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Nutrients Management and Till with Assorted Raised Seedbeds Affecting *Pedocals* Soil Traits

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ABSTRACT

A field experiment was performed to study the effects of integrated nutrient management (INM) and soil till with assorted raised seedbeds in a wheat-maize cultivation system for two years (2019-2021) in *Pedocals* soil. Tillage implements were kept as the main factor; Mould board (M.B) plough + cultivator + rotavator (T2), and rotavator sole (T3) were compared with cultivator + rotavator (T1) as control treatment. The assorted raised seedbeds were kept as the second main factor; no seedbed height (P1), 0.1 m high seedbed (P2), and 0.2 m high seedbed (P3). The sub-factor was INM with four levels, including compost (C2), urea (50%) + compost (50%), blend (C3), and urea (C4) as well as control i.e., no fertilizers (C1) in RCB design. The experiment's outcomes were: T2 resulted in lower soil bulk density (1.30-1.38 g/cm^3), soil strengths (208-291 N/cm^2) and higher soil moisture content (15.9%). P1 provided optimum soil strengths (239-328 N/cm^2). C2 reduced the soil bulk density (1.39-1.48 g/cm^3) and soil strengths (229-314 N/cm^2) with the highest soil moisture content (15.94%). Deep tillage decreases soil bulk density and strength which leads to better plant growth. Compost incorporation increases the water and nutrient-holding capacity of the soil. It is concluded that M.B. plough + cultivator + rotavator as tillage implements and compost incorporation were found effective in enhancing soil environment and eco-system with an average yield of 9.1 and 4.1 T/ha of wheat and maize respectively. Enhancing soil traits, deep tillage and compost incorporation have a significant role but the effect of the dimension of the raised seed bed and its interaction with tillage and INM is not specified for optimum soil traits. Therefore, their effect should be found on soil traits.

Keywords: Bulk density, Flat seedbed, Maize, Soil moisture, Soil strength.

1. INTRODUCTION

Soil is universal medium for plant growth and development. It provides the essential nutrients to the plant for optimum production. Soil structure and physico-chemical properties could be improved with the incorporation of organic matter i.e. compost (Xin et al., 2017), animal fresh manure (Hao et al., 2015), dairy farm slurry (Liu et al., 2012), poultry manure and

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farmyard manure (Xin et al., 2016) etc. Besides these, it improves the water holding capacity of the soil and the application of organic matter provides quality food as well as the practice is environment friendly (Xue et al., 2019).

Soil organic matter is not only important for plant growth, but they also play an important role in soil porosity, strength, water holding capacity, nutrient holding capacity etc. Shuyan et al. (2017) reported that the application of organic matter to the soil improves the soil nutrient holding capacity and ions exchange capacity with better crop yield. Organic sources of nutrients include Farmyard manure (FYM), green manure (GM), and compost that could be incorporated into the soil that result in better plant growth and improve soil properties via multi-disciplinary approach (MDA). MDA refers to the various changes studied in the soil traits, e.g. physical, chemical, biological, and cultural. FYM and chemical fertilizers have a positive effect on the crop yield, N-P-K balance, uptake of nutrients and nutrients use efficiency (Adeel et al., 2019). The tillage operations have an important role for better amendments of organic matter into the soil and for providing optimum soil environment for better plant growth and development.

Tillage is one of the most important agro-management techniques in sustainable agriculture (SA). Advanced tillage systems had been implemented to improve soil characteristics and crop yield. Lower-inconvenience tillage implements are used in SA to reduce tillage operation costs (Behaeen et al., 2013), prevent soil-particle detachment, and increase the capability of soil molecules in terms of moisture and micronutrients (Abu-Hamdeh et al., 2019), decrease in greenhouse gas emission, less reliance on machinery (Godwin et al., 2022). It improves soil properties, crop growth and ultimately crop yield (Xue et al., 2019). Till depths up to 0.3 m had a significant effect on crop yield and soil properties (Gong et al., 2023). Along with the traditional approach to improving soil cultivation, techniques such as, deep tillage, shallow tillage, zero tillage, controlled traffic farming, and other methods e.g. vertical tillage, ridge tillage, mulch tillage were adopted (Zhang et al., 2016; Godwin et al., 2022).

The soil characteristics are dependent on tillage operation as well as crop sowing methods. Traditional sowing method resulted in a decrease in the quality of soil characteristics (Wilczewski and Gałezewski, 2023). A number of studies have found that raised seedbeds improve soil properties such as water use efficiency and nutrient use efficiency of crops. Majeed et al. (2015) compared conventional flat seedbeds to raised seedbeds in terms of wheat production and soil characteristics. They concluded that raised seedbeds take precedence over flat seedbeds in maintaining soil ecosystem. The benefits of raised seed bed are reduction in soil bulk density and penetration resistance, increase in infiltration rate and water use efficiency, provide optimum temperature for seed germination and root penetration (Kashif et al. 2018; Rady et al., 2021).Also, weed density within the raised seed bed was much lower than the conventional flatbed sowing technique.

The farmers concentrate on short-term benefits and disregard soil traits (Majeed et al., 2015). It has received slight consideration in Pakistan due to low-input subsistence farmers. The farmers of Pakistan use cultivator and rotavator more than twice as a primary tillage implement which has a negative effect on soil physico-chemical characteristics and adoption of SA approaches is an important strategic task for improving soil ecology. Pakistan is deficient in essential nutrients therefore different fertilizers, or their combinations are necessary for enhancing soil qualities e.g. soil bulk density, soil strength and soil moisture content. Tillage with integrated nutrient management in the raised seedbed in Pakistan climate and *Pedocals* soil is the scope and limitation of the study Adoption of the SA techniques i.e., integrated nutrient management (INM), raised seedbed, and tillage, either alone or in a blend, could offer substantial assistance to the agricultural shift. In this regard, the objectives of the study were to find optimum tillage method, INM, raised seedbeds and their interactive effect enhancing soil traits i.e. bulk density, soil strength and moisture content. These objectives were achieved by the following methodology.

