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Analysis of effects of tillage practices on resource conservation

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Abstract
In this paper, we have analyzed the effect of tillage practices on soil physical properties with respect to time. For this purpose the analysis of multi-observation data (measurement taken over time) in strip plot RBD has been used. It is concluded that tillage practice T_1 (2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking) is superior to all other tillage practices with respect to bulk density, average moisture content and porosity followed by T_2(2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking + Residue). Therefore, it is suggested that application of T_1or T_2tillage practices may be beneficial for improving soil physical properties which ultimately increase the crop production.

Keywords: Conventional tillage, Strip plot design and Multi-observation data

Introduction

Soil tillage is an essential practice in crop production. Dasharath *et al.* (2014) [8] observed the effect of tillage practices on productivity of soybean crop.Conventional tillage includes the mechanical soil management of a whole field by ploughing (inverting the soil) followed by harrowing. The soil disturbance depends on the number of blades, the type of implement used and type of soil and intended crop type. Tillage plays a significant role in the crop growth and production. Tillage practices can affect the soil physical properties that are substantial for plant growth [Grant and Lafond, (1993)] [12]. These properties are improvement in root penetration, water infiltration and water holding capacity, weed control, supply of nutrients and decomposition of organic matter. Gandura *et al.* (2017) [9] observed that the conventional tillage practicehad lower bulk density, but higher porosity and produced highermaize growth and yield.Małecka *et al.* (2016) [13] analyzed the effect of long-term tillage operations on certain soil characters and yield of pea crop and observed that the application of conventional tillage increases the grain yield.Gholami *et al.* (2014) [10] conducted the experiment andthe results revealed that different soil management practices could cause major changes in the soil bulk density, porosity and weighted moisture content. Meidani (2014) [15] and Mohammadi *et al.* (2013) [16] observed the effects of tillage practices on soil physical properties and yield of wheat. Alizadeh, and Allameh (2015) [2] and Małecka *et al.* (2016) [13] concluded that the soil tillage practice improves soil’s physical properties and enables the plants to show their full potential and growth**.** Soil tillage techniques are used to provide suitable environment for seed growth and development. It helps in managing crop residues, reducing soil erosion and control weed population. It is important to apply appropriate tillage practices in the soil to avoid the degradation of soil structure, to maintain crop yield as well as flora and fauna stability in the soil. Aeration of soil depends mainly on large pores that drain rapidly after rainfall or irrigation. Micro pores play an important role in water retention, which in turn are controlled by the surface tension forces, capillary forces and swelling forces simultaneously. Hence, any improvement in total porosity affects the gaseous exchange and water holding ability of the soil. Therefore, an estimation of becomes inevitable while studying the differences in soil physical properties due to various tillage practices. Vertisols are mostly compressible soil having the tendency to swell and shrink depending upon the moisture status. Both, soil texture and moisture are believed to have largest influence in determining the degree of compaction. The degree of soil compaction is measured generally through bulk density. During the present investigation, an effort has been made to study the effect of various tillage practices on bulk density. Celik (2011) [4] analyzed the effects of tillage practices on bulk density in a clay soil conditions and observed that the values of soil bulk density were significantly greater under reduced tillage and no-tillage system as compared to those under conventional tillage. Total porosity and bulk density are measures of the porous space left in the soil for water movement and air, are inversely proportional to each other [Altikatand Celik (2011)] [3]. The amount of moisture the soil retains under a given condition is closely related to porosity and size of voids as well as properties of the soil particles [Aikins and Afuakwa (2012)] [1]. The soil moisture is modified by tillage through particle to particle contact and porosity of the soil. The root growth and its propagation are directly related to water availability in soil profile. Hence, it is important to study the effect of various tillage practices on soil moisture content.

Sources of data

The field experiment was carried out during *Kharif* season of 2016-17 at the All India coordinated research project on weed management Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, situated at the latitude of 22°42' North and longitude of 77°02' East and 281.12 meter above the mean sea level. The experiment was laid out in strip plot design with three replications. The experiment consisted of eighteen treatment combinations, comprising of six various tillage practices and three weed management practices. The treatments were randomly allotted in each replication. The data were collected on different soil properties and growth components, viz., bulk density (mg m^{-3}), porosity (%) and soil moisture content (%), dry matter, leaf area index $plant^{-1}$. Treatment details viz. Tillage Management Practices and Weed Management Practices are given in Tables 1 and 2.

