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EVALUATING ENERGY CONSUMPTION FOR WHEAT PRODUCTION UNDER DIFFERENT TILLAGE PRACTICES

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ABSTRACT

The choice of right tillage practice is very important for sustainable and economic wheat production. This two-year consecutive (Rabi 2008 and 2009) field study was planned to evaluate the energy consumption for wheat production under different tillage practices. The experiment was laid out in a randomized complete block design on an area of 5400 m^2 (60 m × 90 m). There were three treatments, i.e. T_1: Conventional tillage (CT), T_2: Reduced tillage (RT) and T_3: No-tillage (NT). Each treatment was replicated three times. The results revealed that the speed of operation was maximum (5.51 and 5.56 km hr^{-1}) under CT, followed by RT (5.23 and 5.25 km hr^{-1}) and NT (4.1 and 4.14 km hr^{-1}). Furthermore, the effective field capacity was maximum under CT system (0.48 and 0.49 ha hr^{-1}), followed by NT (0.45 and 0.47 ha hr^{-1}) and lowest under RT (0.30 and 0.32 ha hr^{-1}). Similarly, the power requirement without load and with load was highest under CT (255 and 2077 kg), followed by RT (238 and 1572 kg) and NT (198 and 1270 kg). Likewise, the energy requirement was highest in CT system (33 and 34 KW-hr ha^{-1}), followed by RT (23 and 22 KW-hr ha^{-1}) and NT (14 and 13 KW-hr ha^{-1}). Moreover, the fuel consumption was highest under CT (27.0 and 26.33 Lit ha^{-1}), followed by the RT system (22.33 and 20.66 Lit ha^{-1}) and NT practice (12.33 and 11.0 Lit ha^{-1}). The study concluded that reduced tillage practice is more energy-efficient than conventional tillage practice for sustainable wheat production.

Keywords: Energy consumption, wheat, tillage practices.

INTRODUCTION

In Pakistan and elsewhere, the tillage operations are carried out to modify or alter the top surface of the soil. The surface is plowed and the hard pan is broken into small aggregates. Generally, soil structure is loosened using conventional tillage

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practices (Abu and Abubakar, 2013). These practices are carried out using different implements such as Moldboard Plow, Disc Plow, Rotary Tiller, Disc Harrow, Cultivator, etc. Researchers believe that the loosening of the soil to deeper depths encourages root development, better moisture conservation and weed control (Feng *et al*., 2010). Deep plowing loosens the field to greater depths that expedites the water infiltration and enhances root penetration by reducing compaction. It increases nutrient availability as the nutrient move upward from the B-horizon due to oxidation and releases nutrients from the soil minerals. The use of tillage implements depends on soil type, soil surface condition, vegetative growth, depth of cultivation required and crop to be grown (Campbell *et al*., 1988).

The conventional tillage transforms the properties of soil that conserves soil moisture (Putte *et al*., 2010; Jin *et al*., 2011); enhances the carbon amount in soil as well as enhances the microbial biomass in the topsoil (Babujia *et al*., 2010); decreases the soil temperature in tropical regions and improves biodiversity of soil (Adl *et al*., 2005). With the increase of organic contents in top layer of soil, its fertility and productive capability improves that in turn results in greater yields and plant health (Chandio *et al*., 2012).

Several types of conservation tillage such as minimum tillage, incomplete tillage, reduced tillage, no tillage, etc. are practiced across the world. According to data gathered by the Conservation Technology Information Center (2004) about 40.7% of total crop land on 45.44 million hectares was under conservation tillage systems, of that, zero tillage and strip tillage were used on about 23.6% of land in the United States. However, the implementation of this practice is based on soil properties including type, compaction, retention power of moisture and other factors.

The consumption of energy under conventional system is always more than other modern systems of tillage (Forristal, 2008; Stajnko *et al*., 2009; Kumara *et al*., 2013). Peruzzi *et al*. (1998) reported that no-tillage system, and particularly the reduced tillage system using the combine, was more efficient, in terms of working time, fuel consumption, energy requirement and planting cost as compared to the plowing system. Filipović *et al*. (2004) and Lithourgidisa *et al.* (2006) concluded that about 53% savings in fuel consumption cane be achieved with minimum tillage, while, 48% with reduced tillage in comparison with conventional tillage. This study was planned to evaluate the energy consumption for wheat production under different tillage practices.

MATERIALS AND METHODS

The field study was conducted at the Latif Experimental Farm of Sindh Agriculture University Tandojam (25.42° latitude and 68.53° longitude) during Rabi 2008-9 and 2009-10. The experiment was laid out in a randomized complete block design (RCBD) on an area of 5400 m^2 (60 m × 90 m). There were three treatments, i.e. T_1: Conventional tillage, T_2: Reduced tillage and T_3: No-tillage. Each treatment was replicated three times.

