Review Article

Impact of conservation tillage in potato – A review

Abstracts

In conventional system, potato crop is grown under intensive tillage along with use of high inputs that led to deterioration of soil health and environment. Hence, practicing of intensive tillage create hindrance for accommodating a second crop immediately after harvesting of rice. That's why in many parts of India, rice stubble burning is a common practice done by farmers to advance the time of planting. Thus, rice stubble burning which is accountable for emission of CO_2 considered as serious issue in most of the rice growing areas. Considering the farmer's benefit as well as soil health and environment, conservation tillage i.e., zero/minimum tillage could be one of the vital alternative options that could help to overcome the problem associated with conventional tillage. Therefore, an attempt has been made to interpret the findings of conservation tillage on performance of potato crop and its subsequent effect on soil health. Results showed variable response on crop performances due to conservation tillage, but improved the soil health and quality by increasing the soil organic carbon and nutrient availability.

Keywords: conservation-tillage, stubble, organic carbon, emission

Introduction

Intensive tillage is common in potato farming throughout the cropping cycle, which typically results in soil degradation, erosion and nitrate leaching. To avoid the formation of clods in the potato beds during soil preparation the entire topsoil is loosened and pulverized into minute aggregates. Both mechanical weeding and mechanized harvesting required a great deal of soil movement. Thus, in potato production, conservation agriculture is a resource-saving crop production practice that offers various important techniques for soil conservation. A simple conservation agriculture practice, "no-till or zero-till" cultivation can help to improve soil conservation even more. In no-till or zero-till cultivation, potato is pressed into the soil surface followed by using a thick layer of mulch with straw that prevents rotting of the tuber (Anonymous, 2008). About 20-cm thickness of rice straw mulching (12 t/ha) is applied after planting the tuber and nutrient demand is fulfilled with the help of foliar spray of fertilizers (Sarangi et al. 2018).

They stated that through conservation tillage especially zero tillage/minimum tillage, potato planting can be advanced than conventional tillage by skipping some of the practices along with added advantages of minimum weed infestation, less irrigation water requirement, no intercultural requirement, less damage by rain, easy harvesting, less cost of cultivation, higher yield with better tuber quality. The beneficial effect of mulching on potato yield was also reported by Begum et al. (2014).

The adoption of zero tillage in subsequent crops also led to advancement of planting time by a minimum of 8 days (Quddus et al., 2020). Conservation agriculture (CA) approaches have been created to lessen the impact of negative environmental effects in agriculture and farming, such as soil deterioration and erosion which resulted in lower production. In India, conservation tillage practices such as zero/minimum tillage have been adopted for increasing the cropping intensity and emerged as a new technique for enhancing the productivity as well as profitability in many crops. Hence, comparative assessments need to make between conservation and conventional potato cultivation in respect to growth, yield and quality of potatoes. The advantages of conservation tillage over conventional have been reported by many researchers (Table 1).

Table1. Advantages of conservation tillage over conventional

Sl. No.	Parameters		References
1	Yield advantage	6-10% increase in grain yield as compared to conventional practice	Laxmi et al. 2007
2	Water economy	Irrigation water saving upto 20-35%	Laxmi et al. 2007; Bhushan et al. 2007
3	Monetary benefit	Saving in cost of cultivation up to 5-10%,	Laxmi et al. 2007; Gupta and Seth, 2007
4	Economic benefit	40% increase in benefit-cost ratio	Barua (2022)
5.	Energy saving	Zero tillage led to a significant increase in the energy usage efficiency by 13%,	Kumar et al. (2013)