2. MATERIALS AND METHODS

2.1 Research site and treatments

The research was performed in the Research Farm, the University of Agriculture Peshawar, Pakistan during 2019-2020 and 2020-2021. The soil and compost were tested for their physiochemical characteristics in the laboratory of the Soil and Environmental Sciences Department (Table 1).

Wheat Cv.*Pirsabak* 2015 and maize Cv. *Jalal* were sown at rate of 120 kg/ha and 50 kg/ha, respectively. The wheat Cv. Pirsabak and maize Cv. Jalal were selected for their characteristics. They are easily adaptable and productive in Pedocals soil and Pakistan climate. Furthermore, various researchers of Pakistan performed their research on the basis of these cultivars. All the cultural practices were carried out uniformly. There were three factors. Factor A; integrated nutrient management (INM) i.e., 0, (C_1), compost (C_2), urea + compost (1:1) (C3), and urea (C4). Factor B was composed of three tillage levels i.e., cultivator +

rotavator (T1), M.B. plough + cultivator + rotavator (T2), and rotavator (T3). Factor C was different levels of assorted raised seedbed i.e., 10 m length × 2.4 m width × 0 m height (P1), 10 m length × 2.4 m width × 0.1 m height (P2), and 10 m length × 2.4 m width × 0.2 m height (P3).

Table 1. Descriptions of soil and compost used in the research.

Depth (cm)	***Soil parameters***	***Year-1***	***Year-2***
0-20	Penetration resistance (N/cm^2)	410	400
	Bulk density (g/cm^3)	1.72	1.70
21-40	Penetration resistance (N/cm^2)	450	430
	Bulk density (g/cm^3)	1.83	1.80
0-40	pH	7.7	8.3
	EC (dS/m)	0.54	0.61
	Total N (mg/kg)	0.01	0.02
	Total P (mg/kg)	0.07	0.05
	K (mg/kg)	80.75	81.25
Compost parameters			
	pH	8.1	8.3
	EC (dS/m)	1.03	1.09
	Total N (mg/kg)	1.11	1.15
	Total P (mg/kg)	2.07	2.01
	K (mg/kg)	2.50	2.75

2.2 Experimental Design

The NPK dose applied was 120:60:30 kg/ha and 120:90:60 kg/hafor wheat and maize crop, respectively. The required amount of N (288 kg/plot) was kept constant in wheat-maize crop. The amount of compost required for each plot was calculated by the ratio of 12000 to the analysed %N found in compost. The compost of 20 kg/plot and urea of 0.5 kg/plot were applied in compost sole and inorganic sole plots respectively for attaining constant nitrogen (120 kg/ha). The compost was applied on 15th October while urea was applied in split i.e., half (0.25 kg) at sowing (15th November) and another half at 2nd irrigation (25th December). In compost and urea blend, 10 kg compost was applied on 15th October and 0.25 kg urea at 2nd irrigation (25th December). Amount of required phosphorus (DAP) is calculated by the difference between 60% and %P found in compost. Phosphorus of 144 kg/plot and 216 kg/plot in wheat and maize crop, respectively, was applied during seedbed preparation. The required potassium is already found in soil as shown in table 1;therefore, no potassium fertilizer was applied. The average rainfall (mm) and ambient temperature (°C) during the experiment is shown in table 2.

Tillage practices were performed by using 65 hp tractors. In M.B. plough + cultivator + rotavator treatment, M.B. plough was used a week before using cultivator followed by rotavator. However, in cultivator + rotavator treatment, cultivator was ploughed a week before using rotavator. In 0 m high raised seedbed, no ridge-plough was used while in 0.1 m high and 0.2 m high raised seedbed were prepared by using a ridge-plough attached behind the tractor. Manual calibration was performed for preparing these raised seedbeds.

Table 2. Average rainfall (mm) and ambient temperature (°C) during experiment for the year 2019-2020 and 2020-2021.

	Rainfall (mm)	***Ambient Temperature (°C)***
January	19.7	12
February	23.7	15
March	23.9	21
April	30.4	28
May	36.5	32
June	26.4	37
July	25.8	38
August	33.6	42
September	31.8	37
October	24.6	28
November	19.5	19
December	20.3	11

2.3 Soil and Compost Analysis

After the application of treatments, laboratory procedure and methods were used for soil parameters mentioned by Sher et al. (2018). The soil samples were collected by using a core sampler for soil bulk density (g/cm^3) and soil moisture content (%). Soil strength (N/cm^2) at 0-20 cm and 21-40 cm depth were found by using a penetrometer. Soil bulk density at 0-20 cm depth and 21-40 cm depth were calculated on a dried basis after drying in an oven at 105°C for 24 hours. By oven drying, soil moisture content was found by the ratio of the difference in soil mass to the dried soil volume.

2.4 Statistical Analysis

Tillage and raised seedbeds were applied as a main plot and INM as a sub-plot with randomized complete block design (RCBD) arrangement. All the treatments are randomly assigned within each replication block.Total of 36 treatments were tested in three replications. The significance of differences among the treatments was analyzed with the help of ANOVA through SPSS. Statistical significances were set at a p-value of <0.05 (Liu et al., 2014).

