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Energy Requirement under Different Tillage Treatments and their Impact on Plant Yield Parameters

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Abstract:

The aims of this study were to determine direct input energy and indirect energy in maize production, to evaluate the inputs energy consumption and outputs energy gained for maize production in Islamabad, Pakistan. Result showed that plant height, grains per cob, 1000 grain weight and grain yield were maximum at deep tillage as compared to conventional and zero tillage. Comparing the seasons 2009-2010 the overall better plant height, grains per cob, 1000 grain weight and grain yield were gained during autumn season as compared to spring season due to its residual effect and supplemental fertilizer. The methodology used in the calculation of energy use was broken down into inputs and outputs with the total energy, inputs energy being the sum of all components of energy used in the production of the outputs. Total energy input were maximum with organic fertilizer as compared to inorganic fertilizer, net energy gain were found maximum in inorganic fertilizer as compared to organic fertilizer.

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Key words: Maize, Net Energy, Input-Output Energy, Yield.

Introduction

Energy, economics, and the environment are mutually dependent (Pimentel *et al*, 1994). There is a close relationship between the agriculture and energy. While agriculture uses energy, it also supplies it in the form of bio-energy. At the present time, the productivity and profitability of agriculture depends on energy consumption. Energy demand in agriculture can be separated into direct and indirect energies. Energy inputs comprise the sun and support energy. Direct carry energy is required for land preparation, irrigation, harvest, post-harvest processing, and the transportation of agricultural inputs and outputs. Energy used indirect support in the form of fertilizers and pesticides. The amount of energy used on the level of mechanization, agricultural work quantity of active and cultivable land (Alam *et al*, 2005 and Ozkan *et al*, 2004). In all production systems, increasing the productivity ratio is a main concern. Tillage can be defined as a modification of soil structure resulting from the operation of mechanized implements. The work involves large amounts of energy to break down and inversion layers of soil, clod size reduction, and aggregates reset. Implementation requires action on the soil of the direct energy consumption, mainly fuel, transformed into mechanical energy by a tractor engine. In the cultivation of arable crops, soil tillage is one of the greatest energy and labor consumers. Primary tillage practices require 75% of the total energy consumed before seed-time (Pelizzi *et al*, 1988). Therefore, the selection of an appropriate tillage method includes assessments of the system's energy conservation and environmental pollution control.

Many developing countries strive for an increase of their agriculture production in order to feed the rapidly growing population. Maize is most important cereal crop of the world. It is used for three main purposes as human food, feed for poultry and livestock. Maize being the highest yielding cereal crop in the world is of significant importance for countries like Pakistan, where rapidly increasing population has already out stripped the available food supplies. In Pakistan maize is third important cereal after wheat and rice and 89 % of the crop is grown in Punjab and Khyber Pakhtunkhwa Province. Pakistan grows maize on about 1.11 million hectares with annual production of 4.04 million tons of grain and average yield of 3.62 t ha^{-1} (GOP, 2009). The aims of this study were to determine direct input energy and indirect energy in maize production, to investigate the efficiency of energy consumption.

Materials and Methods

Experimental Design and Treatment Applications: Keeping in view the objectives of the study, the experiment was conducted using randomized complete block design (RCBD) with three replications during spring and autumn season 2009-2010. Plots were divided into sub plots measuring equally to 7 m x 10 m, one-meter path left between each plots. The ploughing of soil was performed with deep tillage (sub-soiler + Mould board plow one pass), conventional tillage (disc harrow + cultivator), and zero-tillage (drill), with fertilizer rates of control, 10000 kg ha^{-1} FYM, 150-75-75 NPK kg ha^{-1} and 150-75-75 NPK kg ha^{-1} + 10000 kg ha^{-1} FYM. During spring sown maize the full doze of fertilizer was applied while in autumn sown maize half dose of fertilizer was applied. Seeds of a maize variety Islamabad Gold were dibbled 5 cm depth, keeping row to row distance 75 cm and seed to seed distance 20 cm. Maize was sown at the rate of 25 kg ha^{-1} and the complete dose of NPK was applied at the time of sowing. The remaining dose of N was applied in two splits; the farm yard manure was also applied before sowing of maize crop. Furthermore, before first irrigation thinning process was applied to keep the plants at proper distance, five plants were selected randomly from each plot and tagged. The agronomic observations were recorded, plant height (cm), 1000-grain weight (g), number of seed cob^{-1} and grain yield (kg ha^{-1}). Energy equivalents shown in Table.1 were used for estimation. The amounts of inputs used in the production of maize were specified in order to calculate the energy equivalences in the study. An energy input includes human labor, diesel fuel, chemical fertilizer, farm yard manure and seed amounts and output yield include grain of maize. The data were statistically analyzed to see the significance difference among various levels of organic and inorganic fertilizer. All the data were subject to analysis of variance (ANOVA) using the analysis of variance procedure (Steel and Torri, 1980). The treatment mean separated using least significant difference (LSD) at 0.05 level of probability.