Crop growth performance

The conservation tillage practices greatly influence the growth parameters like plant population, plant height, crop canopy, leaf area, root development, etc. of potato. The conventional tillage helped in early emergence of potato crop as compared to conservation tillage which was found to be insignificant at 30 days after planting (Mundy et al., 1999). The more friability and proper aeration of soil under conventional tillage created a favourable condition for early emergence of potato crop. Whereas, more soil compaction, bulk density (1.63g cm^{-3}) as well as high soil moisture content under conservation tillage reduced the early germination of potato. Similar results were also reported by Barua (2022). The tillage practices affected LAI at early stage of crop growth, but at later stage of crop growth i.e., 9 and 13 weeks after planting, the conventional tillage practices produced significantly more LAI (2.54 and 3.27) as compared to reduced tillage (1.98 and 2.76) resulting in more above ground dry matter production (1.36 t ha^{-1}) than reduced tillage (1.13 t ha^{-1}) from 9 weeks after planting (Drakopoulos et al., 2016). The early emergence of crop in conventional tillage might have helped in getting more LAI. Similarly, the zero tillage also reduced the root dry weight (20.9) g in comparison to conventional tillage (Nunes et al., 2006). Zero tillage reduced the formation of stem as well as expansion leaf area resulting in less number of stems and leaf area in comparison to conventional tillage (Barakat et al.2020). However, no visible difference was observed in plant height between the minimum and zero tillage practices Yaroson et al.(2019) also reported flat tillage in potato increased the plant growth parameter such as plant height (34cm), number of leaves (289), number of stems (14.8), leaf area (645.1 cm^2), plant cover area (4503.3 cm^2) over zero and ridge tillage. Similarly, Qasim et al. (2013) revealed that planting of potato in line on plain wide beds followed by covering with soil from one side produced the highest PE (88.7%), number of stems/ plant (3.5), plant expansion (45.5 cm) and average number of tubers/plant (10.1) as compared to other tillage practices. Since soil was not tilled properly in zero/minimum tillage it greatly reduced root and shoot development of potato as compared to conventional tillage, whereas, in case of later the intensive tillage and proper pulverization of soil helped better root development and also increased the contents of macronutrients (N, P, K, Ca, and Mg) which helped in attaining more crop growth.

Effect on yield parameters

Tillage practices greatly influenced the grading of potato, green tuber (%) as well as quality of tubers. The conventional tillage produced higher number of tubers/ plant (7.36) and weight of large size tubers/plant (791.09 g) as well as medium size tubers/plant (182.69 g) than the zero and

minimum tillage (Barakat et al., 2020). The better yield under the conventional tillage was due to production of more number as well as large size potato. Abrougui et al. (2014) also reported that the conventional tillage produced more number of large as well as medium size tubers which accounted for 56.54 and 33.33 %, respectively of total tuber production as compared to reduced tillage, whereas, reduced tillage produced the highest yield of small tuber which accounted almost for 61% of total produce. The zero tillage led to production of more green tubers than the conventional tillage (Barua, 2022).

Effect on tuber yield

The conservation tillage with straw mulching conserved the soil moisture and regulated the soil temperature which ultimately helped in early tuber bulking and ultimately increased the tuber yield of potato (Chaki et al., 2014). The crop performed better even in saline soil in zero tillage (ZT) in comparison to conventional tillage (CT) with higher tuber yield (20.17 t/ha) along with better tuber qualities mainly the crude protein, fat, crude fibre and carbohydrate (Sarangi et al., 2018). But, the yield may vary depending upon the mulch material used for example, zero tillage mulched with rice husk produced higher total tuber yield (13.99 t/ha) in potato as compared to mulching with rice straw (11.08 t/ha) in costal saline soil (Ali et al. 2019).

The zero tillage with straw mulching recorded 35.3% higher tuber yield as compared to conventional tillage without mulching (Hou and Li, 2019). The paddy straw mulch regulated the soil temperature as well as soil moisture which subsequently increased the potato tuber yield. The improvement in soil hydrothermal properties which increased the water use efficiency resulted in higher tuber production under conservation tillage with straw mulching. On the other hand, Xianqing Hou and Rong Li (2018) reported that potatoes sown under conventional tillage recorded higher potato yield of 26.86 t/ha over the no-tillage practices (256.97 t/ha) due to the beneficial effect of tillage affecting the physiological processes of the crop and tuber yield formation However, the marketable yield was found to be higher under no-tillage practices over conventional tillage. Whereas, Alva et al. (2010) reported insignificant difference in tuber yield, tuber grades between conventional and reduced tillage.

