Indian Journal of Agricultural Sciences **94** (8): 811–816, August 2024/Article
https://doi.org/10.56093/ijas.v94i8.145235

Tillage practices on soil penetration resistance, soil infiltration, percolation and yield of rice (*Oryza sativa*) in rice-based cropping system

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Received: 14 November 2023; Accepted: 30 May 2024

ABSTRACT

The experiment was conducted during 2019–23 at Tamil Nadu Rice Research Institute (Tamil Nadu Agricultural University, Coimbatore), Aduthurai, Tamil Nadu to analyse the effect of conservation tillage methods on bulk density, soil penetration resistance and soil infiltration rate of clay soil and rice yield in rice-based cropping system. Experiment consisted of three tillage practices, viz. conventional tillage/puddling (CT); zero tillage (ZT); and minimal tillage/dry ploughing (MT) and two rice (*Oryza sativa* L.) cultivars (ADT 43 and CORH 3), replicated four times. The result of the study revealed that the bulk density was significantly lower with zero tillage due to presence of crop residues and addition of organic matter. The mean infiltration rate under zero tillage was 0.16 cm/h as compared to puddling (0.14 cm/h) and dry ploughing (0.20 cm/h). The study further showed that the mean soil percolation rate was significantly altered by the tillage methods and soil percolation rate was 0.12 cm/h in zero tillage as compared to puddling (0.10 cm/h) and dry ploughing (0.16 cm/h). In contrary to the other physical properties, the soil penetration resistance was in the order of dry ploughing>zero tillage>puddling. The mean soil penetration resistance under zero tillage was reduced from 690–500 Kpa, 740–600 Kpa and 760–620 Kpa respectively at 0–5, 5–10 and 10–15 cm depth as compared to puddling. The results further indicated that the yield parameters and rice did not differ among the different tillage practices.

Keywords: Bulk density, Infiltration, Percolation, Puddling, Soil penetration resistance

In Cauvery delta zone of Tamil Nadu, the area under rice (*Oryza sativa* L.) (summer) (*kharif*)-rice (winter) (*rabi*) cropping system is on increase due to more choices of high yielding short and medium duration rice varieties (Subrahmaniyan *et al*. 2015). However due to uncertainty in the south-west monsoon, the *kharif* rice crop planted in more than 1.6 Lakh ha have been subjected to lot of challenges when the release of canal water is delayed beyond 12th June. Consequently, irrigation through borewells resulted in over exploitation of ground water and makes the soils saline. In addition, delay in the planting of *kharif* rice crop due to untimed release of canal water led to harvest loss which coincide with onset of north-east monsoon and delayed planting of *rabi* rice crop as well. The *rabi* rice thus experiences terminal stress as the dam closes by the end of January. In the rice-rice cropping system, the time lag in the land preparation (20–30 days) after the harvest of first rice crop causes further impediment in timely planting of second crop. The poor rice yield in rice-rice cropping system also occurs due to a short turnover phase between first crop harvest and planting of second crop (Subrahmaniyan *et al*. 2016).

Conservation tillage can save fuel, labour and time as compared to conventional method of puddling in rice cultivation (Govindan and Chinnusamy 2014). Alternatives to puddled transplanted rice are required to save water as puddling operation alone requires 250–300 mm of water (Mahajan *et al*. 2011) and one among them is conservation tillage (Singh and Kaur 2012). Haque (2016) compared the non-puddled transplanted rice with conventional puddling and observed similar yield in both the tillage practices, besides savings in irrigation water, energy and fuel in non-puddled transplanted rice. Non-puddled transplanted rice would be a substitute to puddled transplanted rice or direct seeded rice, where machine transplanting could be done in soil tilled with one cultivator and rotavator followed by simple wetting with 50 mm of water (Johansen *et al*. 2019). Saving in labour cost, energy and enhanced net return, in non-puddled transplanted rice was already reported by Islam *et al*. (2019) and Gathala *et al*. (2020). Hence, this study was planned to determine the effects of different tillage practices on soil physical properties and rice yield.