3. RESULTS AND DISCUSSION

The results showed that the tillage (T) and integrated nutrient management (C) significantly affected soil bulk density, soil strength, and moisture content. Assorted raised seedbed (P) significantly affected soil strength and soil moisture content as shown in table 3. Among the interaction effects, C×P, C×T, and C×P×T significantly affected many parameters (Table 3).

Table 3. Mean soil characteristics for two years (2019-2020 and 2020-2021) as affected by tillage, integrated nutrient management, and assorted raised seedbed.

Treatments	***B. D⁺(g/cm³)***	***B. D‡(g/cm³)***	***SS⁺(N/m²)***	***SS‡N/m²***	***MC(%)***
Tillage (T)					
T1	1.34 b	1.50 b	239 b	329 b	14.87 b
T2	1.30 c	1.38 c	208 c	291 c	15.90 a
T3	1.37 a	1.60 a	283 a	376 a	14.54 c
LSD	**0.009**	**0.043**	**5.76**	**3.52**	**0.253**
Assorted Raised Seedbed (P)					
P1	1.338	1.496	239 b	328 b	14.81 b
P2	1.342	1.498	244 ab	335 a	15.03 b
P3	1.342	1.498	246 a	334 a	15.48 a
LSD	**NS**	**NS**	**5.76**	**3.52**	**0.253**
Integrated Nutrient Management (C)					
C1	1.351 a	1.497 b	245 b	339 b	14.66 c
C2	1.318 b	1.480 c	229 c	314 d	15.94 a
C3	1.344 a	1.503ab	244 b	328 c	15.22 b
C4	1.350 a	1.510 a	255 a	348 a	14.61 d
LSD	**0.01060**	**0.0093**	**4.152**	**2.831**	**0.0512**
Year (Y)					
Season-1	1.336 b	1.501	244.07	333.43	16.58 a
Season-2	1.345 a	1.493	242.69	330.83	13.64 b
LSD	**0.0075**	**NS**	**NS**	**NS**	**0.2070**
Interactions					
C × T	***	**	**NS**	***	**NS**
C × Y	**NS**	**NS**	**NS**	**NS**	***
T × Y; Y × P	**NS**	**NS**	**NS**	**NS**	**
C × T × Y	**NS**	**NS**	**NS**	**NS**	**NS**
C × P	***	**NS**	***	***	***
T × P	**NS**	**NS**	**NS**	**NS**	**NS**
C × T × P	***	***	***	**NS**	**NS**
C × Y × P; T × Y ×	**NS**	**NS**	**NS**	**NS**	**NS**
C × T × Y × P	**NS**	**NS**	**NS**	**NS**	**NS**

***Note*: +** = 0-20 cm soil depth; ‡ = 21-40 cm soil depth; **T1** = Cultivator + rotavator; **T2** = M.B + cultivator + rotavator; **T3** = rotavator; **P1** = 10 m × 2.4 m× 0 m; **P2** = 10 m × 2.4 m × 0.1 m; **P3** = 10 m × 2.4 m× 0.2 m; **C1** = Control; **C2** = Compost; **C3** = Compost + urea; **C4** = Inorganic; **LSD** at α= 0.05.

Among the tillage methods, M.B. plough + cultivator + rotavator resulted in lower bulk densities (1.30 g/cm³ in 0-20 cm and 1.38 g/cm³ in 21-40 cm depth), soil strengths (208

N/cm^2 in 0-20 cm and 291 N/cm^2 in 21-40 cm depth) and higher soil moisture content (15.90%) followed by cultivator + rotavator whilst Rotavator sole resulted in no-satisfactory reports.

Amongst the assorted raised seedbed, 10 m length ×2.4 m width × 0 m height raised seedbed (P1) gave lower soil strengths (239 N/cm^2 in 0-20 cm; 328 N/cm^2 in 21-40 cm soil depth), soil moisture content (14.81%) than the other assorted raised seedbeds (P2 and P3).The application of compost sole to the soil produced the lowest soil bulk densities (1.39 g/cm^3 in 0-20 cm and 1.48 g/cm^3 in 21-40 cm depth), soil strengths (229 N/cm^2 in 0-20 cm and 314 N/cm^2 in 21-40 cm depth) and soil moisture content (15.94%), followed by compost and urea blend. The urea sole and no N-fertilizer application gave the highest soil bulk densities and soil strengths though they produced statistically similar results in the research.

The optimum yield of wheat (8.9 T/ha) and maize (3.9 T/ha) was recorded in the first year (2019-2020) of research with interaction of deep tillage and compost application. However, in the second year (2020-2021), the wheat and maize yield increase to 9.3 T/haand 4.3 T/harespectively. The results of yields are supported by Gong et al. (2023), the long-term shallow tillage practice decreases the crop yield when interacting with year but adaptation of deep till increase the crop yield. The reason is that the deep tillage crushes the soil hard-layer produced by the tillage practices. This lead to increase the water and nutrient holding capacity of soil molecules, enhance soil porosity, develop better relationship of soil and crop.

Xin et al. (2017) stated that continuous application of compost enhances the soil structure, porosity, strength, biological reactions, and ions exchange in the soil medium. The frequent compost application over years boosts the crop growth and yield. Arshad et al. (2023) documented that inorganic fertilizer increase the crop growth and yield, but it diminishes the soil environment in terms of high soil strength and weaken soil-plant relationship. As a result, the plant growth may reduce in control condition therefore each plant in each season requires the inorganic nutrients for proper growth.

