Vol. 51, No. 1, pp 11-17, 2023
Indian Journal of Soil Conservation
https://www.iaswc.com/ijsc.html

Effect of crop residue retention and nutrient application rates on soil health dynamics: A study on vertisols of central India

Bharti Parmar[1], A.K. Vishwakarma[2,*], Varsha Gupta[1], Pramod Jha[2], A.K. Biswas[2], K.M. Hati[2], Ganesh Malgaya[1] and A.K. Patra[2]

[1]*Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh;* [2]*ICAR-Indian Institute of Soil Science, Bhopal, Madhya Pradesh.*

**Corresponding author:*
E-mail: akvish16@gmail.com (A.K. Vishwakarma)

ARTICLE INFO

Article history:
Received : December, 2022
Revised : March, 2022
Accepted : March, 2022

Key words:
Conservation agriculture
Crop residue
Nutrient levels
Wheat

ABSTRACT

A field experiment was conducted during *rabi* season of 2020-21 and 2021-22 to evaluate the effect of different levels of crop residue retention and nutrient levels on performance of wheat crop under conservation agriculture (CA). The experiment was laid out in factorial randomized block design (FRBD) comprised of 16 combinations of 4 residue level (0%, 30%, 60% and 90%) and 4 nutrient doses (N_1-RDF (120:60:40 kg N, P_2O_5 and K_2O ha^{-1}), N_2-75% N+100% P_2O_5 and K_2O ha^{-1}, N_3-75% P_2O_5+100% N and K_2O ha^{-1}, N_4-75% K_2O+100% N and P_2O_5 ha^{-1}) with 3 replication under ongoing Consortium Research Platform on Conservation Agriculture (CRP-CA) experiment at ICAR-Indian Institute of Soil Science, Bhopal (Madhya Pradesh). Among yield attributes *viz.,* number of ear head m^{-1} row length (158.69), length of ear head (17.75 cm), number of grains ear $head^{-1}$ (78.5), weight of grains ear $head^{-1}$ (4.41 g) and test weight (39.88 g) were recorded under higher level of crop residue retention (90%). Significantly higher grain yield (6474 kg ha^{-1}) and straw yield (9650 kg ha^{-1}) was also recorded under higher residue level retention treatment. The effect of nutrient levels was found significant on straw and biological yield Significant improvement in soil physical and chemical properties were recorded in all the levels of residue retention treatments in comparison to without / no residue retention treatment. The present investigation proved that retention of higher levels (90%) of crop residue results in significant improvement in crop yield with saving of nutrients to the tune of 25%.

1. INTRODUCTION

Wheat is a crop of global significance, serving as the staple food of the world's largest population after rice (Mathukia *et al.,* 2014) and it is a high-energy food crop that depletes nutrients in huge quantities from soil in rice-wheat cropping systems with generation of large quantities of residues (Thapa *et al.,* 2021). Agricultural vulnerability to climate change is one of the greatest challenges to sustain agricultural production (Kumar *et al.,* 2021). Conservation agriculture (CA) is already adopted in considerable area across the globe as one of the potential resource conserving technologies which not only helps in managing crop residues, soil health and associated problems but also helps in resource conservation, improving crop productivity, reduction in soil erosion and carbon sequestration according to the FAO (2008). CA is largely promoted as one of the few win-win technologies affordable to farmers, in the sense that potentially it improves farmers' yields (Shamna *et al.,* 2023). It is primarily concerned with the management of soil, water, and agricultural resources in order to achieve economically, environmentally, and socially viable agricultural production (*Jat et al.,* 2012). According to Dutta *et al.,* 2022 the country produces more than 683 Mt of crop residue per year, with a surplus of 178 Mt, of which 87 Mt is burned each year, resulting in substantial emission of particulate matter, air pollution and smog, including. Rani *et al*. (2023) resulted that 24.5 Mt of crop residue are burned in the country recently. Retention of crop residues on soil surface is one of the most important aspects of CA. Tillage practices and crop residue retention as mulch have significant impact on soil moisture regime, improvement in soil biota, soil organic carbon (SOC) and nutrient recycling (Choudhary *et al*., 2019), nutrient availability and nutrient use efficiency (Choudhary *et al.,* 2020). Role of SOC in evaluating soil quality, it is essential to utilize all available resources like involving use of balanced fertilization, conservation tillage practices and crop residue management (Sonune *et al.,* 2021). Generally, crop residues burning leads to loss of more than of different crops contain 80% of N, 25% of P, 50% of Sulphur (S) and 20% of K contained in residue (Kumar *et al*., 2020). Continuous retention of crop residue in CA results in enhanced plant nutrient input in soil, resulting in higher macronutrient storage and availability (Nandan *et al.,* 2021; Das *et al*., 2018). In comparison to conventional tillage (CT) systems, CA systems have more complicated nutrient management due to higher residue levels at the soil surface and fewer options for nutrient administration method and timing in the field (Ronanki and Behera, 2018). Despite several advantages, adoption of CA is picking up at a very slow rate in India due to non-availability of suitable CA technologies, machineries and social limitations such as a strong belief in ploughing.