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MATERIALS AND METHODS

The experiment was conducted during 2019–23 at Tamil Nadu Rice Research Institute (Tamil Nadu Agricultural University, Coimbatore), Aduthurai, Tamil Nadu. Field experiments were conducted with three tillage practices, viz. conventional tillage method of puddling (CT); zero or no tillage (ZT); and minimal or reduced tillage/dry ploughing (MT) and one variety and hybrid (ADT 43 and CORH 3) in split-plot design (SPD) having four replications. The analytical results of the initial soil sample indicated that the organic C content was 0.30% and the available N, P and K were 280 kg/ha, 35 kg/ha and 370 kg/ha, respectively.

In the conventional method of puddling, one dry ploughing followed by one rotavator was done prior to two passes of cage wheel puddling. Pre-emergence herbicide Bensulfuron Methyl 0.6% + Pretilachlor 6% GR @10 kg/ha was applied on 3–5 days after planting (DAP). In case of minimal tillage practices, one cultivator ploughing followed by one rotavator in dry soil was done. Similar to conventional tillage, pre-emergence herbicide, Bensulfuron Methyl 0.6% + Pretilachlor 6% GR @10 kg/ha was applied on 3–5 DAP. In no tillage, the previous crop rice stubbles were sprayed with glyphosate @10 ml/litre of water + 2% Ammonium sulphate. The stubbles were completely dried within 7 days and paddy transplanting was done in the decomposed stubbles without any preparatory cultivation and this was followed Bensulfuron Methyl 0.6% + Pretilachlor 6% GR @10 kg/ha applied on 3–5 DAP. Two-hand weeding was done in puddled method of cultivation and in the reduced tillage treatments on 20 and 45 DAP. By employing the cutting ring method, from the undisturbed soil core samples, the soil bulk density was estimated (Li *et al*. 2012). The initial mean bulk density observed was 1.26 g/cc. For estimation of soil penetration resistance, hand penetrometer Eijkelkamp which has an accuracy of 1000 kpa was used to measure the penetration resistance in each treatment randomly at three depths (5 cm interval up to 15 cm from 0 cm) at active tillering [30 DAT (Days after transplanting)], panicle initiation (60 DAT) and flowering (90 DAT) and at harvest. The penetration resistance value was arrived by taking mean of 6 observations made in each treatment. At all the soil depths, the observations were made at constant speed in each sampling points. The infiltration rate was determined as the amount of water per surface area and time unit, which penetrates the soils. The infiltration and percolation rates were determined at 45 DAT using a double ring infiltrometer, which could be used to construct an infiltration buffer, which reduces the main external interference factors on the infiltration process of the inner ring (Li *et al*. 2019). To study the percolation losses process, in centre of each plot, a metal ring with a diameter of 40 cm and a height of 35 cm was pushed into the soil at four points to a depth of approximately 15 cm. The rate of infiltration into each column was monitored throughout a 24 h period. The water level inside the ring was maintained with that outside in the whole plot. Ten plants were randomly harvested in each treatment to assess the growth and yield parameters during harvest. The grain yield observed per plot was converted to total yield/ha and expressed in kg. ANOVA was employed to calculate the variation in the treatments and the critical difference (CD) was used to work out the significant variation among the treatments at 5% probability level (Steel and Torrie 1980).

