Research Article

Influence of Different Tillage Practices on Yield of Autumn Planted Maize (*Zea mays* L.)

Shakeel Ahmad Anjum[1], Muhammad Mohsin Raza[2], Sami Ullah[1,3]*, Malik Muhammad Yousaf[2], Ahmad Mujtaba[1], Mumtaz Hussain[2], Muhammad Jahangir Shah[2], Bashir Ahmad[2] and Ijaz Ahmad[4]

[1]Department of Agronomy, University of Agriculture Faisalabad 38040, Pakistan; [2](PARC) Arid Zone Research Institute, Bahawalpur 63100, Pakistan; [3]Key Laboratory of Plant Nutrition and Fertilizer, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, PR China; [4](PARC) Ecotoxicology Research Institute, National Agricultural Research Centre, Islamabad 44000, Pakistan.

Abstract | Crop establishment is mainly based on techniques used for good seed bed preparation. The objective of this study was to check the influence of various tillage practices on yield of the autumn planted maize crop. The experiment was conducted in summer, 2014 at Agronomic Research Area, University of Agriculture Faisalabad, Pakistan in a randomized complete block design (RCBD) with four replications. Net plot size was maintained 7.0 m × 3.6 m. Different tillage practices, i.e., deep tillage, conventional tillage, minimum tillage, simple cultivation flat sowing, simple cultivation ridge sowing, zero tillage dibbling and zero tillage drill were performed as the experimental treatments. Results showed that maize hybrid sown under deep tillage gave the maximum grain yield (7.2 t ha^{-1}), number of grains cob^{-1} (528), 1000-grain weight (265 g), plant height (205 cm), plant population (7.2 plants m^{-2}) and stem diameter (1.58 cm), cob length (19.1 cm), biological yield (19.5 t ha^{-1}) and harvest index (37.0%), while lowest grain yield (3.08 t ha^{-1}), number of grains per cob (319), 1000 grain weight (204 g), plant height (174 cm), plant population (6.2 plants m^{-2}), stem diameter (1.28 cm), cob length (14.9 cm), biological yield (12.1 t ha^{-1}) and harvest index (30.5%) were obtained from the zero tillage at ($p \leq 0.05$). Economically, maize sown in deep tillage gave maximum net income of Rs 99753 ha^{-1} with VCR (1.75), whereas minimum net income of Rs 13703 ha^{-1} with VCR (1.12) where zero tillage drilling system was adopted. Our study demonstrated that deep tillage is better option for yield enhancement under Faisalabad conditions.

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***Correspondence** | Sami Ullah, Department of Agronomy, University of Agriculture Faisalabad 38040, Pakistan; **Email:** samisheen14@yahoo.com
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Introduction

Tillage is an effective farm activity to improve soil tilth and soil physical conditions (Khan et al., 2010), which increased nutrient use efficiency of crop and eventually leads to good crop yield (Bahadar et al., 2007). Numerous factors, such as attack of pests, diseases, seasonal changes, and irrigation hampered yield of maize but tillage is most imperative factor among them (Rosner et al., 2008). Tillage activity has also positive effect on soil organic matter (SOM) content (Tian et al., 2016), as it can increase aeration of soil, helps in decomposition of residue, organic nitrogen mineralization and availability of nitrogen to plants for use (Dinnes et al., 2002).

Due to heavy farm operations hard subsoil layer is developed, which poses negative impacts on root

