

Impact of Tillage Systems on Economics and System Productivity of Forage Crops-Wheat systems

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Abstract

This investigation was conducted to determine the impact of tillage systems on sustainability and productivity of forage crops-wheat systems for three consecutive years at Punjab Agricultural University, Ludhiana. The six crops as cowpea (*Vigna unguiculata*), Pearl millet/ bajra (*Pennisetum typhoides*), maize (*Zea mays*), sorghum (*Sorghum bicolor*), guara (*Cyamopsis tetragonoloba*) and Teosinte/ makchari (*Euchaleana maxicana*) were grown under zero and conventional tillage followed by zero tilled wheat. The results revealed that ZT-ZT (80.18 q/ha) had the higher average system productivity as compared to CT-ZT system (78.83 q/ha), which was recorded 1.68 % more than CY-ZT system. Similarly, the average net return of Rs. 86588.00 was recorded maximum under ZT-ZT that was 2.9 % more as compared to CT-ZT tillage system (Rs. 84077.00). However, average system productivity was received highest under maize-wheat (90.61 q/ha) that was 11.40, 10.80, 14.82, 24.21 and 15.00 % higher than cowpea-wheat (80.28 q/ha), bajra-wheat (80.82 q/ha), sorghum-wheat (76.80 q/ha), guara-wheat (68.67 q/ha) and makchari-wheat (77.02 q/ha), respectively. The cropping system of maize-wheat gave the highest net return of Rs. 99980.50, which was 13.95, 13.22, 18.65, 2.62, and 18.35 % higher than cowpea-wheat, bajra-wheat, sorghum-wheat, guara-wheat and makchari-wheat, respectively. The adoption of the cropping systems by the farmers mainly depends on the economic return, therefore, the findings of this investigation indicated that all the cropping systems can be grown successfully and

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efficiently with substantial returns without affecting the soil and environment due to the skipping of initial operations for seed bed preparations.

Key words: Forage crops-wheat systems, Net return, System productivity, Tillage systems

1. Introduction

The rice-wheat tilting is the most common agricultural framework in south Asian nations, covering about 13.5 million hectares (mha) inside the Indo-Gangetic Plains (IGP), with 10 mha in India, 2.2 mha in Pakistan, 0.8 mha in Bangladesh, and 0.5 mha in Nepal. This process represents around 33% of total rice land as well as 42% of world wheat area in the four nations mentioned here, accounting for a full third of overall wheat and rice productivity. And over a billion people are relying on these farming systems for their daily needs, so it is critical to the region's food survival and wellbeing [8]. Preserving and rising crop yields in the Indian province of Punjab, Haryana, and western Uttar Pradesh in the northwest (NW) IGP, collectively called as India's "breadbasket," is critical to meeting the country's growing food demand, which would be expected to rise from 1.3 billion in 2015 to 1.6 billion by 2050.

Wheat is cultivated in India on an area about 29.1 mha with productivity of 34.04 q ha⁻¹ in 2018-19 [3]. It shows a marginal increase in the national productivity that is improved by 30.09 to 34.08 q ha⁻¹ during 2012-13 to 2018-19 [26]. In Punjab, it occupied an area of 3.52 mha with production of 18.26 million tones and average productivity of 51.88 q ha⁻¹ in 2018-19 [4].

Farmers are encouraged rice-wheat farming systems, as well as the west section of the Rice-Wheat zone of a Indo-Gangetic Plains (Western Uttar Pradesh, Haryana, and Punjab), while wheat seems to be the major crop, offers a good climate for both wheat and rice fields via guaranteed irrigated agriculture. The aggregate food grain harvests in this region are about double those in the Indo-Gangetic Plains' eastern states. Wheat needs around 400 mm of water for agriculture at each of its six essential production stages [11].