Efforts are being were made under consortia research platform on CRP-CA to study effect of different levels of residue retention (0, 30, 60, and 90% residue) and nutrient doses on wheat productivity and soil properties in vertisols of central India.

2. MATERIAL AND METHODS

Experimental Site and Meteorological Conditions

Field experiments were conducted during *rabi* (Oct to March) of 2020-21 and 2021-22 at the research farm of the ICAR-Indian Institute of Soil Science, Bhopal, India. Geographically, the experimental site is located between 23°18'28.26"N and 77°24'26.00"E at an altitudes of 500 m above mean sea level. Average rainfall in the experimental area is 1,146 mm, of which more than 80% occurs from June to September. The experimental area has a mean annual air temperature of 25°C. The climate of the region is generally humid subtropical, with hot and dry summers and warm and humid monsoons beginning in late June and ending in late September. The summer season begins in the second half of March and ends in mid-June. The winter peaks in January when the temperature may occasionally drop close to freezing on some nights. The experimental soil is categorized as vertisols (black soils) and is slightly alkaline, having pronounced swell-shrink properties (Yadav *et al.,* 2021). The initial status of soil parameters is presented in Table 1.

Treatments and Management Details

The experiment was laid out in FRBD comprised of 16 combinations of 4 residue level (0%, 30%, 60% and 90%) and 4 nutrient doses (N_1-RDF (120:60:40 kg N, P_2O_5 and K_2O ha^{-1}), N_2-75% N+100% P_2O_5 and K_2O ha^{-1}, N_3-75% P_2O_5+100% N and K_2O ha^{-1}, N_4-75% K_2O+100% N and P_2O_5 ha^{-1}) with 3 replications. Wheat variety HDCSW18 was sown at a row to row spacing 27.5 cm in mid-October every year in residual moisture after harvest of preceding soybean crop using a zero-tillage seed drill machine (happy seeder) under different residue levels. A recommended dose of fertilizer (RDF) is 120 kg N, 60 kg P_2O5, and 40 kg K_2O ha^{-1} and 25% reduced doses of N, P and K were applied. Effective weed control methods were applied for management of weeds. The wheat crop was sown in residual moisture condition and six irrigations were applied. During both the year crop was harvested during last week of March. Growth and yield attributes of crop were recorded as per standard procedure at different growth stages.

Sampling, Processing, and Analysis

All the relevant growth and yield parameters were recorded in wheat crop. For the analysis 3 plants were collected randomly from each of the 48 plots and the data analysed as par standard. In 2020 at the beginning of present study the soil samples were collected from different plots representing the soil condition under different residue levels before imposing different nutrient treatments. The soil samples were then mixed and composite samples were prepared for analyzing initial soil physical and chemical

