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COMPARISON OF ENERGY AND YIELD PARAMETERS IN MAIZE CROP

SHAFIQUE QADIR MEMON[1*], MUHAMMAD SAFAR MIRJAT[2], ABDUL QUADIR MUGHAL[2], NADEEM AMJAD[3] AND KHALIL AHMED IBUPOTO[4]

[1]*Allama Iqbal Open University, Islamabad, Pakistan.*
[2]*Sindh Agriculture University, Tandojam, Pakistan.*
[3]*Pakistan Agricultural Research Council, Islamabad, Pakistan.*
[4]*Pakistan Science Foundation, Islamabad, Pakistan.*

Abstract

The aim of this study was to determine direct and indirect input energy in maize production and to investigate the efficiency of energy consumption in maize crop. Result showed that emergence percent, plant height, number of grains per cob and grain yield were the highest in deep tillage as compared to conventional and zero tillage. Total energy input and output were the highest in deep tillage with NPK @ 150-75-75kg/ha. The net energy gain was found the highest in deep tillage followed by conventional tillage and the lowest net energy gain in zero tillage.

Keywords: Maize production, Deep tillage, Zero tillage

Introduction

Tillage operation and cultivation in farming consist of ploughing, preparing the seed bed, levelling, cultivating, covering the seed, making the irrigation furrows and, sometimes, application of fertiliser. Machines used for these types of operation consist of different kinds of subsoiler, disk harrows, mould-board plough, cultivators, leveller, planters and zero tillage drills. Each of this equipment has to be attached with a tractor and used on farm land to accomplish the operations. Seedbed tillage creates a condition ideal for those seedling emergence, plant development and root growth unimpeded (Licht and Kaisi, 2005). In appropriate tillage practices may inhibit crop growth and yield. Choosing appropriate tillage practices on crop production is very important for optimum growth and yield. Good soil management programme protects the soil from water and wind erosion, provide a good seedbed free of weeds for planting, hardpans breaks or dense layers limit root development and may allow for maintenance or even increase of organic matter (Wright et al., 2008).

Tillage is the most important activity in crop production, but because of fuel supply uncertainty and increasing fuel costs, farmers, agricultural engineers and researchers are facing major challenges to devise new methods to reduce the energy cannot disruption of high yield agricultural production. Therefore, research is needed to explore possible ways and means to enable energy consumption to preserve various tillage practices. Very little attention has been given to energy consumption by farmers in Pakistan; hence, as a result energy consumption in mechanised agriculture is quite high. The shortage of fuel supplies, coupled with rapidly increasing food and fiber demands, has stimulated the development of sustainable mechanised agriculture around the world (Swanton et al., 1996). Maize is third largest grain crop in Pakistan after wheat and rice and accounts for 4.8% of the total cropped area, taking 3.5% of the value of agricultural output. According to PARC Report (2005), about 97% of the total production comes from Punjab and Khyber Pakhtunkhwa. Khyber Pakhtunkhwa accounts for 57% of the total area and 68% of total production, while Punjab contributes 38% acreage with 30% of total maize grain production. During the year 2009-2010 and 2010-2011, maize was planted on an area of 935,000ha and 939,000ha with production of 3,262,000 and 3,341,000 tonnes, respectively, about 2.4% increase in production during 2010-11 was witnessed over the preceding years

***Author for correspondence E-mail: shafiq_qm@yahoo.com**

2009-10 (GOP, 2011). The objectives of tillage are to develop a desirable soil structure or suitable tilt for the optimum growth and yield of the crop (Srivastava et al., 2006). Different tillage practices use different energy which may influence the growth and yield of maize.

Materials and Methods

Experimental site: This study was conducted at the experimental site at National Agriculture Research Centre (NARC), Islamabad, Pakistan, during the Spring season 2009. The site is located at latitude 33°40′ North and longitude $73^0$08′ East. The characteristics of the soil at the experimental site are presented in Table 1. The soil was loamy in texture. Soil pH ranged from 7.80 to 7.85, indicating that the soil was slightly alkaline in reaction. Organic matter content ranged from 0.569 to 1.211%, indicating that enough amount of organic matter was present in upper layer. Lime content ($CaCO_3$) ranged between 5.00-5.6%, indicating that the soil was slightly calcareous. While Nitrate-nitrogen (NO_3-N), available phosphorus and available potassium content ranged from 3.5-6.5mg/kg, 0.513-3.12mg/kg and 55-80mg/kg, respectively. The results indicated that NO_3-N and available phosphorus content was found in lower concentrations, whereas potassium was marginal in the soil.