Wheat is mostly cultivated in irrigation water agricultural cycles such as Rice-Wheat, Jowar-Wheat, Bajra-Wheat, Maize-Wheat, Pulse-Wheat, Cotton-Wheat, Soybean-Wheat, and others in various regions of the nation, however the Rice-Wheat system is the most prevalent. Rice production, a moisture crop, depletes water table, decreasing watering options.

Furthermore, indiscriminate and unbalanced fertilisation compromises the system's long-term viability [11].

Tillage methods are a significant consequence on soil physico-chemical and biological features, as well as production and durability [16]. Because of loss and degradation of organic compounds in soils, traditional tillage techniques may have a negative impact on lengthy land production. Zero-tillage has demonstrated its efficacy in maintaining and increasing performance of rice-wheat crop systems (RWCS) while conserving limited natural quantities of power, manpower, time, water, and environmental integrity as an alternate to traditional techniques [13]. Sustainable tillage (including no tillage), increasing crop residual yield, and farming techniques are all examples of sustainable farming practices [19]. No-tillage and reduced-tillage soils have considerably greater organic matter in the soil levels than traditionally tilled soils, according to studies done under a variety of weather circumstances, soil types, and agricultural crop.

Conservation tillage is a method of reducing soil loss by leaving at about 30% of plant leftovers in the land after seeding [25]. Conservation tillage techniques provide several benefits above traditional tillage, including lower farming costs, the ability of agricultural residues to function as an insulation and reduce soil temperature variation, increased soil biological content, and soil moisture preservation. In a long-term conserving tillage system, alterations in soil physicochemical properties like bulk density [27] and stratified of organic matter in the soil have been reported [21]. As a result, conservation tillage alters both physiochemical parameters, resulting in dramatically different homes for microbes and a shift in soil microbial community composition [20]. Microbial soil populations characterized by aerobic bacteria might result from conventional tillage, whereas conservation tillage methods enhance bacterial load and productivity, as well as beneficial organisms [6].

Considering the economic and ecological advantages of limited tillage methods, acceptance remains limited owing to soil compaction, carbon storage, germinating issues, and pest and insect frequency [24]. Long-term no-tillage treatment, on either hand, enhances amount of organic matter, which benefits not only soil quality but also biological growth [12]. Tillage techniques have a long-term effect on total nutrient levels, which is only evident after many years of use. Bacterial action reacts to perturbations more swiftly and in a lesser duration than other metrics.

Cultivation of maize, makchari, bajra, sorghum, cowpea and guara under no-till conditions in *kharif* and cultivation of wheat in *rabi* after foresaid *kharif* crops under no till conditions can play a vital role in reducing the cost of production of these crops in addition to saving of time and energy and increased profit margins. The requisite seed cum fertilizer drill under no-till conditions is already available. This technology will enable the timely sowing (due to skipping of tillage operations) of crops. Keeping in view the above, the present study was conducted to evaluate the performance of maize, makchari, bajra, sorghum, cowpea and guara under no-till and conventional tillage conditions followed by no-tilled wheat.

2. Materials And Methods

For three years, the testing location is situated at the Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana. Ludhiana is located in India's Trans-Gangetic Agro-climatic Zone, in the main plain area of Punjab, at 30° 54' N latitude and 75° 48' E longitudes, at a typical elevation of 247 metres above sea level. The temperature in the area is sub-tropical and semi-arid, with very hot dry summers from April to June, and hot and humid summers from July to September. Winters are cold from November through January, but the weather is pleasant from February to March. During summer and winter, there are significant differences in average lowest and maximum temperatures. Ludhiana receives and over 75% of its yearly rainfall from the south-west monsoon, which occurs from July to September. During the winter months, rainfall are scarce, however cyclonic rains might be expected in December-January or late spring.