Table: 1
Initial status of soil parameters

Properties	Before sowing of wheat crop (2020)				After harvest of wheat (2022)			
	0% residue	30% residue	60% residue	90% residue	0% residue	30% residue	60% residue	90% residue
Soil physical parameters								
Clay content in soil (%)	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4
Bulk density (m gm^{-3})	1.40	1.41	1.41	1.41	1.41	1.41	1.42	1.42
Porosity (%)	47.2	46.8	46.8	46.8	46.8	46.8	46.4	46.4
Soil chemical properties								
Soil pH (1:2)	7.7	7.82	7.73	7.80	7.80	7.81	7.75	7.8
EC (dS m^{-1})	0.21	0.21	0.22	0.21	0.21	0.21	0.22	0.22
SOC (kg^{-1} soil)	8.0	8.7	9.8	11.1	8.1	8.85	10.5	11.6
Available N (kg ha^{-1})	244	276	296	317	245	281	302	325
Available P (kg ha^{-1})	23.5	28	30	32	23.8	28.2	31.3	33.6
Available K (kg ha^{-1})	510	596	697	796	515	612	715	816

properties before start of the experiment. The soil samples were then air-dried, gently grounded, well mixed, and sieved through 2 mm mesh. The processed samples were utilized for the analysis of soil physical and chemical properties. The available N, P and K were measured following the standard procedures. Standard method of "Analysis of variance" was used for analyzing the data (Panse and Sukhatme, 1995).

3. RESULTS AND DISCUSSION

Effect on Crop Growth Parameters

The data presented in the Table 2 revealed that various crop growth parameters at harvest stage were markedly influenced due to the residue levels and nutrient doses. Maximum plant height (113.93 cm) and leaf area (349.70 cm^2) was recorded with higher level of crop residue (90%) retention as compared to no residue retention treatment which recorded significantly lower values of plant height (99.63 cm) and leaf area (248.80 cm^2), respectively. This may be attributed to the fact that higher level of crop residue retention resulted in significant improvement in soil health, better moisture retention and the improved soil micro-environment under zero tillage techniques (Kumar *et al*., 2017). Similarly, maximum dry matter accumulation (DMA) was recorded with 90% residue level (45.31 g) which was at par with 60% residue level (43.73 g) and these were significantly superior to without residue treatment (40.01 g). The maximum DMA under zero tillage with higher level of residue retention may be a result of the soil's moderated temperature, favourable soil moisture, and better soil biota due to the sustained supply of nutrients from residue mineralization (Kumar *et al*., 2017). The highest number of tillers m^{-1} row length at harvest (165.51) were also obtained under 90% residue level followed by 60%, 30% and these were significantly superior to without residue retention treatment (153.87 m^{-1} row length). Bastola *et al.,* 2021 also reported higher number of tillers with residue retention as compare to without residue retention during various growth stages of wheat. Residue retention practice showed higher tillers number as compared to without residue practice during all growth stages similarly Arshadullah *et al.,* 2012 observed significantly higher number of tillers under residue retention treatments than no residue treatments. Among the various nutrient doses, maximum leaf area (307.63 cm^2), DMA (43.49 g), tillers m^{-1} row length (161.08) were retain with N_1 (100% RDF) followed by N_4 (75% K_2O+100% N and P_2O_5) and significantly superior to N_3 (75% P_2O_5+100% N and K_2O) and N_2 (75% N+100% P_2O_5 and K_2O). Similarly, there is non-significant effect of nutrient levels on plant height at harvest. These results are in close confirmation with Patel *et al*., 2018; Mohan *et al.,* 2018; Singh *et al.,* 2017, who also reported higher dry matter production of the wheat crop as a result of greater nutrient availability, particularly nitrogen, which allows the wheat crop to translocate maximum photosynthesis from source to sink and concentrate in specific plant parts. Increased nutrient application may have promoted vegetative development, causing plants to produce grater biomass (Fazily *et al*., 2021).

Application of varied doses of nutrients could not attain level of significance with respect to leaf area production (Table 2). The non-significant effect of nutrient doses may

Table: 2
Effect of residue levels and nutrient doses on growth parameters of wheat crop