Conventional tillage (CT) was performed using a combination of moldboard plow and cultivator, while the reduced tillage was comprised of regular double action disc harrow operated twice, and no tillage, as the word explains, includes no tillage operation except the drilling or planting of seeds. In the conventional tillage, plots were plowed down to a depth of 25 cm and crop was sown using a mechanical drill. In the reduced tillage plots, disc harrow was used to till them to a depth of 15 cm. The plowing was performed using disc harrow with double pass in each plot and crop was sown, whereas, under in no tillage treatment plots, direct seeding was done during both study years.

The weeds were controlled manually and all other agronomic treatments were kept uniform in each plot. The wheat variety TD-1, was sown at the row spacing of 0.15 m with a seed rate of 125 kg ha^{-1}. This allowed 40 rows in each unit under each replication. The outer 5 rows in each replication were used as buffer between plots. Harvesting was done manually from each plot on March 30, 2009 and April 03, 2010.

To measure the speed of operation, outside the long boundary of the test plot, two poles (A and B), 10 meters apart were, placed approximately in the middle of the test run. On the opposite side, two other poles (C and D), 10 meters apart, were placed in a similar position so that all four poles formed corners of a rectangle (ABCD) in a test plot. The speed was calculated from the time required for a tractor and implement to cover the distance of 20 meters between the starting line marked by connecting two (AB) poles and final line connecting two (CD) poles. The stop watch was used to record the time taken by tractor and implement during this operation. To measure the fuel consumption, the fuel tank of Massey Ferguson-375 diesel tractor was filled up to top level before the start of each test under a given treatment in each test plot. The fuel tank of the tractor was refilled up to the same level with 1000 millimeters graduated cylinder. The measurements were replicated for each treatment and fuel consumption was noted. The fuel consumption on per hour and per hectare basis was calculated from the data obtained.

The effects of tillage treatments on the various parameters were evaluated by ANOVA using the SAS statistical software (SAS institute 2004). When F-values were significant, the least significant difference (LSD) test was used for comparing treatment means. In all cases, differences were considered to be significant if $p < 0.05$.

RESULTS

Speed of operation

The speed was significantly affected by tillage treatments (Table 1). Speed of operation (5.51 and 5.56 km hr^{-1}) was maximum under conventional tillage, while it reduced to 5.23 and 5.25 km hr^{-1} under reduced tillage and minimum speed of operation (i.e. 4.10 and 4.14 km hr^{-1}) was noted under no tillage treatment, during 2008 and 2009, respectively. There was significant linear response in speed of operation under various tillage treatments during both study years; while the quadratic response in speed of operation to tillage treatments was non-significant for 2008 and significant for the 2009. The year wise comparison indicates that during 2009 the speed of operation was slightly higher than 2008. The differences in speed of operation between conventional and reduced tillage treatments during 2008 were non-significant and significant for no tillage treatments. The significant differences in speed of operation were observed between tillage treatments during 2009.

Table 1. Speed of operation and effective field capacity under various tillage treatments.

Tillage treatments	Speed of operation (km hr^{-1})		Effective field capacity (ha hr^{-1})	
	Year		Year	
	2008	2009	2008	2009
T_1 (Conventional tillage)	5.51 a	5.56 a	0.48 a	0.49 a
T_2 (Reduced tillage)	5.23 a	5.25 b	0.30 b	0.32 b
T_3 (No-tillage)	4.10 b	4.14 c	0.45 a	0.47 a
LSD	0.56	0.13	0.08	0.03

Table 2. Power requirements (kg) without and with load under tillage treatments during 2008 and 2009.

Tillage treatments	Year			
	2008		2009	
	Power without load	Power with load	Power without load	Power with load
T_1 (Conventional tillage)	255 a	2077 a	251 a	2010 a
T_2 (Reduced tillage)	238 b	1572 b	234 b	1557 b
T_3 (No-tillage)	198 c	1270 c	194 c	1238 c
LSD	8.12	166	4.03	70

Effective field capacity

The tillage treatments had significant effect on effective field capacity during both study years (Table 1). The effective field capacity was slightly higher (i.e. 0.48 and 0.49 ha hr^{-1}) under conventional tillage as compared to no tillage treatment during 2008 and 2009, respectively. However, under reduced tillage, the effective field capacity was significantly low (i.e. 0.30 and 0.32 ha hr^{-1}) for 2008 and 2009, respectively. There was non-significant linear response in effective field capacity to various tillage treatments during both years; while the quadratic response of effective field capacity to tillage treatments was significant. The comparison between years indicates that during 2009 the effective field capacity was slightly higher than 2008. The differences in effective field capacity between conventional tillage and no tillage treatments during both the years were non-significant while the differences were significant under reduced tillage treatments.