3.1 Soil Bulk Density (g/cm^3)

Soil bulk densities at two soil depths were measured i.e., 0-20 cm and 21-40 cm. Figure 1 shows the interaction of assorted raised seedbeds with integrated nutrient management (INM) and tillage with INM on soil bulk density at a depth of 0-20 cm. The compost sole produced a lower soil bulk density of 1.31 g/cm^3 when 10 m length × 2.4 m width × 0.2 m height assorted raised seedbed (P3) was prepared rather than other raised seedbeds (P2 and P3). Furthermore, compost sole application and T2 (M.B. plough + cultivator + rotavator) interaction resulted in lower soil bulk density (1.29 g/cm^3) than other interactions. The compost sole application decreased soil bulk density when M.B. plough + cultivator + rotavator as tillage treatment applied for 10 m length × 2.4 m width × 0.2 m height raised seedbed followed by compost and urea blend. Overall, urea sole and no N-fertilizer resulted in statistically similar results.

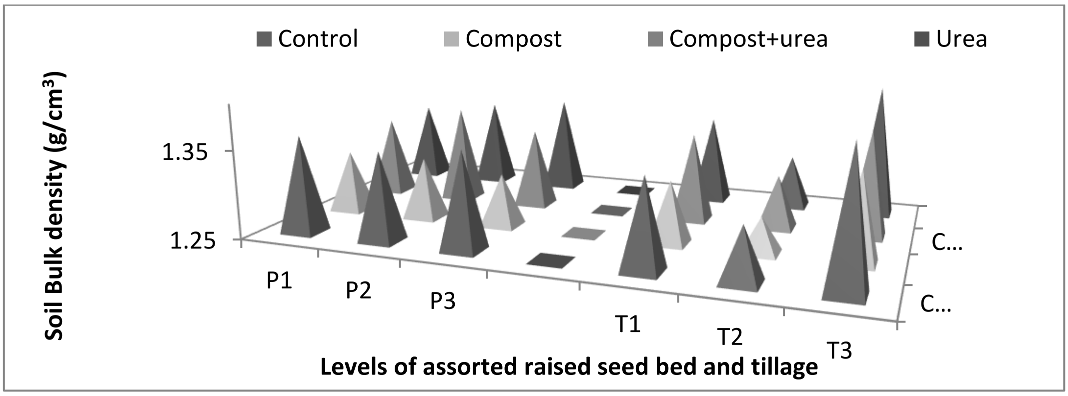

Figure 1. Soil bulk density (g/cm^3) at a depth of 0-20 cm is affected by assorted raised seedbeds with integrated nutrient management and tillage with integrated nutrient management.

The interaction shows that the use of M.B. plough + cultivator + rotavator resulted in less fluctuation in soil bulk densities when interacted with all the assorted raised seedbeds and INM. By using the rotavator sole, this instability increased when changing raised seed dimensions from 10 m length × 2.4 m width to 10 m length × 2.4 m width × 0.2 m height overall INM. Keeping in view the usage of cultivator + rotavator for 10 m length × 2.4 m width and 10 m length × 2.4 m width × 0.2 m raised seedbed, similar statistical results were found with overall INM levels. The research summarizes that compost sole application resulted in lower soil bulk density (1.29 g/cm^3) with M.B. plough + cultivator + rotavator when 10 m length × 2.4 m width or/and 10 m length × 2.4 m width × 0.1 m height were raised seed constructed as shown in figure 1.

Figure 2 shows the interaction of tillage and integrated nutrient management (INM) on soil bulk density at a depth of 21-40 cm. T2 (M.B. plough + cultivator + rotavator), gave the lower bulk density with all the levels of INM followed by T1 (cultivator + rotavator) while T3 (rotavator) resulted in the highest soil bulk density. T2 had the lowest soil bulk density (1.37 g/cm^3) when compost sole was applied followed by urea sole (1.38 g/cm^3). T1 and T3 produced lower soil bulk densities in compost sole application followed by compost and urea blend.

Rotavator cut and mix the soil surface thoroughly in the range of 10-15 cm. Rotavator sole is not an optimum tillage implements but in combination with other tillage implements, it enhances soil bulk density. Therefore, cultivator operation decreases the soil bulk density from 1.37 to 1.34 g/cm^3. In the same way, deep tillage implements i.e., M.B. plough, used with rotavator decrease the soil bulk density to 1.30 g/cm^3.

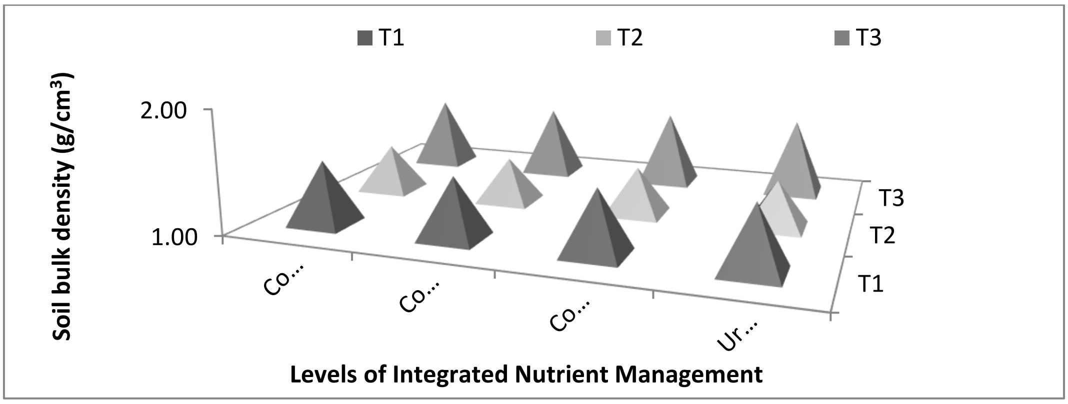

Figure 2. Soil bulk density (g/cm^3) at a depth of 21-40 cm is affected by tillage and integrated nutrient management.