The soil used for the study was sandy loam in texture. The sandy loam soil had 0.33% organic C with the available N, P and K contents of 313.6, 18.3 and 185.9 kg ha⁻¹, which was low in available N and medium in phosphorus and potassium, respectively. The pH of the soil was 7.7 and the electrical conductivity being 0.14 dSm⁻¹. In the field trials, the performance of maize, makchari, bajra, sorghum, cowpea and guara was evaluated under no-tillage and conventional tillage on sandy loam soils for three consecutive years during *kharif* season from 2008-2010 and followed no-tillage wheat continuously. The treatments in the *kharif* consisted of two tillage systems (zero and conventional) in the main plots and six *kharif* crops (maize, makchari, bajra, sorghum, cowpea and guara) in the sub plots. In the *rabi* season, zero till wheat was sown after

the *kharif* crops under no-tillage and conventional tillage plots. The variety of wheat PBW 343 was sown 20 cm apart in the last week of September in all the years. The fertilizer applied at rate of 125 kg N/ha and 62.5 kg P₂O₅/ha. Phosphorus was applied at sowing and N applied in two splits at after first and second irrigation. The forage crops were taken 1-2 times in different years as per given the date of sowing and harvesting but makchhari was introduced in the experiment during 2009 and 2010. All the crops in the *kharif* season were raised following the recommended package of practices of the university (Table 2). The rainfall data was collected from the Agrometeorology Lab of the Punjab Agricultural University, Ludhiana (Table 3).

Table 1. Dates of sowing and harvesting of different *kharif* fodder crops during 2008 to 2010

Year	Cowpea		Bajra		Maize		Sorghum		Guara		Makchhari	
	DOS	DOH	DOS	DOH	DOS	DOH	DOS	DOH	DOS	DOH	DOS	DOH
2008	16/5	4/7	17/5	6/7	17/5	14/7	17/5	15/7	16/5	5/8	-	-
	18/7	8/9	-	28/8	18/7	23/9	-	10/9	-	-	-	-
	-	-	-	6/10	-	-	22/9	6/11	-	-	-	-
2009	24/5	22/7	24/5	22/7	24/5	3/8	24/5	3/8	25/5	4/8	5/7	5/10
	31/7	23/9	-	16/9	4/8	23/10	-	5/10	-	-	-	-
2010	13/5	9/7	13/5	9/7	13/5	24/7	13/5	21/7	28/5	5/8	7/6	20/9
	16/7	24/9	16/7	11/9	29/7	1/10	29/7	15/10	10/8	25/10	-	-

DOS: Date of sowing; DOH: Date of harvesting

Table 2. Inputs used for sowing of different *kharif* fodder crops

Input/practice	Cowpea	Bajra	Maize	Sorghum	Guara	Makchhari	G. grass
Varieties	C-367	Local	J-1006	Local	G-88	Local	PGG 518
Seed (kg/ha)	30	20	75	50	20	40	15
Spacing (cm)	30	22	30	22	30	30	22
Fertilizer (kg/ha)	41.3 urea + 350 super	110 urea	275 urea+50 MOP	110 urea+125 super	50 urea+375 super	220 urea	165 urea+ 165 urea after each cutting
Harvesting time (days after sowing)	55-65	45-55	50-60	65-80	70-80	80-100	50-55, subsequent 30

Table 3. Rainfall (mm) during the growing season of different *kharif* fodder crops

Month	2007	2008	2009	2010
May	6.0	67.3	6.4	4.2
June	89.2	277.3	110.6	33.2
July	150.7	152.7	491.1	381.7
August	110.6	392.8	118.2	105.8
September	56.8	44.7	112.1	127.5

October	-	39.0	26.2	8.8
Total	413.3	973.8	864.6	661.2

Grain yield of what

The grain yield of wheat was recorded per plot by removing the border affect on the rows of the crop and converted in to yield q/ha.

Herbage yield of forage crop

The whole plot was harvested, weighed and converted in to herbage yield q/ha. It supplied to the Guru Angad Dev University, Ludhiana.

Economic analysis

The following socioeconomic variables were calculated using the standard technique, based on current output prices and the expense of different supplies utilised throughout the testing period.