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penetration, soil bulk density, soil porosity and nutrient status, which indirectly lower the crop yield (Ahmad et al., 2009). Deep tillage to depth of (30 cm) is an effective approach to breakup compacted subsoil layer (He et al., 2007; Hou et al., 2012). Furthermore, tillage is positively associated with carbon sequestration, soil structure, and crop yield (Huang et al., 2006). It is well known that intensive tillage is associated negative environmental impacts, such as top soil erosion by use of heavy machinery (Gupta et al., 2002). Therefore, resource conservation technologies need to be introduced (Safeer et al., 2013). Recently no tillage is frequently used to mitigate soil erosion and loss of SOM (Zhang et al., 2005). Moreover, earlier studies indicated that conservation tillage gave higher yield as compared to the intensive tillage (Shao et al., 2016; Zhang et al., 2015; Naudin et al., 2010). Soil organic matter, nitrogen contents, and exchangeable cation are positively influenced under conservational tillage as compared to the conventional tillage. Due to higher SOM contents, soil physical and chemical properties improved and have significant positive effect on crop yield (Thomas et al., 2007). The drastic problem of soil erosion can also be minimized by zero tillage (Karina et al., 2009).

In maize hybrids improper sowing methods results in unproductive plants, however, using improved sowing methods maximum crop potential can be achieved (Alias et al., 2003). Ridge sowing improves the physical characteristics of the soil such as, bulk density and soil moisture contents over flat planting and conventional tillage. Additionally, ridge sowing also produce higher germination percentage as compare to flat sowing (Altuntas et al., 2009).

Due to its importance, a great deal of research had been done on tillage practices but still needed to locate the best tillage methods for sustainable maize crop production and soil reserves. In this study different tillage methods were compared to find out the most suitable and appropriate tillage practice for maize crop production. Therefore, this experiment was planned to evaluate different tillage systems in terms of better crop yield and profitability of maize crop in Faisalabad conditions.

Materials and Methods

Experimental site

A field experiment was conducted to evaluate the effect of different tillage practices on yield of maize at Agronomic Research Area, University of Agriculture Faisalabad, Pakistan during autumn, 2014. The soil of experimental site was Hafi-zabad series (fine-loamy, mixed, hyperthermic, Typic Calciargids) and the soil texture was sandy clay loam. Basic soil characteristics at the start of experiment are shown in Table 1.

Table 1: *Soil characteristics of the experimental site.*

Parameter	Values
Texture Class	Sandy clay soil (Medium hard)
EC	0.15dS m^{-1}
pH	8.00
SOM	0.27%
Nitrogen	0.017%
AP	7.5 ppm
EK	102 ppm

Abbreviations: EC = electrical conductivity, SOM = soil organic matter, AP = available phosphorus, EK = exchangeable potassium.

Experimental design and crop husbandry

The experiment was laid out in randomized complete block design (RCBD) with four replications with a net plot size of 7.0 m × 3.6 m. Row to row spacing was maintained 60 cm and plant to plant spacing was maintained 20 cm. Maize hybrid Monsanto DK-919 was used as experimental material. Uniform seed rate 25 kg ha^{-1} was used. Maize crop was planted on 15th August 2014. The experimental treatments comprised of; deep tillage, conventional tillage, minimum tillage, simple cultivation (flat sowing), simple cultivation (ridge sowing), zero tillage (dibbling), zero tillage (drilling 5 cm). Detailed descriptions of treatments are presented in Table 2. Recommended dose of fertilizer was applied at rate of nitrogen, phosphorus, potassium (NPK) 250:125:125 kg ha^{-1}. Urea, diammonium phosphate (DAP) and sulphate of potash (SOP) were used as a source fertilizer. Whole quantity of phosphorus and potash were applied prior to seeding as a basal dose while nitrogen was applied in three splits (1/3rd at the time of sowing, 1/3rd at five leaf stage, 32 days after sowing (DAS) and 1/3rd at tasseling stage, 55 DAS). First irrigation was applied after seeding and subsequently, 5 irrigations (7.5 cm each) were applied when needed at different plant developmental stages, until the crop reached physiological maturity. Both canal and ground water were used to irrigate the crop.