RESULTS AND DISCUSSION

Bulk density: The effect of tillage practices on soil bulk density was significant. Tillage largely influences the pore size distribution. In the present study, the bulk density was lower with zero tillage as compared to minimal and conventional tillage. The initial bulk density of 1.31 g/cc (end of first season) was reduced to 1.12 g/cc at the end

Table 1 Effect of different tillage practices and rice varieties on soil physical properties during *kharif* season

Treatment	Initial bulk density (g/cc)			Bulk density at the end of 4th year (g/cc)			Infiltration rate (cm/h) at the end of 4th year			Percolation rate (cm/h) at the end of 4th year		
	CORH3	ADT 43	Mean	CORH3	ADT 43	Mean	CORH3	ADT 43	Mean	ADT 43	CORH3	Mean
CT	1.31	1.31	**1.32**	1.34	1.34	**1.34**	0.14	0.14	**0.14**	0.09	0.09	**0.09**
ZT	1.31	1.31	**1.32**	1.12	1.12	**1.12**	0.16	0.16	**0.16**	0.12	0.12	**0.12**
MT	1.28	1.28	**1.28**	1.30	1.30	**1.30**	0.20	0.20	**0.20**	0.15	0.14	**0.15**
Mean	**1.32**	**1.32**		1.23	1.24		0.17	0.17		0.12	0.12	
CD (P=0.05)												
Tillage		NS			0.17			0.04			0.04	
variety		NS			NS			NS			NS	
Tillage × variety		NS			NS			NS			NS	
Variety × tillage		NS			NS			NS			NS	

Treatment details are given under Materials and Methods.

Table 2 Effect of different tillage practices and rice varieties on soil physical properties during *rabi* season (Pooled mean of 4 years)

Treatment	Initial Bulk density (g/cc)			Bulk density at the end of 4th year (g/cc)			Infiltration rate (cm/h) at the end of 4th year			Percolation rate (cm/h) at the end of 4th year		
	CORH3	ADT 43	Mean	CORH3	ADT 43	Mean	CORH3	ADT 43	Mean	ADT 43	CORH3	Mean
CT	1.31	1.31	**1.31**	1.34	1.34	**1.34**	0.14	0.14	**0.14**	0.10	0.10	**0.10**
ZT	1.26	1.26	**1.26**	1.18	1.18	**1.18**	0.16	0.16	**0.16**	0.12	0.12	**0.12**
MT	1.28	1.28	**1.30**	1.30	1.30	**1.30**	0.18	0.19	**0.19**	0.16	0.16	**0.16**
Mean	**1.29**	**1.29**		1.21	1.21		0.18	0.18		0.13	0.13	
CD (P=0.05)												
Tillage		0.03			0.17			0.04			0.04	
Variety		NS			NS			NS			NS	
Tillage × variety		NS			NS			NS			NS	
Variety × tillage		NS			NS			NS			NS	

Treatment details are given under Materials and Methods.

of the 4th-year study (eight seasons) under zero tillage due to surface residue cover, whereas it was 1.30 g/cc under reduced tillage (Table 1). The presence of crop residues in zero tillage continuously for 8 seasons would have resulted in more of root activities, soil biota and organic matter, which in turn reduced the soil compaction and thereby the bulk density. Sharma *et al*. (2005) also observed that puddling operation caused a significant increase in bulk density, which was further increased at the time of harvest. In the present study, there was a slight increase in the original values of bulk density of the soil under puddling from 1.31 g/cc–1.34 g/cc (Table 2). Though the bulk density under/either puddling or reduced tillage decreases with an increase in soil porosity in early stages of the crop growth, it increased at the successive crop growth stages as the particles settled down due to soil compaction. Kalita *et al*. (2020) and Orzech *et al*. (2021) reported that puddling significantly increased the bulk density of the soil over its initial status in two years of field experimentation. In contrary, Bhattacharyya *et al*. (2008) observed significantly higher value of soil bulk density after rice harvest under zero tillage in the surface soil layer due to non-disturbance of the soil matrix as compared to tilled plots.