Effect on tuber qualities

Several scientists reported variable results in case of tuber qualities due to different tillage practices (Barakat et al. 2020; Sarangi et al. 2020). Adequate quantity of nitrate and starch content in potato tuber is considered as an important component of tuber required for the human body. The

zero tillage increased the nitrate content in tuber (104 g/kg fresh mass) over conventional (94.3 g/kg fresh mass), but, no significant difference was observed in starch content of potato (Boligłowa and Gleń, 2003). Protein is an important quality parameter required for daily growth of human being. The practicing of narrow ridges with ridge planting techniques (CR) in potato significantly improved the protein content of tuber (1.60 %) in comparison to other tillage practices such as flat plot without mulch (1.10 %) and other ridge-furrow plastic mulching techniques (Qin et al., 2014). They also reported insignificant differences in starch content of tuber due to different tillage practices.

The reduced tillage practices in potato enhanced the specific gravity (1.08), dry matter content (25.0 %), and starch content (15.7 %) of potato tubers over conventional tillage systems (1.07; 24.1; 13.0%, respectively) (Drakopoulos et al.,2016). The practicing of zero tillage in potato with mulch significantly increased the crude protein (2.1 %), fat (0.81 %), fibre (0.75 %) and carbohydrates (15.7 %) of potato tuber over conventional ridge planting (1.4; 0.08; 0.39;11.9, respectively) (Sarangi et al.,2020). Similarly, Barua H.J. (2022) reported zero tillage and paddy straw mulching treatment significantly enhanced the total soluble sugar, crude fibre total carbohydrates, crude protein content on dry weight basis and dry matter content as compared to conventional and other minimum tillage practices. On the contrary, Barakat et al. (2020) reported higher starch content (14.49 %) as well as tuber dry matter (18.29 %) in conventional tillage than the zero tillage (12.28 & 16.07 %, respectively) and minimum tillage (13.49 & 17.35 %), respectively.

Effect on soil physical properties

The zero tillage with paddy straw mulching in potato reduced the bulk density from 1.49 Mg/m3 to 1.44 Mg/m3 (Sarangi *et al*.,2020). The soil aggregation is one of the important physical parameters of soil. The reduced tillage intensity resulted in a shift in aggregate distribution, with more micro-aggregates and fewer macro aggregates (Piazza *et al.,* 2020). This impact was attributed to the higher soil C content in micro aggregates. In potato, the breakdown of water-stable soil macro-aggregates due to conventional tillage significantly increased the soil micro-aggregates (29.7 %) thereby decreasing the mean weight diameter during the crop growing phase in comparison to conservation tillage (26.7 %) (Carter *et al*., 2009). Whereas, conventional tillage systems decreased the water infiltration rate and destroyed soil aggregates in potato (Yarosone*t al.,* 2019). On the contrary, Qin *et al*. (2014) reported insignificant difference in residual soil

moisture due to conservation tillage practices followed in potato. In a nut shell practicing of conservation tillage improved the soil physical properties by modifying the soil bulk density and improving soil aggregation. Through practicing of conservation tillage the soil condition of poorly aggregates soil can be improved.

Effect on soil organic carbon & nutrient availability

The tillage practices significantly affected the soil chemical properties such as organic carbon, soil pH, and electrical conductivity (EC) and soil microbial biomass carbon. Although the conventional tillage is required for better crop germination and growth, but conservation tillage is gaining popularity because of many disadvantages associated with conventional system such as reduction in soil organic matter, inherent soil fertility in the top soil along with increased risk of soil erosion (Daccache *et al.,* 2011). On the other hand, conservation tillage led to enhancement of soil organic carbon (Singh *et al.* 2014), thereby improved the fertility of the soil. The impact of conservation tillage varies depending upon the factors like initial soil condition, crops and cropping system that is followed. However, improvement in soil organic carbon depended upon the type of soil as well as crop grown. Practicing of zero tillage with paddy straw mulch enhanced soil organic carbon from 0.39 to 0.44% as compared to conventional cultivation in potato (Sarangi *et al.,* 2020). Earlier, Carter *et al.* (2009) also reported increase in soil organic carbon under conservation tillage practices as compared to conventional in potato. Lewis *et al.* (2011) also reported 14% higher labile carbon in conservation tillage than conventional tillage system in cover crops-soybean-maize rotation.