Treatment	Plant height (cm)	Leaf area (cm^2)	DMA (g $plant^{-1}$)	Tillers m^{-1} row length
A. Residue levels				
ZT R_0	99.63	248.80	40.01	153.87
ZT R_{30}	107.68	269.79	42.41	157.31
ZT R_{60}	111.05	321.80	43.73	163.22
ZT R_{90}	113.93	349.70	45.31	165.51
SE(m)	0.49	3.78	0.12	0.20
CD (P=0.05)	1.429	10.919	0.357	0.583
B. Nutrient levels				
N_1 (100% RDF)	108.82	307.63	43.49	161.08
N_2 (75% N+100% P_2O_5 and K_2O)	107.52	293.86	42.33	159.58
N_3 (75% P_2O_5+100% N and K_2O)	107.80	290.77	42.63	159.38
N_4 (75% K_2O+100% N and P_2O_5)	108.15	297.83	43.00	159.88
SE(m)	0.49	3.78	0.12	0.20
CD (P=0.05)	NS	10.92	0.36	0.58
Interaction				
SE(m)	0.99	7.56	0.25	0.40
CD (P=0.05)	NS	NS	0.71	1.17
Grand mean	108.07	297.52	42.86	159.98

be attributed to the fact that there is significant improvement in soil properties and nutrient recycling as a result. Alam *et al.,* 2013 also reported favourable synthesis of components that promote growth in the plant system due to greater nutrient availability, which led to an increase in the number of leaves per unit area and an increase in leaf area. These results are in conformity with Patel *et al.* (2018), who stated that the development of leaf area is a result of an increase in LAI are caused by the availability of sufficient amounts of nutrients, notably nitrogen, during the crop's active growth stages. Interactive effect of residue levels and nutrient doses on DMA and tillers m^{-1} row length was found to be significant.

Maximum DMA was obtained under higher level of residue retention with RDF which was significantly higher as compare to lower level of nutrient and residue retention treatments. Similar trend was recorded with tillers m^{-1} row length.

Yield Parameters

Among different yield attributing characters number of ear head m^{-1} row length, length of ear head (cm), number of grains earhead^{-1}, weight of grains earhead^{-1}and test weight was found to have significantly influenced by different levels of residue retention (90%, 60%, and 30%) as compared to without residue retention treatment. Maximum number of ear head m^{-1} row length (158.69) was found in 90% residue retention treatment and this was significantly higher as compare to other residue retention treatments, 60% (156.56), 30% (150.41) and without residue (146.92), similarly maximum length of ear head (17.78 cm) found with 90% which was significantly superior over 60% (16.96 cm) and 30% (16.64 cm) and without residue (15.51 cm) retention treatments. Similar trend was recorded as number of grain ear head^{-1} maximum number of grains ear head^{-1} (78.50) were recorded with 90% crop residue retention level, which was significantly higher as compared to 60% (74.38), 30% (66.88) and without residue (61.92). The weight of grain earhead^{-1} was found to be significantly influenced as a result of different levels of residue retention. Maximum (4.41 g) weight of grain earhead^{-1} obtains with 90% crop residue retention. Test weight of wheat crop was found maximum (38.88) with higher level of crop residue (90%) This is because proper NPK nutrition is important for improving the grain weight through improved photosynthetic activities and better assimilates translocation (Barker and Pilbeam, 2007).

Significantly lower yield attributing characters were recorded under without residue treatments. Among the different doses of nutrient, the maximum number of ear head m^{-1} row length (154.39), length of ear head (17.21 cm) and number of grains earhead^{-1} (71.92) were recorded with N_1 (RDF) followed by N_4 (75% K_2O+100% N and P_2O_5). Interaction effect of residue levels and nutrient doses on number of ear head m^{-1} row length and weight of grains ear head $^{-1}$ (g) was found to be significant. Maximum number of ear head m^{-1} row length (159.3) and weight of grain earhead^{-1} (4.4 g) was obtain under higher level of residue retention with RDF which was significantly higher as compare to lower levels of nutrients and residue retention treatments.

Yield of Wheat Crop

Grain yield, straw yield and biological yield were

Table: 3
Effect of residue levels and nutrient doses on yield parameters of wheat crop