Penetration resistance: The soil penetration resistance was used to characterize the soil compaction which influences the structural characteristics and functions of soils (Celik *et al*. 2010). The values of soil penetration resistance observed in different layers (0–10 cm, 10–20 cm, 20–30 cm, 30–40 cm and 40–50 cm) (Fig. 1). The data revealed that the penetration resistance was lowest under

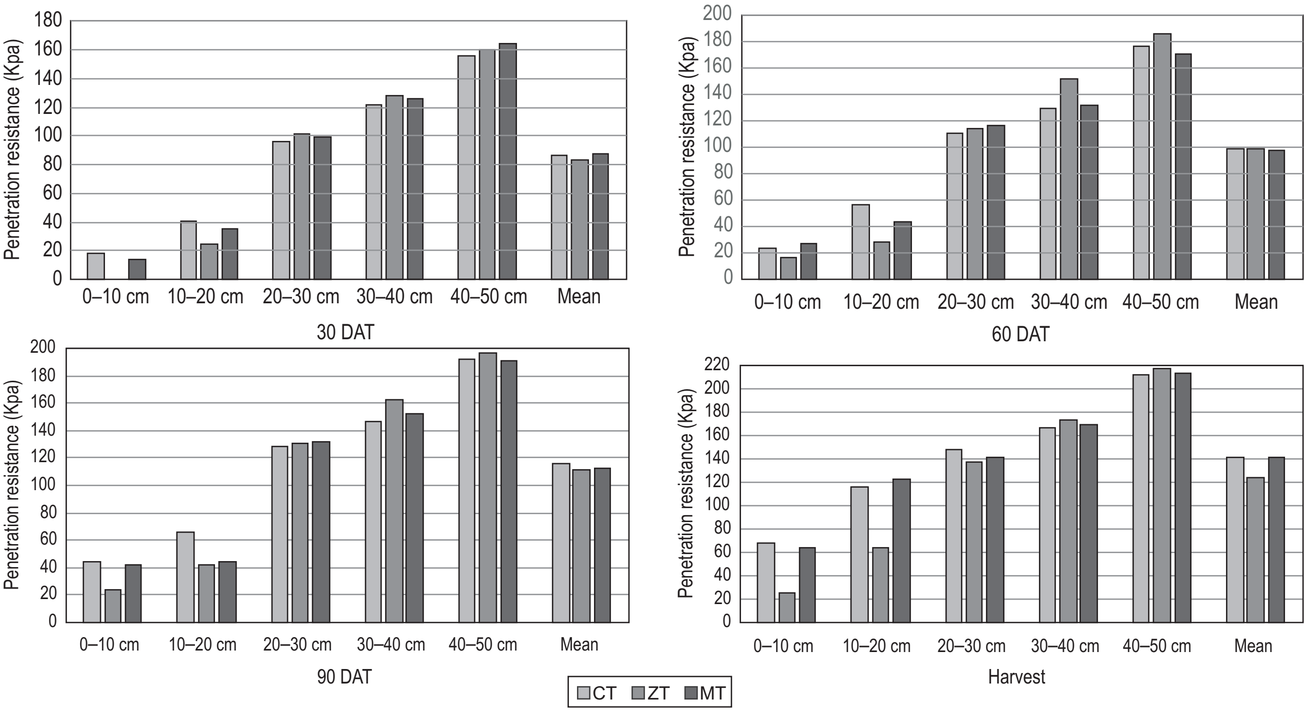

Fig. 1 Effect of different tillage practices on soil penetration resistance.
CT, Conventional tillage; ZT, Zero tillage; MT, Minimal tillage; DAT, Days after transplanting.

no-tillage in 0–10 cm and 10–20 cm layers at all the stages of observation. The decrease in values of penetration resistance under zero and minimal tillage indicated the lesser extent of soil compaction as compared to puddling. Enhancement of soil organic matter through incorporation of stubbles in the surface layers would have reduced soil penetration resistance in zero tillage. During the puddling operation, the hard pan formed in the puddled layer would have increased the soil penetration resistance. The lower values of bulk density and soil penetration resistance obtained in no tillage might be owing to short term loosening effect and incorporation of stubble/stover to soil surface layers of soil. However, Painuli (2000) observed that puddling operation results in decrease of soil penetration resistance. In the deeper layers, the soil penetration resistance was comparatively lesser in puddling as compared to no tillage. Irrespective of the tillage practices, the values of soil penetration resistance increase with an advancement in the crop period. The results indicated that soil penetration resistance was less at the initial stage due to intensive puddling. As the soil particles down, the resistance increased till the maturity of the crop and hence penetration resistance after the harvest of the rice crop was more in conventional tillage than reduced tillage. The physical degradation of soil due to puddling was reported to increase in soil penetration resistance and bulk density (Alam *et al*. 2020)

