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Short note *(Araştırma Notu)*

Higher Yield and Economic Benefits for Wheat Planted in Conservation Till Systems

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Abstract : Conservation till system can reduce the cost of production; improve yield as well as the economic outputs of a cropping system. Four tillage systems (The conventional tillage, reduced tillage, zero tillage, and deep tillage) were evaluated for their effects on soil organic matter, nutrients concentrations, yield, yield related traits and economic benefits in wheat crop. The experiment was conducted at the Agronomic Research Institute Faisalabad, Pakistan during 2010-11. Soil analysis carried out towards the harvest of the crop depicted no statistical variation among the experimental units for organic matter as well as phosphorus and potassium concentrations. Wheat sown under conservation till systems [zero till (ZT) and reduced till (RT)] had significantly higher grain yield (4457 and 4449 kg ha^{-1}, respectively) than the wheat planted in conventional till system (CT) (4192 kg ha^{-1}). Although, the highest grain yield (4566 kg ha^{-1}) was recorded for wheat plots sown after deep tillage, this treatment had lower net returns (US$ 508) than the ones gained in conservation till systems (ZT and RT). ZT and RT systems attained the highest net returns (US$ 558 and 535, respectively) and benefit cost ratio (2.02 and 1.94, respectively). The lowest net returns (US$ 445) and benefit cost ratio (1.72) were recorded for CT system. In conclusion, conservation tillage can be practiced to harness higher wheat grain yields and economic benefits.

Keywords: Conservation tillage, Economic benefits, Nutrients, Wheat, Yield

Korumalı Toprak İşleme Sistemlerinde Yetiştirilen Buğday için Daha Yüksek Verim ve Ekonomik Faydalar

Özet : Korumalı toprak işleme sistemi üretim maliyetini azaltabilir; ürün yetiştirme sisteminde ekonomik çıktıların yanı sıra verimi de iyileştirebilir. Dört toprak işleme sistemi (geleneksel toprak işleme, azaltılmış toprak işleme, anıza ekim ve derin toprak işleme), toprak organik madde, besin konsantrasyonları, verim, verim ilgili özellikleri ve buğdayda ekonomik faydalar üzerindeki etkileri bakımından değerlendirildi. Deneme, Pakistan Faisalabad Tarımsal Araştırma Enstitüsü'nde 2010-2011 yıllarında yürütülmüştür. Mahsulün hasatına doğru yapılan toprak analizi sonuçlarında organik madde yanı sıra fosfor ve potasyum konsantrasyonları için deneysel birimler arasında istatistiksel varyasyon belirlenememiştir. Korumalı toprak işleme sistemleri (anıza ekim (AE) ve azaltılmış toprak işleme (ATİ)), geleneksel toprak işleme sistemine (GTİ) göre, buğday veriminde istatistiki olarak daha yüksek buğday verimine sahip olmuştur (sırasıyla 4457 kg/ha, 4449 kg/ha ve 4192 kg/ha). Buğdayda en yüksek tane verimi (4566 kg/ha) derin toprak işleme sisteminde (DTİ) elde edilmesine rağmen, bu toprak işleme sisteminin net geliri (508 $), korumalı toprak işleme sistemleri (AE ve ATİ) net gelirinden daha düşük çıkmıştır. AE ve ATİ sistemleri en yüksek net getiri (sırasıyla 558 $ ve 535 $) ve fayda maliyet oranını (sırasıyla 2.02 ve 1.94) ulaşmıştır. En düşük net getirileri (445 $) ve fayda maliyet oranı (1.72) GTİ sistemi için kaydedilmiştir. Sonuç olarak, korumalı toprak işleme sistemi yüksek buğday tahıl verimi ve ekonomik faydalarının sağlanmasında uygulanabilir.

Anahtar kelimeler: Korumalı toprak işleme, Ekonomik faydalar, Besin, Buğday, Verim

Introduction

Wheat is the most grown food crop of the world and being cultivated over all the inhabited continents of the world. The huge annual production (>700 m t) of wheat ensures its inevitable role in the world's food security. Hundreds of food products are made from the wheat grain while the straw is fed to animals. During the recent decades, the high priced inputs, energy crisis and ever increasing fuel costs are making the farming un-profitable. The traditional way of manipulating soils for agriculture entrepreneur includes the intensive cultivation of lands (Erenstein 2010; Usman et al. 2010). These intensive cultivations not only pose deleterious impacts on the soil health but also increase the production cost of a crop (Saharawat et al. 2010). Several of the ill effects that result from intensive cultivation include soil compaction, nutrients losses, increased carbon losses from the soil and higher cost of production (Farooq et al. 2011).