System productivity

The overall efficiency were estimated by translating the output of all of the crops grown in the farming pattern were translated into rice equivalent yield (REY) (q ha⁻¹) on the grounds of the existing market rate of a crop.

System productivity = Grain yield of wheat + Equivalent yield of forage crop

Cost of cultivation

The crop yield was calculated by adding together every one of the costs spent. Land clearing, seeds and fertilisers, irrigation, herbicides, insecticides, human labour, crop protection, harvest, milling, and other indirect expenses are included in the overall cost of agriculture.

Gross returns

The whole amount of revenue or yield, comprising manufacturing costs and expenses, is referred to as gross exchange. The net profit was determined by combining the per hectare yield achieved following different procedures by the wholesale market price at the time.

Net returns

Net returns were calculated by deducting the cost of cultivation from the gross returns of the individual treatment.

Net returns = Gross returns-Total cost of cultivation

Statistical analysis

The information for the current studies were subjected to statistical analysis using the [10] standardized protocol for split-plot layout, which was adopted [9] in the statistical programme CPCS-I. The analyses were conducted at a value of significant of 5%.

3. Results And Discussion

Impact of tillage systems

The herbage yield of forage crops, equivalent yield wheat yield and wheat yield were not influenced by zero tillage (ZT)-zero tillage (ZT) and conventional tillage (CT) – zero tillage (ZT) systems during all the years of study (Table 4). In 2011 and 2012, the grain yield of wheat did not vary statistically with tillage systems [1]. The system productivity was recorded of 81.95, 79.36 & 79.24 and 78.47, 75.29 & 82.74 q/ha under ZT-ZT and CT-ZT systems of tillage, respectively which was 3.48, 4.07 q/ha higher under ZT-ZT compared to CT-ZT in 2008-09 and 2009-10, it was 3.50q/ha lower in ZT-ZT in 2010-11, respectively. The ZT-ZT and CT-ZT system had no much difference in average system productivity and average net return but slightly higher average return from ZT-ZT tillage system due to the skipping of initial operations of seed bed preparation. It could be due to the similar productivity of various crops and average gross return under the respective tillage systems. Similar results have been reported [1]. They observed such tillage techniques like ZT, minimum tillage (MT), CT, and deep tillage (DT) were effect favorably on soil characteristics and agricultural production. All tillage processes as well gave identical production after the crop rotation cycles of four years. Based on expected positive savings per hectare in the different farming systems, it is apparent that the low number of cultivating processes in NT cut manufacturing costs as comparison to CT [31].

Impact of cropping systems

Conservation tillage methods (Table 4) such as no-till (NT), minimal or reduced tillage (RT) are commonly regarded to have positive benefits on crop cultivation as compared to conventional tillage (CT) [31]. Crop varieties utilized in spinning, rotating series and application frequently of

specific plants [5, 29], rotational duration, agronomist histories on farms, and land properties all influence the value and effectiveness of crop rotations [7, 22]. Several variables may impact ground wellness in various aspects. For illustration, cropping systems could provide greater prospects just for some land responsive microbes development and restrict illness tension by dissolving the life span of soil-borne pathogenic organisms related to specific plant as well as plant genetic background. Because specified crops do better in rotational than numerous others, identifying the ideal rotation pattern to maximise soil benefits may be hard [15]. The illustrative example, crop cycling with legume crops can enhance yield but also peptide composition of grains as the next crops, owing to enhanced soil accessible N from fixing atmospheric nitrogen following vegetables. Changing the genotypes (cultivars) of chickpeas or legume plants (such as pea and chickpea) in sequence could alter soil organisms' biodiversity and affect pulse crop yields as well as the following grain yield [30]. Diverse plants can generate various residues and organic residues, which can assist to increase soil microbe diversity and productivity, as well as microbial soil organic matter and C and N rotation [18, 22].