Crop harvest, crop characteristics, and yield parameters

The crop was harvested manually on 10th December,

2014. After harvesting, the plants were left in the field for one week for sun drying. All the plants were counted at maturity of crop individually from each plot and then converted into m^{-2} for plant population. Five plants were selected at random from each plot and their height was measured from ground surface to top with the help of a meter rod and the average height was calculated. Five randomly selected plants from each plot were tagged and stem diameter from the base, middle and top was measured with Vernier caliper and then average was calculated. Five representative cobs from each plot were taken; cob length was calculated and averaged. Numbers of grains per cob were counted from five randomly selected cobs from each treatment and then average was calculated. Thousand grains were taken from seed lot of each plot and then weight was recorded in grams by using automatic electric balance. After harvesting and threshing, the clean maize grains were air-dried, bulked and weighed to record the grain yield. The grain weight was adjusted to 14% moisture contents and expressed in t ha^{-1}. The crop was harvested at maturity, tied up into small bundles and left in their respective plots for few days for sun drying. The sun-dried bundles were weighted with the help of spring balance and the biological yield was calculated. Harvest index as ratio of economic yield to total above biological yield was derived for each experimental unit and expressed in percentage. Meteorological data of Faisalabad was collected from the Department of Crop Agronomy, University of Agriculture, Faisalabad and is shown in Figure 1.

Table 2: *Description of treatments.*

Treatments	Tillage implement (no of operations)					Seeding implement
	MB plough	Cultivator	Rotavator	Ridger	Dibbler	Hand drill
Deep tillage	1	2	1	1	NA	1
Conventional tillage	NA	2	1	1	NA	1
Minimum tillage	NA	NA	1	1	NA	1
Simple cultivation flat sowing	NA	2	NA	NA	NA	1
Simple cultivation ridge sowing	NA	2	NA	NA	NA	1
Zero tillage dibbling	NA	NA	NA	NA	1	NA
Zero tillage drill	NA	NA	NA	NA	NA	1

Abbreviations: MB plough = mould board plough, NA = not any.

Economic analysis

Economic analysis was carried out to look into comparative benefits of different treatment combinations. Net return was calculated by subtracting the total cost from the gross income of each treatment combination (CIMMYT, 1988). Net return = Gross income - Total cost. Value cost ratio (VCR) for each treatment was calculated by dividing gross income on total cost. VCR = Gross income / Total cost. The data regarding input costs (tractor use, seed, fertilizer, fuel, biocides, irrigation, and labour) and outputs were obtained from current market price paid for inputs. The cost of human labour used for tillage, seeding, irrigation, fertilizer and pesticide application, weeding, and harvesting was based on person-day ha^{-1}. The time (h) required to complete a particular field operation in a given treatment was recorded and expressed as person-day ha^{-1}, considering 8 h to be equivalent to 1 person-day. Similarly, time (h) required by a tractor-drawn machine to complete a field operation such as tillage, seeding, fertilizer application and harvesting was recorded, and expressed as h/ha^{-1}.

Statistical analysis

The collected data was tested with analysis of variance (ANOVA) using software package SAS version 8.0. One-way ANOVA was used to compare treatments effects. The least significant difference (LSD) test at $P < 0.05$ was deployed to determine the differences between the means.

Results and Discussion

Plant population (m^{-2})

Higher germination per square meter is directly related to the plant population which may positively influence the maize crop yield. The results are presented in Table 3. Statistically higher plant population (7.3 m^{-2}) was found in deep tillage treatment and showed statistical parity with conventional tillage and simple cultivation ridge sowing treatments respectively. Whereas, statistically the minimum plant population (6.2 m^{-2}) was noted in zero tillage drill treatment, which also showed statistical parity with zero tillage dibbling treatment, simple cultivation flat sowing and minimum tillage treatments respectively. Maximum plant population in deep tillage and conventional tillage treatments might be due to good seed germination and better crop stand as compared to minimum and zero tillage treatments respectively. Higher plant population could be due to good soil