Description of the Study Location: This study was conducted at the experimental site in National Agriculture Research Center (NARC), Islamabad, Pakistan, in spring and autumn season 2009. The site is located at Latitude 33^0 40′ North and Longitude 73^0 08′ East.

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

$$ED = h \times AFU \times PEU \times RU \qquad 1$$

where:

ED = Specific direct energy use (fuel) for a field operation, MJ ha^{-1}.

h = Specific working hours per run, h ha^{-1}

AFU = Average fuel use per working hour, L h^{-1}

PEU = Specific energy value per litre of fuel, MJ L^{-1}

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

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

$$EID = RATE \times MATENF \qquad 2$$

where:

EID = indirect energy input, MJ ha^{-1}
RATE = application rate of input, kg ha^{-1}
MATENF = energy factor of material used, $MJkg^{-1}$

The rate of labour use in the maize production process was determined for each operation. The labour energy input (MJ ha^{1}) at every stage in the production process was estimated by the following equation:

$$LABEN = \frac{LABOUR \times TIME \times LABENF}{AREA} \qquad 3$$

where:

LABEN= labour energy, MJ ha^{-1}
LABOUR = number of working labourers
TIME = operating time, h
AREA = operating area, ha
LABENF = labour energy factor, MJ h^{-1}

Net energy gain was calculated by the following equation: (Hatirli, 2005 and Mohammadi, 2008).

$$Net\ energy\ gain = Energy\ output\ (MJ/ha) - Energy\ input\ (MJ/ha) \qquad 4$$

Results and Discussions

Plant height (cm)

The effect of tillage as well as fertilizer levels on plant height was recorded maximum in deep tillage as compared to conventional tillage and zero tillage. Gill *et al* (1996) observed that greater plant height in case of deep tillage. The plant height was higher in the autumn growing season than spring season. In spring season the maximum increase in plant height (190 cm) was recorded in deep tillage that received NPK + FYM followed by conventional tillage (187 cm) and zero tillage (178 cm). During autumn season a maximum plant height (195 cm) was recorded in deep tillage after application of ½ NPK + ½ FYM, followed by (192 cm and 170 cm) plant height after application of ½ NPK and ½ FYM alone respectively. The minimum plant height (155 cm and 160 cm) was recorded in control plots during both seasons (Fig 1). The increase in plant height in response to higher levels of nitrogen has been confirmed by the previous finding of (Akbar *et al*, 2002 and Rasheed *et al.,* 2004).

Grains cob^{-1}

The results showed an increase in number of grain per cob among all fertilizer treatments in deep tillage except zero tillage during both the seasons (Fig 2). But generally, application of NPK + FYM produced maximum number of grain per cob in deep tillage (377) followed by conventional tillage (370) and zero tillage (350) during spring season 2009-2010. During autumn season the maximum number of grain per cob (390) was recorded in deep tillage after application of ½ NPK + ½ FYM, followed by (375) number of grain per cob after application of ½ NPK alone. The minimum number of grain per cob (153 and 165) was appeared in control plots during both seasons. These results on in line with Rowe and Johnson (1995) who reported more grain per spike under high level of nitrogen applied.

1000-grain weight (g)

It is evident from (Fig 3) that significant differences in 1000-grain weight were recorded in various tillage methods; the higher 1000-grain weight was found in deep tillage (248 g) followed by conventional tillage (241 g) and minimum was recorded in zero tillage (236 g) with the application of NPK + FYM during spring season 2009-2010. During autumn season 2009-2010 maximum 1000-grain weight was recorded in deep tillage (260 g) after application of ½ NPK + ½ FYM followed by conventional tillage (247 g) and zero tillage (241 g). The minimum 1000-grain weight (156 g and 160 g) was appeared in control plots during both seasons. If we compare the season, overall better 1000-grain weight was gained during autumn season as compared to spring season. This might be due to its residual effect and supplemental fertilizer application. These results are in confirmation with the finding of Khaliq *et al* (2004) who observed that the use of fertilizer and organic manure gave maximum 1000-grain weight in case of maize.

