Original Research Article

Sunflower Growth and Soil Properties under Different Straw Management Practices in a Rice-Based System

Comment [DD1]: Need it in proper way

ABSTRACT

A field experiment was conducted to evaluate the *kharif*rice residue management on sunflower growth and physical health of the soil under rice-sunflower system during 2022-23 and 2023-24, in randomized block design (RBD) in an alfisols. The results revealed that more dry matter accumulation per plant was recorded straw incorporation with adjustment of C:N or C:P ratio treatments with highest was recorded in straw C:N:P ratio to 30:1:0.3 before incorporation (T_7) treatment with 20.59 g plant^{-1} as compared to straw removal or burning treatments. The highest BD (1.38 Mg m^{-3}) was observed in the RR burning + RDF and RR removal + RDF treatments, compared to treatments involving RR incorporation, where the strawC:N, C:N:P, or C:P ratios were adjusted before incorporation. In contrast, the lowest BD (1.34 Mg m^{-3}) was recorded in the residue retention + ZT SF + RDF treatment. The higher GM content was recorded in adjustment of straw C: N: P ratio to 30: 1: 0.3 prior to incorporation, at all growth stages. The lowest GM content was recorded in residue removal+RDF treatment.

Key words: Rice residue, Sunflower, Straw C:N:P ratio, Dry matter, Bulk density, Moisture content, Alfisols.

1. Introduction

India, being an agrarian nation, generates significant amounts of crop residues owing to its diverse range of crops. According to the Government of India, approximately 500mt of crop residues are produced annually. Among Indian states, Uttar Pradesh leads in crop residue production, generating 60 mt annually, followed by Punjab with 51 mt and Maharashtrawith 46 mt. Notably, around 70% of the total crop residues originate from cereals such as rice, wheat, maize, and millets (Gupta *et al.*, 2022). In Siddipet district alone nearly 8 to 12 lakh tonnes of rice residue per annum are being produced from the current level of area and production. This crop residue can disrupt various field operations, so it needs to be managed carefully.

Managing rice straw is a significant challenge, particularly in intensive farming systems with short fallow periods. Various residue management options are available, such as burning, baling, in-situ incorporation into the soil, residue removal, and partial or complete retention on the soil surface. Despite these options, farmers often resort to burning because it is the fastest and most cost effective method for clearing fields. Although incorporating rice straw into the soil is an alternative, it is less favored due to the slow decomposition process. This practice of burning has contributed to severe pollution and soil degradation. Stubble burning negatively impacts soil health and fertility by depleting organic matter, essential nutrients, and beneficial microorganisms. These losses disrupt soil structure, reduce fertility, and hinder overall productivity (Pradhan *et al.*, 2024). Consequently, maintaining and enhancing soil fertility has become essential for sustaining future agricultural productivity (Kumar *et al.*, 2019).

Numerous studies highlight that crop straw, rich in nutrients and organic matter, serves as a natural organic fertilizer and can act as an alternative to chemical fertilizers. As such, straw incorporation offers a promising approach to maintaining and restoring soil fertility. Research has demonstrated that straw incorporation significantly benefits both crop yields and soil properties (Gupta*et al.*, 2022). For example, it can enhance crop yields, increase soil organic matter, and boost the availability of essential soil nutrients. Additionally, straw return improves soil physical properties by enhancing hydraulic conductivity, reducing bulk density, and promoting aggregate formation.

Adequate soil organic matter (SOM) and essential nutrients, such as nitrogen (N), phosphorus (P), potassium (K), along with soil microbes, are crucial for high crop production and serve as key indicators of soil fertility. These elements play vital roles in nutrient cycling within the soil. Additionally, soil physical properties, including porosity, bulk density, hydraulic conductivity, and aggregation, significantly influence soil fertility and crop yield (Zhao *et al.*, 2019).This manuscript aimed to assess the impact of various straw management practices on soil physical properties within the rice–sunflower cropping system.

2. MATERIALS AND METHODS

2.1 Experimental site

The experiment was carried out plot no. 19 of “A” block at Agricultural Research station, Tornala in Siddipet district, Telangana situated in Central Telangana Zone. The experimental field is geographically situated at 18^{o} 06'35" North latitude and 78^{o} 44'27" East.

