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Effect of tillage and weed management practices on soybean (*Glycine max* L. (Merrill.) under entisols soil

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Abstract
Considering the needs to standardize the package of tillage and weed management over entisols of crop production this investigation was planned. To study effect of tillage and weed management practices on soybean (*Glycine max* L. (Merrill.) under entisols soil was conducted at field of research farm of AICRP on Weed Management, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra) during the *kharif* season of 2018-19. There were twenty treatment combinations. The other cultural practices were kept common, as recommended. Results shows that, rainfed soybean grown on entosolic soil with conventional tillage exhibited better growth and yield attributes and recorded significantly higher seed yield. In respect of weed management in soybean weed free treatment found significantly superior in controlling weeds in soybean crops. However, among the herbicidal treatments, the PE application of diclosulam 0.030 kg a.i./ha + POE application of propaquizafop + imazethapyr 0.125 kg a.i./ha at 20 DAS in soybean were noted better in controlling weeds in soybean. Improvement in soil physical properties *viz*., soil moisture content, porosity, mean weight diameter, rate of infiltration, hydraulic conductivity was observed with tillage practice of conventional tillage and weed free treatment. Significantly higher gross monetary returns and net monetary returns along with maximum benefit: cost ratio was obtained with conventional tillage followed by reduced tillage treatment.

Keywords: Tillage management, weed management, conventional tillage, reduced tillage, zero tillage, diclosulam, and propaquizafop + imazethapyr

Introduction

Tillage which is essential sometimes, for higher crop production, may be reduced or modified in some cases to some extent, to achieve the maximum economic production of crop of different types in different season under different cropping system, provided all about tillage is known by the growers. So knowledge about tillage will help in improving the crop cultivation for higher production of crops, in untapped areas and even in tapped areas, where intensity of cropping may be raised with different tillage operation. Now day tillage is costly proposition. Reduced tillage or non tillage relay crops get momentum in some areas, both for crop yield, maintain of soil fertility, with higher production economics, both under rainfed and irrigated conditions. Over the last few decades, there has been increasing interest in environmentally sound and sustainable soil management. The soils of Vidarbha region are mostly vertisols but entisols soils are also found and these soils are dominated by clay and these soils have the tendencies toward swelling and shrinkage depending on the availability of the moisture. Further, the continuous cultivation at similar depth of soil creates a layer of hard plough-pan beneath the soil surface. Recently, most of farmers in Vidarbha region prefer the soil cultivation through tractor drawn rotavator or rotavator + blade harrow implement. The use of this implement has become so popular that, the preparatory tillage is being conducted either using rotavator/rotavator + blade harrow directly after the harvest of preceding crop; or after cultivating the soil through one pass of tyne harrow.

Soybean (*Glycine max* L. Merrill) is the world's most important seed legume, which contributes to 25% of the global edible oil, about two-thirds of the world's protein concentrate for livestock feeding. Soybean due to its various uses is rightly called Golden gift of nature to mankind also known as 'miracle bean' occupies 60 per cent of the total world production of oilseed and is considered as the most importance source of protein and oil. It is a short season leguminous crop that grows in a warm climate with intermediate to heavy rainfall. It is a annual, normally bushy, erect, usually less than 75 cm in height, much branched, with well-developed roots and produces numbers of small pods containing round, usually yellow seeds. Pulses are integral part of cropping system because these are fit well in the crop rotation and crop mixture and are most suited diversifying crops in cropping systems. In India the area occupied by soybean has been steeply increased from 10.11 million hectare in 2011-12 to 12.27 million hectare in 2021-22 respectively, with an average production of 12.99 million tones and yield of 1059 kg/ha. Whereas, in Maharashtra the area under soybean was 4.69 million hectare which produced 5.47 million tones with productivity of 1168 kg/hectare. In Vidarbha, area was 19.85 Lakh hectares which produced 22.75 Lakh MT with productivity of 1175 kg/ hectare (Ministry of Agriculture, New Delhi, Economics Times, and Fourth Estimates 2021-22).

Tillage management can influence soil moisture status because tillage influences infiltration; runoff, evaporation, and soil water storage, with conventional tillage, perennial and annual weeds that competes with crops for moisture, nutrients space and sunlight are mechanically removed and destroyed. Many researchers have draw attention that the good soybean yields could achieved by minimizing the cost of tillage through minimum tillage also, i.e. just to till the land once or twice with light tyne cultivator harrowing or only rototill for providing easiness in sowing only.

