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Pooja
Department of Agronomy, CSK HPKV, Palampur. Himachal Pradesh, India

Janardan Singh
Department of Agronomy, CSK HPKV, Palampur. Himachal Pradesh, India

Sandeep Manuja
Department of Agronomy, CSK HPKV, Palampur. Himachal Pradesh, India

Shilpa
Department of Agronomy, CSK HPKV, Palampur. Himachal Pradesh, India

Varsha Rattan
Department of Soil Science, CSK HPKV, Palampur. Himachal Pradesh, India

Raveena
Department of Agronomy, CSK HPKV, Palampur. Himachal Pradesh, India

Corresponding Author:
Pooja
Department of Agronomy, CSK HPKV, Palampur. Himachal Pradesh, India

Soybean-gobhi sarson cropping: Harnessing soil potential through tillage and NPK management

Pooja, Janardan Singh, Sandeep Manuja, Shilpa, Varsha Rattan and Raveena

Abstract
A field experiment was conducted from *Kharif* 2021 till *Rabi* 2023, to study the effect of tillage and NPK levels on soil properties after harvest of soybean and gobhi sarson at Integrated Research Farm, Department of Organic Agriculture and Natural Farming of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experiment consisted of twelve treatment which included three tillage systems in main plots *viz;* minimum tillage, minimum tillage + crop residue and conventional tillage and four NPK levels in sub plots *viz;* 50 per cent recommended dose of nutrients (RDN), 75% RDN, 100% RDN and 125% RDN which were tested in split plot design replicated thrice. Results revealed that minimum tillage + crop residue improved the bulk density, particle density of soil and water holding capacity of the soil. pH, organic carbon and carbon sequestration also improved the minimum tillage + crop residue followed by minimum tillage. Among different NPK levels tested, 50 per cent recommended dose of nutrients (NPK) improved the bulk density and particle density of the soil whereas 100 per cent recommended dose of nutrients (NPK) improved water holding capacity, pH, organic carbon and carbon sequestration of the soil. Based on findings, it can be concluded that minimum tillage + crop residue and 100 per cent recommended dose of nutrients (NPK) can be adopted to improve the soil properties under soybean – gobhi sarson cropping system.

Keywords: Tillage, conservation tillage, fertilizer, pH, organic carbon

Introduction

For thousands of years, tillage has been a fundamental practice in agriculture worldwide. Tillage serves several important purposes, including weed control, soil compaction alleviation, and nutrient mixing. However, this continuous disturbance of the soil has unintended consequences, such as high rates of erosion, damage to soil organisms, and weakening of soil structure. In the last century, a significant consequence has been the extensive deterioration of soil quality and the desertion of agricultural land at a pace surpassing 10 million hectares annually when combined with other factors impacting soil health. It poses a significant challenge to fulfil current and future food demands worldwide. The researchers and farmers need to adopt alternative and environment friendly methods in concern to environment (Shilpa *et al*., 2021) [11]. Conservation tillage practices are encouraged to restore and maintain soil health for long-term crop productivity. Conservation tillage is characterized by retaining at least 30 percent of crop residues on the soil surface and is often achieved through low-impact tillage methods like no-till or strip till. Further, mulching reduces evaporation, weed population and there by enhance infiltration rate (Shilpa *et al*., 2022) [12]. The presence of residues and reduced soil disturbance improves water retention and drainage, prevents erosion, and enhances organic matter in the soil (quantity and quality). Traditionally, many crops, including soybean and gobhi sarson, have been grown using conventional tillage techniques. However, these methods are now considered costly in terms of labour and fuel usage and carry a high erosion risk. Conservation tillage techniques, such as zero-till, minimum tillage, and ridge-till, leave 30 percent crop residues on the surface and provide better erosion control. Additionally, conservation tillage reduces the need for labour and fuel, making it a more sustainable choice. In addition to choosing suitable tillage methods, achieving an increase in average yield per hectare can be accomplished by maintaining soil fertility through the correct application method and dosage of fertilizers (Shilpa *et al*., 2023) [13, 14]. Application of fertilizers is widely recognized as a way of improving crop productivity and sustainability. In addition to selecting appropriate tillage techniques, maintaining soil fertility through proper fertilizer application is essential for increasing average yields per hectare.