The soil of the experimental field is sandy clay loam in texture, having 66.40% sand, 8.30% silt, and 25.30% clay.

2.2 Climate

During the *rabi* season of 2022–23, the mean weekly maximum temperature ranged from 27.71°C to 37.71°C, while the mean weekly minimum temperature ranged from 17.36°C to 24.21°C. In the *rabi* season of 2023–24, the mean weekly maximum temperature varied between 28.07°C and 38.21°C, and the mean weekly minimum temperature ranged from 13.50°C to 26.87°C. The mean annual rainfall of siddipet district is 784.2 mm in 2022-23 and 753.6mm, which is mostly received during July–September with occasional rain during winter.

2.3 Experimental details

The experiment was laid out in randomized block design (RBD) with seven treatments and three replications during two successive years of 2022-23 and 2023-24 during both the *kharif* and *rabi* seasons. Treatments consisted of *viz*. T_1: Burning of rice residue (RR) 2 weeks after harvesting + RDF, T_2: RR removal + RDF, T_3: RR retention and zero till (ZT) sowing of sunflower + RDF, T_4: Incorporation of residue as such after harvest + RDF, T_5: Adjusting C-N ratio of residue to 30:1 by applying part of 1st dose of N through urea at the time of incorporation + Remaining RDN in 3 splits and P, K as recommended, T_6: Adjusting the C-P ratio of residue to 30:0.3 by applying part of recommended dose of P through SSP at the time of incorporation + remaining RDP as basal & N, K as recommended and T_7: Adjusting C-N-P ratio of residue to 30:1:0.3 by applying part of 1st dose of N through urea and part of recommended dose of P through SSP at the time of incorporation + Remaining RDN in 3 splits and P, K as recommended. The layout plan for sunflower cultivation remained identical for both seasons, ensuring that the same treatments were applied to the same plots. The net plot size was 8.0 × 7.2 m, while the gross plot size was 57.6 m². Urea and SSP were used as sources of nitrogen and phosphorus for the sunflower crop, according to the treatments. Muriate of potash was applied to supply potassium.

Treatment imposition involved quantifying the rice residue/straw (3 and 5.186 t/ha) after the *kharif* crop harvest. The straw carbon (35.75% and 36.75%), nitrogen (0.65% and 0.71%), and phosphorus (0.28% and 0.22%) contents were analyzed, recording C:N ratios of

55:1 and 51.76:1, C:P ratios of 126:1 and 167.05:1, and C:N:P ratios of 55:126:1 and 51.76:167.05:1 for the 2022–23 and 2023–24 seasons, respectively.

Based on these results, the straw C:N ratio was adjusted to 30:1 before incorporation by applying part of the first dose of nitrogen (284 g and 338 g urea plot^{-1}). The C:P ratio was adjusted to 30:0.3 by applying part of the first dose of phosphorus (111.5 g and 275 g SSP plot^{-1}). Similarly, the C:N:P ratio was adjusted to 30:1:0.3 using urea (284 g plot^{-1}) and SSP (111.5 g plot^{-1}) as sources of nitrogen and phosphorus.

For residue incorporation treatments (T_4 to T_7), a rotary mulcher was used to chop the straw, which was then incorporated into the soil using standard tillage operations, including two passes with a cultivator followed by rotavation. For treatments involving residue burning or removal (T_1 and T_2), two cultivator passes followed by rotavation were performed. In the control treatment (T_3), rice stubble regrowth was controlled by spraying paraquat at 5 ml L^{-1}, the rice residue was retained, and zero-till sunflower sowing was carried out along with the application of the recommended dose of fertilizer (RDF).

The sunflower hybrid DRSH-1, with a maturity period of 90–95 days, was sown at a rate of 2 kg ha^{-1}. Two seeds were manually dibbled per hill, maintaining the recommended spacing of 45 cm × 20 cm.