The prevailing national agricultural research trend has inclined towards the concept of reduced tillage practices on a sustainable basis with integrated weed management practices. In view of testing the various preparatory tillage implements either single or in combination on soils of Vidarbha region along with herbicide weed management practices and further to evaluate its effect on the dominant crop of the region, i.e. soybean, In this context, the proposed study aim to evaluate the different tillage and weed management practice on soybean productivity, physical properties of soil, weed dynamics and economics of the treatment.

Materials and Methods

The fixed plot field experiment was carried out at field of AICRP on Weed Management, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola on entisols under rainfed condition during *kharif* season of 2018-19. The experimental site is situated in the subtropical zone at latitude 20^0.42' N and longitude $77.^0$ 01' E. The altitude of the place is 307.41 meters above mean sea level. The climate of Akola is semi-arid and characterized by three distinct seasons *viz*., summer being hot and dry from March to May, warm and humid monsoon from June to October and winter with mild cold from November to February. Most of the rainfall received from south-west monsoon during June to October with mean annual normal precipitation of 741.8 mm in 40 rainy days. The total rainfall received during 2018-19 (*kharif* season) was 821.6 mm in 42 rainy days. The experiment was laid out in strip plot design having 4 main tillage management treatments i.e. factor (A) T_1- One ploughing + two harrowing by tyne cultivator + one harrowing by blade harrow; T_2 - one harrowing by tyne cultivator + one rototill; T_3 - One Rototill; T_4 - Zero tillage and five weed management treatments i.e. factor (B), W_1- diclosulam 0.030 kg a.i./ha PE; W_2- propaquizafop + imazethapyr 0.125 kg a.i./ha POE at 20 DAS; W_3 - diclosulam 0.030 kg a.i./ha PE Fb, 0.125 kg a.i./ha POE at 20 DAS; W_4 - Weed free (2H at 15 & 30 DAS + 1HW at 20 DAS); W_5 - Weedy check (Unweeded).

As per soil profile study the experimental field soil depth was shallow type i.e.30-35cm deep and topography fairly uniform in nature. Soil was analyzed for testing its physical and chemical properties. After analysis it was observed that the textural class of the soil was Clayey in nature with 57.08 per cent clay. Available N, P and K content of the soil was 186.48, 14.94 and 308.36 kg ha-1, while pH, EC and organic carbon content of the soil was 7.9, 0.268 dSm-1 and 0.48%, respectively.Rainfall received during various crop growth stages *viz*., 0-20, 20-40, 40-60, 60-80 DAS and 80DAS and at harvest was 253.42, 178.40, 35.20, 87.60, and 141.60 mm, respectively. In general, the status of rainfall (696.22 mm) was quite higher than the normal during the crop period. Rainfall distribution over the crop growth stages was good, except during 40-60 DAS and at harvesting, where there was slightly moisture stress condition. Soybean crop (Var. PDKV Yellow Gold) was sown on 22^{nd} June, 2018. Prior to sowing, all the tillage treatments were applied to the selected site of experimentation. All recommended packages of practices are given to soybean. Simultaneously weed management practices like spraying of pre-emergence herbicide and post emergence and weed free treatment 2 hoeing at 15 and 30DAS and 1 hand weeding at 20 DAS were also carried out in soybean. Crop was harvested on 10^{th} October, 2018.

Results and Discussion

The result obtained from present investigation as well as relevant discussion have been summarized under heads

A) Soil physical properties

Soil Moisture content (%)

Soil moisture content was measured by 'Micro-Gopher Soil Moisture Profiling System' made by Dataflow Systems Pty Ltd, New Zealand, which consists of a sensor head, marked staff, data logger with LCD dot matrix display and access tubes. Initially three access tubes were installed permanently in each plot for measuring the soil moisture content. Later on the calibration of the site was made and finally, the sensor head attached with cable was inserted in to the access tube at desired depth and the moisture content from that depth was noted with the help of data logger which directly display the soil moisture content on per cent basis from the same depth.