There is a broad consensus or widespread acknowledgment that the judicious fertilizer use can boost crop production and sustainability. However, excessive use of synthetic fertilizers can harm the soil and the environment. So, it is crucial to establish a production system that maximizes productivity while minimizing environmental damage. In light of these considerations, current research is focused on finding sustainable agricultural practices that prioritize soil health, minimize erosion, reduce labour and fuel requirements, and optimize fertilizer use. These efforts are crucial for ensuring food security and environmental sustainability in the face of growing global demands.

Materials and Methods

A field experiment was conducted to investigate the impact of different tillage methods and NPK fertilizer levels on soil properties in a soybean and gobhi sarson cropping system. The experimental site was situated at 32°6'N latitude, 76°3'E longitude, and had an elevation of 1290.8 meters above sea level. Each treatment was randomly assigned to plots using a random number table and was replicated three times. The soil in the experimental area was determined to be silty clay loam with a pH of 4.5. There were twelve treatment combinations, consisting of three tillage systems (minimum tillage, minimum tillage with gobhi sarson/soybean crop residue at 3 t/ha, and conventional tillage) and four fertility levels (50% of the recommended dose of nutrients - RDN, 75% RDN, 100% RDN, and 125% RDN). These treatments were arranged in a split-plot design, with tillage systems in the main plots and fertility levels in the subplots. The soybean variety 'Harit Soya' and the gobhi sarson variety 'Sheetal' were planted at spacing of 45 cm × 10 cm and 30 cm × 10 cm, respectively, in each plot measuring 4.5 × 3.0 m². Soybean seeds were treated with bavistin at a rate of 2.5 g/kg of seed before sowing to protect against seed-borne diseases. Fertilizers were applied at rates corresponding to 50%, 75%, 100%, and 125% of the recommended doses (20:60:40 for soybean and 60:40:40 for gobhi sarson) at the time of sowing, using urea, single superphosphate, and muriate of potash, respectively. Pendimethalin (Stomp 30 EC) was applied at a rate of 4.5 l/ha within 48 hours of sowing for weed control.

Observations recorded

Soil properties were assessed by collecting surface soil samples (0-15 cm depth) from each experimental plot. These samples were air-dried, ground, passed through a 2 mm sieve, and then analyzed for their physical and chemical characteristics, as detailed in Table 1. Soil carbon sequestration was calculated using Equation 1, as described by Srinivasarao *et al*. in 2012 [17]. To determine whether there were significant differences resulting from the split plot design, the collected data underwent statistical analysis through analysis of variance (ANOVA). Conclusions were made with a confidence level of 5%. In each case, a standard error of the mean calculation was applied. In instances where the 'F' value obtained from the analysis of variance tables showed significance, a minimum significant difference was computed.

Table 1: Procedures used for determination of physio-chemical properties of the soil

S.No.	Soil studies	Method employed	References
	Physico-chemical properties		
1.	Bulk density	Core sampler	Singh, 1980
2.	Particle density	Pycnometer	Gupta and Dhakshinamoorthy, 1980
3.	Water holding capacity	Keen's moisture box	Piper, 1966
4.	Organic Carbon	Wet digestion (rapid titration)	Walkley and Black, 1934

Profile SOC stock = [SOC] (g/kg) × Bulk density (Mg/m^3) × d (m) × 10 …. eq. 1

where "d" represents the sampling depth in meters (m) and "[SOC]" represents the concentration of soil organic carbon in a soil mass in grams per kilogram (g/kg), is used to estimate soil carbon sequestration. This equation helps calculate the amount of organic carbon stored in the soil at a specific depth, which is crucial for assessing soil health and its potential role in mitigating climate change.

