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Original Research Article

TILLAGE PRACTICES AFFECT THE WATER CONSERVATION BENEFITS OF RAINWATER HARVESTING IN SEMI-ARID CONDITIONS

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Abstract *Livelihood in the Pothwar region of Pakistan is largely dependent on rainwater. Therefore, storing and conserving rainwater for its subsequent use when required is crucial. Amongst various means of in-field moisture conservation, tillage practices play a dynamic role, especially in loose soils of Pothwar area. Under this study, the efficiency of commonly used tillage implements i.e., mould board (MB) plough, disc plough and cultivator, was evaluated for moisture conservation and improvement in wheat (Triticum aestivum L) yield. The three years' study showed that maximum soil moisture and grain yield were obtained in the field tilled with MB plough followed by disc plough. It has been observed that soil water was improved by 11.3, 10.6, 9.9 and 11.5 % in the treatment of MB plough, while this increase was recorded as 5.7, 9.0, 5.2 and 6.8 % in disc plough as compared to cultivator at sowing, 02 months & 04 months after sowing and harvesting stage, respectively. In the treatment of MB plough, improvements were observed as a wheat grain yield 16%, wheat straw yield 19%, productive tillers 6% and plant height by 2%. Furthermore, MB plough enhanced its productivity and profitability with the highest benefit-cost ratio of 1.83. The role of disc plough in soil water conservation and crop productivity enhancement was observed less than MB plough. The current study observed that use of MB plough is beneficial in soil water conservation and improvement of crop yield.*

Keywords: *Cultivator; Disc plough; Mold Board plough; Soil water; Tillage practices; v*

Introduction

Wheat, the epicentre of global food security, is a staple food for over 40 percent of the world's population and contributes about 20 percent to global dietary calories and protein needs (Braun et al., 2010). Wheat is a widely cultivated cereal crop on 214292 thousand hectares, having 734045 thousand tons annual production with an average production of 3.425 tons per hectare. Good tillage and irrigation result in better yield i.e., 6 to 9 tons per hectare (FAOSTAT, 2018). Global wheat demands have doubled since 1980, and this rapidly growing demand is more in developing parts of the world, which share about 50% of wheat production. The growing world population is projected to need 60% more wheat by 2050 (Tadesse et al., 2017); as a result, an increased I wheat production of about 25-70% above current levels will be necessary to meet this growing demand (Hunter et al., 2017). Although rain-fed (barani) farms account for about 48% of all wheat farms and 25% of global production, they have lesser yield efficiency than irrigated farms (ALI, 2022; BASHIR et al., 2023; Kiani and Houshyar, 2012; Kiani and Houshyar, 2013). Whole agriculture in rain-fed areas depends on rainfall, which is usually erratic, as two-thirds of rainfall occurs in monsoon, therefore rainwater conservation is very important for good crop production (Rashid et al., 2000). Therefore, holistic management of arable land is essential to deal with complex, interrelated soil properties, thus sustaining the production of agricultural systems. Substantial efforts are needed to incorporate crop tolerance to abiotic stresses to increase grain yield (Acevedo et al., 2018; Rasheed and Malik, 2022; REHMAN et al., 2020).

In Pakistan, wheat is a major food staple which complements daily food needs. It is cultivated on 8,825 thousand hectares with around 25 million tons of production, accounting for 8.7 percent in value addition agriculture and 1.7 percent share of the national GDP. Despite the large area under wheat cultivation, its average yield is below the world average and crop potential (GOP, 2020). Green revolution has resulted in a rapid increase in cereal yield, but another such agricultural revolution may not be possible in the short run. So, exploring all options for improved agricultural practices is necessary to achieve maximum yield potential. Although multiple factors contribute to wheat yield e.g. genotype, climate, soil, planting time, irrigation cultural practices etc. Among cultural practices, soil bed preparation is vital to good crop stand and productivity. Seedbed environment is the main determinant of crop production systems' success as hard seedbed restricts seedling growth and severely affects crop productivity. It is an important agricultural practice to achieve uniform crop emergence and good plant growth with higher yield under varying pedo-climatic conditions under dry areas (Aaliya et al., 2016; Alamooti, 2019; Ali et al., 2016; Ali et al., 2014). Tillage operations significantly affect the soil's physical properties and its moisture-holding capacity. Bulk density is minimized in the case of deep tillage compared to minimum tillage (Khurshid et al., 2006). Different tillage instruments have varying abilities to pulverize and condition the soil, and it has been observed that crop yield is positively affected through good tillage practices (Alam et al., 2014; Safeer et al., 2013).