Infiltration and percolation rate: The data indicated that effect of different tillage method on soil infiltration and percolation rates were non-significant. Though greater infiltration due to greater contribution of flow-active macropores in zero tillage is expected, but in the present study reverse trend of result was observed. The undisturbed soil in the zero tillage would have reduced the infiltration rate due to soil compaction. Even though total porosity was increased by tillage, the macropores connecting the soil surface to the subsoil were enhanced and thus infiltration rate was on par with zero tillage. In the present study, comparable values of soil infiltration and percolation of soil observed under no till soil with puddled soil might be due to relatively high organic matter in the study soil and sealing ability to arrest the entry of water due to soil compaction. Further it was also reported that sorptivity of soils, which was said to be control the initial infiltration rate might be the reason for low infiltration rate under no tillage. Rapid flow along inter-aggregate pores has been demonstrated in earlier studies (Lin *et al*. 1996). Rezaei *et al*. (2012) reported that the percolation rate was decreased up to 92% due to puddling operation which varies with depth, puddling intensity and soil texture. In contrary, earlier results obtained by Kar and Kumar (2009) indicated that tillage enhanced soil infiltration rate and the higher infiltration rate in puddled soils was due to higher pressure potential gradient.

Grain yield: The data indicated that the yield parameters and yield of rice did not differ significantly for different tillage practices, though there was a slight yield reduction in case of no tillage. The mean yield reduction in zero tillage and minimum tillage was higher during the first

Table 3 Effect of different tillage practices and rice varieties on yield parameters, yield and economics during *kharif* and *rabi* seasons (Pooled mean of 4 years)

Treatment	Panicles/m^2						Grain yield (t/ha)						Benefit cost ratio					
	Kharif			*Rabi*			*Kharif*			*Rabi*			*Kharif*			*Rabi*		
	CORH3	ADT 43	Mean	CORH3	ADT 45	Mean	CORH3	ADT 45	Mean	CORH3	ADT 45	Mean	CORH3	ADT 45	Mean	CORH3	ADT 45	Mean
CT	321	310	315.5	285	272	278.5	5.70	5.50	5.60	5.46	5.19	5.33	1.98	1.90	1.94	1.89	1.78	1.84
ZT	311	301	306.0	278	268	273.0	5.40	5.30	5.35	5.21	5.98	5.60	2.01	1.93	1.97	1.94	1.83	1.89
MT	314	302	308.0	276	270	273.0	5.60	5.30	5.45	5.32	5.04	5.18	2.01	1.94	1.98	1.93	1.80	1.87
Mean	**315**	**304**		**280**	**270**		**5.60**	**5.40**		**5.33**	**5.40**		**2.00**	**1.92**		**1.92**	**1.80**	
CD (P=0.05)																		
Tillage		NS			NS			NS			NS							
Variety		8			12			0.11			NS							
Tillage × variety		NS			NS			NS			NS							
Variety × tillage		NS			NS			NS			NS							

Treatment details are given under Materials and Methods. NS, Non-significant.

year. However, the grain yield difference among the tillage practices drastically reduced in the subsequent seasons. The mean yield reduction in the zero tillage and minimum tillage was 4.5 and 2.5% (Table 3), respectively as compared to conventional tillage during both the seasons. The presence of crop residues in zero tillage continuously for 8 seasons and decomposition would have added more of organic matter and contributed for higher yield parameters and yield as well. Earlier Hossain *et al*. (2021) reported that crop yield in the non-puddled system was more than the puddled transplanting under proper weed control. Similarly, Chaki *et al*. (2021) also observed no significant variation in rice grain yield between puddled transplanted rice and minimal tillage practices. Though the grain yield obtained was highest with puddled transplanted rice, benefit cost (B:C) ratio was highest with reduced tillage and no tillage method of rice cultivation during both the seasons studied. The hybrid and varieties did differ themselves for yield parameters and yield as well. The hybrid CORH 3 had more number of panicles/m^2 during both the seasons, which was reflected in grain yield also. The higher yield obtained with hybrid CORH3 ultimately resulted in higher B:C ratio. However, no interaction was observed between genotypes and tillage practices for yield parameters and yield.