Experimental details

1. Name of crop : Soybean
2. Botanical Name : *Glycine max* L. Merill.
3. Variety : JS-335
4. Season : *Kharif*2016-17
5. Experimental Design : Strip plot design
6. No. of Treatments : Eighteen (18)
7. No. of Replications : Three (03)
8. Plot size : Gross size : 7.2 m x 6 m
   : Net size : 6.30 m x 5.50 m
9. Total no. of plots : Fifty four (54)
10. Spacing : Row to row : 45 cm : Plant to plant : 05 cm
11. Method of Sowing : Drilling
12. Seed Rate : 75kg ha^{-1}

Treatment details

Table 1: Horizontal Factor (A) – Tillage Management Practices

Treatment	Treatment Details (*Kharif* seasons soybean)
T_1	2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking
T_2	2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking + Residue
T_3	1 Rototill
T_4	1 Rototill + Residue
T_5	Zero till
T_6	Zero till + Residue

Residue: Soybean crop residue

Table 2: Vertical Factor (B) – Weed Management Practices

Treatment	Treatment details (Kharif season Soybean)
H_1	Diclosulam 30g/ha (PE), *fb*Imazethapyer + Imazamox 100 g/ha (POE) 20 DAS
H_2	Hand weeding (20 DAS) *fb*Imazethapyer + Imazamox 100 g/ha (POE) 40DAS.
H_3	Un weeded

3. Statistical Methods

When a character in an experiment is measured over time, the researcher generally may be interested in observing the rate of change from one time point to another. It is essential to determine the interaction between treatment and stages of observations, hence the common method is to combine data from all stages of observations and get single analysis of variance [Gomez and Gomez (1984)] [11]. Themultiple measurements of response variables are obtained over several time periods from each experimental unit. This may include comparison of time or average over time. The main feature of such experiments that requires special attention in data analysis is the correlation pattern among the responses on the same individual over time.

3.1 Strip Plot Design

The mathematical model for strip-plot design in randomized block design is

$y_{ijk}=\mu+\gamma_i+\alpha_j+(\gamma\alpha)_{ij}+\beta_k+(\gamma\beta)_{ik}+(\alpha\beta)_{jk}+(\gamma\alpha\beta)_{ijk}$

$i=1,2,\ldots,r\ ;\ j=1,2,\ldots,p\ ;\ k=1,2,\ldots,q$

In which, μ - is overall effect,$y_{ijk}$is the observation corresponding to i^{th} replicate, j^{th} main plot and k^{th} subplot, γ_i- is i^{th} block effect,α_j- effect of j^{th} level of horizontal plot (A), β_k–effect ofk^{th} level ofvertical plot (B), $(\gamma\alpha)_{ij}$- error I, $(\gamma\beta)_{ik}$- error II and $(\gamma\alpha\beta)_{ijk}$- error III.

In addition α_j and β_k are fixed effects of horizontal and vertical factors respectively with$\sum\alpha_j=\sum\beta_k=0$.$(\alpha\beta)_{jk}$ is interactions effect of j^{th} level of A and k^{th} level of B with$\sum(\alpha\beta)_{jk}=0$.

Here $(\gamma\alpha)_{ij}$= Error I ~ $N(0,\sigma^2_I)$, $(\gamma\beta)_{ik}$= Error II ~ $N(0,\sigma^2_{II})$, $(\gamma\alpha\beta)_{ijk}$~ $N(0,\sigma^2_{III})$. All these error terms are independent random errors.

3.2 Statistical Analysis

Here,

Total Sum of squares = TSS=$\sum_{ijk} y^2{}_{ijk} - \frac{y^2_{\ldots}}{pqr}$

Replicate sum of squares = $SS_R = \sum_i \frac{y^2_{i..}}{pq} - \frac{y^2_{\ldots}}{pqr}$

Horizontal Factor (A) sum of squares = $SS_A = \sum_j \frac{y^2_{.j.}}{rq} - \frac{y^2_{\ldots}}{pqr}$

ErrorI Sum of Squares = $SS_{EI} = (\sum_{ij} \frac{y^2_{ij.}}{q} - \frac{Y_{\ldots}}{pqr}^2) - SS_A - SS_R$