As a fundamental agro-technical operation, soil tillage influences soil properties, environs, and crop production. Soil conditions must provide enough water, air and nutrients for good root growth hence, the tillage implements and methods affect the soil's physical properties (Husnjak et al., 2002). It also provides sufficient soil moisture and a suitable environment for better seedling and root growth by suppressing weed infestation and reducing soil erosion (Ehsanullah et al., 2013). Soil moisture is vital for plant growth as it constitutes 80-90% of herbaceous plants and helps to transport nutrients and minerals from soil to plants (Ahmad and Rashid, 2003). Tillage improves rainwater penetration in arid regions; evaporation and soil water distribution are affected (Hou et al., 2009; Schwartz et al., 2010). Soil organic matter decomposition is stimulated by tillage and contributes to releasing more CO_2 (Baker et al., 2007). Tillage tools fragment the soil into small aggregates. The size of these aggregates is affected by many factors, such as soil physio-chemical properties, climatic conditions, and type of tillage implements. Tillage operations influenced soil water content and aggregate size distribution (Barzegar et al., 2004), seed bed structure, seedling emergence, residual distribution, and improved physical conditions (Ali and Malik, 2021; Guerif et al., 2001; Iqra et al., 2020; Mazhar et al., 2020; Zubair et al., 2016). Farmers must be encouraged to increase the number of farm machines to reduce waiting time for completing farming operations (Kiani and Houshyar, 2013). Many tillage systems have been established for better moisture conservation in rain-fed areas using many tillage implements. Henceforth, selecting proper tillage implements depending on soil and climate is desired to provide ideal growing conditions. The importance of tillage methods is increased manifolds, particularly in drier and rain fed parts of the world, where scattered rainfall and prolonged dry spells need efficient and timely tillage management employing the most suitable tools. Selection of tillage methodology and time is the main crop yield determining factor in rain-fed agriculture. Considering the importance of tillage implements and operation, a field study was executed to evaluate the effect of tillage implements on soil moisture conservation and wheat yield under rain-fed conditions of Pothwar. To achieve the study's objectives, different tillage implements were compared under the same pedoclimatic condition.

Materials & Methods

Site Description

The site for the current experimental study was selected almost in the center of the Pothwar region, where the Research Farm of Soil and Water Conservation Research Institute (SAWCRI), Chakwal, Pakistan, is located at 32°55.756′N latitude,72°43.650′E longitude having an elevation of 1689 feet above mean sea level. The climate of Chakwal is semi-arid, with hot summers and cold winters. The average rainfall of the area is 565 mm (http://climate-data.org).

Soil Characteristics

Soil samples were collected down to depths 0-15 cm and 15-30 cm from various random locations in the experimental field. Composite soil samples of the experimental site were prepared to determine the soil status i.e., texture, organic matter, pH, ECe, available phosphorus and extractable potassium, as given in Table 1.

Table 1. Soil properties of the experimental field

Parameters	Depth (cm)	Value
pH	0-15	7.68
	15-30	7.66
EC_e (dSm^{-1})	0-15	0.57
	15-30	0.49
Organic Matter (%)	0-15	0.48
	15-30	0.45
Available P (mg kg^{-1})	0-15	4.80
	15-30	3.30
Ext. K (mg kg^{-1})	0-15	88.00
	15-30	80.00
Textural class	0-15	Sandy loam

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	15-30	Sandy loam

Weather data

Variable weather conditions existed during the study period, and more prominently, seasonal rain was important for soil moisture and wheat growth. Daily weather data recorded at SAWCRI measured rainfall for the entire experimental period. Metrological data from the study period (2015-18) is presented in Tables 2 to 4.

Table 2. Metrological data during the crop growth period (2015-16)

Month	Air temp (°C)		Rainfall (mm/month)	Pan Evaporation (mm/day)	Mean Relative Humidity (%)
	Min	Max			
Nov 2015	7.4	22.9	9.2	1.9	64.7
Dec 2015	2.2	19.9	1.2	1.5	66.4
Jan 2016	2.3	17.3	19.4	0.9	83.8
Feb 2016	4.4	22.2	38.0	1.8	72.9
Mar 2016	10.7	24.1	66.1	2.4	76.5
Apr 2016	13.7	32.3	1.3	5.6	59.0
May 2016	20.5	38.8	33.4	8.5	41.4

Table 3. Metrological data during crop growth period (2016-17)

Month	Air temp (°C)		Rainfall (mm/month)	Pan Evaporation (mm/day)	Mean Relative Humidity (%)
	Min	Max			
Nov 2016	8.6	26.1	2.1	2.1	60.7
Dec 2016	4.5	23.2	0.0	2.2	67.2
Jan 2017	4.2	15.4	48.1	0.8	86.0
Feb 2017	5.8	21.0	25.1	2.0	68.2
Mar 2017	9.4	25.7	11.5	2.9	62.0
Apr 2017	15.4	31.5	94.3	5.0	47.1
May 2017	21.3	37.3	52.1	6.2	47.1

Table 4. Metrological data during crop growth period (2017-18)

Month	Air temp (°C)		Rainfall (mm/month)	Pan Evaporation (mm/day)	Mean Relative Humidity (%)
	Min	Max			
Nov 2017	8.1	24.1	I6.4	1.3	77.0
Dec 2017	3.5	20.6	17.5	1.4	81.5
Jan 2018	0.9	19.8	1.0	1.5	65.1
Feb 2018	5.1	21.4	18.5	1.9	63.9
Mar 2018	11.4	27.5	39.3	2.5	61.7
April 2018	15.8	30.7	82.8	4.0	53.0
May 2018	19.2	35.0	56.4	6.7	39.8