The continuous usage of high dense tillage implements, and tractor operations pressed the soil particles together and removed the pore spaces which caused a decrease in the volume of pores (Amin et al., 2013; Bahrani et al., 2017). Therefore, in 2019-20 the soil bulk density was 1.33 g/cm^3 but it increased to 1.34 g/cm^3 in 2020-21. Sher et al. (2018) stated that soil bulk density is affected by various factors, but the most concentrating factor is the use of organic fertilizer. The result showed that the compost sole decreases the soil bulk density due to the increasing porosity of the soil. As the porosity increase, the volume of the sole increase and results in a decrease in soil bulk density.

M.B plough increases the soil porosity volume up to the optimum limit but can't pulverize the soil. The use of rotavator sole doesn't decrease the soil bulk density within the range of 21-40 cm depth (Bahrani et al., 2017). In the same way, the cultivator can't penetrate below 20 cm deep soil. Cultivator and rotavator are used conventionally but they are not able to decrease the soil bulk density at 21-40 cm depth. The soil bulk density (21-40 cm) may not be significantly affected using organic fertilizer. The reason is that the organic fertilizer can't leach down into the subsoil at 21-40 cm but as the M.B. plough cut the subsoil surface vertically, it may create a chance for organic fertilizer to leach down into the subsurface soil. This was the reason for the result that compost decreases the soil bulk density (21-40 cm) up to 1.48 g/cm^3. The result coincides with Mohsin et al. (2019).The research suggests that incorporation of compost to the soil, tilling deep and higher raised seedbed produced lowest bulk density.

3.2 Soil Strength (N/cm^2)

Soil strengths at two soil depths were found i.e., 0-20 cm and 21-40 cm. Figure 3 shows the interaction effect of assorted raised seedbeds with INM on soil strength at a depth of 0-20 cm. In urea sole and no N-fertilizer (control) is favourable for lowest soil strength at a depth of 0-20 cm when 10 m length × 2.4 m width raised seedbed prepared. The compost sole application produced lower soil strength (220 N/cm^2) when 10 m length × 2.4 m width × 0.1 m height raised seedbed (P2) was prepared rather than other raised seedbeds (P1 and P3). The compost and urea bend application produce lower soil strength when 10 m length × 2.4 m width × 0.2 m height raised seedbed prepared.

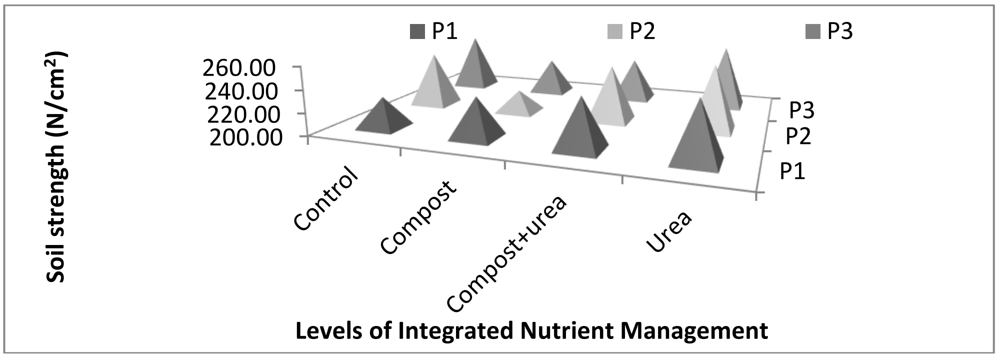

Figure 3. Soil strength (N/cm^2) at a depth of 0-20 cm is affected by assorted raised seedbeds and integrated nutrient management.

The use of M.B. plough + cultivator + rotavator resulted in less fluctuation in soil strength when interacted with all the assorted raised seedbeds and INM. Use of the rotavator sole, the instability in soil strength increased when changing raised seed bed dimensions from 10 m length × 2.4 m width to 10 m length × 2.4 m width × 0.2 m height. In the case of cultivator + rotavator, 10 m length × 2.4 m width and 10 m length × 2.4 m width × 0.1 m height raised seedbed with INM showed approximately similar results, but 10 m length × 2.4 m width × 0.2 m height raised seedbed showed higher soil strength when interacted with INM and tillage. The research summarizes that compost sole application resulted in lower soil strength with M.B. plough + cultivator + rotavator (T2) or cultivator + rotavator (T1) with all the levels of INM and assorted raised seedbeds.

Figure 4 shows the interaction of assorted raised seedbeds with INM and tillage with INM on soil strength at a depth of 21-40 cm. The compost sole is the most favourable INM followed by compost and urea blend than the other levels of INM when interacted with tillage and assorted raised seedbed. The compost sole application produced lower soil strength 311 N cm^2 when 10 m length × 2.4 m width × 0.2 m height raised seedbed (P3) prepared rather than other raised seedbeds (P2 and P3). Furthermore, compost sole application and T2 (M.B. plough + cultivator + rotavator) interaction resulted in lower soil strength (271 N cm^2) than the other interactions. The compost sole application decreases soil strength to optimum level when M.B. plough + cultivator + rotavator as tillage treatment applied for 10 m length × 2.4 m width × 0.2 m height raised seedbed followed by compost and urea blend. Overall, urea sole and no N-fertilizer resulted in statistically similar results.