Results and Discussion

Bulk density, particle density and water holding capacity

Tillage practices did not affect the bulk density and particle density during all four seasons of experiment. However, water holding capacity (WHC) of soil was not affected because of different tillage practice during *Kharif* 2021 and *Rabi* 2021-22 but was significantly affected during *kharif* 2022 and *rabi* 2022-23. Highest water holding capacity was recorded in minimum tillage along with crop residue. Implementing tillage practices that retain legume mulch on the soil's surface has been shown to yield several soil benefits. Specifically, it reduces soil bulk density while enhancing soil porosity, sorption capacity, and aggregation. These improvements, in turn, enhance the soil's capacity to absorb water. These findings align with the research conducted by Kocira *et al*. in 2020 [7], where they noted that the presence of legume cover crops positively influenced soil physical properties.This enhancement in soil quality can be attributed to various factors associated with legume cover crops. Legumes, owing to their fibrous root systems, facilitate the creation of channels in the soil, reducing compaction and promoting improved soil structure. Furthermore, as legume residues decompose, they enrich the soil with organic matter, increasing its porosity and facilitating better water infiltration and air circulation. Collectively, these effects result in a reduction in bulk density, which positively affect soil health, ultimately agricultural productivity. It's important to note that bulk density can fluctuate over the course of a season due to various variables such as rainfall patterns and intensity, soil drying and wetting cycles, land topography, and the type of crops cultivated. The transition from conventional to minimum tillage practices may lead to slight increases or decreases in bulk density, which is consistent with similar findings reported by Pachepsky and Park in 2015 [9], who found that tillage practices had minimal influence on bulk density. Regarding the application of NPK (nitrogen, phosphorus, and potassium) levels, the study found that no treatment significantly affected BD, PD, or WHC during soybean and gobhi sarson harvest. However, slightly higher values were observed when applying 125 percent of the recommended nutrient dose. This aligns in conjunction with the results reported by Hati *et al*. in 2014 [6] and Logsdon and Karlen in 2004 [8], which showed similar outcomes. The data regarding the interaction between tillage practices and NPK levels on BD, PD and WHC were determined to be statistically non-significant (Table 2).

Table 2: Effect of tillage practices and NPK levels on physical properties of soil

Treatments	**Bulk Density (Mg/m^3)**				**Particle Density (Mg/m^3)**				**Water Holding Capacity (%)**			
Tillage practices	**2021**	**2021-22**	**2022**	**2022-23**	**2021**	**2021-22**	**2022**	**2022-23**	**2021**	**2021-22**	**2022**	**2022-23**
Minimum Tillage	1.24	1.24	1.25	1.26	2.60	2.60	2.62	2.64	45.75	45.16	44.66	44.58
Minimum Tillage + Crop Residue	1.23	1.22	1.21	1.20	2.57	2.57	2.55	2.53	46.50	46.92	47.35	47.52
Conventional tillage	1.24	1.24	1.24	1.24	2.59	2.59	2.59	2.59	45.25	45.64	45.79	45.87
SEm ±	0.05	0.05	0.05	0.04	0.10	0.10	0.10	0.09	0.92	0.69	0.39	0.39
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.52	1.52
NPK levels												
50 % RDN	1.22	1.23	1.22	1.24	2.58	2.58	2.58	2.58	45.60	45.27	45.27	45.27
75 % RDN	1.23	1.23	1.24	1.23	2.58	2.58	2.59	2.58	45.84	45.72	45.72	45.84
100 % RDN	1.24	1.23	1.23	1.22	2.59	2.59	2.59	2.59	45.85	46.19	46.30	46.30
125 % RDN	1.24	1.24	1.24	1.24	2.59	2.59	2.60	2.60	46.03	46.44	46.44	46.56
SEm ±	0.04	0.04	0.04	0.04	0.09	0.09	0.09	0.09	0.92	0.55	0.44	0.41
LSD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