Vertical Factor (B) sum of squares = $SS_B = \sum_k \frac{y^2_{..k}}{rp} - \frac{y^2_{\ldots}}{pqr}$

Error II Sum of Squares = SS_{EII} = $(\sum_{ik}\frac{y_{i.k}^2}{p} - \frac{y_{....}^2}{pqr})$- SS_B -SS_R

A*B (Interaction) Sum of Squares = SS_{AB} =$(\sum_{.jk}\frac{y_{.jk}^2}{r} - \frac{y_{....}^2}{pqr})$- SS_A - SS_B

ErrorIII Sum of Squares = TSS-(SS_R+SS_A+SS_B+SS_{AB}+SS_{EI}+SS_{EII})

Hypotheses

H_{0A}: All levels of horizontal factor A are equally effective.
H_{0B}: All levels of vertical factor B are equally effective.
H_{0AB}: Interaction (A*B) is insignificant.
We test these hypotheses against their two sided alternatives.
A test for H_{0A} is given by
F_A=MS_A/ MS_{EI} where MS_A=SS_A/(p-1) & MS_{EI}=SS_{EI}/(p-1) (r-1)
$F_A \sim F_{(p-1),(p-1)(r-1)}$under H_{0A}
A test for H_{0B} is given by
F_B=MS_B/ MS_{EII} where MS_B=SS_B/(q-1) & MS_{EII}=SS_{EII}/(q-1)(r-1)
$F_B \sim F_{(q-1),(q-1)(r-1)}$ under H_{0B}
A test for interaction effect is given by
F_{AB}=MS_{AB}/ MS_{EIII} where MS_{AB}=SS_{AB}/(p-1) (q-1)&MS_{EIII}=SS_{EIII}/(p-1) (r-1) (q-1)
$F_{AB} \sim F_{(p-1)(q-1),(p-1)(r-1)(q-1)}$ under H_{0AB}
If F-ratio for the vertical factor (A), horizontal factor(B) or interaction(A*B) is larger than the corresponding F-value obtained from the statistical table at α level of significance, then corresponding effect (horizontal factor effect, vertical factor effect or interaction effect) is significant otherwise insignificant.
If $H_{0A}$is rejected then we make pair-wise comparison of different levels of factor A by using Duncan multiple range tests (DMRT). Similar test may be used for making pair-wise comparison of different levels of factor B.
We can also find the coefficient of variation (CV) for horizontal factor, vertical factor effect and interaction of horizontal and vertical factor effect by using

C.V. (A) =$\frac{\sqrt{MS_{EI}}}{overall\ mean}\times 100$

C.V. (B) =$\frac{\sqrt{MS_{EII}}}{overall\ mean}\times 100$

C.V. (A*B) =$\frac{\sqrt{MS_{EIII}}}{overall\ mean}\times 100$

Table 3 Shows the ANOVA Table for above said model.

Table 3: ANOVA Table for Strip-Plot Design

Source of Variation	DF	SS	Mean Square	F-Ratio
Replication	r-1	SS_R	MS_R=SS_R/(r-1)	
Factor A	p-1	SS_A	MS_A=SS_A/(p-1)	FA=MS_A/ MS_{EI}
Error I	(p-1)(r-1)	SS_{EI}	MS_{EI}=SS_{EI}/(p-1) (r-1)	
Factor B	q-1	SS_B	MS_B=SS_B/(q-1)	FB=MS_B/ MS_{EII}
Error II	(q-1) (r-1)	SSB_{EII}	MS_{EII}=SS_{EII}/(q-1) (r-1)	
A*B	(p-1) (q-1)	SS_{AB}	MS_{AB}=SS_{AB}/(p-1) (q-1)	FAB=MS_{AB}/ MS_{EIII}
Error III	(p-1) (q-1) (r-1)	SS_{EIII}	MS_{EIII}=SS_{EIII}/(p-1) (q-1) (r-1)	
Total Total	pqr-1	TSS		

3.3 Pooled Analysis of Variance for Measurement over Time

Let t be the number of times data were collected from each plot. The steps for data analysis are given as:
Step 1: We compute analysis of variance for each one of the t stages of the observation, following the procedure for standard analysis of variance based on experimental design used. In our study we use strip plot RBD.
Step 2: We test the homogeneity of t error variances, for our study, the chi- square test of homogeneity of variance is applied to the error mean square.
We compute the χ^2 value by using

$$\chi^2=\frac{(2.306)(f)(t\log s_p^2-\sum \log s_i^2)}{1+\frac{(t+1)}{3tf}}$$

where, *f*is error d.f. for individual growth stage.