Comment [DD2]: There should be uniformity in units

2.4 Plant biometric data

2.4.1 Dry matter production

For the purpose of estimating the accumulation of dry matter at vegetative stage, flowering stage, and at harvest, five plants from each border row were removed (cut at the base) and partially dried in the sun. Stems and leaves were separated, placed in brown paper bags and dried in an oven at 60°C to a constant weight, and the dry weight was recorded.

2.5 Soil sample collection and analysis

The plot-wise soil samples from 0-15 cm were collected at prior to straw incorporation, at the time of sowing of sunflower crop and at 45 and 90 days /at harvest of crop during *rabi*, 2022-23 and 2023-24 and analyzed to assess the effects of rice residue management on soil physical properties.

2.5.1Bulk density

Bulk density of soil sample was determined by using a known volume of core sampler (5.3cm inner diameter and 4.4cm height) having a volume of 97.12cm^3. Driven the sharp hedge of core sampler in to soil up to 1/3rd by hammering on iron plate on core sampler. After that soil cores were dried to constant weight at 105^0C in an oven for 48 hr. Bulk density was calculated by dividing weight of dried soil by the volume of core used (Blake and Hartge, 1986).

$$BD= (X-Y)/V$$

where, X= weight of core with oven dry soil (g); Y= weight of the core (g); V = volume of the core (cm^3)

2.5.2 Gravimetric moisture content

Gravimetric soil moisture content was determined by using standard procedure outlined by Kulte (1986). For this moist sample from field was collected by using auger and kept in pre weighed aluminium boxes than closed with lids immediately. Recorded the weight of moist soil along with aluminium boxes, than oven dried the soil at 105^oC for 48 hr till constant weight obtained. Than soil gravimetric moisture content (%) calculated by using following formula.

$$\text{Gravimetric moisture content} = \frac{\text{Weight of moist soil} - \text{Weight of oven dried soil}}{\text{Weight of oven dried soil} - \text{Weight of empty box}} \times 100$$

Statistical analysis

All data collected during the study were statistically analyzed using analysis of variance (ANOVA) following the procedures applicable to a randomized block design (RBD) as outlined by Panse and Sukhatme (1985). Treatment effects were evaluated for significance using the F-test, and differences between means were determined using the least significant difference (LSD) at a 0.05 probability level.

3. Results and Discussion

3.1 Plant dry matter accumulation

The average dry matter production showed a gradual increase up to the vegetative stage, followed by an exponential rise between the vegetative and flowering stages. After flowering, the production continued to increase until harvest, albeit at a slower pace (Table 1). The pooled data over two years for dry matter production per plant in *rabi* sunflower, as presented in the table, indicate no significant interaction effect between treatments and years.

During the vegetative stage, the treatment that adjusted the straw C:N:P ratio to 30:1:0.3 before incorporation (T_7) recorded the highest dry matter accumulation of 20.59 g plant^{-1}. This was statistically comparable to the residue retention combined with zero tillage sowing of sunflower and recommended RDF (T_3) treatment, which yielded 19.95 g plant^{-1}, as well as the straw C:N ratio adjustment to 30:1 before incorporation (T_5), which produced 18.33 g plant^{-1}, and the straw C:P ratio adjustment to 30:0.3 before incorporation (T_6), which recorded 18.08 g plant^{-1}. The residue incorporation as such with recommended RDF (T_4) resulted in a lower dry matter accumulation than T_7 but was on par with T_5, recording 16.59 g plant^{-1}. The lowest dry matter accumulation was observed in the residue removal with recommended RDF (T_2), at 11.21 g plant^{-1}, followed by residue burning with recommended RDF (T_1), which produced 13.30 g plant^{-1}.Similar trend was observed at flowering stage also. While at harvest, adjusting the straw C: N: P ratio to 30: 1: 0.3 prior to incorporation (T_7) recorded highest dry matter production (76.42 g plant^{-1}), followed by adjusting the straw C: N ratio to 30: 1 prior to incorporation treatment (T_5) with 73.22 g plant^{-1}, which was on par with residue retention + zero tillage sowing of sunflower + RDF as recommended (T_3) with 72.96 g plant^{-1} and straw C: P ratio to 30: 0.3 prior to incorporation treatment (T_6) with 70.66 g plant^{-1}. The residue incorporation + RDF (T_4) with 61.25 g plant^{-1} and residue removal + RDF (T_2) with 60.47 g plant^{-1} are at par and outperformed residue burning + RDF (T_1), which recorded lowest dry matter accumulation with 56.45 g plant^{-1}.In this study, dry matter production per plant increased steadily, reaching its peak at harvest, due to nitrogen's role in promoting vegetative growth and boosting carbohydrate levels in leaves, which led to greater dry matter accumulation (Babu *et al.*, 2016).Dry matter production, which is closely related to grain productivity, plays a significant role in the source-sink relationship (Deepika *et al.*, 2022).