Experimental layout

The experiment was laid out in a randomized complete block design (RCBD) to evaluate the efficacy of different tillage implements for moisture conservation and yield improvement of wheat (*Triticum aestivum* L.) under rain-fed conditions. The soil was tilled under three treatments: T_1: Control (normal tillage with cultivator); T_2: Deep ploughing by moldboard (MB) plough; and T_3: Deep ploughing by Disc plough. The seed of wheat (*Triticum aestivum* L.) was treated with Topsin M @ 2 gram per kg before sowing and was sown at a rate of 125 kg per hectare with row spacing of 22.5 cm between the last week of October and the first week of November in all treatments. Mineral fertilizer @120-80-60 kg N-P_2O_5-K_2O per hectare was applied before crop sowing, and other agronomic practices were kept uniform in all treatments. Wheat plant population was recorded after germination, while other crop traits such as the number of fertile tillers, straw and wheat grain yield were recorded on crop maturity using standard procedures.

Soil moisture data

Soil samples were collected periodically at a depth of 0-30 cm before sowing, after two months & four months, and finally at harvest. Gravimetric method was used to determine soil moisture contents by drying pre weighed soil samples in an oven at 105 ^{0}C for 24 hours. Sample weight loss after drying was measured as moisture content using equation (1) as described by (Ryan et al., 2001).

$$Soil\ moisture\ (\%) = \frac{(weight\ of\ wet\ soil)-(weight\ of\ oven\ dried\ soil)}{(weight\ of\ oven\ dried\ soil)} x100 \quad (1)$$

Economic Analysis

The cost-Benefit ratio is the most important factor in the sustainability of any technique for which economic analysis of the experiment was carried out. All costs involved ,profits obtained and/or savings in all three treatments were recorded during the study period. Economic analysis of tillage treatments was carried out for commercial-scale application of the proposed tillage technique in wheat. Net return from wheat crop was determined by subtracting the total cost of production from the gross income of each treatment as described by (Program, 1988) and also applied for benefit-cost ratio (BCR) using equation (2) given hereunder.

Net income = Gross income – Cost of production

(2)

BCR = Gross income/ Cost of production

Statistical analysis

Collected data was statistically analyzed through the analysis of variance (ANOVA) technique with two factors in a randomized complete block design (RCBD), while treatment and year means were compared by applying LSD test at 0.05 level of probability as described by (Steel and Torrie, 1980).

Results and Discussion

Rainfall distribution in the study area

The varied rainfall pattern has been observed during 2015-18, with significant rainfall at the initial stage of the growing season 2017-18 i.e., Nov-Dec while non-significant rainfall was observed in 2015-16 and 2016-17 at the early stages. No rainfall occurred during Jan 2016, and very little rainfall during March 2017. Comparatively high rainfall was recorded near maturity in 2017 and 2018 (Fig. 1). Effective rainfall of the entire wheat season rainfall also varied as 151.4 mm, 148.7 mm and 126.4 mm during 2017-18, 2016-17 and 2015-16, respectively (Fig. 2).