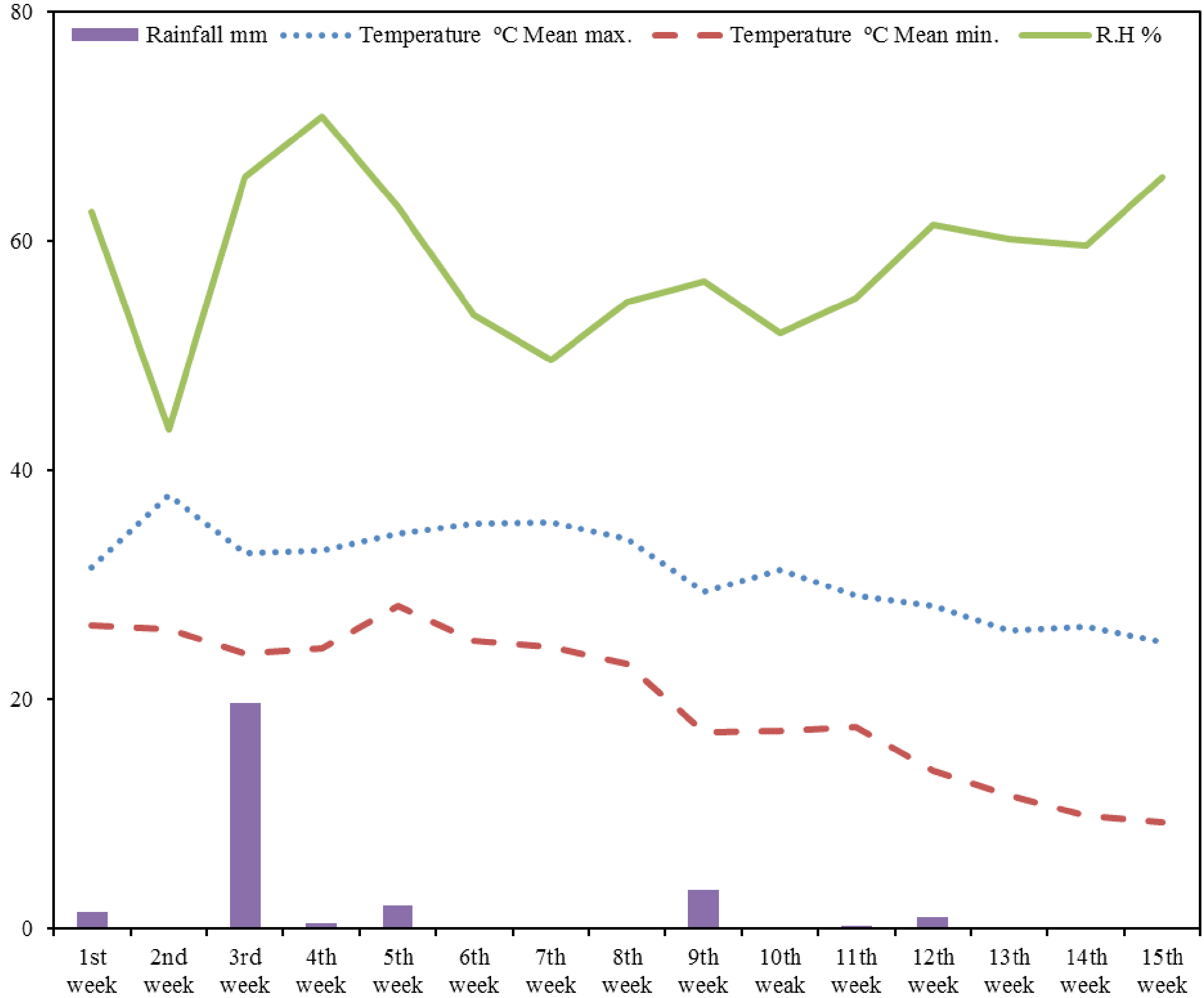

Figure 1: *Mean maximum and mean minimum temperature during the growth period of crop, mean relative humidity during the growth period of crop and mean rainfall during the growth period of crop.*

Table 3: *Influence of different tillage practices on yield of autumn planted maize.*