Already, a major portion of developing countries is either undernourished or facing severe hunger due to food shortage (Hussain and Routray 2012). The aggravated crop production costs would further increase food prices ultimately to threaten the world food security. Decreased soil quality as a result of intensive cultivation would also contribute towards the decreased crop output.

In this scenario of threatened food security as a result of high cost of production and deteriorating soil quality, measures are needed that not only help in protecting the soil resources but also aid in minimizing the crop production expenditures. The conservation tillage methods such as zero and reduced tillage are the attractive options to minimize the cost of production and preserve as well as improve the soil quality (Farooq et al. 2011). Conservation tillage including reduced and zero tillage are well renounced for several of environmental benefits and reduced cost of production. Although the conservation tillage for wheat crop is advocated by researchers in South Asia, however, the conservation tillage has been rarely compared for its economic and yield advantages over the conventional tillage. Hence these studies were conducted with the objectives of assessing the conservation tillage systems (zero and reduced tillage) in comparison with the conventional tillage for the economic returns and yield outputs.

Material and Methods

Site and soil

The experiment was conducted at the research area of Agronomic Research Institute Faisalabad, Pakistan (31.40°E, 73.07°N; 122 m a.s.l.) during 2010-11. The soil of the experimental area was sandy loam with a pH 7.8. The experimental soil contained organic matter 8.9 g kg^{-1}, available phosphorus 7.1 mg kg^{-1} and available potassium 105 mg kg^{-1}. The weather data during the experimental period is presented in the Table 1.

Table 1. Weather data during the course of study (2010-2011)

	November	December	January	February	March
Rainfall (mm)	0	0.5	34	0	0
Relative humidity (%)	87.7	83.9	80.5	78.95	77.8
Average maximum temperature (°C)	28.3	21.9	19.4	22.2	27.4
Average minimum temperature (°C)	8.4	4.9	4.8	7.6	12.6

Treatments

The experiment comprised of four tillage treatments. The land was prepared according to the nature of treatments. The conventional tillage included four cultivations followed by two plankings. Reduced tillage comprised of single cultivation with subsequent planking while zero tillage was given no cultivation. Deep tillage included two ploughings using sub-soiler followed by the same number of cultivations and plankings.

Experimental details

The experiment was arranged in a randomized complete block design with a plot size of 10 x 15 m. The sowing was done with a tractor drawn seed-drill and the rows were spaced 22.5 cm apart. Seeds of wheat cultivar Millat-11 were sown on 24th of November 2010 using a seed rate of 125 kg ha^{-1}. The fertilizers including di-ammonium phosphate, urea and potassium sulphate were applied to fulfill the nitrogen, phosphorus and potassium equal to 120-60-60 kg ha^{-1}.

Data recording

The crop was harvested on April 20 2011. The data on productive tillers (m^{-2}) was recorded before harvesting by selecting two locations from each of the experimental unit. Twenty plants were selected randomly from each of the experimental unit to record the plant height (cm), spike length (cm), number of spikelets per spike, number of grains per spike, 1000-grain weight (g), biological yield (kg ha^{-1}) and grain yield (kg ha^{-1}). Harvest index was obtained by dividing grain yield by biological yield and multiplying by hundred to express it in percentage. Soil samples (0-10 cm) were collected from each of the experimental unit after the harvest of the crop. Available phosphorus was determined by the method of Watanabe and Olsen (1965) while organic matter and available potassium were determined according to the procedures given in the Hand Book No. 60 of the U.S. Salinity Lab. Staff (1954).

Statistical and economic analysis

The collected data were analysed using Fisher's analysis of variance technique and the treatments' means were separated using least significant difference test. Economic analysis was done by calculating the gross income (US$/ha) and total expenditure (variable + permanent costs). Net field benefits were calculated as the difference of total income and variable cost while net returns were calculated as the difference of total income and total expenditure. Benefit-cost ratio was recorded by dividing the total income by total cost.

Results

Results indicated that the plant height, number of spikelets per spike, productive tillers, 1000-grian weight, biological yield and harvest index were not affected by the different tillage systems (Table 2). Wheat sown under conventional tillage had the lowest spike length (11.6 cm) while the wheat sown under deep and conservation (zero and reduced) tillage had higher and statistically similar spike length (Table 2).