A perusal of data in table 01 showed that, tillage practices posed significant effects over mean moisture content at the depth of 0-20cm.The status of soil moisture (0-20cm) at 20, 40, 60, 80 DAS and at harvest recorded conventional tillage (CvT) 33.77%, 29.52%, 33.24%, 25.66% and 19.92%. However, the status of soil moisture (20 cm) at all periodical stages recorded in onventional illage (CvT) was at par with the reduced tillage (RT) and minimum tillage(MT) and significantly superior over zero tillage (ZT). This improvement in higher water conservation with conventional tillage (CvT) may attributed to loosening of soil to a higher depth coupled with increased porosity and higher mean weight diameter. Wesley *et al*. (1993) [39] also reported an improved moisture status resulting from conventional in soybean on clay soil as compared to other shallow tillage plots. Further Kailapan *et al.* (2001) [16], Karuma *et al.* (2014) [15] and Meidani (2014) [23] reported greater moisture conservation with deep and very deep tillage practices.

Weed Management treatment did not show any significant improvement in moisture conservation throughout growing period of soybean crop. However, only numerically higher value of moisture was recorded with weed free treatment in which two hoeing at 15 and 30 DAS and one hand weeding was given to soybean crop.

Table 1: Moisture (%) at the depth of 20 cm as influenced by tillage and weed management practices during kharif season of 2018-19

Treatments	2018-19				
	20 DAS	40DAS	60DAS	80DAS	At harvest
A) Tillage Management					
T_1 CvT 1Plou. +2Culti. 1Bl.harrow	33.77	29.52	33.24	25.66	19.9
T_2 RT 1Culti. + 1RotoTill	32.94	28.75	32.41	25.04	19.35
T_3 MT 1Roto Till	32.54	28.37	32.00	24.70	19.03
T_4 ZT Zero Till	32.06	27.98	31.54	24.41	18.79
SE(m)±	0.16	0.12	0.17	0.14	0.13
CD at 5%	0.55	0.40	0.60	0.48	0.43
B) Weed management					
W_1 Pre.Diclo. 0.030kga.i/ha	32.76	28.61	32.24	24.85	19.20
W_2 PoE 0.125kg a.i./ha at 20DAS	32.82	28.49	32.25	24.96	19.17
W_3 Pre.Diclo.0.030kga.i/ha+ PoE 0.125kg a.i./ha at 20 DAS	32.78	28.58	32.24	24.84	19.15
W_4 WF(2H at 15 & 30 DAS +1HW at 20 DAS)	32.89	28.89	32.41	25.06	19.49
W_5 Weedy Check	32.89	28.69	32.35	25.05	19.35
SE(m)±	0.39	0.30	0.38	0.33	0.26
CD at 5%	NS	NS	NS	NS	NS
C) Interaction (A x B)					
SE(m)±	0.44	0.46	0.59	0.49	0.38
CD at 5%	NS	NS	NS	NS	NS
GM	32.83	28.65	32.30	24.95	19.27

Interaction effect between the tillage and weed Management did not evident during both the years of investigation.

Table 2: Bulk density, Porosity (%) and rate of infiltration as influenced by tillage and weed management practices during kharif season of 2018-19

Treatments	Bulk density (Mg/m3)		Porosity (%)		Rate of Infiltration cm/hr	
	At sowing	At harvest	At sowing	At harvest	At sowing	At harvest
A)Tillage Management						
T1 CvT 1 Pl.+ 2Cult. + 1Bl.	1.36	1.37	48.53	48.45	2.22	2.15
T2 RT 1 Cult. + 1 RT	1.37	1.38	48.23	47.90	2.09	1.97
T3 MT 1 Roto Till	1.38	1.39	47.80	47.47	2.00	1.87
T4 ZT Zero Till	1.38	1.40	47.80	47.09	1.88	1.87
SE(m)±	0.001	0.01	0.34	0.47	0.06	0.05
CD at 5%	NS	NS	NS	NS	0.20	0.17
B) Weed management						
W1 PE appl.of Dicl.0.0030kg a.i./ha	1.37	1.38	48.21	47.86	2.02	1.94
W2 PoE appl. of Prop.+ Ima.0.125kga.i./ha At 20DAS	1.37	1.38	48.27	47.86	2.06	1.99
W3 PE appl. of Dicl. 0.030kg a.i/ha+ POE appl. of Ima.0.125kg a.i./ha At 20DAS	1.38	1.39	47.96	47.55	2.09	2.02
W4 WF (2H at 15 & 30 DAS +1HW at 20DAS)	1.37	1.38	48.40	47.99	2.02	1.95
W5 Weedy Check	1.39	1.39	47.61	47.39	2.01	1.93
SE(m)±	0.02	0.01	0.63	0.53	0.04	0.05
CD at 5%	NS	NS	NS	NS	NS	NS
C) Interaction (A x B)						
SE(m)±	0.041	0.04	1.54	1.38	0.146	0.10
CD at 5%	NS	NS	NS	NS	NS	NS
GM	1.38	1.39	48.09	47.73	2.04	1.95
Initial value	1.38		47.92		1.88	