Herbage yield

There was great variation in the herbage yield of forage crops under various cropping systems during the study period which might be due to the weather in the growing seasons (Table 4). The significantly higher herbage yield was recorded under bajra-wheat as compared to other systems, followed by maize-wheat had recorded the significantly higher than sorghum-wheat and guara-wheat but it was at par that those obtained under cowpea-wheat in 2008-09. However, the results changed in 2009-10, the highest and statistically more herbage yield was obtained in sorghum-wheat than other cropping systems. But followed by it was found in maize-wheat, which was also significantly more as compared to others. However, cowpea-wheat, bajra-wheat and makchari-wheat were at par in herbage yield during 2009-10. In 2010-11, the maximum and significantly higher herbage yield was found in bajra-wheat than all other treatments. Followed by maize-wheat had recorded the highest and significantly more herbage yield than makchari-wheat, sorghum-wheat, cowpea-wheat and guara-wheat. The lowest was recorded in guara-wheat cropping system during all the years of study could be due to slow growth and single crop taken in the two seasons. The higher herbage yield under different cropping systems in the study period might due to the fast growth and development of the respective crops. Crop production might be enhanced with the following proper tillage operations and choice of suitable crops in the

cropping sequence including legume crops [2, 28]. Cropping systems were followed initially to increase yield from agro-systems, but modern technique used are mainly concerned with the sustainability of environment due to cropping systems [14].

Equivalent wheat grain yield

The results related to equivalent wheat grain yield are presented in table 4. In 2008-09, the equivalent yield was recorded highest under maize-wheat, which was significantly equal that obtained under bajra-wheat. It was significantly better than others. In 2009-10, sorghum-wheat gave the statistically higher equivalent yield as compared to all other cropping systems. However, the maize-wheat cropping had the maximum equivalent yield than the other cropping systems. The maize-wheat gave the maximum and significantly more equivalent yield compared to all other cropping systems. However, bajra-wheat and makchri-wheat cropping, which were significantly differed in equivalent yield each other in 2010-11. It was happened in all the growing seasons could be due to the respective higher herbage yield of forage crops.

Wheat grain yield

The highest wheat grain yield was received after the guara crop, which was significantly better than other forage crops (Table 4). But the yield obtained after cowpea, bajra and maize were at par with each other in the first year of study. However, grain yield of wheat did not vary after all the forage crops but it was higher after the guara and cowpea crops as compared to other crops in the second year. In the last year, the highest grain yield of main crop was recorded after the cowpea and it was at par significantly that obtained after guara, which was significantly better than those obtained after the other crops. However, the grain yield obtained after bajra, sorghum, maize and makchari were significantly at par each other. The higher grain yield was obtained after the leguminous crops because of their ability of fixing of atmospheric nitrogen and addition in the soil, which improve the soil chemical properties and resulted in higher yield of wheat.

Average of system productivity

The average system productivity was obtained highest under maize-wheat that was 11.40, 10.80, 14.82, 24.21 and 15.00 % higher than cowpea-wheat, bajra-wheat, sorghum-wheat, guara-wheat and makchari-wheat, respectively (Table 5). This variation in the average total productivity could be due to the respective total productivity recorded under various cropping systems. The lower

average system productivity under sorghum-wheat and guara-wheat could be due to slow growth and development and late harvesting for herbage than other crops.

Average net return

The average return varied among the different cropping systems (Table 5). But the highest was recorded with maize-wheat (Rs. 99,980.50) followed by bajra-wheat (Rs. 86764.00), cowpea-wheat (Rs. 86035.00), makchari-wheat (Rs. 81634.00), sorghum-wheat (Rs. 81337.00) and guara-wheat (Rs. 70361.50). The cropping systems as bajra-wheat, cowpea-wheat, makchari-wheat, sorghum-wheat and guara-wheat gave the 13.22, 13.95, 18.35, 18.65 and 29.62 % lower average net return as compared to maize-wheat cropping system. The higher average return from the cropping systems could be due to the substantial herbage yield of the forage crops and more gross return. However, the lowest net return recorded from guara-wheat because of lower herbage of guara in all the years of study and also lower gross return. The maize-wheat cropping system could be identified as more profitable compared to all other cropping systems if grown for sale in the market and easily take the two crops of maize before the sowing of wheat because it becomes ready for harvesting in 50 days after sowing [3].