3.2 Bulk density

Bulk density (BD) is assessed to describe soil compactness influenced by land use and soil management practices. The Figure 1illustrates data concerning the impact of rice residue management options on soil bulk density during both seasons. During *rabi* 2022-2023 and 2023-24, Soil bulk density showed no significant variation across the different residue and nutrient management practices. However, it was observed that the BD under RR burning + RDF (T_1) and RR removal + RDF (T_2) treatments were recorded 1.38 Mg m^{-3} at a soil depth of 0-15 cm was numerically higher by 3.62% compared to RR incorporation, with the C:N, C:N:P, or C:P ratios of the straw were adjusted prior to incorporation and residue retention + ZT SF + RDF (T_3) treatments, which recorded lowest BD of 1.34 Mg m^{-3}. It was followed by 1.35 Mg m^{-3} instraw incorporation as such + RDF (T_4) treatment which was higher then T_3, T_5, T_6 and T_7 treatments. This results are confirmed with Adak *et al.* (2019).Lower bulk density at surface soil under RR incorporation with nutrient management may be attributed to the decomposition of residue, leading to a significant increase in polysaccharides and microbial gum synthesis within the soil. These microbial decomposition products resist further degradation and act as binding agents. This may help in soil aggregation and consequently lowering its BD (Bhatt *et al.*, 2019).Kharub*et al.* (2004) also reported that straw burning, straw removal and straw incorporation had no significant effect on BD, but slight decrease in straw incorporation treatment in rice-wheat system. Incorporation of crop residues provide food for microbial activities to proliferate, which slowly and gradually decompose the residue and ultimately improve the organic matter content of the soil which helps in increased soil aggregation resulted in reduction in the BD (Gupta *et al.*, 2022). Valzano*et al.* (1997) reported that in a direct-drilled system, bulk density showed no significant differences between burned and unburned plots, indicating that burning has no short-term negative effects on certain physical soil properties. Memon *et al.* (2018) also demonstrated that incorporating residues into the soil significantly improved soil structure and reduced soil dry bulk density compared to treatments that did not include straw.