Bulk density (D_b)

The observations on bulk density was recorded at sowing and at harvest for quantifying the bulk density (D_b) from the depth of 0-15 cm are presented in Table 2.Before adopting the tillage treatments composite three soil samples of undisturbed soil was taken with the help of core sampler method (Blake and Hartge, 1986) [6]. The undisturbed core samples were then oven dried at 105^{0}C for about 24-48 hours, till the constant weight was obtained. The bulk Density was calculated by using the following formula.

$$\text{BD (Mg m}^{-3}\text{)} = \frac{\text{Oven dry weight of soil}}{\text{Volume of soil}}$$

The initial value of bulk density was 1.38 and mean values indicate that D_b increased gradually from 1.36 to 1.37 Mgm^{-3} and 1.37 to 1.38 at this depth from the period of sowing to harvest in conventional and reduced tillage, respectively. Thus bulk density data pertaining to tillage management treatment didn't show any statistically significant effect on soil bulk density at the time of sowing and harvest however, moderate improvement was noted with conventional tillage (Cvt) and reduced tillage (RT) treatments as compared to zero tillage, minimum tillage (MT) and rest of all weed management practices.

Porosity (P_t)

A fairly straight forward formula is used to calculate Soil Porosity = (1 - (Bulk Density ÷ Particle Density) x 100. This will indicate the percentage of the soil that contains pores. The noticeable differences were observed in Table 02, when effect of tillage was examined over porosity. At 0-15cm depth, P_t there was no statistically significant improvement in porosity at sowing and harvest with tillage management practices. However, numerically better effect was noticed with conventional tillage (CvT),to all other tillage treatment at sowing and at harvest. Performance of zero tillage and minimum tillage was almost similar with each other for P_t. Zero tillage (ZT) noted lowest values of P_t, at 0-15, it was in close proximity with roto tillage treated plots.

Weed management treatments did not influence P_t to a level of significance. Interaction between tillage practices adopted and weed management was found to be absent when the experimental data was analyzed statistically.

Rate of Infiltration (cm/hr)

Infiltration rate is the maximum rate at which a soil in a given condition, at a given time can absorb the water. Quantitatively, it may be the volume of water passing in to the soil per unit time. Double ring Infiltrometer was used for measurement of infiltration because of its reliability and accuracy.

At sowing and harvest, conventional tillage treatments (CvT and RT) significantly improved soil rate of infiltration with corresponding value of 2.22 and 2.09, respectively. It was followed by treatment MT by registering infiltration rate of 2.00. Significantly lowest infiltration rate (1.88) was registered with treatment ZT. At harvest reduced tillage (RT), minimum tillage (MT) and zero tillage (ZT) were at par with each other and conventional tillage was significantly superior in improving the rate of infiltration.

It appears from the result analysis, that tillage had a distinct effect on porosity, reduction in bulk density, improvement in mean weight diameter, reduced soil strength with conventional may casually enhanced soil physical properties including porosity. Same kind of results were observed earlier by Pagliani *et al*. (2004) [31], Ahmad *et al*. (2007) [2], Abdullah *et al*. (2008) [1], Wang *et al*. (2014) [38] and C.M Jagtap and A.V. Kumbhar (2023) [14].

Weed management treatments also did not influence rate infiltration to a level of significance.

An interaction effect of various tillage treatments and weed management practices on rate infiltration was found to be non-significant during the course of investigation.