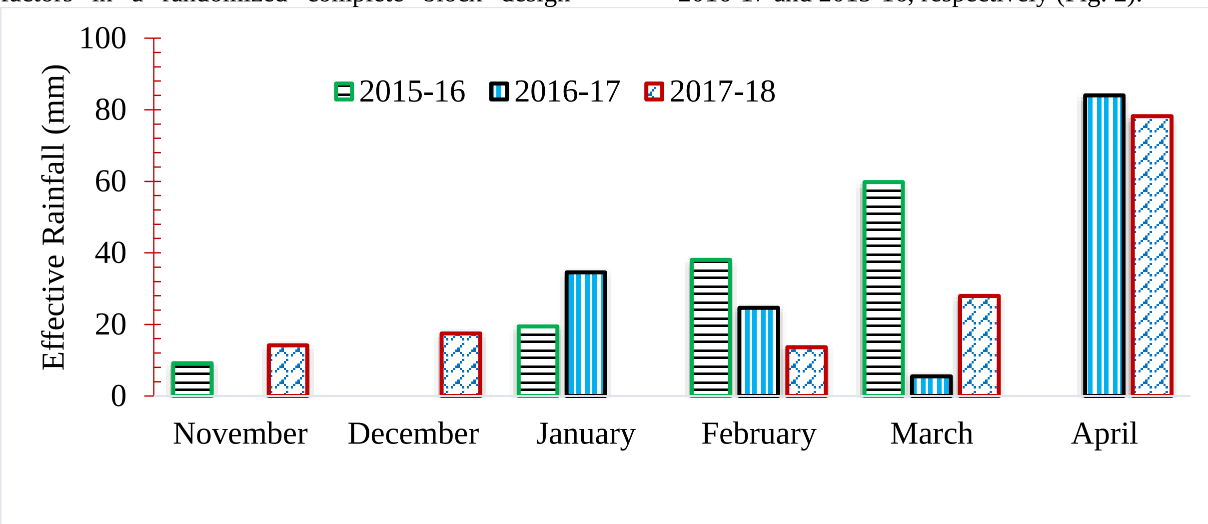

Fig 1. Mean monthly effective rainfall during study period

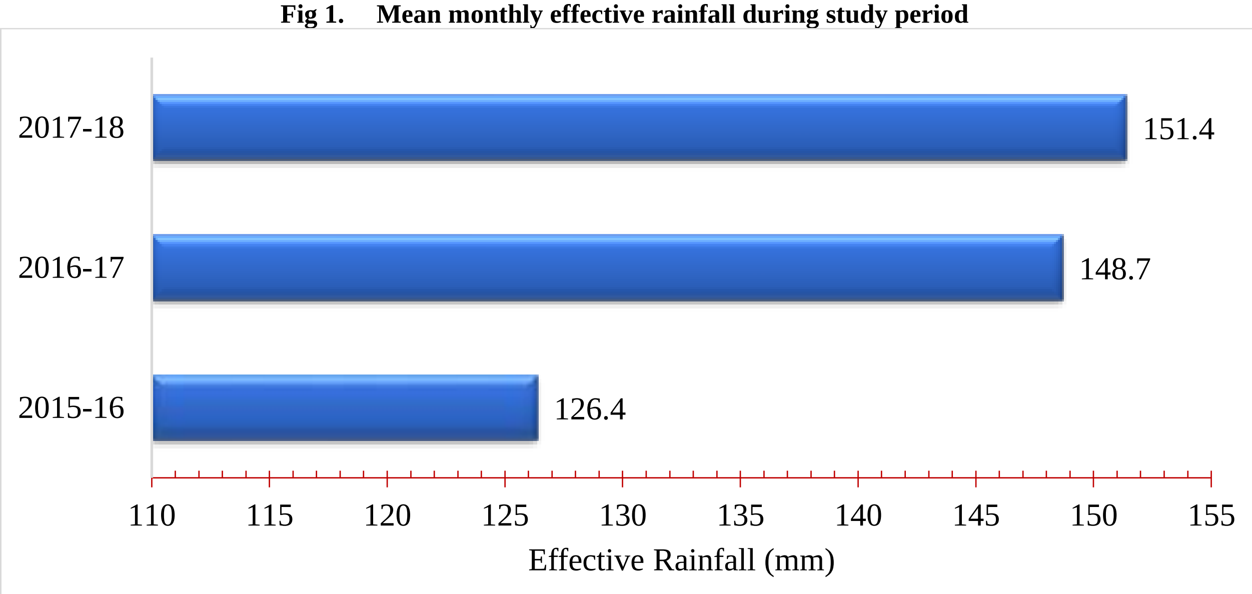

Fig 2. Wheat growing season effective rainfall during study period

Tillage practices and rain water harvesting

Soil tillage plays a crucial role in conserving and storing water in-field/in-rootzone for crop growth that guarantee the success of any sustainable agricultural practice for crop production. It also affects germination, plant population and, ultimately, the yield of crops. In Pothwar like areas, where rain is erratic, it is vital to store rainwater, in either a reservoir, storage tank or in-situ before sowing crop to fulfil subsequent crop water requirements.

Effect of intensity and depth of tillage using commonly used implements i.e., MB plough, Disc plough and cultivator as a control, was evaluated for soil water availability at the time of sowing, two & four months after sowing, and finally at harvest. The quantity of available soil water at crop sowing was significantly higher (37.3 mm) with MB plough compared with cultivator (33.5 mm). It was statistically at par with disc plough during the entire experimental duration 2015- 2018. Mean water availability was also affected during the three-years study period, as more soil water availability was observed during 2016-17, followed by 2015-16 while lesser during 3rd year i.e., 2017-18 and mean water availability varied from 27.2 mm to 38.1 mm during the experimental period at the time of wheat sowing as shown in table 5.

Table 5. Effect of tillage practices on soil water at sowing time

Treatments	Available water (mm) from 30 cm depth			
	2015-16	**2016-17**	**2017-18**	**Mean**
Control (Cultivator)	37.2 a	38.8 a	24.5 b	**33.5 B**
MB Plough	38.5 a	43.5 a	29.8 b	**37.3 A**
Disc plough	38.5 a	40.5 a	27.3 b	**35.4 AB**
Mean	**38.1 B**	**40.9 A**	**27.2 C**	-

LSD: treatment & year = 2.6882 interaction = 6.3355

Similarly, MB plough outperformed other treatments after two months (table 6) with 34.3 mm available water while disc plough and cultivator had 33.8 mm and 31 mm available soil water.