Treatment	Number of ear head m^{-1} row length	Length of ear head (cm)	Number of grains ear head^{-1}	Weight of grains ear head^{-1} (g)	Test weight (g)
A. Residue levels					
ZT R_0	146.92	15.91	61.92	3.76	35.12
ZT R_{30}	150.41	16.64	66.88	3.91	36.25
ZT R_{60}	156.56	16.96	74.38	4.18	38.02
ZT R_{90}	158.69	17.78	78.50	4.41	39.88
SE(m)	0.22	0.16	0.46	0.02	0.199
CD (P=0.05)	0.64	0.46	1.32	0.06	0.57
B. Nutrient doses					
N_1 (100% RDF)	154.39	17.21	71.92	4.11	37.80
N_2 (75% N+100% P_2O_5 and K_2O)	152.50	16.71	69.54	4.04	37.16
N_3 (75% P_2O_5 +100% N and K_2O)	152.65	16.51	70.00	4.04	37.10
N_4 (75% K_2O+100% N and P_2O_5)	153.03	16.86	70.21	4.06	37.22
SE(m)	0.22	0.159	0.46	0.02	0.19
CD (P=0.05)	0.64	0.46	1.32	NS	NS
Interaction					
SE(m)	0.44	0.32	0.91	0.04	0.39
CD (P=0.05)	1.28	NS	NS	0.12	NS
Grand mean	153.14	16.82	70.42	4.06	37.32

Table: 4
Effect of residue levels and nutrient doses on yield of wheat crop

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
A. Residue levels				
ZT R_0	5413	8075	13488	40.10
ZT R_{30}	5619	8621	14240	39.41
ZT R_{60}	6062	9220	15283	39.64
ZT R_{90}	6474	9650	16125	40.10
SE(m)	121.66	43.42	145.56	0.47
CD (P=0.05)	351.38	125.39	420.39	NS
B. Nutrient doses				
N_1 (100% RDF)	6034	9117	15152	39.73
N_2 (75% N+100% P_2O_5 and K_2O)	5824	8734	14559	40.00
N_3 (75% P_2O_5+100% N and K_2O)	5821	8801	14623	39.78
N_4 (75% K_2O+100% N and P_2O_5)	5888	8913	14802	39.73
SE(m)	121.66	43.42	145.56	0.47
CD (P=0.05)	NS	125.39	420.39	NS
Interaction				
SE(m)	243.32	86.83	291.11	0.94
CD (P=0.05)	NS	250.78	NS	NS
Grand mean	5892.51	8891.9	14784.5	39.81

significantly influenced as a result of different levels of residue retention. Grain yield (6474 kg ha $^{-1}$), straw yield (9650 kg ha^{-1}) and biological yield (16125 kg ha^{-1}) were recorded maximum with 90% crop residue retention (Table 4). Additionally, implementing ZT + residue retention in wheat may increase wheat production, the ZT with surface residue retention was more advantageous in terms of energy, time, and cost effectiveness reported by Choudhary *et al*. (2019). Sen *et al.* (2002) also reported significantly higher yield of wheat under zero tillage than under CT system. Govaerts *et al.* (2009) also found that residue retention is necessary in no-till systems and have improvements in crop yields with partial or with full residue retention. Significant effect of different nutrient doses on straw and biological yield was observed, but in case of grain yield there was no influence of nutrient doses. Maximum grain (6034 kg ha^{-1}), straw (9117 kg ha^{-1}) and biological yield (15152 kg ha^{-1}) obtain with 100% RDF followed by N_4 (75% K_2O + 100% N and P_2O_5). However, Ros *et al*., 2003 reported non-significant effect of fertilizer application time on grain yield. Minimum grain (5824 kg ha^{-1}), straw (8734 kg ha^{-1}) and biological yield (14559 kg ha^{-1}) resulted with N_2 (75% N + 100% P_2O_5 and K_2O) (Table 4). Ghosh *et al*., 2007 reported that there was more nitrogen available when soybean was the preceding crop, which is also the cause of the noticeably greater wheat production in the soybean-wheat cropping combination. Harvest index (HI) of wheat found non-significant with residue level and nutrient doses. There was no discernible impact on yield from the interaction between residue levels and nutrient doses except on straw yield. Maximum straw yield found under higher residue retention with RDF which was significantly higher as compare to lower levels of nutrients and residue retention treatments.