Table 3: Hydraulic conductivity (Cm/hr) and mean weight diameter (mm) of soil in soybean at sowing and at harvest as influenced by tillage and weed management practices during kharif season of 2018-19

Treatments	Hydraulic Conductivity (Cm/hr)		MWD (mm)	
	At sowing	At harvest	At sowing	At harvest
A) Tillage Management				
T1 CvT 1 Pl.+ 2Cult. + 1Bl.	2.70	2.49	0.71	0.72
T2 RT 1 Cult. + 1 R T	2.52	2.42	0.69	0.70
T3 MT 1 Roto Till	2.34	2.27	0.66	0.67
T4 ZT Zero Till	1.68	1.69	0.65	0.65
SE(m)±	0.070	0.060	0.010	0.012
CD at 5%	0.23	0.20	0.036	0.0409
B)Weed Management				
W1 PE appl. of Dicl.0.030kg a.i./ha	2.31	2.22	0.68	0.69
W2 PoE appl. of Prop.+ Imaz.0.125 kg a.i./ha at20DAS	2.28	2.19	0.67	0.68
W3 PE appl. of Dicl.0.030kg a.i/ha + POE appl.of Imaz. 0.125 kg a.i./ha At 20DAS	2.38	2.28	0.68	0.69
W4 WF (2H at 15 & 30 DAS +1HW at 20DAS	2.32	2.23	0.69	0.70
W5 Weedy Check	2.26	2.17	0.67	0.68
SE(m)±	0.100	0.064	0.019	0.017
CD at 5%	NS	NS	NS	NS
C) Interaction (AXB)				
SE(m)±	0.135	0.159	0.04	0.05
CD at 5%	NS	NS	NS	NS
GM	2.31	2.22	0.68	0.69
Initial value	1.68		0.65	

Mean weight Diameter (mm)

Mean weight diameter (mm) was determined by Yoder's wet sieving method by Kemper and Rosenau (1986) [18]. The most widely used index for this purpose is the mean weight diameter, as the sum of the weighted mean diameters of all size classes, the weighting factor of each class being its proportion of the total sample weight.

A perusal of data in table 3 paraded that Mean weight diameter was found to be significantly improved with conventional tillage (CvT) ranging from 0.71 and 0.72mm and reduced tillage (RT) ranging from 0.69 and 0.70mm at sowing and at harvest of the crop, respectively indicating improved soil aggregation status, indicating suitability of the tillage practice both for greater underground storage of moisture and improved aeration.

Weed management practices did not improve the MWD of soil. Interaction effect of tillage management and weed management was found to non-significant.

Hydraulic conductivity (Cm/hr): The rate of movement of saturated flow mainly depends upon the magnitude of the potential gradient and of the transmission coefficient of the soil. Hydraulic conductivity depends mainly on the size, shape and distribution of the pores. It also depends on the viscosity, density of the water and temperature of soil. It has been cleared from the experiment that the logarithm of the saturated hydraulic conductivity increases linearly as void ratio increases. During the course of present investigation the saturated hydraulic conductivity was measured over a disturbed soil samples, collected from the depth of 0-20 cm profile with the help of Constant Head Permeameter (Klute and Dirksen, 1986) [19].

The data from the table 3 regarding hydraulic conductivity indicates that Zero tillage was recorded the lowest value of Hydraulic conductivity of soil. Treatment minimum tillage and reduced was on par with each other. However, Conventional tillage recorded significantly the highest value of hydraulic conductivity 2.70 and 2.49 at sowing at harvest, respectively besides reduced tillage was on par with each other.

Due to compatible lower bulk density with CvT, it can be assumed that status of porosity (macro pores) must have been improved, which ultimately accelerate the aeration, supporting greater multiplication of aerobic microorganisms within the soil layer causing stabilized soil particles of higher diameter. Therefore, it can be specified that under entisols with semi-arid climatic conditions, the one ploughing +2 tyne cutivator +1 blade harrowing (CvT) significantly improves the water stable aggregates as compared to zero tillage, which result in improvement in MWD, RI and HC. These results are in accordance with those recorded by, Mikha and Rice (2004) [28], Pagliani *et al.* (2004) [31], Oswal (2007) [27] and Alvaro-Fuentes *et al.* (2008) [4] and C. M Jagtap and A.V. Kumbhar (2023) [14].

Interaction Effect

The interaction effect due to tillage with any of weed management treatment could not be obtained significantly.