Table 6. Effect of tillage practices on soil water after 2 months of sowing

Treatments	Available water (mm) from 30 cm depth			
	2015-16	**2016-17**	**2017-18**	**Mean**
Control	32.0 ab	29.0 b	32.0 ab	**31.0 B**
MB Plough	36.5 a	32.8 ab	33.8 ab	**34.3 A**
Disc plough	36.0 a	31.5 ab	33.8 ab	**33.8 AB**
Mean	**34.8 A**	**31.1 B**	**33.2 AB**	-
LSD: treatment & year = 2.8587, interaction = 6.7374				

Significantly higher moisture availability was recorded during 1st year of experimentation i.e., 60 mm compared with 2nd and 3rd year of study. Trend of water availability after four months of sowing was almost similar with more soil water availability 39.9 mm with MB plough in comparison with disc plough and cultivator i.e., 38.2 mm and 36.3 mm, respectively (table 7). Significantly higher water availability (54 mm) during 2014-15 was observed compared to 2015-16 and 2016-2017 i.e., 39.3 mm and 21.1 mm respectively. Finally, soil water measurements indicated similar efficacy of MB plough and Disc plough against control tillage practice i.e., cultivator. The soil water availability was significantly higher (33 mm) with MB plough followed by disc plough (31.6 mm) and control tillage treatment (29.6 mm) as indicated in Table 8. Varying soil water levels were observed during three years of the experimental period.

Table 7. Effect of tillage practices on soil water after 4 months of sowing

Treatments	Available water (mm) from 30 cm depth			
	2015-16	**2016-17**	**2017-18**	**Mean**
Control	53.0 a	37.5 b	18.5 c	**36.3 B**
MB Plough	55.8 a	41.0 b	23.0 c	**39.9 A**
Disc plough	53.5 a	39.5 b	21.8 c	**38.2 AB**
Mean	**54.0 A**	**39.3 B**	**21.1 C**	-
LSD: treatment & year = 1.9335, interaction = 4.5568				

Table 8. **Effect of tillage practices on soil water at harvesting stage**

Treatments	Available water (mm) from 30 cm depth			
	2015-16	**2016-17**	**2017-18**	**Mean**
Control	29.0 cde	24.3 e	35.5 ab	**29.6 B**
MB Plough	31.8 bc	28.0 cde	39.3 a	**33.0 A**
Disc plough	30.5 bcd	26.5 de	37.8 a	**31.6 AB**
Mean	**30.4 B**	**26.3 C**	**37.5 A**	-
LSD: treatment & year = 2.1509, interaction =5.0693				

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The results of the current experimental study indicated the significance of tillage implements and practices for moisture conservation under rain-fed conditions of Pothwar. It has been observed that MB plough outperformed other tillage operations in the soil available water at four intervals, with disc plough performing at par in most of the cases, while cultivator lags in conserving rainwater, the life line of rain-fed agriculture. The improved soil water availability indicated better moisture conservation through MB and disc plough. Similar results were reported by (Mari et al., 2011), who reported that shallow soil tillage implements e.g., cultivator retained less soil moisture in soil comparison with deep tillage implements i.e., Chisel and moldboard plough. These implements go deeper into the soil and pulverize soil much more than cultivator. The results also depict that deep tillage can better conserve soil moisture and ensure water availability for wheat production. Findings of the current study are also in line with (Laddha and Totawat, 1997), who reported that deep tillage with disk and chisel plough was better than shallow tillage, significantly improving soil water content. Tillage implements significantly affect soil moisture percentage, and chisel plough helped to conserve more moisture when compared with disc plough and ridger (Amin et al., 2014; Makki and El-amin Mohamed, 2008). Tillage significantly improved soil moisture at 0-20 and 20-40 cm depths (Salehi et al., 2017) and soil analysis after harvest presented a beneficial effect of tillage depth on soil moisture contents (Javaid et al., 2005). Hence, better soil moisture at critical wheat stages can support better crop stand and yield.

Effect of tillage on wheat crop production

This study judged and compared wheat crop production in response to rainwater harvested through various tillage practices by recording plant population, productive tillers, plant height, straw and grain yield. These responses are described as under:

Plant population

Experimental data (table 9) regarding plant population (per square meter) was recorded each year from each treatment. The data indicated that tillage implements significantly affected wheat crop populations as higher plant populations were observed in MB plough treatment than other treatments. Highest plant population of wheat was observed under treatment T_2 when MB plough was used in comparison with other tillage implements during three years of study, whereas a lower plant population was observed under treatment T_1 i.e., cultivator. Similarly, variable plant population was observed during the study period, indicating the role of yearly rainfall, and significantly less plant population was observed during 2017-18. The lesser plant population was due to lower soil water (27.2mm) at the time of sowing. On one hand, it showed that plant population increased with soil water. On the other, it endorsed the role of tillage in rainwater conservation, thus ultimately giving more plant population. Our results confirm the findings of (Rizwan et al., 2017), who reported better germination with MB plough than with cultivator.