Based on the 4 years of study, it may be concluded that no tillage and reduced tillage method of rice cultivation could be a substitute tillage method in rice cultivation in order to conserve the physical properties of soil and also to facilitate early planting of second crop by reducing the lag of time in field preparation to increase the productivity and profitability in rice-based cropping system.

REFERENCES

Alam M K, Bell R W, Hasanuzzaman M, Salahin N, Rashid M H, Akter N, Akhter S, Islam M S, Islam S and Naznin S. 2020. Rice (*Oryza sativa* L.) establishment techniques and their implications for soil properties, global warming potential mitigation and crop yields. *Agronomy* **10***:* 888. https://doi.org/10.3390/agronomy10060888

Bhattacharyya R, Kundu S, Pandey S C, Singh, K P and Gupta H S. 2008. Tillage and irrigation effects on crop yields and soil properties under the rice-wheat system in the Indian Himalayas. *Agricultural Water Management* **95**: 993–1002.

Celik I, Gunal H, Budak M and Akpinar C. 2010. Effects of long-term organic and mineral fertilizers on bulk density and penetration resistance in semi-arid Mediterranean soil conditions. *Geoderma* **160**(2): 236–43.

Chaki A K, Gaydon D S, Dalal R C, Bellotti W D, Gathala M K, Akbar Hossain, Siddquie N E A and Menzies N W. 2021. Puddled and zero-till unpuddled transplanted rice are each best suited to different environments-An example from two diverse locations in the eastern Gangetic Plains of Bangladesh. *Field Crops Research* **267**: 108151.

Gathala M K, Laing A M, Tiwari T P, Jagadish Timsina, Saiful Islam, Bhattacharya P M, Tapamay Dhar, Arunava Ghosh, Sinha A K, Chowdhury A K, Shakhawat Hossain, Ilias Hossain, Samim Molla, Mamunur Rashid, Sanjay Kumar, Ranvir Kumar, Dutta S K, Srivastwa P K, Bedanand Chaudhary, Jha S K, Prakash Ghimire, Biswash Bastola, Chaubey R K, Ujjwal Kumar and Bruno Gerard. 2020. Energy-efficient, sustainable crop production practices benefit smallholder farmers and the environment across three countries in the Eastern Gangetic Plains, South Asia. *Journal of Cleaner Production* **246**: 118982.

Govindan R and Chinnusamy C. 2014. Tillage, crop establishment and weed management in rice under conservation agriculture system. *Indian Journal of Weed Science* **46**(2): 117–22.

Haque M E, Bell R W, Islam M A and Rahman M A. 2016. Minimum tillage unpuddled transplanting: An alternative crop establishment strategy for rice in conservation agriculture cropping systems. *Field Crops Research* **185**: 31–39.

Hossain M M, Begum M, Abul Hashem, Rahman M M and Bell R W. 2021. Minimum tillage non-puddled transplanted rice (*Oryza sativa* L.): Weed control and economics under conservation agriculture practice in Bangladesh. *Acta Scientifica Malaysia* **5**(2): 47–55.

Islam S, Gathala M K, Tiwari T P, Timsina J, Laing A M, Maharjan S, Chowdhury A K, Bhattacharya P M, Dhar T, Mitra B, Kumar S, Srivastwa P K, Dutta S K, Shrestha R, Manandhar S, Sherestha S R, Paneru P, Siddquie N E A, Hossain A, Islam R, Ghosh A K, Rahman M A, Kumar U, Rao K K and Gerard B. 2019. Conservation agriculture based sustainable intensification: Increasing yields and water productivity for smallholders of the eastern Gangetic Plains. *Field Crops Research* **238**: 1–17.