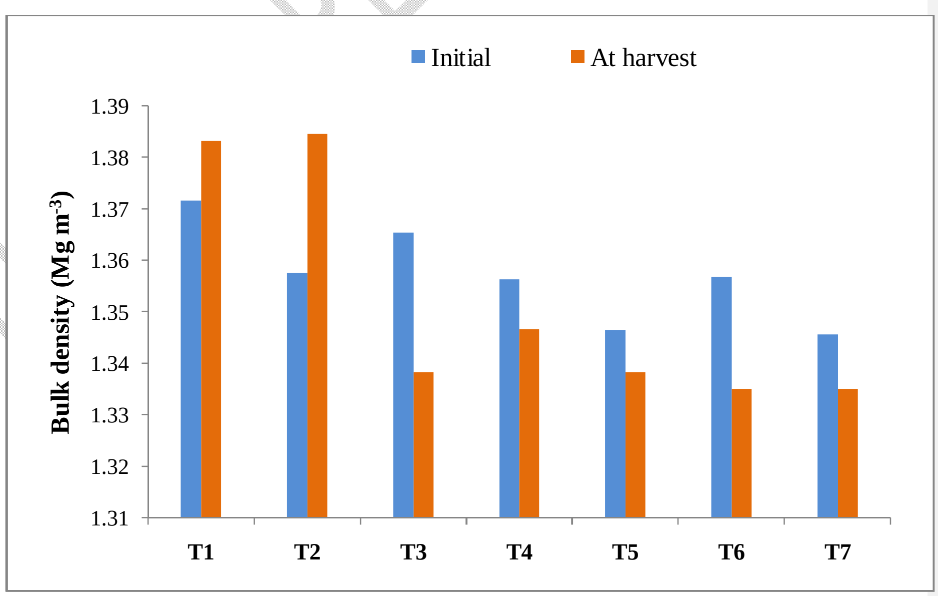

Figure 1. Bulk density of soil as influenced rice residue management

3.3 Gravimetric moisture content

The data on effect of rice residue and nutrient management practices on gravimetric moisture (GM) content at 0, 45 and 90 DAS/at harvest was presented in Figure 2 shows that GM content significantly affected by rice residue nutrient management practices. The GM content of the soil ranged from 12.50% to 18.65% at 0 DAS, 12.33% to 19.50% at 45 DAS, and 12.02% to 19.24% at 90 DAS/harvest across treatments. Notably, the GM content in the soil at 90 DAS/harvest was higher compared to the initial moisture content at 0 DAS of the experiment.

The pooled data of two years showed that, at 0 DAS, the higher moisture (18.65%) content was recorded in the treatments which were adjustment of straw C: N: P ratio to 30: 1: 0.3 (T_7) prior to incorporation, which was significantly superior over rest of the treatments, followed by residue retention + ZT SF + RDF (T_3) treatment (16.69%) was on par with incorporation of straw by adjusting the C: N ratio to 30: 1 (T_5) treatment (16.53 %), residue incorporation as such + RDF (T_4) treatment (15.65%) and adjustment of C: P of residue to 30: 0.3 before incorporation (T_6) treatment (15.77%). The lowest moisture content (12.50%) was observed with straw removal + RDF (T_2) treatment and it was on par with straw burning + RDF (T_2) treatment (14.00%). At 45 DAS, the higher moisture (19.31%) content was recorded in the treatments which were adjustment of straw C: N:P ratio to 30: 1:0.3 (T_7) prior to incorporation (19.50%) and it was on par with T_5(19.22%), T_6 (18.02%) and T_3 (17.63%). The lowest moisture content (12.33%) was observed with straw removal + RDF (T_2) treatment. At 90 DAS/at harvest, highest GM content was recorded in T_7 (19.24%) and it was on par with T_5 (18.72%), T_6 (17.52%) and T_3 (17.54%). The lowest GM content was recorded in T_2 (12.02%).

The increase in available moisture content in soil after application of organics might be due to the fact that it improves the physical structure of soils which increased water holding capacity (Mitran *et al.*, 2017). Maneepitak*et al.* (2019) also reported that the incorporation of rice straw typically decreases soil bulk density and enhances soil porosity, which helps the soil retain moisture more effectively.Langeroodi (2015) reported that omitting tillage and retaining straw often improved the capacity of soil to store water, also, the increase in total porosity, particularly micro-porosity, due to addition of organic matter probably led to enhancement of the moisture retention capacity and the presence of the residue on the surface of the soil had mulching effects on the soil surface under sunflower crop. According to Valzano*et al.* (1997), in a direct-drilled system, there were no significant differences in volumetric water content between burned and unburned plots, suggesting that burning does not cause short-term adverse effects on certain physical soil properties.

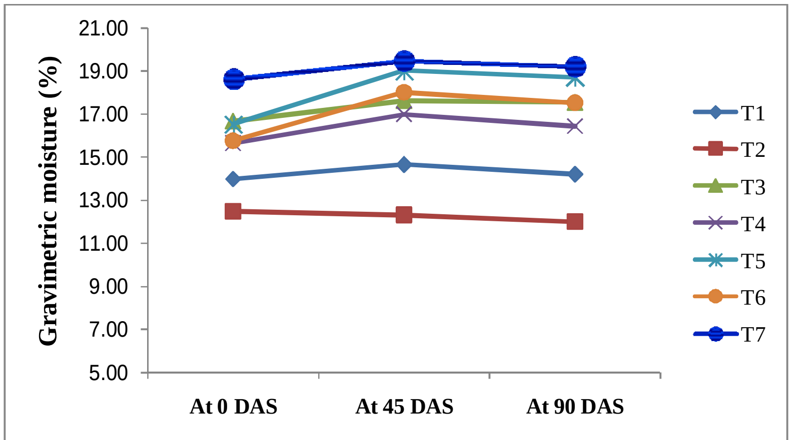

Figure 2. Gravimetric moisture content of soil as influenced rice residue management