Table: 5
Crop residues production and its retention in the zero-tillage black soil under wheat crop on pooled basis

Residue retention	Straw yield t ha^{-1}	Residue retention t ha^{-1}
0% residue	8.10	0
30% residue	8.60	2.58
60%residue	9.20	5.52
90% residue	9.65	8.68

Crop Residue Retention

A huge quantity of residues was recycled during both the years (Table 5). It is evident from the data that higher quantity of residues was retained under 90% residue level (8.68 t ha^{-1}) as compared to 60% (5.52 t ha^{-1}) and 30% (2.58 t ha^{-1}) during the period of investigation. The increasing rate of residues retention under zero-tillage in black soil has resulted in improved nutrient recycling and improved soil properties that have substantial effect on organic carbon (OC) build up. These findings were in close confirmation with (Ghimire *et al*., 2017; Zhang *et al*., 2020) who also reported plant residues retention as sustainable environmentally sound sources, which when retained after harvest, met soil and nutrient needs, and accumulated higher OC in the soil to protect against erosion and maintain soil health. (Yadav *et al.,* 2021) also reported higher recycling of crop residue on surface of the soil which increased the amount of carbon and nutrient recycling in soil under CA.

4. CONCLUSIONS

CA is an advanced method of crop production which can save lot of resources and energy without compromising crop productivity besides improvement in soil properties and reducing cost of cultivation. The present study concluded that adoption of conservation agricultural practices along with higher level of crop residue retention (90%) and reduced rate of fertilizer application (-25%) in established CA fields can produce crop yield equivalent to crop productivity as recorded under recommended rates of fertilizer application and significantly higher yields can be obtained with higher level of crop residue retention as compared to without residue retention treatment with same level of fertilizer application. Significant quantities (2.58-8.69 t ha^{-1}) of residue can be recycled through residue retention, which helps in enhancing the crops growth, yield attributes and soil physical, chemical and biological parameters and sustained release of nutrients to the crop thus helps in economizing the rate of fertilizer application to the crop.

ACKNOWELEDGEMENTS

I am very much grateful to Director, ICAR-Indian Institute of Soil Science, Bhopal and Head, Division of Soil Chemistry and Fertility for allowing me to work under the programme CRP-CA. I would like to thank the staffs of IISS, Bhopal for their support.

REFERENCES

Alam, M.S. 2013. Growth and yield potentials of wheat as affected by management practices. *Afr. J. Agric. Res.,* 8(47): 6068-6072.

Arshadullah, M., Ali, A., Hyder, S.I. and Khan, A.M. 2012. Effect of wheat residue incorporation along with n starter dose on rice yield and soil health under saline sodic soil. *J. Animal Plant Sci.,* 22(3):753-757.

Barker, A.V. and Pilbeam, D.J. 2007. Hand book of plant nutrition. CRC press, Boca Raton, Florida, USA.

Bastola, A., Karki, T., Marahatta, S. and Prasad, A. 2021. Growth, phenology, yield and yield attributes of rice as influenced by tillage, residue and nitrogen management practice in Chitwan, Nepal. *Afr. J. Agric. Res.,* 17(1): 128-136.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci.,* 59(1): 39-46.

Chaudhary, A., Chhokar, R.S., Yadav, D.B., Sindhu, V.K., Ram, H., Rawal, S., Khedwal, R.S., Sharma, R.K. and Gill, S.C. 2019. *In-situ* paddy straw management practices for higher in Indo-Gangetic Plains (IGP). *Indian J. Cereal Res.,* 11(3): 172-198.

Choudhary, R.L., Behera, U.K., Singh, H.V., Meena, M.D., Dotaniya, M.L. and Jat, R.S. 2020. Energetics and nitrogen-use efficiency of *kharif* maize in conservation agriculture-based maize (*Zea mays*) - wheat (*Triticum aestivum*) sequence. *Int. J. Chem. Stud.,* 8(2): 1252-1258.

Das, A., Lyngdoh, D., Ghosh, P.K., Lal, R., Layek, J. and Ramkrushna, G.I. 2018. Tillage and cropping sequence effect on physico-chemical and biological properties of soil in eastern Himalayas, India. *Soil Till. Res.,* 180: 182-193.

Dutta, A., Patra, A., Hazra, K.K., Nath, C.P., Kumar, N. and Rakshit, A. 2022. A state-of-the-art review in crop residue burning in India: Previous knowledge, present circumstances and future strategies. *Environ. Challenges,* 100581.