We compare the computed χ^2 value with the table value, with (t -1) degree of freedom. If $\chi^2 > \chi^2_{\alpha,(t-1)}$ then there is heterogeneity of variances.
Step: 3 Based on the result of the test for homogeneity of error variances of step 2, we apply suitable analysis of variance. If heterogeneity of variance is displayed, we choose proper data transformation that can stabilize the error variances and compute the pooled analysis of variance based on transformed data.
Hypothesis for pooled analysis of variance
H_{0T} : All growth phases (different time points) are insignificant.
H_{0AT} : Interaction (A*T) is insignificant.
H_{0BT} : Interaction (B*T) is insignificant.
H_{0ABT} : Interaction (A*B*T) is insignificant.
Table 4 shows the ANOVA table for strip-plot RBD.

Table 4: Pooled ANOVA for Strip-Plot Design

Source of Variation	DF	SS	Mean Square	F-Ratio
Replication	(r-1)	SS_R	MS_R=SS_R/(r-1)	
Factor A	(p-1)	SS_A	MS_A=SS_A/(p-1)	F_A=MS_A/ MS_{EI}
Error I	(p-1) (r-1)	SS_{EI}	MS_{EI}=SS_{EI}/(p-1) (r-1)	
Factor B	q-1	SS_B	MS_B=SS_B/(q-1)	F_B=MS_B/ MS_{EII}
Error II	(q-1) (r-1)	SSB_{EII}	MS_{EII}=SS_{EII}/(q-1) (r-1)	
A*B	(p-1) (q-1)	SS_{AB}	MS_{AB}=SS_{AB}/(p-1) (q-1)	F_{AB}=MS_{AB}/ MS_{EIII}
Error III	(p-1) (q-1)(r-1)	SS_{EIII}	MS_{EIII}=SS_{EIII}/(p-1). (q-1) (r-1)	
T (Time)	(t-1)	SS_T	MS_T= SS_T/(t-1)	F_T=MS_T/MS_{EIV}
T*A	(t-1) (p-1)	SS_{AT}	MS_{AT}= SS_{AT}/(t-1) (p-1)	FT_A=MS_T/MS_{EIV}

T*B	(t-1) (q-1)	SS_{TB}	$MS_{BT}= SS_{TB}/(t-1)(q-1)$	$F_{TB}=MS_{TB}/MS_{EIV}$
T*A*B	(t-1) (p-1) (q-1)	SS_{TAB}	$MS_{TAB}= SS_{TAB}/(t-1).(p-1)(q-1)$	$F_{TAB}=MS_{TB}/MS_{EIV}$
Error IV	(t-1) (r-1). (p-1) (q-1)	SS_{EIV}	$MS_{EIV}= SS_{EIV}/(t-1).(r-1)(p-1)(q-1)$	
Total	pqrt-1	TSS		

4. Results and Discussion

4.1 Bulk Density

The data related to bulk density wereanalyzed by pooled analysis of variance for measurement over time in the strip plot RBD. The ANOVA table is given below:

Table 5: Tests of Between-Subjects Effects for Bulk Density

Source	Type III Sum of Squares	Df	Mean Square	F	Sig. p	Observed Power[b]
Corrected Model	2.199[a]	105	0.021	7.825	0.000	1.000
Intercept	391.854	1	391.854	1.464E5	0.000	1.000
Replication	0.007	2	0.004	1.378	0.255	0.293
Tillage	0.410	5	0.082	30.633	0.000	1.000
Replication * Tillage	0.038	10	0.004	1.434	0.169	0.707
WCM	0.004	2	0.002	0.739	0.479	0.174
Replication * WCM	0.005	4	0.001	0.435	0.783	0.150
Tillage * WCM	0.021	10	0.002	0.791	0.637	0.407
Time	1.277	4	0.319	119.294	0.000	1.000
Time * Tillage	0.296	20	0.015	5.537	0.000	1.000
Time * WCM	0.010	8	0.001	0.486	0.865	0.221
Time * Tillage * WCM	0.130	40	0.003	1.210	0.204	0.961
Error	0.439	164	0.003			
Total	394.492	270				
Corrected Total	2.638	269				