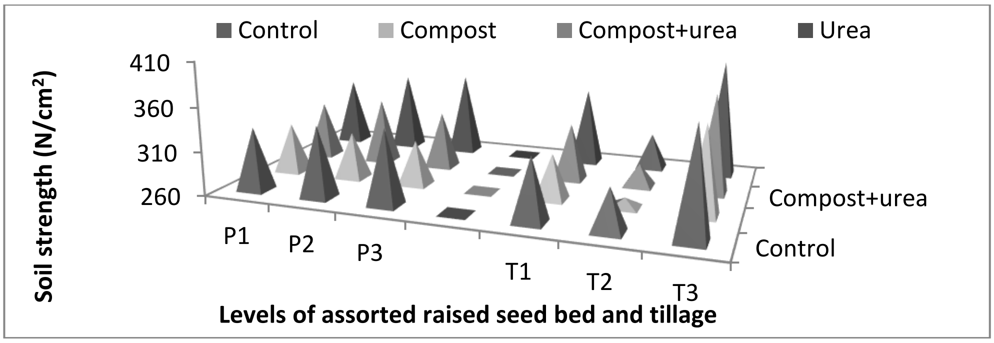

Figure 4. Soil strength (N/cm^2) at a depth of 21-40 cm is affected by assorted raised seedbeds with integrated nutrient management and tillage with integrated nutrient management.

Keller et al. (2019) stated that soil strength indicates the force or pressure exerted by the root to penetrate and expand within the soil surface and subsurface. When the soil particles close together, they form a hard layer within the subsurface of the soil. They resulted that this layer demolishes all the physic-chemical properties of soil as well as crop yield. By applying deep tillage, the soil strength decreases at a significant level while shallow tillage reduces it slightly (Zhang et al., 2019). Therefore, M.B. plough with cultivator and rotavator decreases soil strength (0-20 cm) up to 207 N/cm^2. On the other hand, the rotavator produces soil strength of 283 N/cm^2 at 0-20 cm depth. Organic fertilizer enhances crop growth by availing conditions for proper root growth. It increases the soil porosity due to which the soil biochemical properties boost (Michal, 2014). The decrease in soil strength up to 230 N/cm^2 decreases the root penetration resistance and enhances water-nutrient sap movement within the soil molecules (Wang et al., 2021). As the soil strength increases from the optimum level, the nutrient's ions become tend to stop, resulting poor plant growth

(Unkovich et al., 2023). Similar results were found in the research, the compost sole decrease the soil strength to 229 N/cm^2.

The result concluded that soil strength has direct relation with compost incorporation to the soil when raised seedbed dimension kept constant.

3.3 Soil Moisture Content (%)

Soil moisture content (%) was significantly affected by all the treatments, the interaction of year with INM (Y×C) and tillage with the year (T×Y), the interaction of assorted raised seedbed with INM (P×C), and the interaction of year with assorted raised seedbed (Y×P).The statistical analysis clarifies that 2020-2021 (2nd year) provided lower soil moisture content (%) when interacted with INM and tillage than 2019-2020 (1st year). The compost sole (C2) and T2 (M.B. plough + cultivator + rotavator) resulted in the highest moisture content i.e., 17.8% and 17.6% respectively while the lowest soil moisture content was recorded in C1 (no N-fertilizer) and T3 (cultivator + rotavator) in 1st year. The same sequence was found in 2nd year. Overall results showed that 1st year had better soil moisture content than the 2nd year. It is due to the optimum rainfall in 1st year but in 2nd year, in the crop growth stages where rainfall is required, less rainfall was recorded.

Figure 5 shows the interaction effect of assorted raised seedbeds with INM and assorted raised seedbeds with year on soil moisture content (%). 10 m × 2.4 m× 0.2 m raised seedbeds provided higher moisture content than the other raised seedbeds although 2019-2020 (1st year) received higher soil moisture content than the 2020-2021 (2nd year) throughout the interaction of year and assorted raised seedbeds. Similarly, the interaction of assorted raised seedbeds and INM showed that 10 m × 2.4 m× 0.2 m raised seedbed is the favourable raised seedbed. The compost sole capture more soil moisture content in all the raised seedbeds than the other levels of INM.

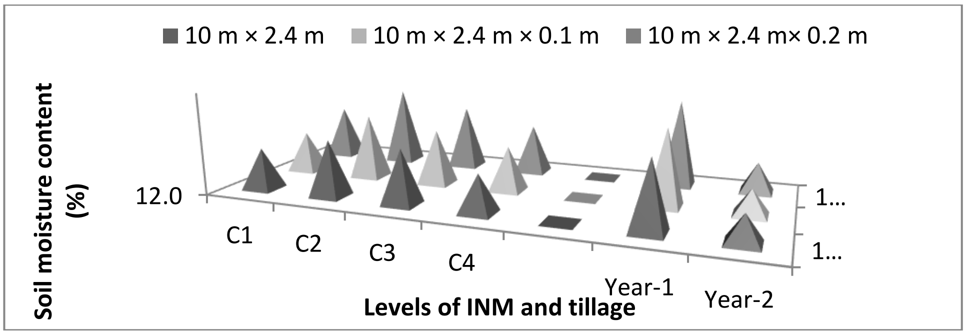

Figure 5. Soil moisture content (%) as affected by assorted raised seedbed with integrated nutrient management and assorted raised seedbed with year.