FAO. 2008. What is conservation agriculture in: conservation agriculture website of FAO, http://www.fao.org/ag/ca/1a.html.

Fazily, T., Thakral, S.K. and Dhaka, A.K. 2021. Effect of integrated nutrient management on growth, yield attributes and yield of wheat. *Int. J. Adv. Agric. Sci. Tech.*, 8(1): 106-118.

Ghimire, B., Ghimire, R., Van Leeuwen, D. and Mesbah, A. 2017. Cover crop residue amount and quality effects on soil organic carbon mineralization. *Sustainability*, 9: 2316.

Ghosh, P.K., Bandyopadhyay, K.K., Wanjari, R.H., Manna, M.C., Misra, A.K., Mohanty, M. and Rao, A.S. 2007. Legume effect for enhancing productivity and nutrient use-efficiency in major cropping systems - an Indian perspective: a review. *J. Sustain. Agric.*, 30(1): 59-86.

Govaerts, B., Verhulst, N., Sayre, K.D., Kienle, F., Flores, D. and Limon-Ortega, A. 2009. *Implementing conservation agriculture concepts for irrigated wheat-based systems in Northwest Mexico: a dynamic process towards sustainable production.* In: Innovations for improving efficiency, equity and environment. Lead papers for the 4th world congress on conservation agriculture held 4-7th Feb, 2009 in New Delhi, India. 4th world congress on conservation agriculture, New Delhi, India.

Jackson, N.L. 1973. Soil chemical analysis. 2nd ed. New Delhi: Prentice Hall of India Pvt. Ltd, 498 p.

Jat, R.A., Wani, S.P. and Sahrwat, K.L. 2012. Conservation Agriculture in the semi-arid tropics: prospects and problems. *Adv. Agron.,* 2(117): 191-273.

Kumar, M., Reddy, J.P., Kumawat, S., Bansal, R. and Badwal, D.P.S. 2020. Impact of stubble burning in Punjab - A review. *J. Pharmacog. Phytochem.,* SP 6: 245-250.

Kumar, N., Kamboj, B.R., Thakral, S.K. and Singh, M. 2017. Growth parameters and productivity of wheat as influenced by crop establishment methods and different seed rate. *Int. J. Pure Appl. Biosci.,* 5(4): 2134-2140.

Kumar, S., Singh, D.R. and Kumar, A. 2021. Understanding soil and water conservation benefits adoption paradox in drought prone areas of Karnataka, India through financial viability: Case of field bunds. *Indian J. Soil Cons.,* 49(1): 32-37.

Kumar, V., Naresh, R.K., Kumar, S., Kumar, S., Kumar, S., Vivek Singh, S.P. and Mahajan, N.C. 2018. Tillage, crop residue, and nitrogen levels on dynamics of soil labile organic carbon fractions, productivity and grain quality of wheat crop in *Typic Ustochrept* soil*. J. Pharmacog. Phytochem.,* 7: 598-609.

Li, Y., Zhang, Q., Cai, Y., Yang, Q. and Chang, S.X. 2020. Minimum tillage and residue retention increase soil microbial population size and diversity: Implications for conservation tillage. *Sci. Total Environ.*, 716: 1-33.

Manna, M.C., Rao, A.S. and Mandal, A. 2015. Impact of agricultural land management practices on soil carbon sequestration. *Indian J. Soil Cons.,* 43(3): 204-212.

Mathukia, R.K., Gajera K.D. and Mathukia, P.R. 2014. Validation of leaf color chart for real time nitrogen management in wheat. *J. Dynam. Agric. Res.,* 1-4.

Mohan, B., Kumar, P. and Yadav, R.A. 2018. Effect of integrated nutrient management on yield attributes and yield of wheat (*Triticum aestivum* L.). *J. Pharmacog. Phytochem.,* 7(1): 1545-1547.

Nandan, R., Poonia, S.P., Singh, S.S., Nath, C.P., Kumar, V., Malik, R.K., McDonald, A. and Hazra, K.K. 2021. Potential of conservation agriculture modules for energy conservation and sustainability of rice-based production systems of Indo-Gangetic plain region. *Environ. Sci. Poll. Res.,* 28: 246-261.