Table 4: Yield Attributes of Soybean of soil in soybean at sowing and at harvest as influenced by tillage and weed management practices during kharif season of 2018-19

Treatments	2018-19		
	No. of Pods per plant	**No. of Seeds per pod**	**Test wt.(g)**
A)Tillage Management			
T1 CvT 1Plou.+2Culti. +1Bl. Harrow	40.84	3.00	11.49
T2 RT 1Culti + 1Roto Till	36.13	2.97	11.46
T3 MT 1Roto Till	33.96	2.88	11.46
T4 ZT Zero Till	26.99	2.68	11.45
SE(m)±	0.432	0.08	0.07
CD at 5%	1.50	NS	NS
B) Weed management			
W1 PE appl.Diclo.@0.0030kga.i/ha	29.90	2.73	11.43
W2 PoE appl. Propa.+Imaze. 0.125kg a.i./ha at 20 DAS	35.22	2.92	11.44
W3 PE appl.Diclo. 0.030kg a.i.i/ha+ PoE +Imaze. 0.125kg a.i./ha at 20DAS	41.38	3.03	11.50
W4 WF (2H at 15 & 30 DAS + 1HW at 20 DAS	46.13	3.11	11.57
W5 Weedy Check	19.77	2.63	11.40
SE(m)±	0.67	0.13	0.06
CD at 5%	2.17	NS	NS
C)Interaction (AXB)			
SE(m)±	1.92	0.14	0.13
CD at 5%	2.63	NS	NS
GM	34.48	2.88	11.47

Yield contributing characters i.e. no. of pods per plant, no. of seed per pod and test weight etc. select the ability of the soybean plant to convert the plant metabolites in to final plant product. Management practices largely influences the plant and soil environment, affecting the plant growth and development, and similarly the all properties of soil. The changes thus induced due to managerial involvement are precisely reflected in the yield contributing characters of the plants. Hence, any significant differences observed in the values of various yield attributes can directly be correlated with the treatment effects. Therefore, an effort has been made to measure all these characters to the highest extent of accuracy. The relevant data is placed at table 04.

The treatment conventional tillage (CvT) recorded significantly the highest no. of pods per plant (40.84) and lowest was recorded by zero tillage treatment (26.99) (ZT). No. of pods per plant obtained in reduced tillage(RT) was significantly higher than minimum tillage (MT) .Similarly, in case of no. of seed per pod and test weight no significant effect of tillage practices were seen but numerically higher value were obtained with decreasing trend namely with conventional tillage, reduced tillage, minimum tillage and zero tillage.

From the perusal of yield attribute figures in table, it is obvious that changes in management practices, especially by way of modifying the depth and intensity of preparatory tillage, might have resulted in obtaining significant differences in the yield attributes of soybean crop in entisols. Deep tillage practices resulted in soil with all the favorable physical characters, reflecting in healthy plant growth through profuse root system, as compared to other treatments, eventually producing higher amount of metabolites and carbohydrates, and their successful diversion towards the final plant product, i.e. pods and the grains.

Weed management practices significantly influenced the no. of pods per plant. The highest no. of pods per plant was recorded with treat weed free (W_4). Among, herbicidal treatment (W3) i.e. application of diclosulam @ 0.030 kg per ha as a PE + POE application of propaquizafop + imazethapyr 0.125 kg per ha at 20 DAS recorded significantly highest no. of pods per plant .

The number no. of seed per pod and test weight data pertaining to weed management treatment didn't show any significant effect due to various weed management practices, as revealed at the time of harvest. However, treatment recorded numerically maximum number of seed per pod and test weight. Kayombo (2000) [17], Singh and Sharma (2005) [36], Samra and Dhillon (2000) [33] also found the increased growth and yield attributes.

B) Seed, straw and biological yield (kg ha^{-1}) and harvest index (%)

Economically, seed yield is an end product of soybean crop production, and physiologically a cumulative result of many factors applied to the crop right from pre-sowing operations to the harvest of the crop. Moreover, studies of soil physical properties and plant growth parameters are much more immediate (direct) measures of the plant response to applied treatments than yield. During the period of present investigation, the net plot yield values were converted to per hectare yield by using the hectare factor. The relevant data in respect of seed and straw yield as obtained are presented in Table 05.