The moisture content of the soil is dependent on the structure, texture, organic matter, slop, porosity, and characteristics of the soil. The soil characteristics are affected by the type of tillage, organic matter application, and sowing method. These factors enhance the soil's physic-chemical characteristics by increasing the pore volume of soil (Liyue et al., 2016; Limin et al., 2018). The results are in line with these conclusions. The highest moisture content of soil found was 15.9% and 15.94% in M.B plough + cultivator + rotavator and compost applied plots respectively. The highest soil moisture content (15.48%) was found in the 10 m × 2.4 m width × 0.2 m high raised seedbed due to the accumulation of a high amount of rainfall across the seedbed. In a flat seedbed, there is runoff water from the seedbed. The raised seedbed of height of 0.10 m accumulates lesser water than the 0.2 cm high raised seedbed because the seedbed and their furrows were at the same height from the soil surface. Florian et al. (2019) stated that the moisture content of the soil is dependent on the frequency and concentration of rainfall. This statement supports the result, which shows that in 2019-20 the soil moisture content was (16.5%) but in 2020-2021, it was 13.6% due to lesser rainfall water than in 2019-2020.

The result showed that both deep tillage and compost application increase soil moisture content when raised seedbed dimension kept constant. Among assorted raised seedbed, highest raised seedbed gives more soil moisture content.

4. CONCLUSION

Effect of integrated nutrient management (INM) and till with assorted raised seedbed on soil physiochemical characteristics were tested. The results declared that the tillage and integrated nutrient management significantly affected the soil parameters. Assorted raised seedbed (P) significantly affected soil strength and soil moisture content. M.B. plough + cultivator + rotavator were the most favourable treatment for enhancing soil traits (soil bulk density of 1.30-1.38 g/cm^3, soil strength of 208-291 N/cm^2 and higher soil moisture content of 15.9%). In INM, compost sole was decided as an optimum factor for better soil traits (soil bulk density of 1.39-1.48 g/cm^3, soil strength of 229-314 N/cm^2 with highest soil moisture content of 15.94%). 10 m length ×2.4 m width × 0 m height or 10 m length ×2.4 m width × 0.2 m height raised seedbed produced better results (soil strength of 239-328 N/cm^2 with 15.8% soil moisture content) than the 10 m length ×2.4 m width × 0.1 m height. The farmers or practitioners may apply the levels of INM and assorted raised seedbed for achieving optimum soil traits, resulting better crop growth and yield. The future research may be done by using various organic sources with the ratios adopting in the research. Furthermore, their interactions with local farmer's tillage practices may be checked for the soil traits and crop yields.

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6. CONFLICT OF INTERESTS

No conflict of interests.

7. REFERENCE

Abu-Hamdeh, N. H., Ismail, S. M., Al-Solaimani, S.G & Hatamleh, R. I. 2019. Effect of tillage systems and polyacrylamide on soil physical properties and wheat grain yield in arid regions differing in fine soil particles. *Archives of Agronomy and Soil Science*,**65(2)**:182–196.

Adeel, L., Khan, N., Nawaz, F., Ullah, S., Hussain, Z & Khan, A. R. 2019. Growth of wheat as affected by fresh and composted poultry manure, urea and beneficial microbes. *Pure and Applied Biology*, **8(2)**: 1408-1419. http://dx.doi.org/10.19045/bspab.2019.80081.

Amin, M., Khan, M. J & Jan, M. T. 2013. Effect of tillage practices and sowing methods on weeds and biological yield of wheat under semi-arid environment. *Pakistan Journal of Weed Science Research*, **19(1)**: 109-121.

Arshad, T., Naqve, M., Asif, M., Javaid, M. M., Athar, M., Nadeem, M. A & Khan B. A. 2023. Conservation Tillage for Sustainable Agriculture. *Climate-Resilient Agriculture*,**1**; 313–327.

Bahrani, M., Davoodi, M & Kazemeini, S. 2017. Wheat Yield as Influenced by Nitrogen Rates, Sources and Tillage Systems. *International Journal of Plant and Soil Science*, **20(1)**: 1–8. http://dx.doi.org/10.9734/ijpss/2017/37457.

Behaeen, M., Ashrafmansoori, G & Hamdi, F. 2013. Effect of different tillage methods in monogerm seedbed preparation on yield and quality of sugar beet. *Journal of Sugar Beet*, **28(2)**:135–123.

Florian, U., Avelar, D., Hobson, P., Penha-Lopes, G., Dias, T., Maguas, C & Cruz, C. 2019. Sustainable urban agriculture using compost and an open-pollinated maize variety. *Journal of Cleaner Production,* **212**: 622-629.

Godwin, R. J., David, R. W., Edward, T. D., Magdalena, K. D., William, A. J., Millington, E & Paula, A. M. 2022. The effects of traffic management systems on the yield and economics of crops grown in deep, shallow and zero tilled sandy loam soil over eight years. *Soil & Tillage Research,* **223**: 105465, https://doi.org/10.1016/j.still.2022.105465.

Gong, D., Dai, G., Chen, Y & Yu, G. 2023. Optimal tillage depths for enhancing rice yield, quality and lodging resistancein the rice production systems of northeast China. *Peer Journal*, **11**:e15739, DOI 10.7717/peerj.15739.

Hao, X.J., Zhang, T.Q., Tan, C.S., Welacky, T., Wang, Y.T., Lawrence, D & Hong, J.P. 2015. Crop yield and phosphorus uptake as affected by phosphorus-based swine manure application under long-term corn-soybean rotation. *Nutrient Cycle & Agroecosystem,* **103**: 217-228.

Kashif, M., Javed, M., Ullah, S., Ali, A & Khan, G. R. 2018. Effect of Planting Methods and Nitrogen Sources on Yield, Yield Components and N-Uptake of Spring Maize. *Advance Crop Science and Technology*, **6**: 373, http://dx.doi.org/10.4172/2329-8863.1000373.

Keller, T., Sandin, M., Colombi, T., Horn, R & Or, D. 2019. Historical increase in agricultural machinery weights enhanced soil stress levels and adversely affected soil functioning. *Soil & Tillage Research,* **194**: 1-12.