4. Conclusion

Sustainability is the process of producing the crops with full potential without influencing the environment. The maximum net return of Rs. 86588.00 was recorded under ZT-ZT that was 2.9 % higher as compared to CT- tillage system (Rs. 84077.00). The cropping system of maize-wheat gave the highest net return of Rs. 99980.50 which was 13.95, 13.22, 18.65, 29.62, and 18.35 % higher than cowpea-wheat, bajra-wheat, sorghum-wheat, guara-wheat and makchari-wheat, respectively. Economic performance is play vital role in the adoption of cropping systems by the farmers. Therefore, the results of this investigation indicated that all the cropping systems can be grown successfully and efficiently with substantial returns without affecting the soil and environment due to the skipping of initial operations for seed bed preparation. However, the crops grown with CT impact the soil and sustainability of environment.

References

1. Alam Md. Khairul, Islam Md. Monirul, Salahin Nazmus, Hasanuzzaman Mirza, "Effect of Tillage Practices on Soil Properties and Crop Productivity in Wheat-Mungbean-Rice Cropping System under Subtropical Climatic Conditions", *The Scientific World Journal*, vol. 2014, Article ID 437283, 15 pages, 2014. <https://doi.org/10.1155/2014/437283>

2. Alam M. K., Effect of tillage depths and cropping patterns on soil properties and crop productivity [M.S. thesis], Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University, 2010.
3. Anonymous, Package of Practices for *kharif* Crops, Punjab Agricultural University, Ludhiana, 71-72, 2019.
4. Anonymous, Package of Practices for *rabi* Crops, Punjab Agricultural University, Ludhiana, 1-20, 2019.
5. Bainard L.D., Navarro-Borrell A., Hamel C., Braun K., Hanson K., Gan Y.. Increasing the frequency of pulses in crop rotations reduces soil fungal diversity and increases the proportion of fungal pathotrophs in a semiarid agroecosystem. *Agric. Ecosyst. Environ.*, 240 (2017), pp. 206-214.
6. Balota EL, ColozziFilho A, Andrade DS, Dick RP. Microbial biomass in soils under different tillage and crop rotation systems. *Biol. Fert. Soil.* 38 (2003), 15-20.
7. Bennett A.J., Bending G.D., Chandler D., Hilton S., Mills P. Meeting the demand for crop production: the challenge of yield decline in crops grown in short rotations. *Biol. Rev.*, 87 (2012), pp. 52-71.
8. Chauhan B.S., Mahajan G., Sardana V., Timsina J., Jat M.L. Productivity and sustainability of the rice-wheat cropping system in the Indo-Gangetic Plains of the Indian subcontinent: problems, opportunities and strategies. *Adv. Agron.* 117 (2012), 315-369.
9. Cheema, H. S. and Singh, B. Software statistical package CPCS-I. Department of Statistics Punjab Agricultural University, Ludhiana, India, 1991.
10. Cochran, W. G. and Cox, G. M. Experimental designs. John and Wiley publishers, New York, 1967.
11. DES, DAC, MoA, Govt of India, 2013.
12. Desanctis G, Roggero PP, Seddaiu G, Orsini R, Porter CH, Jones JW. Long-term no tillage increased soil organic carbon content of rain-fed cereal systems in a Mediterranean area. *Eur. J. Agron.* 40 (2012), 18-27.
13. Dikgwatlhe SB, Chen Z, Lal R, Zhang H, Chen F. Changes in soil organic carbon and nitrogen as affected by tillage and residue management under wheat–maize cropping system in the North China Plain. *Soil Till. Res.* 144 (2014), 110-118.
14. Fargione J.E., Bassett S., Boucher T., Bridgham S.D., Conant R.T., Cook-Patton S.C., Ellis P.W., Falcucci A., Fourqurean J.W., Gopalakrishna T., Gu H., Henderson B., Hurteau M.D., Kroeger K.D., Kroeger T., Lark T.J., Leavitt S.M., Lomax G., McDonald