Table 9. Effect of tillage practices on plant population of wheat

Treatments	Plant population per m^2			
	2015-16	**2016-17**	**2017-18**	**Mean**
Control	216 c	246 b	125 d	**196 B**
MB Plough	219 c	271 a	130 d	**207 A**
Disc plough	218 c	250 b	128 d	**199 B**
Mean	**218 B**	**256 A**	**128 C**	**Mean**
LSD: treatment & year = 7.7859, interaction = 18.350				

Productive tillers

Data on number of productive tillers showed significant variation among years and treatment means are non-significant as given in table 10.

Table 10. Effect of tillage practices on fertile tillers of wheat

Treatments	Fertile tillers per m^2			
	2015-16	**2016-17**	**2017-18**	**Mean**
Control	436 a	189 b	211 b	**278 A**
MB Plough	445 a	219 b	221 b	**295 A**
Disc plough	441 a	204 b	215 b	**287 A**
Mean	**441 A**	**204 B**	**216 B**	-
LSD: treatment & year = 26.282, interaction = 61.942				

It has been observed that the maximum number of fertile tillers (441) were observed during the year 2015-16 wherein rainfall was well distributed during the wheat season with dry spell of 69 days during the wheat growth period and significantly a smaller number of productive tillers (204) were produced during 2016-17 when the longest dry period (113 days) was observed. Deep ploughing increased productive tillers compared to control, but the increase was statistically non-significant. However, deep ploughing by MB plough increased (6%) the number of productive tillers in confirmation to

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(Rizwan et al., 2017) who reported that tillage with (MB plow, Rotavator and Planker) produced significantly higher tillers than other tillage implements. Productive tillers were significantly higher in deep tillage than other tillage implements. Similarly, better water use efficiency (WUE) was recorded with deep tillage practice (Ehsanullah et al., 2013).

Plant Height

The plant height data presented in table 11 was recorded at maturity, and showed that plant height was significantly affected by using different tillage implements. Maximum plant height (95.1 cm) was obtained by deep ploughing with MB plough, and it was significantly higher than control (without deep ploughing). The results of our experiment were statistically at par with the use of Disc plough. The increase in plant height was 2.4 % and 1.3 % as compared to control by the use of MB plough and Disc plough, respectively. Results are supported by(Hussain et al., 2013), who reported more plant height (66.75 cm) with disc plow in comparison with cultivator (58.37 cm) while lower plant height (51.51cm) was observed with minimum tillage. This increase might be due to the positive role of soil moisture on plant growth. The effect of year on plant height was also significant where maximum plant height (100.3 cm) was obtained during 2016-17. The interactive effects of treatment and year were also significant on the plant height of wheat. The interaction effect was affected during 2nd year of study. Poor soil conditions, such as higher bulk density, cause poor crop establishment (Atkinson et al., 2007).

Table 11. **Effect of tillage practices on plant height**

Treatments	Plant height (cm)			
	2015-16	**2016-17**	**2017-18**	**Mean**
Control	89.8 b	99.3 a	89.6 b	**92.9 B**
MB Plough	91.7 b	102.0 a	91.6 b	**95.1 A**
Disc plough	91.5 b	99.8 a	91.1 b	**94.1 AB**
Mean	**91.0 B**	**100.3 A**	**90.8 B**	-
LSD: treatment & year = 1.6254, interaction = 3.8306				

Straw Yield

Data on straw yield under all treatments were recorded in table 12. Statistical analysis revealed significant variations during the experimental period of 3 years. Straw yield data also showed significant differences among tillage implements during the study period (2015-16 to 2017-18). The results indicated that the MB plough significantly improved the straw yield of wheat as compared to the control and disc plough. While statistically significant better wheat straw yield was obtained in 1st year followed by 2nd and 3rd year of study. Concerning the interaction of year and tillage implements, deep ploughing showed best results during 1st and 2nd year of study, followed by 3rd year.

Table 12. **Effect of tillage practices on straw yield of wheat**

Treatments	Wheat straw yield (kg ha^{-1})			
	2015-16	**2016-17**	**2017-18**	**Mean**
Control	6356 a	4762 bc	3895 c	**5004 B**
MB Plough	7247 a	5960 ab	4584 bc	**5930 A**
Disc plough	6698 a	4726 bc	4115 e	**5179 B**
Mean	**6767 A**	**5149 B**	**4198 C**	
LSD: treatment & year = 620.09, interaction = 1461.04				

Maximum straw yield (5930 kg ha^{-1}) was obtained by MB ploughing followed by disc plough (5179 kg ha^{-1}). The yield was 5004 kg ha^{-1} in the treatment where deep ploughing was not carried out. The increase in yield was 18.5 and 3.5 per cent by MB plough and disc plough, respectively. The straw yield was 6767, 5149 and 4198 kg ha^{-1} during 1st, 2nd and 3rd year of study, respectively. The maximum straw yield of 6767 kg ha^{-1} was obtained during 1st year of study. It was 31 and 61 per cent higher than 2nd and 3rd year of study, respectively. Straw yield was improved by deep ploughing as compared to control. Above results confirm the findings of (Barzegar et al., 2003), who reported deep tillage with a chisel plough was the most effective tool for improving soil physical properties, increasing chickpea dry matter and grain yield compared to other tillage tools. Similarly, maximum total dry matter production was noted in the case of deep tillage compared to less tillage (Khurshid et al., 2006; Salehi et al., 2017). Significant improvement in the biological yield of wheat was observed in deep tillage compared with other tillage implements (Ehsanullah et al., 2013).