Grain yield (kg ha^{-1})

The effect of tillage practice on maize grain yield is presented in (Fig. 4). Analysis of variance showed significant difference in maize grain yield between the different tillage practices over the period of the experiment, the highest grain yield was found in the deep tillage (6116 kg ha^{-1}) followed by conventional tillage (5660 kg ha^{-1}) plots, while the lowest grain yield was observed with zero tillage (5141 kg ha^{-1}) plots with the application of NPK + FYM during spring season 2009-2010. During autumn season 2009-2010 maximum grain yield was recorded in deep tillage (6832 kg ha^{-1}) after application of ½ NPK + ½ FYM followed by conventional tillage (6416 kg ha^{-1}) and zero tillage (6345 kg ha^{-1}). The minimum grain yield (3119 kg ha^{-1} and 3286 kg ha^{-1}) was appeared in control plots during both seasons. If we compare the season, overall better grain yield was gained during autumn season as compared to spring season. This might be due to its residual effect and supplemental fertilizer application. These results are in agreement with studies made by other authors Shata *et al*

(2007), Sial *et al* (2007), Adeniyan and Ojeniyi (2005) who reported that application of chemical and organic manure improved maize grain yield.

The energy inputs/outputs

This study evaluated the energy inputs and outputs maize yield parameters for different tillage system, the methodology used in the calculation of energy use was broken down into inputs and outputs with the total energy, inputs energy being the sum of all components of energy used in the production of the outputs (Table 2). The results revealed that total input energy consumed for maize production was higher in deep tillage (52837.9 MJ ha^{-1}) followed by conventional tillage (50685.7 MJ ha^{-1}) and zero tillage (50049.6 MJ ha^{-1}) with the application of NPK + FYM during spring season, whereas NPK and FYM alone consumed minimum input energy and lowest in control plots where no fertilizer was applied. During autumn season low input energy consumed due to half fertilizer was applied. The inputs energy was higher in spring season than autumn season. The output energy values recorded in maize production revealed that output energy for maize production was higher in deep tillage (89905.2 MJ ha^{-1}) followed by conventional tillage (83202 MJ ha^{-1}) and low output energy by zero tillage (75577.11 MJ ha^{-1}) with the application of NPK + FYM . The comparison between both seasons the output energy was maximum gain in deep tillage (100430.4 MJ ha^{-1}) followed by conventional tillage (94319.61 MJ ha^{-1}) and low output energy gain in zero tillage (93271.5 MJ ha^{-1}) with the application of ½ NPK + ½ FYM followed by ½ NPK and ½ FYM whereas lowest in control plots where no fertilizer was applied. The output energy values gain highest in deep tillage as compared to conventional tillage and zero tillage in both growing seasons. The net energy gain of maize production was maximum by application of NPK fertilizer alone, as compared to NPK + FYM, FYM and control in both seasons.

Conclusion

It was concluded that plant height, number of grain per cob, 1000-grain weight and maize grain yield maximum in deep tillage followed by conventional tillage and zero tillage. However, higher values for plant height, number of grain per cob, 1000-grain weight and grain yield were recorded in those plots treated with combined NPK + FYM. Net energy gained maximum in NPK alone followed by NPK + FYM, FYM and control.

Table 1: Energy equivalents of inputs and outputs in maize production

Input	Unit	Energy equivalent MJ/Unit	Reference
Human labor	hour	2.3	Yaldiz *et al.* 1990
Fuel (Diesel)	liter	47.8	Safa *et al.* 2002
Chemical fertilizer	kg		
Nitrogen		61.53	Pimental, 1979
Phosphorus		12.56	Pimental, 1979
Potassium		6.7	Pimental, 1979
Cow manure	kg	3.8	Green, 1987
Seed	kg	14.7	Panesar, B.S. 2002
Output			
Maize grain	kg	14.7	Panesar, B.S. 2002

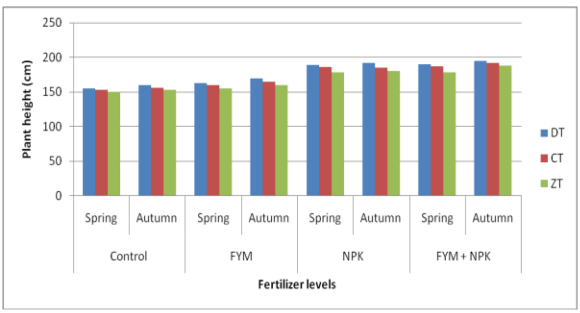

Fig 1: Effect of tillage practice, chemical fertilizer and farmyard manure on plant height (cm)