Treatments	PP (m^{-2})	PH (cm)	SD (cm)	CL (cm)	GPC	1000 GW (g)	GY (t ha^{-1})	BY (t ha^{-1})	HI (%)
Deep tillage	7.3a	197a	1.58a	19.1a	528a	265a	7.23a	19.5a	37.0a
Conventional tillage	7.2a	192ab	1.48b	17.9b	501ab	255ab	6.68a	18.2ab	36.7a
Minimum tillage	6.7bc	181cd	1.39c	16.5c	426cd	225cd	4.60bcd	14.3cd	32.0b
Simple cultivation flat sowing	6.6bc	185bc	1.40bc	16.9bc	432cd	228bcd	4.78bc	14.8cd	32.5b
Simple cultivation ridge sowing	6.9ab	186bc	1.42bc	17.3bc	457bc	236bc	5.41b	15.6bc	34.2ab
Zero tillage dibbling	6.4c	176cd	1.35cd	16.5c	410cd	210cd	4.08cd	13.0cd	31.0b
Zero tillage drill	6.2c	174d	1.28d	14.9d	391d	204d	3.80d	12.1d	30.5b

Values with different letters in a column differ significantly at $P < 0.05$; **Note:** *PP: plant population, PH: plant height, SD: stem diameter, CL: Cobe length, GPC: Grains per cob, 100 GW: 1000 Grain weight, GY: Grain yield, BY: Biological yield, HI: Harvest index.*

conditions in deep and conventional tillage treatments in which seedbed was not well prepared for seed germination and crop establishment.

These results were supported by (Vetsch and Randall, 2002), who claimed that tillage improved seeds germination and also results early establishment of stand as compare to no tillage treatment. Potter et al. (1996) results were also in accordance with our results as they said that the higher maize seed emergence was noted in conventional tillage rather than reduced tillage treatment. According to Mari and Changyin (2006) low plant population in no tilled soils is due to compacted soils, which has high bulk density resulting in poor seed germination. Gul et al. (2009) also concluded that tillage practices had significant effect on plant population. Moreover, (Hussain et al., 1990) stated that zero tilled soils had low temperature, which negatively influenced the plant population by poor seed germination and seedling establishment.

Plant height at maturity (cm)

Plant height is regarded as important trait of plant in terms of biomass. The results shown in Table 3 indicated that various tillage practices significantly influenced plant height. At harvest higher plant height (197 cm) was observed in deep tillage treatment, which was statistically at par with conventional tillage treatment (192 cm) whereas statistically minimum plant height (174 cm) was found in zero tillage treatment, which was statistically at par with minimum tillage and zero tillage dibbling treatments respectively. Higher plant height in deep tillage treatment is due to better physical conditions of soil uniform nutrients distribution and higher porosity. Borghei et al. (2008) and Wasaya et al. (2011) found that sub-soiling enhanced average plant height. Additionally, Vetsch and Randall (2002) and Diaz-Zortia (2000) found that plant height was significantly higher in tilled soils as compare to no tilled soils. However, Karunatilake et al. (2000) obtained statistically not significant results in plant height in tilled soil as compare with no tilled treatments.

Stem diameter (cm)

Under field conditions stem diameter has pivotal role in grain yield as well as plant biomass of maize crop. It also supports the plant to stand against strong winds and resist lodging. The results in Table 3 revealed that various tillage practices significantly affected stem diameter. Statistically maximum plant stem diameter (1.58 cm) was obtained in deep tillage treatment whereas statistically minimum plant stem diameter (1.28 cm) was observed in zero tillage drill treatment, which showed statistical parity with zero tillage dibbling treatment. Our results are contradicted with Aikins et al. (2012) and Anjum et al. (2014), stated that stem diameter was not significant in tilled and no tilled treatments.