Different tillage management had a significant influence on the seed, straw and biological yield (kg ha-1) of soybean. From the data, it revealed that conventional tillage (CvT) recorded significantly higher seed yield (2429 kg ha^{-1}), straw yield (2816 kg ha^{-1}) and biological yield (5245 kg ha^{-1}) which was statistically at par with reduced tillage (RT) for seed yield (2078 kg ha^{-1}) However, CvT in case of straw yield (2243 kg ha^{-1}) and biological yield (4322 kg ha^{-1}) was significantly superior. Lowest seed yield, straw yield and biological yield was recorded with Zero tillage (1317, 1521 and 2838 kg ha^{-1}) .Similarly seed yield of Reduced tillage was statistically on par with minimum tillage treatment (1790) and straw yield and biological yield was higher in reduced tillage 2142 and 3932 kg ha^{-1})respectively. Harvest index was also highest in CvT(45.75%) followed by RT(45.69%), MT(45.50%) and ZT(45.46%).

Superior yield level with conventional tillage and reduced tillage was due to better indication of growth characters - leaf area, branches and dry matter accumulation resulting in increased yield components. In fact these tillage treatments benefitted the crop through availability of more moisture through better absorption and retention of water, greater root proliferation through loose and porous soil strata and in turn better nutrition to plants. This particularly benefits the crop during moisture deficit period. Lower seed yield with zero tillage where the soil was undisturbed could be attributed to the lower growth and yield attributing characters. It showed that plant did not respond well to zero and shallow tillage which might be due to non-improvement of soil physical status with shallow and no tillage operation. This is also in accordance with the findings of Choudhary (2014) [7], Monsefi *et al*. (2014) [26], Khalid *et al*.(2014), Feng *et al*.(2014) [9], Alizadeh and Allameh (2015) [3], Ferhat Ozturk and Tahsin Sogut (2016) [1]; and Mourtzinis *et al.* (2017) [27] and DD Meshram *et al*.(2019) [22] reported that deep ploughing allows maximum absorption of rain water and reduces weed populations at the initial stage of crop growth, which ultimately increased crop yields under disc and chisel ploughing treatments.

Table 5: Seed, straw, biological yield (kg ha^{-1}) and harvest index (%) of soybean as influenced by different tillage and nutrient management treatments during 2018-19

Treatments	Soybean yield (kg ha^{-1})			Harvest index (%)
	Seed	Straw	Biological	
A) Tillage Management				
T1 CvT 1 Plou.+ 2Culti. + 1Bl. harrow	2429	2816	5245	45.75
T2 RT 1 Culti + 1 Roto Till	2078	2243	4322	45.69
T3 MT 1 Roto Till	1764	2051	3815	45.50
T4 ZT Zero Till	1317	1521	2838	45.46
SE(m)±	102	53	131	-
CD at 5%	351	184	452	-
B) Weed management				
W1 Pre. appl. of Diclo. 0.030kg a.i./ha	1498	1680	3178	45.56
W2 PoE appl. of Propa.+ Imaze. 0.125kg a.i./ha at 20 DAS	1888	2148	4036	45.54
W3 Pre. Diclo. 0.030kg a.i/ha + PoE0.125kg a.i./ha at 20 DAS	2464	2851	5315	45.67
W4 (WF (2H at 15 & 30 DAS + 1HW at 20 DAS)	2578	2951	5528	45.72
W5 Weedy Check	1060	1160	2219	45.51
SE(m)±	35	67	104	-
CD at 5%	116	218	339	-
C) Interaction (A x B)				
SE(m)±	55	44	98	-
CD at 5%	161	129	285	-
GM	1897	2158	4055	45.60

Seed, straw, biological yield (kg ha^{-1}) and harvest index (%) of soybean was significantly influenced by weed management. From the data it was apparent that weed management practices, weed free (W_4) treatment recorded significantly highest seed (2578 kg ha^{-1}), straw yield (2951 kg ha^{-1}) and biological yield (5528 kg ha^{-1}) over rest of tillage treatments but it was found at par with (W_3) Diclosulam @ 0.030 kg a.i. /ha PE fb Propaquizafop +Imazethapyr @ 0.125Kg a.i. /ha POE at 20DAS followed by treatment (W2) Propaquizafop +Imazethapyr @0.125Kg a.i. /ha POE at 20DAS (W2). In weedy check (W_5) treatment the lowest seed, straw and biological yield was measured. The lower seed and straw with treatments of minimum tillage (consisting only one rototill) and zero tillage (no tillage) where the soil was undisturbed could be attributed to the inferior value of plant growth and yield attributing characters. It indicates that plant did not respond well to shallow tillage. The evidential reason behind this that of non improvement of soil physical status with shallow tillage operation. The treatments where somewhat deep cultivation was practiced by using conventional tillage (consisting ploughing and two harrowing) and reduced tillage (consisting harrowing and one rototill) were found to be superior likely due to improvement in soil compactness and aeration resulting in better absorption and retention of water supplemented with greater root proliferation through loose and porous soil strata and higher absorption of nutrients for the deeper layer of soil. Similar results were obtained by Feng *et al.*(2014) [9], Similar results were obtained by Hitesh Borana and Ishwar Singh (2023) [13] and Monsefi Ali And U.K. Behera(2014) [26].