- R.I., Megonigal J.P., Miteva D.A., Richardson C.J., Sanderman J., Shoch D., Spawn S.A., Veldman J.W., Williams C.A., Woodbury P.B., Zganjar C., Baranski M., Elias P., Houghton R.A., Landis E., McGlynn E., Schlesinger W.H., Siikamaki J.V., Sutton-Grier A.E., Griscom B.W.. Natural climate solutions for the United States. *Sci. Adv.*, 4 (2018).
15. Gan Y.T., Miller P.R., McConkey B.G., Zentner R.P., Stevenson F.C., McDonald C.L.. Influence of diverse cropping sequences on durum wheat yield and protein in the semiarid northern Great Plains. *Agron. J.*, 95 (2003), pp. 245-252
 16. Giller KE, Andersson JA, Corbeels M, Kirkegaard J, Mortensen D, Erenstein O. Beyond conservation agriculture. *Front Plant. Sci.* 6 (2015), 1-14.
 17. GOI. Agricultural statistics at a glance. Ministry of Agriculture, Department of Agriculture and cooperation, Directorate of economics and statistics, Government of India, pp 68-70, 2019.
 18. Gurr G.M., Lu Z., Zheng X., Xu H., Zhu P., Chen G., Yao X., Cheng J., Zhu Z., Catindig J.L., Villareal S., Van Chien H., Cuong L.Q., Channoo C., Chengwattana N., Lan L.P., Hai L.H., Chaiwong J., Nicol H.I., Perovic D.J., Wratten S.D., Heong K.L.. Multi-country evidence that crop diversification promotes ecological intensification of agriculture. *Nature Plants*, 2 (2016).
 19. Hobbs PR, Sayre K, Gupta R. The role of conservation agriculture in sustainable agriculture. *Phil. Trans. R. Soc. B.* 363 (2008), 543-555.
 20. Kandeler E, Tscherko D, Spiegel H. Long term monitoring of microbial biomass, N mineralization and enzyme activities of a chernozem under different tillage management. *Biol. Fertility Soils.* 28(4) (1999), 343-351.
 21. Kushwa V, Hati KM, Sinha NK, Singh RK, Mohanty M, Somasundaram J et al. Long-term conservation tillage effect on soil organic carbon and available phosphorous content in vertisols of central India. *Agri. Res.* 5(4) (2016), 353-361.
 22. Li X., Jousset A., de Boer W., Carrión V.J., Zhang T., Wang X., Kuramae E.E.. Legacy of land use history determines reprogramming of plant physiology by soil microbiome. *ISME J.*, 13 (2019), pp. 738-751.
 23. Mahajan A., Gupta R.D. The Rice–Wheat Cropping System. In: Mahajan A., Gupta R.D. (eds.) *Integrated Nutrient Management (INM) in a Sustainable Rice—Wheat Cropping System.* (2009) Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-9875-8_7
 24. Mankevičienė ASS, Kadžienė G, Kačergius A, Feizienė D, Feiza V, Semaškienė R et al. The impact of tillage and fertilization on *Fusarium* infection and mycotoxin production in wheat grains. *Zemdirbystė Agri.* 99(3) (2012), 265.