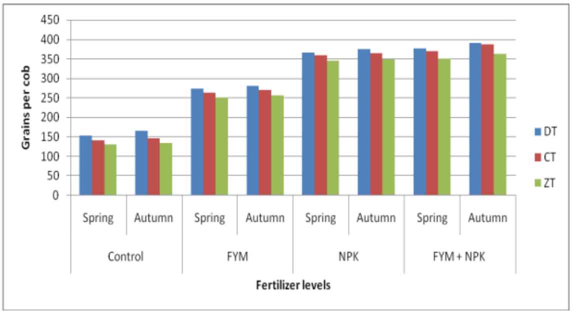

Fig 2: Effect of tillage practice, chemical fertilizer and farmyard manure on grains per cob

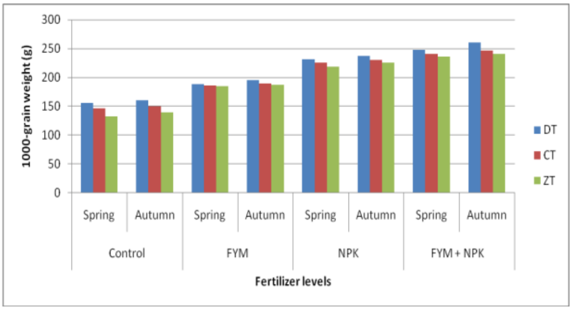

Fig 3: Effect of tillage practice, chemical fertilizer and farmyard manure on 1000-grain weight (g)

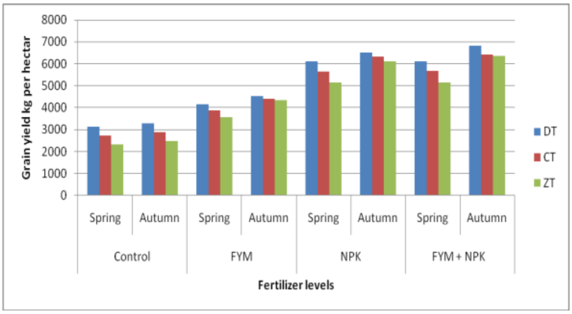

Fig 4: Effect of tillage practice, chemical fertilizer and farmyard manure on grain yield (kg ha^{-1})

Table 2: The energy inputs/outputs for spring and autumn 2009-2010 sown maize

Input energy (MJ ha^{-1})	Deep Tillage (DT)		Conventional Tillage (CT)		Zero Tillage (ZT)	
	Spring	Autumn	Spring	Autumn	Spring	Autumn
Human labour (MJ ha^{-1})						
Sowing	184	184	184	184	----	----
Harvesting	368	368	368	368	368	368
Diesel (MJ ha^{-1})						
Subsoiler	1724.8	1749.5	----	----	----	----
M.B. Plow	1519.6	1432.4	----	----	----	----
Disc harrow	----	----	585.7	578.3	----	----
Cultivator	----	----	506.5	530.6	----	----
Zero tillage	----	----	----	----	640.1	674.7
Fertilizer (kg)						
Control	----	----	----	----	----	----
FYM	38000	19000	38000	19000	38000	19000
NPK	10674	5337	10674	5337	10674	5337
FYM + NPK	48674	24337	48674	24337	48674	24337
Seed (MJ ha^{-1})	367.5	367.5	367.5	367.5	367.5	367.5
Total input energy (MJ ha^{-1})						
Control	4163.9	4101.4	2011.7	2028.4	1375.6	1410.2
FYM	42163.9	23101.4	40011.7	21028.4	39375.6	20410.2
NPK	14837.9	9438.4	12685.7	7365.4	12049.6	6747.2
FYM + NPK	52837.9	28438.4	50685.7	26365.4	50049.6	25747.2
Output energy (MJ ha^{-1})						
Control	45849.3	48304.2	40160.4	42522.6	34123.11	36558.9
FYM	61294.59	66429.3	56943.39	64827	52562.79	63606.9
NPK	89817.0	95780.7	83109.39	92904	75494.79	89890.5
FYM + NPK	89905.2	100430.4	83202.0	94319.61	75577.11	93271.5
Net energy gain (MJ						

ha-1)						
Control	41685.4	44202.8	38148.7	40494.29	32747.5	35148.7
FYM	19130.7	43327.9	16931.7	43798.6	13187.2	43196.7
NPK	74979.1	86342.39	70423.7	85538.6	63445.2	83143.3
FYM + NPK	37067.3	71992	32516.3	67954.21	25527.5	67524.3

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