The accumulation of organic carbon took place up to a depth of 25 cm in clay loam, 15 cm in loam and 10 cm in sandy loam soil indicating more accumulation of organic carbon with increase in fineness in soil texture (Singh *et al.,* 2014). Many researchers reported that the soil organic carbon was greatly increased under conservation tillage below 10 cm as compared to conventional tillage method (Berner *et al.,* 2008; Mishra *et al.,* 2010; Gadermaier *et al.,* 2011). While, some of the researchers reported higher levels of organic carbon in the top 10 cm layer soil (Blanco-Canqui, and Lal, 2008; Vian *et al.,* 2009). The difference in soil organic carbon mainly occurred due to difference in soil texture, native organic carbon, temperature, and moisture and soil depth. In case of conservation tillage systems of potato, more application of surface-applied residues created a favorable environment for build up soil microorganisms that immobilized nitrogen thereby increasing the soil available nutrients (Collins *et al*., 2010).

Summery and conclusion

Practicing of zero/minimum tillage increased overall tuber production of potato crop reduced the production of large size potato. In some cases, inadequate application of mulch material leads to tuber greening. Hence, standardization of mulch material should be done to reduce the intensity of tuber greening. Conservation tillage with mulch improved the soil health by increasing the soil organic, soil microbial biomass carbon and ultimately increased the nutrient availability to crop. Conservation tillage in potato also improved the soil health by improving soil aggregation. Hence, this technique could be a vital approach for potato cultivation under the changing climatic condition.

References

Abrougui, K.; Chehaibi, S.; Boukhalfa, H.H.; Chenini, I.; Douh, B. and Nemri, M. (2014). Soil Bulk Density and Potato Tuber Yield as Influenced by Tillage Systems and Working Depths. Greener Journal of Agricultural Sciences. 4(2): 46-51.

Ali, M.A.; Shahadat, M.K. and Rashid, M.H. (2019). Performance of zero tillage potato cultivation with different mulch materials in the South-Western Saline Area of Bangladesh. MDPI Proceedings. 36: 29.

Alva, A.K.; Collins, H.P. and Boydston, R.A. (2010). Potato Response to Tillage and Nitrogen Management. International Soil Science Congress Proceedings. 19th World Congress of Soil Science, soil solutions for a changing world, 1-6 August 2010, Brisbane, Australia.

Anonymous (2008). Food and Agriculture Organization of the United Nations, 2008. FAOSTAT database. Rome, Italy.

Barakat, M.; Ganem, M.; Soliman, S. and Asaad, S. (2020). Effect of Different Tillage Depths and Practices on Growth and Productivity of Potato (Solanum tuberosum L.). SSRG International Journal of Agriculture & Environmental Science. 7(1): 48-55.

Barua H.J. (2020). Effect of conservation tillage practices in potato production systems. MSc. Thesis. Assam Agricultural University, Jorhat.

Begum, M, Saikia, M (2014). Effect of irrigation and mulching on growth and yield attributes of potato. Agricultural Science Digest. 34(1): 76-78. doi: 10.5958/j.0976-0547.34.1.018

Bhushan, L.; Ladha, J.K.; Gupta, R.K.; Singh, S.; Padre-Tirol A.; Sarawat, Y.S.; Gathala, M. and Pathak, H. (2007). Saving of water and labour in rice–wheat system with no tillage and direct seeding technologies. Agron. J. 99: 1288-1296.

Boligłowa, E. and Gleń, K. (2003). Yielding and quality of potato tubers depending on the kind of organic fertilization and tillage methods. Elec. J. Pol. Agroc. Univ. Ser. Agron. 1: 10-15.