25. National Research Council (NRC). (April). The impact of genetically engineered crops on farm sustainability in the United States. Washington, DC: The National Academies Press, 2010.
26. Sendhi, R., Kumar, T.M. and Singh, G.P. Wheat Production in India: Trends and Prospects. Open access peer-reviewed chapter, 2019.
27. Singh R, Serawat M, Singh A, Babli. Effect of tillage and crop residue management on soil physical properties. *J. Soil Salinity Water Quality*. 10(2) (2018), 200-206.
28. SRDI, “Bhumi and Mrittika Sampad Bhavohar Nirdeshika, Gazipur Sadar Upazila, Gazipur Zilla,” Soil Resource Development Institute. Ministry of Agriculture, Government of the Peoples Republic of Bangladesh, 2005.
29. Tiemann L.K., Grandy A.S., Atkinson E.E., Marin-Spiotta E., McDaniel M.D.. Crop rotational diversity enhances belowground communities and functions in an agroecosystem. *Ecol. Lett.*, 18 (2015), pp. 761-771.
30. Yang C., Hamel C., Gan Y., Vujanovic V.. Pyrosequencing reveals how pulses influence rhizobacterial communities with feedback on wheat growth in the semiarid Prairie. *Plant Soil*, 367 (2013), pp. 493-505.
31. Žurovec O, Sitaula BK, Čustović H, Žurovec J, Dörsch P. Effects of tillage practice on soil structure, N₂O emissions and economics in cereal production under current socio-economic conditions in central Bosnia and Herzegovina. *PLoS ONE* 12(11) (2017): e0187681. <https://doi.org/10.1371/journal.pone.0187681>.

Table 4. Productivity in terms of grain yield of wheat as influenced by different treatments

Treatment	2008-09				2009-10				2010-11			
	Herbage yield (q/ha)	Equivalent wheat grain yield (q/ha)	Wheat grain yield (q/ha)	Total productivity (q/ha)	Herbage yield (q/ha)	Equivalent wheat grain yield (q/ha)	Wheat grain Yield (q/ha)	Total productivity (q/ha)	Herbage yield (q/ha)	Equivalent wheat grain yield (q/ha)	Wheat grain yield (q/ha)	Total productivity (q/ha)
Tillage system												
ZT-ZT	529.6	39.95	42.00	81.95	372.8	30.12	49.24	79.36	530.1	37.51	41.73	79.24
CT-ZT	523.9	35.10	43.37	78.47	365.9	29.71	45.58	75.29	544.0	39.48	43.26	82.74
CD(P=0.05)	NS	NS	NS	-	NS	NS	NS	-	NS	NS	NS	-
Cropping system												
Cowpea-wheat	494.6	36.53	44.01	80.54	289.4	27.22	49.00	76.22	421.4	36.01	48.07	84.08
Bajra-wheat	839.1	47.49	40.59	88.08	280.8	17.77	47.72	65.49	921.0	48.39	40.51	88.90
Maize-wheat	518.9	48.04	43.49	91.53	461.3	41.94	47.49	89.43	603.4	51.57	39.31	90.88
Sorghum-wheat	376.1	23.68	36.05	59.73	752.8	53.03	44.76	97.79	488.8	31.33	41.55	72.88
Guara-wheat	281.9	22.18	53.69	75.87	178.0	13.75	49.65	63.40	289.0	20.99	45.75	66.74
Makchari-wheat	-	-	-	-	253.8	25.80	45.87	71.67	498.8	42.63	39.74	82.37
CD(P=0.05)	131.3	10.34	3.68	-	42.1	3.35	NS	-	48.7	3.64	3.94	-

Table 5. Productivity in terms of grain yield of wheat as influenced by different treatments

Treatment	Mean total productivity (q/ha)	Mean gross return (Rs./ha)	Mean net returns (Rs./ha)
Tillage system			
ZT-ZT	80.18	108931.50	86588.00
CT-ZT	78.83	106420.50	84077.00
Cropping system			
Cowpea-wheat	80.28	108378.00	86035.00
Bajra-wheat	80.82	109107.00	86764.00
Maize-wheat	90.61	122323.50	99980.50
Sorghum-wheat	76.80	103680.00	81337.00
Guara-wheat	68.67	92704.50	70361.50
Makchari-wheat	77.02	103977.00	81634.00

Wheat rate- Rs.1350/q Cost of cultivation- Rs. 22343/ha