[a] R Square = 0.583 (Adjusted R Square = 0.726)
[b] Computed using alpha = 0.05

Table 5 reveals that the ANOVA model used for the analysis of bulk density datais highly significant and the proportion of variability in the bulk density explained by the model is 72.6% (Adjusted R^2 = 0.726). The tillage effect is highly significant (p<0.01, $F_{5,164}$ = 30.633) for average bulk density. The effect of growth phases i.e. different time points is also highly significant (p<0.01, $F_{4,164}$= 119.294). The interaction effect between time and tillage is also found to be highly significant (p<0.01, $F_{8,164}$ = 5.537) for bulk density. All other effects are insignificant. DMRT is also applied for comparing tillage effects pair-wise, as given in Table 6.

Table 6: Duncan's Multiple Range Test (DMRT) for Bulk Density

Tillage	N	Subset		
		1	2	3
T_1	9	1.1509		
T_2	9	1.1767		
T_3	9	1.1798		
T_4	9		1.2256	
T_5	9		1.2504	1.2504
T_6	9			1.2633
Sig.		0.080	0.110	0.397

Means for groups in homogeneous subsets are displayed."
The error term is mean square (error) = 0.001."

Table 6 reveals that mean bulk densities for tillage practicesT_1, T_2, T_3(2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking, 2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking + Residue and 1 Rototill.) are insignificant (p = 0.08) i.e. average bulk density for these three tillage treatments do not differ significantly. Likewise average bulk density for tillage treatments T_4, T_5 (1 Rototill + Residue and Zero till) (p = 0.110) and T_5, T_6 (Zero till and Zero till + Residue) (p = 0.397) shows insignificant results. All other comparisons differ significantly. Maximum bulk density is obtained for T_6 (Zero till + Residue) and minimum for T_1 (2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking). A slightly more bulk density than T_1 has been observed for Tillage Practice T_2 (2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking + Residue). This shows that Tillage practice T_1(2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking) with minimum bulk density is superior to other tillage practices with respect to bulkdensity followed by T_2 (2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking + Residue), as exhibited by Table 6.

4.2. Moisture Content

The data related to moisture content were also analyzed under multi-observation data in the strip plot RBD. The ANOVA table is given below:

Table 7: Tests of Between-Subjects Effects for Moisture Content

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Observed Power[b]
Corrected Model	5790.302[a]	123	47.076	16.154	0.000	1.000
Intercept	169993.122	1	169993.122	5.833E4	0.000	1.000
Replication	14.317	2	7.159	2.457	0.088	0.490
Tillage	94.886	5	18.977	6.512	0.000	0.997
Replication* Tillage	26.663	10	2.666	0.915	0.520	0.476
WCM	0.579	2	0.289	0.099	0.906	0.065
Replication * WCM	5.688	4	1.422	0.488	0.745	0.165
Tillage * WCM	17.550	10	1.755	0.602	0.811	0.309
Time	5458.883	5	1091.777	374.650	0.000	1.000
Time * Tillage	110.519	25	4.421	1.517	0.062	0.960
Time * WCM	8.816	10	0.882	0.303	0.980	0.160
Time * Tillage * WCM	52.401	50	1.048	0.360	1.000	0.412
Error	582.824	200	2.914			
Total	176366.249	324				
Corrected Total	6373.126	323				

[a]R Square = 0.921 (Adjusted R Square = 0.859)
[b]Computed using alpha = 0.05

Table 7 exhibits that the ANOVA model used for the analysis of moisture content data is highly significant and the proportion of variability in the moisture content explained by the model is 85.9% (Adjusted R Square = 0.859). The effect of tillage practices for moisture content is highly significant ($p<0.01$, $F_{5,200} = 6.512$). The effect of growth phases i.e. different time points is also significant ($p<0.01$, $F_{5,200} = 374.650$). All other factors and their interactions are insignificant.