Table 1. Selected soil physical and chemical properties at the experimental site.

Soil Property	Soil layers (cm)		
	0-15	15-30	30-45
Sand (%)	39	47	35
Silt (%)	41	35	40
Clay (%)	20	18	25
pH	7.85	7.80	7.82
Organic Matter (%)	1.211	0.621	0.569
$CaCO_3$ (%)	5.0	5.5	5.6
NO_3-N (mg/kg)	6.5	4.3	3.5
P (mg/kg)	3.12	2.28	0.513
K (mg/kg)	80	62	55

Experimental Design and Treatment Application: The experimental process was designed to be a randomised complete block design with three tillage methods, viz., deep tillage (subsoiler + mouldboard plough one pass) (DT), conventional tillage (disc harrow + cultivator one pass) (CT) and zero tillage (drill) (ZT). Three fertiliser treatments, (F1) control, (F2) NPK @ 100-50-50 kg/ha, (F3) NPK @150-75-75 kg/ha. Each treatment was replicated three times on a plot measuring 7m × 10m with seeds of maize variety Islamabad Gold dibbled 5cm depth, keeping row-to-row distance of 75cm and a seed to seed distance of 20cm. Maize was sown at seed rate of 25kg/ha and the complete dose of phosphorus, potassium and half dose of nitrogen (N) was applied at the time of sowing. The remaining dose of N was applied in two splits after sowing of maize crop. Furthermore, before first irrigation thinning process was carried out to keep the plants at proper distance, five plants were selected randomly from each plot and tagged. The observations were recorded as emergence percentage, plant height, grains per cob and grain yield. Energy equivalents are shown in Table 2 for estimation. The amounts of inputs used in the production of maize were specified in order to calculate the energy equivalences in the study. Energy input sources were human labour, diesel fuel, chemical fertilisers and seed amounts while output yield include grains of maize.

Data Analyses: All the data was subjected to analysis of variance (ANOVA), using the analysis of variance procedure (Steel and Torrie, 1980). The treatment mean was separated using least significant difference (LSD) at 0.05 level of probability.

Table 2. Energy equivalents of inputs and outputs in maize production

Input	Unit	Energy equivalent MJ/unit	Reference
Human labour	h	2.3	Yaldiz et al., 1990
Fuel (Diesel)	l	47.8	Safa and Tabatabaeefar, 2002
Chemical fertiliser			
Nitrogen	kg	61.53	Pimentel and Pimentel, 1979
Phosphorus	kg	12.56	Pimentel and Pimentel, 1979
Potassium	kg	6.7	Pimentel and Pimentel, 1979
Seed	kg	14.7	Panesar, 2002
Output			
Maize grain	kg	14.7	Panesar, 2002

The direct energy use per hectare for each field operation was computed by the following equation (Moerschner and Gerowitt, 2000):

$$ED = h \times AFU \times PEU \times RU \quad \ldots \quad (1)$$

where,

ED = Specific direct energy use (fuel) for a field operation, MJ/ha.

h = Specific working hours per run, h/ha

AFU = Average fuel use per working hour, L/h

PEU = Specific energy value per liter of fuel, MJ/L

RU = Runs, number of applications in the considered field operation

The indirect energy per unit area for other production inputs such as fertiliser and seed was expressed as,

$$EID = RATE \times MATENF \ldots \quad (2)$$

where

EID = indirect energy input, MJ/ha

RATE = application rate of input, kg/ha

MATENF= energy factor of material used, MJ/kg

The rate of labour used in the maize production process was determined for each operation. The labour energy input (MJ/ha) at every stage in the production process was estimated by the following equation:

$$LABEN = \frac{LABOUR \times TIME \times LABENF}{AREA} \ldots \quad (3)$$

where

LABEN= labour energy, MJ/ha

LABOUR = number of working labourers

TIME = operating time, h

AREA = operating area, ha

LABENF = labour energy factor, MJ/h

Output-input energy ratio, energy productivity, net energy gain and specific energy were calculated (Hatirli et al., 2005; Muhammadi et al., 2008), using the following equations, respectively:

$$\text{input} - \text{output ratio} = \frac{\text{output energy (MJ/ha)}}{\text{input energy (MJ/ha)}} \ldots (4)$$

$$\text{Energy productivity} = \frac{\text{Maize output (kg/ha)}}{\text{Input energy (MJ/ha)}} \ldots (5)$$

$$\text{Specific energy} = \frac{\text{Input energy (MJ/ha)}}{\text{Grain output (kg/ha)}} \ldots (6)$$

$$\text{Net energy grain} = \text{Energy output (MJ/ha)} - \text{Energy input (MJ/ha)} \ldots (7)$$