Table 2. Effect of conventional and conservation tillage systems on the grain yield and related traits of wheat crop (2010-2011)

Treatments	Plant height (cm)	Spike length (cm)	Spikelets per spike	Grains per spike	Productive tillers (No. m^{-2})	1000-Grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Wheat sown under conventional tillage	98.3	11.6b	16.9	38.1b	251.3	39.5	4192.0b	9074.1	46.2
Wheat sown under reduced tillage	99.3	12.3a	18.1	42.5a	285.3	40.9	4449.3ab	9037.0	49.3
Wheat sown under zero tillage	99.3	12.2a	17.1	40.8a	304.7	39.1	4457.3ab	9000.0	49.8
Wheat sown under deep tillage	96.8	12.3a	18.2	40.7ab	310.3	40.8	4566.0a	9370.4	48.8
LSD at $P \leq 0.05$	NS	0.48	NS	2.72	NS	NS	283.6	NS	NS

NS = Non-significant; Means not sharing a letter in common in each column differ significantly at $P \leq 0.05$

The highest number of grains per spike were noted for wheat under conservation tillage (i.e. reduced and zero; 42.5 and 40.8, respectively) followed by the wheat in deep tilled fields (40.7) (Table 2). Wheat sown using conventional tillage had the lowest number of grains per spike (38.1) (Table 2). The highest grain yield (4566 kg ha^{-1}) was recorded for the wheat sown under the deep tillage followed by the conservation tillage treatments (Table 2). Conservation tillage treatments including wheat sown under reduced tillage and zero tillage had the statistically similar grain yield (4449 and 4457 kg ha^{-1}, respectively) (Table 2). The lowest wheat grain yield was recorded for the wheat sown under conventional tillage (Table 2).

The results for economic analysis exhibited that the highest expenditures were done on wheat sown under deep tillage and conventional tillage (631 and 616 US$ ha^{-1}) (Table 3). Wheat sown by zero tillage required the lowest expenditures (548 US$ ha^{-1}). Wheat sown under deep tillage had the highest gross income (1138 US$ ha^{-1}) followed by the wheat sown under conservation tillage (zero and reduced tillage; 1106 US$ ha^{-1}). Wheat sown by conventional tillage had the lowest gross income (1061 US$ ha^{-1}). Similarly, wheat sown under deep tillage had the highest net field benefits (590 US$ ha^{-1}) followed by wheat under conservation tilalge (zero and reduced tillage; 558 US$ ha^{-1}) and wheat sown uncer convetional tillage (513 US$ ha^{-1}). The highest net returns and benefit-cost ratio (BCR) were recorded for wheat sown under zero tillage (558 US$ ha^{-1} and 2.02, respectively) followed by the wheat sown under reduced tillage (535 US$ ha^{-1} and 1.94). The wheat sown under the convetional tillage had the lowest net returns (445 US$ ha^{-1}) and BCR (1.72). Results of the soil analysis after the harvest of the crop depicted no variation among the tillage treatments for the organic matter, available phosphorus and available potassium (Table 4).

Table 3: Comparative economic returns of the conventional and conservation tillage systems in wheat crop (2010 2011)

Treatments	Variable cost (US$ ha^{-1})	Total cost (US$ ha^{-1})	Gross income (US$ ha^{-1})	Net field benefits (US$ ha^{-1})	Net returns (US$ ha^{-1})	Benefit cost ratio
Wheat sown under conventional tillage	67.5	615.5	1060.81	512.81	445.31	1.72
Wheat sown under reduced tillage	22.5	570.5	1105.88	557.88	535.38	1.94
Wheat sown under zero tillage	0	548	1106.07	558.07	558.07	2.02
Wheat sown under deep tillage	82.5	630.5	1138.13	590.13	507.63	1.81

Variable cost included the cost for tillage. Fixed cost was estimated to be US$548. The fixed cost included prices for land rent, seed, sowing charges, fertilizers, herbicide, water application and harvesting.

