using equation 4 (Devasenapathy et al., 2009). The output energy equivalent was taken at of 12.95 $MJkg^{-1}$ (Aslam et al., 2020; Fathi et al., 2020). The harvesting processes of silage corn were made during periods when the plant dry matter content was 30-35% (Ren et al., 2020). The energy efficiency indicators used in calculations are given in equations 5-8 (Velmurugan et al., 2020).

$$T_{oe} = (Y_c \times E_{eq}) + (Y_b \times E_{eq\text{-}b}) \quad (4)$$

Here;

T_{oe}: Total energy output ($MJha^{-1}$), Y_c: Main product yield ($kgha^{-1}$), E_{eq}: Energy equivalent of the main product ($MJkg^{-1}$) and $E_{eq\text{-}b}$: The energy equivalent of the by product ($MJkg^{-1}$).

Energy Ratio = Energy Output / Energy Input (5)
Specific Energy ($MJkg^{-1}$) = Total Energy input / Total yield (6)
Energy Productivity ($kgMJ^{-1}$) = Total Yield / Total energy input (7)
Net Energy Production ($MJha^{-1}$) = Total energy Output – Total energy input (8)

Table 2: Energy equivalents for input output crop factor in agricultural production

Energy source	Energy equivalent (MJ/unit)	Literature
Human Workforce (h)	2.3	Ozkan *et al*., 2011
Machine Production Energy (kg)		
Tractor	158.3	Khan et al., 2018
Soil tillage tool	121.3	Khan et al., 2018
Fuel (L)		
Diesel	47.8	Nabavi et al., 2016
Oil	42.5	Mohammadi et al., 2008
Chemical Fertilizers (kg)		
Nitrogen	60.6	Mengistu et al., 2018; Devasenapathy et al., 2009
Phosphorus	11.1	Singh et al., 2008; Devasenapathy et al., 2009; Mengistu et al., 2018
Pharmaceutical (kg)		
Herbicide	269	Pellegrini and Fernández 2018
Seed (kg)	104	Pellegrini and Fernández 2018
Irrigation (m³)	0.63	Ozkan et al., 2011

3. Results and Discussion

The energy equivalents for input-output factors and energy ratio of silage corn production were presented in Table 3. The lowest total input energy was obtained in the DS method (22300.24 MJha^{-1}), on the other side energy values in RT-RP (23715.71 MJha^{-1}) and RT-FP (23750 MJha^{-1}) were found to be close to each other. When the total energy outputs were examined, the highest energy output was obtained with 245594.16 MJ ha^{-1} in the SE method with the highest yield, followed by 221940.21 MJ ha^{-1} and DS method with 201999.28 MJ ha^{-1}.

This study showed that the highest energy output-input ratio was obtained in SE method with 10.36, while this rate was 9.34 in the RT-FP method and 9.06 in the DS method. DS sowing method had lowest total input energy, the reason the energy ratio was low in this method was because the efficiency was less than other methods.

Results showed that the energy balance under three treatments (reduced tillage, ridge sowing and direct sowing) methods in the production of silage maize grown as a second product of wheat-vetch mixture (winter intermediate product) was tried to be determined. As a result of the study, fertilizer energy with the highest share of production inputs in all methods was 13552.50 MJ ha.

In the production of silage corn, which is grown as a second product after the winter intermediate product (wheat-vetch mixture), a saving has been achieved in terms of energy input in the direct cultivation method compared to other methods. However, the efficiency in the direct cultivation method is lower than the efficiency of other methods, the energy value required to produce 1 kg of product was higher than the other methods, and the energy output-input ratio was lower. While the energy output-input ratio was obtained as 10.36 in the RT-RP cultivation method, this ratio was obtained as 9.34 in the reduced tillage cultivation method and 9.06 in the direct cultivation method.

Table 3: Energy balance sheet in silage corn production

Crop factors	RT-FP		RT-RP		DS	
	Land (ha)	Total Energy input (MJha^{-1})	Land (ha)	Total Energy input (MJha^{-1})	Land (ha)	Total Energy input (MJha^{-1})
Human Workforce (h)	**27.64**	**63.57**	**28.57**	**65.71**	**25.70**	**59.11**
Soil tillage	1.94	4.462	2.87	6.60	0.00	0.00
Planting and other operations	23.70	54.51	23.70	54.51	23.70	54.51
Harvesting	2	4.60	2.00	4.60	2.00	4.60
Machine (h)	**21.16**	**1202.08**	**23.02**	**1265.08**	**16.28**	**1099.03**
Tractor	10.08	359.29	11.01	415.44	7.64	317.06
Soil tillage	1.94	48.65	2.87	55.49	0.00	0.00
Planting and other operations	8.14	341.86	8.14	341.86	7.64	329.68
Harvesting	1	452.29	1.00	452.29	1.00	452.29
Fuel + Oil (L)	**79.99**	**3805.49**	**77.90**	**3706.07**	**51.78**	**2463.25**
Soil tillage	29.26	1391.95	27.17	1292.53	0.00	0.00
Planting and other operations	29.83	1419.3	29.83	1419.29	30.88	1469.00
Harvesting	20.90	994.3	20.90	994.25	20.90	994.25
Fertilizers (kg)	**280**	**13552.50**	**280**	**13552.50**	**280**	**13552.50**
Phosphorus (P)	69	765.90	69	765.90	69	765.90
Nitrogen (N)	211	12786.60	211	12786.60	211	12786.60
Chemicals (kg)	**1,25**	**336.25**	**1.25**	**336.25**	**1.25**	**336.25**
Herbicide	1.25	336.25	1.25	336.25	1.25	336.25
Seed (kg)	**29.40**	**3057.60**	**29.40**	**3057.60**	**29.40**	**3057.60**
Irrigation (m^3)	**2750**	**1732.50**	**2750**	**1732.50**	**2750**	**1732.50**
Total Energy input (MJha^{-1})		**23750**		**23715.71**		**22300.24**
B- OUTPUT						
Yield (kg)	53557	221940.208	59265	245594.16	48745	201999.28
Total Energy Output (MJha^{-1})		**221940.21**		**245594.16**		**201999.28**
Energy Ratio		9.34		10.36		9.06
Specific Energy (MJkg^{-1})		0.44		0.40		0.46
Energy Productivity (kgMJ^{-1})		2.26		2.50		2.19
Net Energy Efficiency (MJha^{-1})		198190.21		221878.45		179699.04

5. Conclusion

When all these ratios were taken into consideration, it can be said that the cultivation of the ridge is a more energy efficient and profitable production technique for silage corn cultivation, which is grown in Potohar region after the winter wheat crop.

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Author Contributions

Rana Shahzad Noor contributed in Conceptualization of research study, Design & Development of the experiment, Data collection, Formal Analysis, Investigation, Methodology, Visualization, writing an original draft, reviewed, supervised and Write-up editing. Fiaz Hussain contributed in Data collection, Formal Analysis, Investigation, Methodology, Visualization and Writing an original draft. Muhammad Umar Farooq and Abu Saad contributed in Data collection and data formal analysis. Muhammad Umair contributed to perform formal analysis of this manuscript. Yong Sun supervised the entire research work. Prof. Dr. Yong sun contributed as internal reviewer for the manuscript.

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