Johansen C, Haque M E, Bell R W, Thierfelder C and Esdaile R J. 2019. Conservation agriculture for small holder rainfed farming: Opportunities and constraints of new mechanized seeding systems. *Field Crops Research* **132**: 18–32.

Kalita J, Ahmed P and Baruah N. 2020. Puddling and its effect on soil physical properties and growth of rice and post rice crops: A review. *Journal of Pharmacognosy and Phytochemistry* **9**(4): 503–10.

Kar G and Kumar A. 2009. Evaluation of post-rainy season crops with residual soil moisture and different tillage methods in rice fallow of eastern India. *Agricultural Water Management* **96**: 931–38.

Li M, Liu T, Duan L, Luo Y, Ma L, Zhang J, Zhou Y and Chen Z. 2019. The scale effect of double-ring infiltration and soil infiltration zoning in a semi-arid steppe. *Water* **11**: 1457. https://doi.org/10.3390/w11071457

Li R, Hou X Q, Jia Z K, Han Q F, Ren X L and Yang B P. 2012. Effects of rainfall harvesting and mulching technologies on soil water temperature, and maize yield in Loess Plateau region of China. *Soil Research* **50**: 105–13.

Lin H S, McInnes K J, Wilding L P and Hallmark C T. 1996. Effective porosity and flow rate with infiltration at low tensions in a well-structured subsoil. *Transactions of the ASAE* **39**: 131–33.

Mahajan G, Timsina J and Kuldeep Singh. 2011. Performance and water-use efficiency of rice relative to establishment methods in north-western Indo-Gangetic Plains. *Journal of Crop Improvement* **25**: 597–617.

Orzech K, Wanic M and Załuski D. 2021. The effects of soil compaction and different tillage systems on the bulk density and moisture content of soil and the yields of winter oilseed rape and cereals. *Agriculture* **11**(7): 666. https://doi.org/10.3390/agriculture11070666

Painuli D K. 2000. Annual report 1997–1999. All India Coordinated Research Project on Soil Physical Constraints and their Amelioration for Sustainable Crop Production. Indian Institute of Soil Science, Bhopal, Madhya Pradesh, India.

Rezaei M, Tabatabaekoloor R, Mousavi seyedi S R and Aghili Nategh N. 2012. Effects of puddling intensity on the *in situ* engineering properties of paddy field soil. *Australian Journal of Agricultural Engineering* **3**(1): 22–26.

Sharma P, Tripathi R P and Singh S. 2005. Tillage effects on soil physical properties and performance of rice-wheat cropping system under shallow water table conditions of Tarai, northern India. *European Journal of Agronomy* **23**: 327–35.

Singh A and Kaur J. 2012. Impact of conservation tillage on soil properties in rice-wheat cropping system. *Agricultural Science Research Journal* **2**: 30–41.

Steel R G D and Torrie J H. 1980. *Principles and Procedures of Statistics*, pp. 65–94. McGraw-Hill, New York, USA.

Subrahmaniyan K, Ravi V, Parasuraman P, Subramanian E, Senthi Kumar G and Rajaendran R. 2015. Impact of conservation tillage on weed dynamics in rice-rice cropping system. *(In) 25th Asian-Pacific Weed Science Society Conference on Weed Science for Sustainable Agriculture, Environment and Biodiversity*, Hyderabad, India, October 13–16, pp. 153.

Subrahmaniyan K, Ravi V, Parasuraman P, Senthi Kumar G and Sharmila Rahane. 2016. Impact of conservation tillage on soil properties and rice yield of rice-rice cropping system. *(In) Proceeding of 4th International Agronomy Congress, New Delhi, India*, November 22–26, pp. 1081–82.