3.4 CORRELATION

The correlations presented in the Table 2, based on the results from Table 1 and Figures 1 and 2, highlight key relationships between the variables. Bulk density exhibited a negative correlation with both moisture content and plant dry matter production across all growth stages, indicating that an increase in bulk density tends to reduce moisture content and plant dry matter production. Conversely, gravimetric moisture content showed a significant positive correlation with plant dry matter production at every growth stage, suggesting that higher gravimetric moisture content is associated with increased plant dry matter production.

Conclusion

In this study, the incorporation of rice straw into the soil, combined with adjustments of its C:N, C:P, or C:N:P ratios to 30:1, 30:0.3 and 30:1:0.3 during the preceding sunflower crop, demonstrated significant benefits. Higher dry matter accumulation per plant and gravimetric moisture content were observed, alongside a reduction in bulk density. Among the residue management practices, the treatment involving retention +ZT + RDF and straw incorporation + RDF outperformed residue removal or burning. These results highlight the potential of straw incorporation with appropriate nutrient adjustments to enhance soil physical properties and crop growth in a rice-sunflower cropping system.

REFERENCES

Adak, S.U.J.A.N., Bandyopadhyay, K.K., Sahoo, R.N., Purakayastha, T.J., Shrivastava, M. and Mridha, N.2019. Soil physical characteristics, productivity and input use efficiency of wheat (*Triticum aestivum*) as affected by different tillage, residue mulch and nitrogen management in maize-wheat cropping system. *Journal of Agricultural Physics*, 19(2): 239-250.

Babu, S., Rana, D.S., Yadav, G.S and Singh, R. 2016. Influence of sunflower stover and nutrient management on growth, yield and energetics of sunflower (*Helianthus annuus*) in a pigeonpea (*Cajanus cajan*)-sunflower cropping system. *Indian Journal of Agricultural Science*. 86: 315-320.

Bhatt, M., Singh, A.P., Singh, V., Kala, D.C. and Kumar, V. 2019. Long term effect of organic and inorganic fertilizers on soil physico-chemical properties of a silty clay loam soil under rice-wheat cropping system in Tarai region of Uttarakhand. *Journal of Pharmacognosy and Phytochemistry*, 8(1): 2113-2118.

Deepika, C.L and Singh, R.S.E. 2022a. Effect of nitrogen and sulphur levels on growth and yield of sunflower (*Helianthus annuus* L.). *The Pharma Innovation Journal*. 11(3): 2049-2052.

Gupta, R.K., Hans, H., Kalia, A., Kang, J.S., Kaur, J., Sraw, P.K., Singh, A., Alataway, A., Dewidar, A.Z. and Mattar, M.A. 2022. Long-term impact of different straw management practices on carbon fractions and biological properties under rice–wheat system. *Agriculture*, 12(10): 1733.

Kharub, A.S., Sharma, R.K., Mongia, A.D., Chhokar, R.S., Tripathi, S.C and Sharma, V.K. 2004. Effect of rice (*Oryza sativa*) straw removal, burning and incorporation on soil properties and crop productivity under rice-wheat (*Triticum aestivum*) system. *Indian journal of agricultural science*. 74(6): 295-299.

Klute, A.1986. Hydraulic conductivity and diffusivity: Laboratory methods. In *Method of Soil Analysis Part 1: Physical and Mineralogical Methods*. Soil Science Society of America, Madison. 413-423.

Kumar, A., Kushwaha, K.K., Singh, S., Shivay, Y.S., Meena, M.C and Nain, L. 2019. Effect of paddy straw burning on soil microbial dynamics in sandy loam soil of Indo-Gangetic plains. *Environmental technology and innovation*, 16: 100469.