Cob length (cm)

Cob length has direct relation with number of grains in a cob. The results shown in Table 3 indicated that cob length was significantly influenced under different tillage practices. Statistically maximum cob length (19.1 cm) was found in deep tillage treatment whereas statistically minimum cob length (14.9 cm) was observed in zero tillage drill treatment. Deep tillage showed maximum cob length. It would be due to maximum vegetative growth and leaf area index to capture sunlight and food reserves in deep tillage than no till treatments. While our results are contradictory to Pabin et al. (2006), who indicated that different tillage practices failed to influence maize cob length. Difference might be due to soil structure and texture with different environmental conditions. Arif et al. (2001) reported that different sowing methods meaningfully influenced cob length.

Number of grains per cob

Grains are the final product of the photosynthesis. Results in Table 3 indicated that tillage practices influence number of grains per cob. Statistically highest grains per cob (528) were obtained in deep tillage treatment which showed statistical parity with conventional tillage treatment whereas statistically less grain per cob (391) were found in zero tillage drill treatment which showed statistical parity with zero tillage dibbler, simple cultivation flat sowing and minimum tillage treatments respectively.

Above results were compatible with Wasaya et al. (2011), who stated that higher grains per cob were observed in deep till treatments. Albuquerque et al. (2001) also observed similar results as they stated that number of grains per cob were highest in conventional tillage treatment as compare to zero tillage treatment. Alternatively, Shao et al. (2016) in China claimed that conservation tillage treatment significantly enhanced higher number of grains per cob than deep tillage treatment. Meanwhile Sang et al. (2016) obtained not significant results for number of grains per cob by using different deep tillage operations.

1000-grain weight (g)

1000-grain weight is considered as most important component of grain yield. It is also called as seed index, an important yield contributing component. Statistically the maximum 1000-grain weight (265 g) were observed in deep tillage treatment which was statistically at par with conventional tillage treatment whereas minimum 1000-grain weight (204 g) were observed in zero tillage drill treatment which was statistically at par with zero tillage dibbling treatment, simple cultivation flat sowing and minimum tillage treatments respectively (Table 3).

These results were compatible with studies conducted by Wasaya et al. (2011), who manifested that tillage operations meaningfully influenced 1000-grain weight in deep tilled plots. In the same way Khurshid et al. (2006) and Khan et al. (2001) elucidated that1000-grain weight of maize significantly increased in conventional till plots rather than no tilled plots. Interestingly Shao et al. (2016) in China manifested that 1000-grain weight was significantly higher in conservation tilled plots.

Grain yield (t ha^{-1})

Gain yield is final objective of farmers. Table 3 results depicts that grain yield was significantly influenced under various tillage practices. Statistically maximum grain yield (7.23 t ha^{-1}) was noted in deep tillage treatment, which showed statistical parity with conventional tillage treatment whereas statistically lowest grain yield (3.70 t ha^{-1}) was found in zero tillage drill treatment, which depicts statistical parity with zero tillage dibbling and minimum tillage treatments respectively.

These results are supported by findings of Memon et al. (2011) and Arora et al. (1991) who indicated that deep tillage proved better results regarding grain yield. Unlike the finding of Chinese authors Zhang et al. (2015), who found that grain yield was (4.4%) higher in no tilled soils over tilled soil. In another field trial in India Sharma et al. (2011) said that grain yield showed statistical parity with conventional and no tillage.

Biological yield (t ha^{-1})

Biological yield represents the above ground biomass produced by the crop. Results presented in Table 3 indicates that statistically maximum biological yield (19.5 t ha^{-1}) was noted in deep tillage treatment which was statistically at par with conventional tillage treatment whereas statistically lowest biological yield (204 t ha^{-1}) was found in zero tillage drill treatment which was statistically at par with zero tillage dibbling, simple cultivation flat sowing and minimum tillage treatments respectively.

Khan et al. (2009) manifested that tillage produced higher biomass as compared to no till treatments. These results were also similar with Diaz-Zortia (2000) and Patil et al. (2006) who reported that there was higher biomass in deep tilled soils than no tilled ones. On the other hand, Malhi and Lemke (2007) reported that biological yield was higher in no tilled soil than that in tilled ones.