Table 4. Effect of conventional and conservation tillage systems on the nutrient status of the soil after the harvest of crop (2010 2011)

Treatments	Organic matter (g kg^{-1})	Available phospohrus (mg kg^{-1})	Available potassium (mg kg^{-1})
Wheat sown under conventional tillage	8.7	7.21	115.0
Wheat sown under reduced tillage	9.1	8.55	110.0
Wheat sown under zero tillage	9.3	8.42	110.0
Wheat sown under deep tillage	8.6	8.12	120.0
LSD at $P \leq 0.05$	NS	NS	NS

NS = Non-significant

Discussion

Conservation tillage is advocated all over the world owing to several of its benefits. Improved soil properties, increased carbon sequestration, reduced soil erosion and improved water infiltration are considered as the salient advantages of conservation tillage (Farooq et al. 2011; Derpsch et al. 2014; Krishna and Veettil 2014). Reduced production cost is the other important aspect of conservation tillage (Jabran et al. 2013). Finding the ways to lower the production cost is inevitable owing to constant increase in diesel, electricity and fertilizer prices especially for the crops like wheat, rice and maize which are inevitable for food security throughout the world (Armah et al. 2011; Jabran et al. 2014).

The production cost of wheat can be lowered significantly if a significant portion out of the worldwide wheat area may be brought under conservation tillage (Hobbs 2007). However, the information regarding the real cost savings is desired before shifting to conservation tillage from conventional tillage for wheat fields in South Asian countries (Hobbs 2007; Erenstein 2010). Nonetheless, the effect of adopted conservation tillage on the productivity of wheat crop in comparison with the conventional tillage should also be known. Further, the other question is, either zero tillage is more suitable or reduced tillage?

Our study provided clarified answers to several of these questions. Cost of production for wheat crop was significantly reduced when sown by either of zero or reduced tillage instead of conventional tillage. The wheat productivity was also improved by adopting the conservation tillage (Usman et al. 2010). A 6.3 and 6.1% increase in wheat grain yield was noted when grown by zero and reduced tillage, respectively compared with the conventional tillage. This increased wheat grain yield in conservation tillage treatments were the result of probable positive influence of conservation tillage on the soil properties (Stevenson et al. 2014). The other possible reasons for higher grain yield in conservation tillage were the lower weed emergence and early crop emergence (data not shown) in these treatments compared with the conventional systems. Minimum soil manipulations in conservation tillage (zero and reduced tillage) compared with the conventional tillage do not allow the weed seeds to reach the soil surface from deeper layers, and hence a lower weed emergence is observed. Similarly, the crop seeds are put uniformly near to the soil surface when sown with conservation tillage which results in early crop emergence, excellent crop stand and higher crop yields.

Reduced and zero tillage helped to improve grains per spike of wheat compared with the conventional tillage. Probably the lower weed intensity and strong crop stand in zero and reduced tillage helped to produced more photosynthates in wheat crop plants sown under conservation tillage, which ultimately resulted in higher number of grains per spike. Further, the number of grains per spike and 1000-grain are generally negatively correlated with each other. Hence, the conservation tillage treatments positively influenced the grains per spike but had a non-significant on 1000-grain weight.

Different tillage systems in the study had a non-significant effect on the soil nutrient status after crop harvest. Short duration of experiment was the most probable reason for non-significant effect of tillage systems on soil nutrient status. The difference in soil properties for the conservation and conventionally tilled soils is generally evident after practicing the conservation tillage for longer durations. For example, the results of a study from Australia indicated the superior soil properties were noted for a soil under no till system for 34 years compared with the one which was treated with conventional tillage during this period of time (McGarry et al. 2000). Similarly, another study from Spain indicated the accumulation of higher concentrations of soil organic carbon, available potassium and Olsen-P in soil after 16 years of conservation tillage compared with the short duration conservation tillage i.e. four years (López-Garrido et al. 2011).

Wheat cultivation by zero tillage was more economical than the wheat cultivation by reduced tillage mainly due to lower cost of production (Farooq et al. 2011). However, both had similar productivity in terms of grain yield and yield contributing parameters. Hence, zero tillage possessed higher net returns and benefit cost ratio than the other tillage systems in the study. Similar results have been reported by Jabran et al. (2013) for rice crop, where rice sown by either of conservation and conventional tillage had similar grain yield, but the economic returns were higher for rice sown by conservation tillage practices. Although, wheat sown with deep tillage had higher yield, however it had highest cost of production among all treatments. Further, this higher cost of production resulted in lower net returns and benefit cost ratio for deep tillage compared with the conventional and conservation tillage.

Conclusions

The tillage systems did not affect the 1000-grain weight, soil organic matter, P and K concentration. However, conservation tillage was helpful in reducing the cost of production for wheat crop and improving its productivity. Zero tillage was more advantageous than reduced tillage in terms of cost savings and productivity. Hence, conservation tillage systems including zero and reduced tillage may be adopted for reduced cost of production, increased net returns, grain yield and benefit cost ratio for wheat crop.

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