Grain yield

Data on wheat grain yield, as given in Table 13 showed significant differences among different tillage implements during an experimental period of 3 years (2015-16 to 2017-18). The results indicated that the MB plough significantly improved wheat grain yield compared to the control and disc plough. While statistically significant better yield of wheat

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was obtained during 1st year as compared to 2nd and 3rd year of study. The maximum grain yield (3650 kg ha^{-1}) was obtained during 2015-16 followed by 2017-18, while the minimum yield (2611 kg ha-1) was obtained during 2016-17. The interaction of year and tillage implements, deep ploughing showed the best results during 1st year of study followed by 3rd year of study. Maximum grain yield (3245 kg ha^{-1}) was obtained by MB ploughing, followed by yield (2967 kg ha^{-1}) obtained by disc plough. The yield was 2798 kg ha^{-1} in the treatment where deep ploughing was not carried out. The increase in yield was 16 and 5.7 per cent by MB plough and disc plough, respectively, compared to control. The grain yield was 3650, 2611 and 2749 kg ha^{-1} during 1st, 2nd and 3rd year of study, respectively. The maximum grain yield of 3650 kg ha^{-1} was obtained during 1st year of study. It was 39.8 and 32.8 per cent greater than the study period's 2nd and 3rd year, respectively. Similarly, deep tillage showed better grain yield than other tillage practices(Ramos et al., 2011; Rizwan et al., 2017). Deep tillage is recommended for better crop production and yield(Amin et al., 2014; Safeer et al., 2013). Moreover, tillage also improves grain weight (Gholami et al., 2014). Results from previous research showed that deep ploughing by disc plough resulted in more grain yield than the cultivator. Higher yield may result in better soil conditions, e.g., lower soil bulk density improved grain yield and vice versa(Atkinson et al., 2007; Hussain et al., 2013). Average yield increments up to 13% have been reported with deep vertical tillage and conventional tillage compared to no Tillage practice(Ordoñez-Morales et al., 2019; Salehi et al., 2017).

Table13. Effect of tillage practices on grain yield of wheat

Treatments	**Wheat grain yield (kg ha^{-1})**			
	2015-16	**2016-17**	**2017-18**	**Mean**
Control	3526 ab	2370 d	2498 cd	**2798 B**
MB Plough	3824 a	2860 cd	3050 bc	**3245 A**
Disc plough	3601 ab	2603 cd	2699 cd	**2967 B**
Mean	**3650 A**	**2611 B**	**2749 B**	
LSD: treatment & year = 262.05, interaction = 617.60				

Cost and Return Analysis

Tillage operations require draft power; here 75 HP tractor was used. Hence, fuel consumed in drafting these implements was the main variable; thus, fuel consumption in each tillage by three implements was recorded. The results showed that the lowest fuel was required for cultivator (7.87 L/ha) due to the lower depth of tillage, While fuel consumption was almost two times more in disc plough (13.64 L/ha) and MB plough (16.60 L/ha). Considering the prevailing rates of diesel, cost of fuel consumed in each tillage per hectare was thus calculated as given in table 14.

Table 14. Detail of fuel consumption by each implement under experiment

Name of Implement	**Plot area m^2**	**Fuel consumed**		**Cost of fuel (Rs ha^{-1})**			
		mL plot^{-1}	**Liters ha^{-1}**	**2015-16**	**2016-17**	**2017-18**	**Average**
Cultivator	506	3980	7.87	693	575	645	637
M.B plow	506	8400	16.60	1461	1212	1361	1345
Disc plow	506	6900	13.64	1200	996	1118	1105
Fuel price (Rs L^{-1})				88	73	82	81

Cost-benefit analysis of the experiment indicates an interesting trend for tillage operations: the cost of wheat production was the least with cultivator i.e., 54798 PKR ha^{-1} while for disc plough and MB plough, was 57626 and 58673 PKR ha^{-1}, respectively. However, grain yield was higher with MB plough (3245 kg ha^{-1}) followed by Disc plough (2967 kg ha^{-1}) and cultivator (2798 kg ha^{-1}). Highest economic return from wheat under tillage with MB plough (107085 rupees) was obtained as depicted in table 15 and Fig.3. It translates into an additional amount of 3875 rupees with MB plough and 2828 rupees per hectares with disc plough.