Power requirement without and with load

Three tillage treatments were significantly different in power requirement during two wheat growing seasons (Table 2). During 2008, conventional tillage required 255 kg, followed by reduced tillage which required 238 kg, while no tillage required 198 kg without applying load. Whereas, 2077, 1572, and 1270 kg were required under conventional tillage, reduced tillage, and no tillage, respectively with the application of load. Similarly during 2009, conventional tillage required 251 kg, followed by reduced tillage which required 234 kg, while no tillage required 194 kg without load application. Whereas, 2010, 1557, and 1238 kg were required under conventional tillage, reduced tillage, and no tillage, respectively with load. There was non-significant linear response in power requirements with and without load under various tillage treatments during both the years; while the quadratic response in power requirement without load under tillage treatments was significant for 2008 and 2009 and non-significant with load during both the years.

Energy requirement

Tillage treatments had significant effect on energy requirement during both the seasons (Table 3). The highest energy (i.e. 34 and 33 KW-hr ha^{-1}) was required under conventional tillage during 2008 and 2009, respectively. Whereas energy requirement decreased under reduced tillage where 23 and 22 KW-hr ha^{-1} were used while, no tillage consumed minimum energy i.e. 14 and 13 KW-hr ha^{-1} during 2008 and 2009, respectively. A significant linear response in energy requirement between tillage treatments was recorded during both the seasons; while the quadratic response in energy required treatments was non-significant during both the seasons. The seasonal comparison suggested that slightly higher energy was required during 2008 as compared to 2009.

Table 3. Energy requirement and fuel consumption (Lit ha^{-1}) under various tillage treatments during two wheat cropping seasons.

Tillage treatments	Energy requirement (KW-hr ha^{-1})		Fuel consumption (Lit ha^{-1})	
	Year		Year	
	2008	2009	2008	2009
T_1 (Conventional tillage)	34 a	33 a	27.00 a	26.33 a
T_2 (Reduced tillage)	23 b	22 b	22.33 b	20.66 b
T_3 (No-tillage)	14 c	13 c	12.33 c	11.00 c
LSD	6.25	4.03	4.60	3.46

Fuel consumption

The results showed significant impact on fuel consumption between tillage treatments during both the wheat seasons (Table 3). During 2008 and 2009, the highest fuel consumption (i.e. 27.00 and 26.33 Lit ha^{-1}) was recorded under conventional tillage, whereas it was significantly decreased under reduced tillage (i.e. 22.33 and 20.66 Lit ha^{-1}) and in no tillage treatments (i.e. 12.33 and 11.00 Lit ha^{-1}), respectively. A significant linear response in fuel consumption under various tillage treatments was noted during both the seasons; while the quadratic response in fuel consumption under various tillage treatments was non-significant during both the wheat growing seasons. The seasonal comparison suggests that the fuel consumption was relatively higher in 2008 than the fuel consumption treatments in 2009.

DISCUSSION

These findings are further supported by various researchers (Kumara *et al*., 2013). In a conventional cropping system the greatest energy consumer is soil tillage. Peruzzi *et al*. (1998) reported that no-tillage system, and particularly the reduced tillage system was more efficient, in terms, of working time, fuel consumption, energy requirement and planting cost as compared to the plowing system. Moreover, the agronomic performance of the no-till drills and the combine for direct drilling was fairly good as compared to plowing system. Filipović *et al*. (2004) and Lithourgidisa *et al.* (2006) concluded that about 53% savings in fuel consumption was achieved with minimum tillage, while, 48% with reduced tillage in comparison with conventional tillage. They further indicated that wheat can be grown successfully under conservation tillage systems with yields equal to those of conventional tillage using less fuel inputs. Stajnko *et al*. (2009) concluded that the highest fuel consumption was under the CT system; CO_2 emission was 225 kg ha^{-1} on silty clay loam and 188 kg ha^{-1} on silty loam. Presuming the use of CT system in the growing of corn silage on the arable land would decrease from its current 93.70% by 30% as forecasted. Forristal (2008) stated that primary cultivation energy requires approximately 37% of that required by plowing; the overall fuel use of the minimum tillage system is just 50% that of conventional systems.

CONCLUSION

The study concluded that reduced tillage practice is more energy-efficient than conventional tillage practice for sustainable wheat production.

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