RDN: Recommended dose of nutrients (NPK)
Initial values- BD = 1.241

pH, organic carbon status and carbon sequestration

pH of soil remained unaffected during all the crop seasons. However it improved under minimum tillage + crop residue treatment during all the crop seasons. The outcomes were in line with those of Shilpa *et al*. in 2023 [13, 14], who also observed that tillage had no influence on soil pH. Organic carbon status of soil remained unaffected during *kharif* 2021 and *rabi* 2021-22 but significantly affected during second year (*kharif* 2022 and *rabi* 2022-23) (Table 3). The findings were in line with the report by Bhatt in 2017, which indicated that the initial stages of tillage in clay loam soils had no noticeable impact on soil organic matter content. However, when minimum tillage was combined with crop residue mulch, higher levels of organic carbon were observed. This phenomenon may be attributed to the enhanced decomposition of agricultural residues, a process closely associated with higher levels of soil organic carbon in reduced tillage practices. The combination of crop residue from previous crops with tillage, along with improved soil retention, promotes soil aeration and microbial activity, which in turn accelerates the mineralization of soil organic matter. Furthermore, the practice of rotating legume crops may also contribute to an increase in soil microbial carbon and organic matter levels. The practice of legume rotation and straw retention helps maintain ideal levels of soil organic matter and C:N ratios, ultimately leading to higher organic carbon content. These findings were consistent with those reported by Singh *et al.* in 2020. Bhattacharyya *et al.* in 2015 also noted that short-term conservation tillage led to an accumulation of topsoil carbon, while conventional tillage resulted in lower organic carbon levels. This difference could be attributed to tillage enhancing air circulation in the soil, resulting in the oxidation of organic matter within the soil. Regarding nutrient doses, no treatment significantly influenced soil pH and organic carbon levels in both years. However, there was a numerical trend of higher organic carbon content in plots treated with 125 percent of the recommended nutrient dose, followed by those treated with 100 percent of the recommended nutrient dose. This observation may be attributed to more even distribution of water and essential nutrients throughout the soil profile. These nutrients, when utilized by a variety of organisms, enhance the cycling of available nutrients. These findings are somewhat in agreement with the studies conducted by Brar *et al*. in 2015 [3] and Evangelou *et al*. in 2021 [4]. Moreover, the interaction effect between tillage practices and NPK levels on organic carbon was determined to be statistically non-significant in both years.

Tillage practices and NPK levels did not exhibit a significant impact on the carbon sequestration status of the soil in both years. However, there was a numerical trend of higher carbon sequestration observed in minimum tillage, especially when combined with crop residue, followed by minimum tillage from the *kharif* season in 2021 to the *rabi* season in 2022-23.

Table 3: Effect of tillage practices and NPK levels on organic carbon and carbon sequestration of soil

Treatments	pH				Organic Carbon (g/kg)				Carbon Sequestration (Mg C/ha)			
Tillage practices	**2021**	**2021-22**	**2022**	**2022-23**	**2021**	**2021-22**	**2022**	**2022-23**	**2021**	**2021-22**	**2022**	**2022-23**
Minimum Tillage	5.40	5.40	5.40	5.37	8.41	8.27	8.21	8.19	15.60	15.34	15.37	15.47
Minimum Tillage + Crop Residue	5.43	5.42	5.40	5.40	8.47	8.58	8.65	8.70	15.55	15.75	15.76	15.71
Conventional tillage	5.33	5.32	5.35	5.35	8.38	8.23	8.19	8.15	15.53	15.27	15.18	15.12
SEm ±	0.11	0.11	0.11	0.11	0.18	0.14	0.07	0.08	0.34	0.43	0.31	0.36
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	0.26	0.31	NS	NS	NS	NS
NPK levels												
50 % RDN	5.40	5.38	5.38	5.33	8.26	8.18	8.25	8.15	15.23	15.05	15.21	15.03
75 % RDN	5.34	5.34	5.34	5.34	8.34	8.32	8.25	8.28	15.39	15.37	15.24	15.27
100 % RDN	5.39	5.39	5.37	5.37	8.47	8.36	8.37	8.44	15.69	15.47	15.46	15.60
125 % RDN	5.40	5.40	5.45	5.45	8.60	8.59	8.53	8.52	15.93	15.91	15.84	15.83
SEm ±	0.10	0.10	0.10	0.10	0.16	0.10	0.10	0.10	0.45	0.38	0.41	0.41
LSD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

RDN: Recommended dose of nutrients (NPK)
Initial values- pH= 5.4, Organic Carbon (g/kg) = 8.4

Conclusion
Minimum tillage + crop residue and 100 per cent recommended dose of nutrients can be adopted to improve the soil properties under soybean – gobhi sarson cropping system.

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