Panse, V.G. and Sukhatme, P.V. 1995. Randomized design and square and factorial experiment in statistical methods of agricultural workers (2nd edn.), ICAR, New Delhi.

Patel, G.G., Sadhu, A.C., Patel, H.K., Shan, S.N. and Lakum, Y.C. 2018. Effect of organic and inorganic fertilizers in comparison with humic acid on growth and yield of wheat (*Triticum aestivum* L.). *Int. J. Agric. Sci.,* 10: 6524-6527.

Rani, K., Datta, A., Jat, H.S., Choudhary, M., Sharma, P.C. and Jat, M.L. 2023. Assessing the availability of potassium and its quantity-intensity relations under long term conservation agriculture based cereal systems in North-West India. *Soil Till. Res.,* 228: 105644.

Ronanki, S. and Behera, U.K. 2018. Effect of tillage, crop residues and nitrogen management practices on growth performance and soil microbial parameters in wheat. *Int. J. Curr. Microbio. Appl. Sci.,* 7(1): 845-858.

Ros, C.O.D., Salet, R.L., Porn, R.L. and Machado, J.N.C. 2003. Effects of fertilization methods on soil nitrogen availability for wheat and corn production. *Ciência Rural Santa Maria,* 33: 799-804.

Sen, A., Sharma, S.N., Singh, R.K. and Pandey, M.D. 2002. Effect of different tillage systems on the performance of wheat. *Proc. Int. Symp. on herbicide resistance management and zero tillage in rice-wheat cropping system*, March 4-6, CCS Haryana Agricultural University, Hisar, India, pp 115-16.

Shamna, A., Jha, S.K., Kumar, S. and Roy, M.L. 2023. Prospects and constraints in adoption of conservation agricultural practices. In: *Conservation Agriculture and Climate Change*, CRC Press, pp 449-456.

Sharda, V.N., Mandal, D. and Dogra, P. 2019. Assessment of cost of soil erosion and energy saving value of soil conservation measures in India. *Indian J. Soil Cons.,* 47(1): 1-6.

Singh, H., Singh, A.K., Alam, S., Singh, T., Singh, V.P., Parihar, A.K.S. and Singh, R. 2017. Effect of various integrated nutrient management models on growth and yield of wheat in partially reclaimed sodic soil. *Int. J. Curr. Microbio. Appl. Sci.,* 6(3): 803-808.

Singh, Y., Parihar, C.M., Sahrawat, Y.S., Jat, H.S. and Jat, M.L. 2021. Nutrient management in conservation agriculture-based production systems. *J. Agric. Phy.,* 21(1): 165-181.

Sonune, B.A., Kharche, V.K., Gabhane, V.V., Jadhao, S.D., Mali, D.V., Katkar, R.N., Kadu, P.R., Konde, N.M., Deshmukh, D.P. and Goramnagar, H.B. 2021. Sustaining soil health and cotton productivity with tillage and integrated nutrient management in Vertisols of Central India. *Indian J. Soil Cons.,* 49(1): 1-11.

Subbiah, B.V., Asija, G.L. 1956. A rapid procedure for the determination of available nitrogen in soils*. Curr. Sci.,* 25: 259-260.

Thapa, B., Khanal, B.R. and Marahatta, S. 2019. Effect of conservation agriculture on yield and yield attributing properties of wheat. *Adv. Plants Agric. Res.,* 9(2): 329-335.

Vishwakarma, A.K., Meena, B.P., Das, H., Jha, P., Biswas, A.K., Bharati, K., Hati, K.M., Chaudhary, R.S., Shirale, A.O., Lakaria, B.L. and Gurav, P.P. 2023. Impact of sequential herbicides application on crop productivity, weed and nutrient dynamics in soybean under conservation agriculture in vertisols of Central India. *PloS one*, 18(1): p.e0279434.

Walkely, A. and Black, I.A. 1934. An examination of the digested method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.,* 37: 29-38.

Yadav, D., Vishwakarma, A.K. and Sharma, N.K. 2021. Sustaining the properties of black soil in Central India through crop residue management in a conservation-agriculture-based soybean-wheat system*. Land Deg. Dev.,* 32: 2906-2921.