Chaki, A.K.; Salam, M.A.; Khan, A.S.M.M.R.; Choudhury, A.K. and Pramanik, M.E.A. (2014). Soil Moisture Conservation as Influenced by Mulching and Tillage and its Effect on Potato Yield in High Barind Tract. In: Proceedings of the Conference on Conservation Agriculture for Smallholders in Asia and Africa. 7-11 December 2014, Mymensingh, Bangladesh. (Eds. WH Vance, RW Bell, ME Haque). pp. 62-63.

Drakopoulos, D.; Scholberg, J.M.S.; Lantinga, E.A. and Tittonell, P.A. (2016). Influence of reduced tillage and fertilization regime on crop performance and nitrogen utilization of organic potato. Org. Agr. 6: 75-87.

Gupta, R.K. and Seth, A. (2007). A review of resource conserving technologies for sustainable management of the rice wheat systems of the Indo-Gangetic plains. Crop Protect. 26: 436-447.

Hou, X. and Li, R. (2019). Interactive effects of autumn tillage with mulching on soil temperature, productivity and water use efficiency of rainfed potato in loess plateau of China. Agricultural Water Management. 224, 105747.

Kumar, V.; Saharawat, Y.S.; Gathala, M.K.; Jat, A.S.; Singh, S.K.; Chaudhary, N. and Jat, M.L. (2013). Effect of different tillage and seeding methods on energy use efficiency and productivity of wheat in the Indo-Gangetic Plains. *Field Crops Research.* **142**: 1-8.

Laxmi, V.; Erenstein, O. and Gupta R.K. (2007). Impact of Zero Tillage in India's Rice-Wheat Systems. Mexico, D.F.: CIMMYT.

Mundy, C.; Creamer, N.G.; Crozier, C.R.; Wilson, L.G. and Morse, R.D. (1999). Soil Physical Properties and Potato Yield in No-till, Subsurface-till, and Conventional-till Systems. Hort Technology. 9(2): 240-247.

Nunes, J.C.S.; Fontes, P.C.R.; Araújo, E.F. and Sediyama, C. (2006). Potato plant growth and macronutrient uptake as affected by soil tillage and irrigation systems. Pesquisa Agropecuária Brasileira. 41(12): 1787-1792.

Qasim, M.; Khalid, S.; Naz, A.; Khan, M.Z. and Khan, S.A. (2013). Effects of different planting systems on yield of potato crop in Kaghan Valley: A mountainous region of Pakistan. Agricul. Sciences. 4(4): 175-179.

Qin, S.; Zhanga, J.; Dai, H.; Wanga, D. and Li, D. (2014). Effect of ridge-furrow and plastic-mulching planting patterns on yield formation and water movement of potato in a semi-arid area. Agricul. Water Manag. 131: 87- 94.

Quddus, M.A.; Naser, H.B.; Siddiky, M.A.; Ali, M.R.; Mondol, A.T.M.A.I. and Islam, M.A. (2020). Impact of Zero Tillage and Tillage Practice in Chickpea Production. Journal of Agricultural Science. 12(4): 106-118.

Sarangi, S.K.; Maji, B.; Digar, S.; Mahanta, K K.; Sharma, P.C. and Mainuddin, M. (2018). Zero tillage potato cultivation, an innovative technology for coastal saline soils. Ind. Farming. 68(04): 23-26.

Sarangi, S.K.; Maji, B.; Sharma, P.C.; Digar, S.; Mahanta, K.K.; Burman, D.; Mandal, U.K.; Mandal, S. and Mainuddin, M. (2020). Potato (Solanum tuberosum L.) Cultivation by Zero Tillage and Paddy Straw Mulching in the Saline Soils of the Ganges Delta. Potato Research. 64: 277-305.

Yaroson, A. Y.; Henry, U. I.; Adeniyi, T. O.; Ibrahim Iro, I. and Adam, D. (2019). Effect of Different Tillage Practices on the Performance of Potato (Solanum tuberosum) on the Jos Plateau. Intern. J. of Scientific and Research Publications. 9(2): 618-625.