Harvest index (%)

Harvest index indicates the efficiency of the plant in proportion of the photosynthates of the plant. Data regarding harvest index is presented in Table 3. Statistically higher harvest index (37%) were observed in deep tillage treatment which showed statistical parity with conventional tillage treatment and simple cultivation ridge sowing treatments respectively, whereas statistically minimum harvest index (30.5%) was obtained in zero tillage drill treatment which was statistically at par with zero tillage dibbling, simple cultivation flat sowing and minimum tillage treatments respectively. These results are consistent with Ahadiyat and Ranamiukhaarac-hchi (2008), who showed that in deep tilled plots gave higher harvest index. On the other hand, Bakht et al. (2011) and Rasheed et al. (2003) demonstrated that ridge sowing is proves to be more beneficial in terms of harvest index % than the flat sowing method.

Net return per hectare

Data regarding the economic analysis are presented in Table 4. In this analysis prices of inputs prevailing in the local market were used to calculate the economic analysis of various tillage systems. Results demonstrated that maximum net return (Rs. 99753) was obtained in deep tillage treatment whereas minimum net return (Rs. 13703) was achieved where maize grown under zero tillage drill treatment. The lowest return of zero tillage treatment was due to minimum grain yield which could not cover the cost of production efficiently as compared to deep and conventional tillage treatments respectively. These results are in line with Khattak et al. (2007) who elucidated that mean highest net income (Rs. 95518 ha^{-1}) was obtained in the deep tillage plots and the lowest (Rs. 70728 ha^{-1}) was found in the shallow tillage plots. The reason of the difference was that deep tillage plots provided favourable soil environment for better growth and grain yield of maize crop when compared to shallow tillage plots, whose final effect was on the net income of the crop.

Table 4: *Influence of different tillage practices on yield of autumn planted maize economic analysis.*

Treatments	Grain yield Value (Rs. ha^{-1})	Straw yield Value (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Value cost ratio
Deep tillage	216900	15951	232851	133098	99753	1.75
Conventional tillage	200400	14976	215376	126613	88763	1.70
Minimum tillage	138000	12610	150610	116997	33613	1.28
Simple cultivation flat sowing	143400	13026	156426	117733	38693	1.32
Simple cultivation ridge sowing	162300	13247	175547	120434	55113	1.45
Zero tillage dibbling	122400	11596	133996	112093	21903	1.20
Zero tillage drill	114000	10790	124790	111087	13703	1.12

Price of grain yield per ton = Rs. 30,000/-; Price of straw yield per ton = Rs. 1300/-

Value cost ratio

Table 4 results demonstrated that maximum value cost ratio (1.75) was noted where deep tillage was practiced whereas minimum (1.12) value cost ratio was observed where zero tillage with drill was applied. Anjum et al. (2014) also found the similar results as the higher value cost ratio was achieved in those plots where deep tillage was practiced as compare to minimum or conventional tillage.

Conclusions and Recommendations

In summary, after comparing various tillage practices it is cleared that deep tillage and conventional tillage treatments gave maximum grain yield, then minimum tillage and zero tillage treatments. Deep tillage and conventional tillage treatments also performed better in parameters regarding crop growth. Additionally, higher net return and VCR was also obtained from deep tillage and conventional tillage treatments respectively. Therefore, Intensive tillage practices could be preferred over minimum and zero tillage practices for higher yield in semi-arid zone like Faisalabad.

Author's contribution

Shakeel Ahmad Anjum conceived the study idea, designed and supervised the experiment, Sami Ullah wrote-up manuscript. Ahmad Mujtaba conducted experiment and took data from field. Mumtaz Hussain and Muhammad Jahangir Shah performed statistical analysis. Bashir Ahmad gathered revive of literature. Malik Muhammad Yousaf critically revised the manuscript. Muhammad Mohsin Raza and Ijaz Ahmad helped in editing of article.

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