Langeroodı, A.R.S. 2015. Sunflower and soil response to seven years of tillage, residue management and nitrogen fertilizer. *Turkish Journal of Field Crops*, 20(2): 194-202.

Maneepitak, S., Ullah, H., Datta, A., Shrestha, R.P. and Shrestha, S. 2019. Effect of water and rice straw management practices on soil organic carbon stocks in a double-cropped paddy field. *Communications in Soil Science and Plant Analysis*, 50(18): 2330-2342.

Mitran, T., Mani, P.K., Basak, N., Biswas, S. and Mandal, B. 2017. Organic amendments influence on soil biological indices and yield in rice-based cropping system in coastal sundarbans of India. *Communications in soil science and plant analysis*, 48(2): 170-185.

Panse, V.C and Sukhatme, P.V. 1978. *Statistical methods for Agricultural workers*. Indian Council of Agricultural Research, New Delhi. 87-89.

Pradhan, P., Sinha, A.K. and Pandit, T.K., 2024. The Effect of Stubble Burning and Residue Management on Soil Properties: A Review. *International Journal of Plant & Soil Science*, 36(6): 36-49.

Yoder, R. E. 1936. A direct method of aggregate analysis of soils and a study of the physical nature of erosion losses. *Journal of American Society of Agronomy*, 28:337351.

Zhao, X., Yuan, G., Wang, H., Lu, D., Chen, X and Zhou, J. 2019. Effects of full straw incorporation on soil fertility and crop yield in rice-wheat rotation for silty clay loamy cropland. *Agronomy*. 9(3): 133.

Table1. Dry matter production (g plant^{-1}) at different growth stages of *rabi* sunflower under different rice straw management options

	At vegitative stage			At Flowering			At harvest		
	2022-23	**2023-24**	**Pooled**	**2022-23**	**2023-24**	**Pooled**	**2022-23**	**2023-24**	**Pooled**
T_1	14.59	12.00	13.30	25.83	22.54	24.18	55.16	57.74	56.45
T_2	13.12	9.29	11.21	21.48	19.45	20.46	59.27	61.67	60.47
T_3	19.72	20.17	19.95	34.64	31.85	33.24	72.75	73.18	72.96
T_4	17.89	15.30	16.59	23.47	22.54	23.01	58.42	64.08	61.25
T_5	20.61	16.04	18.33	31.11	28.45	29.78	72.14	74.30	73.22
T_6	19.24	16.97	18.10	28.75	26.95	27.85	69.47	71.84	70.66
T_7	22.49	18.69	20.59	33.64	28.67	31.16	73.89	78.95	76.42
SE(m)± for years			0.46			0.628			0.51
SE(m)± for treatments	0.89	1.47	0.86	1.808	1.5	1.175	1.01	1.64	0.96
SE(m)± for years X treatments			1.21			1.662			1.31
CD (P=0.05) for years			1.35			1.833			1.50
CD (P=0.05) for treatments	2.756	4.543	2.52	5.571	4.63	3.43	3.91	5.06	2.81
CD (P=0.05) for years × treatments			NS			NS			NS
CV (%)	8.497	16.486	12.25	11.02	10.09	10.623	2.64	4.13	3.502

Table2. Correlation between bulk density, moisture content and plant dry matter production.

	Initial BD	BD At harvest	GM % At 0 DAS	GM % At 45 DAS	GM % at 90DAS	Dry matter at vegitative	Dry matter at flowering	Dry matter at harvest
Initial BD	1							
BD At harvest	0.560	1						
GM % At 0 DAS	-0.544	-0.876	1					
GM % At 45 DAS	-0.568	-0.938	0.947	1				
GM % at 90DAS	-0.565	-0.939	0.956	0.998	1			
Dry matter at vegetative	-0.448	-0.946	0.962	0.950	0.961	1		
Dry matter at flowering	-0.253	-0.775	0.841	0.812	0.841	0.9063	1	
Dry matter at harvest	-0.635	-0.860	0.848	0.834	0.858	0.8876	0.880	1