DMRT for moisture content shows thatthe average moisture contents percentages for treatments T_1, T_2, T_3, T_4 (2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking, 2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking + Residue, 1 Rototill and 1 Rototill + Residue.) are insignificant (p =.090) i.e. average moisture content for these tillage practices do not differ significantly, likewise tillage practices T_3, T_4, T_5 (1 Rototill, 1 Rototill + Residue and Zero till) are insignificant (p =.055). T_4, T_5, T_6 (Zero till and Zero till + Residue and Zero till + Residue) also show insignificant difference with respect to mean moisture content (p = 0.076). All other comparisons are significantly different. Maximum moisture content percentage is observed for T_6 (Zero till + Residue) and minimum for T_1 (2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking). The results are shown in Table 8. A slightly more than moisture content has been observed for Tillage Practice T_2 (2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking + Residue). This shows that Tillage practice T_1(2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking) with minimum moisture content is superior to other tillage practices with respect to moisture content followed by T_2 (2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking + Residue), as exhibited by Table 8.

Table 8: Duncan's Multiple Range Test for Moisture Content

Tillage	N	Subset		
		1	2	3
T_1	9	22.1952		
T_2	9	22.4537		
T_3	9	22.6469	22.6469	
T_4	9	22.9472	22.9472	22.9472
T_5	9		23.4783	23.4783
T_6	9			23.7128
Sig.		0.090	0.055	0.076

Means for groups in homogeneous subsets are displayed.
The error term is mean square (error) =.680"

4.3 Porosity

The datarelated to porosity were analyzed under multi-observation data in the strip plot RBD. The ANOVA table is given below:

Table 9: Tests of Between-Subjects Effects for Porosity

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Observed Power[b]
Corrected Model	2026.388[a]	87	23.292	78.111	0.000	1.000
Intercept	535593.028	1	535593.028	1.796E6	0.000	1.000
Replication	0.496	2	0.248	0.832	0.438	0.190
Tillage	727.016	5	145.403	487.618	0.000	1.000
Replication* Tillage	2.169	10	0.217	0.727	0.697	0.367
WCM	0.101	2	0.051	0.170	0.844	0.076
Replication* WCM	1.039	4	0.260	0.871	0.483	0.271
Tillage * WCM	17.774	10	1.777	5.961	0.000	1.000
Time	933.796	3	311.265	1.044E3	0.000	1.000
Time * Tillage	287.620	15	19.175	64.303	0.000	1.000
Time * WCM	6.796	6	1.133	3.798	0.002	0.958
Time*Tillage* WCM	49.581	30	1.653	5.542	0.000	1.000
Error	38.168	128	0.298			
Total	537657.585	216				
Corrected Total	2064.556	215				

[a] R Square = 0.982 (Adjusted R Square = 0.969)
[b] Computed using alpha = 0.05

It is revealed from Table 9 that the ANOVA model used for the analysis of porosity data is highly significant and the proportion of variability in porosity is explained by the model is 96.9% (Adjusted R Square = 0.969). The effects of tillage practices and WCM are highly significant ($p<0.01$). The effect of growth phases i.e. different time points is also significant ($p<0.01$). The interaction effects time*tillage, time*WCM and time*tillage*WCM are also found to be significant ($p<0.05$) for porosity. The maximum porosity is found for T_1 followed by T_2. Minimum porosity is observed for $T_,$ as exhibited by Table 10. Thus, tillage practice T_1(2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking) with maximum porosity is superior to other tillage practices followed by T_2 (2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking + Residue).

Table 10: Duncan's Multiple Range Test for Porosity

Tillage	N	Subset					
		1	2	3	4	5	6
T_6	9	47.3433					
T_5	9		47.6278				
T_4	9			49.2433			
T_3	9				51.1439		
T_2	9					51.5522	
T_1	9						51.8628
Sig.		1.000	1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
The error term is mean square (error) = 0.077

Conclusion

From the above study we conclude that that mean bulk densities, average moisture content percentage and porosity for different tillage practices differ significantly. Tillage practice T_1 (2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking) is found to be superior to other tillage practices yielding minimum bulk density and average moisture as well as maximum porosity followed by T_2 (2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking + Residue). Therefore, it is suggested that application of T_1 (2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking) or T_2 (2 Harrowing by tyne cultivator + 1 Harrowing by blade harrow + Planking + Residue) tillage practices may be beneficial for improving soil physical properties.

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