Table15: Economic analysis of wheat production under various treatments of tillage

Parameters	Cultivator	MB plough	Disc plough
Average grain yield (kg ha^{-1})	2798	3245	2967
Average sale price (Rs kg^{-1})	33	33	33
Return (Rs ha^{-1})	92334	107085	97911
Benefit over control (Rs ha$^{-1)}$	0	14751	5577
Average production cost (Rs ha^{-1})	54798	58673	57626
Increase Rs ha^{-1}	0	3875	2828
Net return (Rs ha^{-1})	37536	48412	40285
Benefit cost ratio	1.68	1.83	1.70

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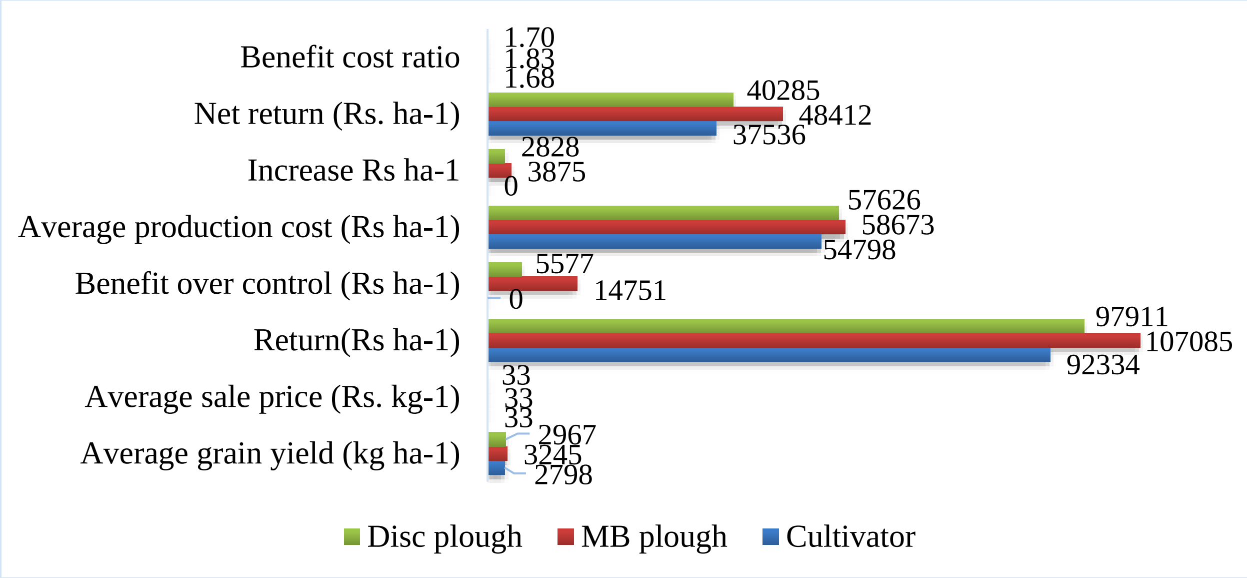

Fig.3. Cost and benefit analysis wheat with different tillage implements.

Net return obtained from tillage treatments was to Cultivator < Disc plough < MB plough, with a cost befit ratio of 1.68, 1.70 and 1.83, respectively. Our results indicated that MB plough tillage was most effective in enhancing wheat productivity and farm profitability. Our results align with (Javaid et al., 2005), who reported a higher net return of MB plough than cultivator. Similar trend was reported by(Ehsanullah et al., 2013), who observed that deep tillage produced a maximum net return of 63193 PKR ha^{-1} with benefit cost ratio (BCR) of 1.51 higher than all other tillage (happy seeder, zone disc tiller, conventional tillage) and mulch treatments. The benefit-cost ratio for MRP (MB plow, Rotavator, and Planker) was higher than that of other tillage practices (Rizwan et al., 2017). Conventional tillage had a Higher cost benefit ratio than no tillage (Safeer et al., 2013).

Conclusions

The current study concluded that deep tillage with mold board plough compared to disc plough and cultivator is the most beneficial in conserving soil moisture and giving net return from the crop production. This implement pulverized the soil to its maximum extent and thus provides the more opportunity for rain water harvesting and conserving the soil moisture in-field. Thus, the authors recommend the use of MB plough in water-scarce areas.

Novelty of the Study

Agriculture in rain-fed areas worldwide is confronted with scarcity andin-time availability of water. The current study present a unique finding for the farmers of such areas to have the opportunity to select the most efficient and economical tillage implement. The mold board plough requires more draft power for its operation, but the overall benefit is that the farmers of rain-fed areas use most other implements.

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Declarations

Data Availability statement

All data generated or analyzed during the study are included in the manuscript.

Ethics approval and consent to participate

Ethical approval was given from Ethical Review committee of department.

Consent for publication

The consent form was approved from Ethical Review committee of department.

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Conflict of Interest

Regarding conflicts of interest, the authors state that their research was carried out independently without any affiliations or financial ties that could raise concerns about biases.

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Author Contribution

SAR conducted research and wrote up initial draft of manuscript. WN, GM, SA and TH provided resources. RR, NL, and AU made final editing in the manuscript. All authors approved final version of manuscript.

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