Results and discussions

Depth, width, fuel consumption, effective field capacity and fuel energy: The results on depth, width, fuel consumption and effective field capacity of implements were recorded. The results revealed that average depth of subsoiler was greater (27.350cm) as compared to mould-board plough (21.333cm), disc harrow (10.867cm) and cultivator (6.917cm), whereas zero tillage drill recorded slightly less depth (4.738cm). The average width of implements was recorded for subsoiler (1.133m), mouldboard plough (1.766m), disc harrow (2.603m), cultivator width (2.800m) and zero tillage drill (1.688m). There was significant difference in all depth and fuel consumption of the implements, which are shown in Table 3. The fuel consumption associated with the different production systems is of great importance, especially to farmers, particularly, during times of fluctuating fuel costs. Fuel consumption may be of prime importance when choosing tillage methods. It was observed that hourly fuel consumption increased with the working depth during ploughing. The results on fuel consumed by various implements during land operation were recorded. The data revealed that subsoiler consumed the highest fuel (24.140 l/ha), followed by mouldboard plough (21.250 l/ha); zero tillage (drill) consumed (13.583 l/ha), disc harrow consumed fuel average (7.660 l/ha) while cultivator consumed lesser fuel (7.520 l/ha). There was a significant difference in all the implements. Values for effective field capacity of subsoiler (0.294ha/h), mouldboard plough (0.318ha/h), disc harrow (0.543ha/h), cultivator (0.505ha/h) and zero tillage (0.376ha/h) were observed. With respective diesel fuel energy consumed in subsoiler (1724.8MJ/ha), mould-board plough (1519.6MJ/ha), disc harrow (585.7

MJ/ha), cultivator (506.5 MJ/ha) and zero tillage (640.1MJ/ha), the results revealed that maximum fuel energy was consumed by subsoiler and the lowest fuel energy was consumed by cultivator.

Table 3. Average depth, width, fuel consumption, effective field capacity and fuel energy of various implements

Implements	Depth (cm)	Width (m)	Fuel Consumption (l/h)	Fuel Consumption (l/ha)	EFC (ha/h)	Fuel Energy (MJ/ha)
Subsoiler	27.350 a	1.133 e	6.966 a	24.140 a	0.294	1724.8
Mould Board Plough	21.333 b	1.766 c	6.693 b	21.250 b	0.318	1519.6
Disc Harrow	10.867 c	2.603 b	4.018 d	7.660d	0.543	585.7
Cultivator	6.917 d	2.800 a	3.771e	7.520 d	0.505	506.5
Zero-Tillage	4.738e	1.688d	5.171c	13.583c	0.376	640.1
*SE	0.1803	0.0232	0.0509	0.0779	--	--
**LSD	0.4121	0.0483	0.1625	0.1625	--	--

*SE. Standard Error ** LSD. Least Significant Difference

Yield: The field experiment was performed in order to evaluate the productivity of each tillage methods and to relate it to the energy consumption. The mean yield results are shown in Table 4. The analysis of variance for emergence (%), plant height (cm), number of grains per cob and grain yield (kg/ha) in different tillage methods with the application of fertilisers were used. The results revealed a significant increase in emergence (90%), plant height (189.00cm), number of grains per cob (367.33) and grain yield (6110.00kg/ha), which was the highest in deep tillage with the application of fertiliser NPK @ 150-75-75kg/ha as compared to conventional tillage, while the lowest in zero tillage. These results are compared with finding of Arora et al. (1991), purporting that deep tillage is beneficial for maize. Kersten and Hack (1991) observed that best results could be achieved by ploughing against no till cultivation. However, the lower emergence percentage, plant height, number of grains per cob and grain yield was observed in NPK @ 100-50-50kg/ha and the lowest was observed in control plots, where no fertiliser was applied. These results were in accordance with findings of the response to higher levels of nitrogen of Akbar et al. (2002), Mitchell and Tu (2005) and Rasheed et al. (2004).