Limin, Y., Gao, W., Shamshiri, R., Tao, S., Ren, Y., Zhang, Y & Su, G. 2018. Review of research progress on soil moisture sensor technology. *International Journal of Agricultural and Biological Engineering,* **14(4)**: 32-42, https://doi:10.25165/j.ijabe.20211404.6404.

Liu, C. W., Sung, Y., Chen, B. C & Lai, H. Y. 2014. Effects of Nitrogen Fertilizers on the Growth and Nitrate Content of Lettuce (Lactuca sativa L.). *International Journal of Environmental Research and Public Health,* **11(4)**: 4427–4440, http://dx.doi.org/10.3390/ijerph110404427.

Liu, J., Aronsson, H., Ulen, B & Bergstrom, L. 2012. Potential phosphorus leaching from sandy topsoils with different fertilizer histories before and after application of pig slurry. *Soil Use Management*,**28**: 457–467.

Liyue, G., Wua, G., Lic, Y., Lia, C., Liu, W., Menga, J., Liua, H., Yua, X & Jiang, G. 2016. Effects of cattle manure compost combined with chemical fertilizer on topsoil organic matter, bulk density and earthworm activity in a wheat–maize rotation system in Eastern China. *Soil & Tillage Research*, **156**: 140-147.

Majeed, A., Atif, M., Abid, N., Shahid, J., Zahid, A., Syed, S. H & Asrar, H. 2015. Bed planting of wheat (Triticum aestivum L.) improves nitrogen use efficiency and grain yield compared to flat planting. *Crop Journal,* **3(2)**: 118-124, http://dx.doi.org/10.1016/j.cj.2015.01.003.

Michal, L. 2014. Factors affecting soil temperature as limits of spatial interpretation and simulation of soil temperature. Acta Universitatis PalackianaeOlomucensis – *Geographica*, **45**(**1**): 5-21, http://geography.upol.cz/geographica-45-1a.

Mohsin, M., Shakeel, M. A., Ullah, S., Yousaf, M., Mujtaba, A & Hussain, M. 2019. Influence of different tillage practices on yield of autumn planted maize. *Pakistan Journal of Agricultural Research,* **32(2)**: 293-301, http://dx.doi.org/10.17582/journal.pjar/2019/32.2.293.301.

Rady, M. O. A., Wael, M. S., Saad, M. H., Taia, A & El-Mageed, A. 2021. Raised beds modulate physiological responses, yield and water use efficiency of wheat (Triticum aestivum L) under deficit irrigation. *Agricultural Water Management*, **245**: 106629, https://doi.org/10.1016/j.agwat.2020.106629.

Sher, A., Naveed, K., Ahmad, G., Khan, A., Saeed, M & Masaud, S. 2018. Phenology and biomass production of wheat in response to micronutrients and nitrogen application. *Sarhad Journal of Agriculture,* **34(4)**: 712-723, http://dx.doi.org/10.17582/journal.sja/2018/34.4.712.723.

Shuyan, L., Li, J., Zhang, B., Li, D., Li, G & Li, Y. 2017. Effect of different organic fertilizers application on growth and environmental risk of nitrate under a cereal-vegetable field. *Science Report,* **7**: 17020, http://dx.doi.org/10.1038/s41598-017-17219-y.

Unkovich, M., Therese, M., Michael, M & Lynne, M. M. 2023. High soil strength and cereal crop responses to deeper tillage on sandy soils in a semi-arid environment. *Field Crops Research,* **291(2023)** :108792, https://doi.org/10.1016/j.fcr.2022.108792.

Wang, X., Shen, J., Hedden, P., Phillips, A. L., Thomas, S. G., Ge, Y., Ashton, R. W & Whalley, W.R. 2021. Wheat growth responses to soil mechanical impedance are dependent on phosphorus supply. *Soil & Tillage Research*, **205**, 104754.

Wilczewski, E & Gałezewski, L. 2023. Effect of Sowing Method on Yield of Different Plants Grown as a Catch Crop. *Sustainability,* **15**: 14829, https://doi.org/10.3390/su152014829.

Xin, X. L., Zhang, J. B., Zhu, A. N & Zhang, C. Z. 2016. Effects of long-term (23 years) mineral fertilizer and compost application on physical properties of fluvo-aquic soil in the North China Plain. *Soil and Tillage Research,* **156**: 166–172.

Xin, X., Shengwu, Q., Zhang, J., Zhu, A., Yang W & Zhang, X. 2017. Yield, phosphorus use efficiency and balance response to substituting longterm chemical fertilizer use with organic manure in a wheat-maize system. *Field Crops Research,* **208**: 27–33.

Xue, L., Khan, S., Sun, M., Anwar, M., Ren, A., Gao, Z., Lin, W., Xue, J., Yang, Z & Deng, Y. 2019. Effects of tillage practices on water consumption and grain yield of dryland winter wheat under different precipitation distribution in the loess plateau of China. *Soil &Tillage Research*, **191**: 66–74, http://dx.doi.org/10.1016/j.still.2019.03.014.

Zhang, S., Yang, X & Lovdahl, L. 2016. Soil management practice effect on water balance of a dryland soil during fallow period on the Loess Plateau of China. *Soil& Water Research,* **11(1)**: 64-73, http://dx.doi.org/10.17221/255/2014-swr.

Zhang, Y. Y., Wu, W & Liu, H. 2019. Factors affecting variations of soil pH in different horizons in hilly regions. *PLoS ONE*, **14(6)**: 1-13, e0218563, https://doi.org/10.1371/journal.pone.0218563.