Table 4. Effect of tillage methods and fertiliser on maize yield

Fertilisers	Tillage methods	Emergence (%)	Plant height (cm)	Number of grain (per cob)	Grain yield (kg/ha)
Control	Deep tillage	79 d	155f	153 e	3119 f
	Conventional Tillage	78 de	153g	141 f	2732 g
	Zero tillage	77 e	150h	131 g	2321 h
NPK @ 100-50-50 (kg/ha)	Deep tillage	88 ab	176c	354 b	5180 c
	Conventional Tillage	87 b	172d	345 c	4775 d
	Zero tillage	84 c	168e	333 d	4251 e
NPK @ 150-75-75 (kg/ha)	Deep tillage	90 a	189 a	367 a	6110 a
	Conventional Tillage	89a	186b	360 b	5653 b
	Zero tillage	85 c	178c	345 c	5135 c
SE		0.8958	0.8607	2.7532	55.550
LSD		1.8990	1.8245	5.8366	117.76

Input-output energy use: The input and output energy values used in maize production are illustrated in Table 5a. Total input energy was observed in maize plots which were located high in deep tillage (14837.9MJ/ha), where fertiliser was applied with NPK @ 150-75-75 kg/ha followed by conventional tillage (12685.7MJ/ha) and zero tillage (12049MJ/ha) as compared to NPK @ 100-50-50 kg/ha. The lowest input energy was found in control plots, where no fertiliser was applied. The results indicated that higher output energy was obtained in deep tillage (89817.0MJ/ha), where fertiliser was applied with NPK @ 150-75-75 kg/ha, followed by conventional tillage (83109.39MJ/ha) and zero tillage (75494.79MJ/ha) as compared to NPK @ 100-50-50 kg/ha. However, the lowest output energy was obtained in control plots, where no fertiliser was applied. The net energy was found maximum in deep tillage (74979.1MJ/ha), followed by conventional tillage (70243.7MJ/ha) and the lowest net energy gain in zero tillage (63445.2MJ/ha), as shown in Table 5b.

Table 5a. Energy output/input relationship for Spring maize crop production

Input energy (MJ/ha)	DT	CT	ZT
Human labour (MJ/h)			
Sowing	184	184	---
Harvesting	368	368	368
Diesel (MJ/ha)			
Subsoiler	1724.8	---	---
Mouldboard plough	1519.6	---	---
Disc harrow	---	585.7	---
Cultivator	---	506.5	---
Zero tillage (drill)	---	---	640.1
Fertiliser (kg)			
0-0-0 NPK kg/ha	---	---	---
100-50-50 NPK kg/ha	7116	7116	7116
150-75-75 NPK kg/ha	10674	10674	10674
Seed (MJ/ha)	367.5	367.5	367.5
Total input energy (MJ/ha)			
0-0-0 NPK kg/ha	4163.9	2011.7	1375.6
100-50-50 NPK kg/ha	11279.9	9127.7	8491.6
150-75-75 NPK kg/ha	14837.9	12685.7	12049.6
Output energy grain (MJ/ha)			
0-0-0 NPK kg/ha	45849.3	40160.4	34123.11
100-50-50 NPK kg/ha	76150.41	70202.79	62494.11
150-75-75 NPK kg/ha	89817.0	83109.39	75494.79

Table 5b. Energy output/input relationship for Spring maize production

Output/input ratio			
0-0-0 NPK kg/ha	11.0	20.0	24.8
100-50-50 NPK kg/ha	6.8	7.7	7.4
150-75-75 NPK kg/ha	6.1	6.6	6.3
Specific energy (MJ/kg)			
0-0-0 NPK kg/ha	1.34	0.74	0.59
100-50-50 NPK kg/ha	2.18	1.91	2.00
150-75-75 NPK kg/ha	2.43	2.24	2.35

Contd…

Concld…

Energy productivity (kg/MJ)			
0-0-0 NPK kg/ha	**0.75**	**1.36**	**1.69**
100-50-50 NPK kg/ha	**0.46**	**0.52**	**0.50**
150-75-75 NPK kg/ha	**0.41**	**0.45**	**0.43**
Net energy gain (MJ/ha)			
0-0-0 NPK kg/ha	**41685.4**	**38148.7**	**32747.5**
100-50-50 NPK kg/ha	**64870.5**	**61075.1**	**54002.5**
150-75-75 NPK kg/ha	**74979.1**	**70423.7**	**63445.2**

Conclusion: Different tillage methods were evaluated on the basis of emergence, plant height, number of grain per cob and grain yield components of maize crop. Deep tillage followed by conventional tillage had the maximum emergence; the tallest plants produced the highest number of grains per cob and grain yield. Zero tillage treatment gave the lowest emergence percent and number of grains per cob with small plant height which ultimately resulted in the lowest yields under this treatment. It was concluded that NPK @ 150-75-75 kg/ha gave more grain yield in deep tillage against conventional tillage and low grain yield recorded zero tillage. Deep tillage used high energy as compared to conventional and zero tillage. For farmers looking for low-budget solutions, conventional tillage can be recommended to grow maize crop successfully on the basis of energy input-output.

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