Economics of the treatment

Economic studies provide the economic feasibility of the crop or cropping system. It is the analysis of input cost incurred and the gross and net output obtained from cultivating the specific crop. Considering the prevailing cost of labors and inputs required for different treatments, economics of different treatments *viz*. Cost of cultivation, Gross Monetary Return, Net Monetary return and B:C ratio were worked out and presented in table 06.

Cost of cultivation (Rs ha^{-1})

Cost of cultivation (Rs/ha) differed to some extent due to tillage operations of various magnitudes in different tillage management treatments. Maximum increase in cultivation cost was noted with conventional tillage treatment (Rs. 32588 ha^{-1}) which might be due to increased number of tillage operations (1 ploughing+ 2 tyne harrowing+1 blade harrowing at vertical depth of 25-30 cm). Reduced tillage (1 tyne harrowing+1 blade harrowing (Rs. 29175 ha^{-1}31525).Minimum tillage (1Rototill Rs. 27548 ha^{-1} & Zero tillage treatment showed the minimum cost of cultivation (Rs.24843 ha^{-1}) due to no tillage operation, respectively. Blaise *et al*. (2005) [5] also reported that herbicide is the single most costly input.

Higher cultivation cost was noted with W4 WF treatment because of two hoeing operation charges and cost for weeding (2H at 15 & 30 DAS + 1HW at 20 DAS) Rs.34836/-ha and W3 PE appl.Diclosulam@.0.030 kg a.i./ha + PoE Propaquizafop + Imazethapyr @ 0.125kg a.i./ha at 20DAS (Rs.30507/- ha) due to an expenditure incurred towards controlling the weeds in those plots by using herbicides two herbicide for spraying.

Table 6: Effect of tillage and nutrient treatments on Cost of Cultivation, Gross Monetary Returns (GMR) Rs ha^{-1}, Net Monetary Returns (NMR) Rs ha^{-1} and B:C ratio.

Treatments	2018-19			
	GMR	NMR	COC	B:C Ratio
A)Tillage Management				
T1 CvT 1Plou.+2Culti. +1Bl. Harrow	91030	58441	32588	**2.75**
T2 RT 1Culti + 1Roto Till	77399	48223	29175	**2.60**
T3 MT 1Roto Till	66145	38597	27548	**2.33**
T4 ZT Zero Till	49349	24506	24843	**1.92**
SE(m)±	3365	3196	-	-
CD at 5%	11643	11059	-	-
B) Weed management				
W1 PE appl.Diclo. Propa.+ 0.030kg a.i/ha	55958	29802	26156	**2.18**
W2 PoE appl. Imaz. 0.125kg a.i./ha at 20 DAS	70622	42706	27916	**2.66**
W3 PE appl. Diclo. 0.030 kg a.i./ha+ PoE Propa. +Imaz. 0.125kg a.i./ ha at 20DAS	92326	61819	30507	**2.96**
W4 WF (2H at 15 & 30 DAS + 1HW at 20 DAS)	96489	61653	34836	**3.08**
W5 Weedy Check	39510	16230	23280	**1.73**
SE(m)±	1551	1480	-	-
CD at 5%	5057	4827	-	-
C) Interaction (A x B)				
SE(m)±	2403	2283	-	
CD at 5%	7014	6663	-	
GM	70981	42442	28539	2.54

Differences in cost of cultivation were due use of various tillage management treatments and weed management and the application of various rate of herbicide.

Gross Monetary Return (GMR Rs.ha^{-1})

Among tillage management practices, gross monetary returns was maximum with CvT-Conventional tillage (Rs.91030 ha^{-1}) and Reduced tillage RT (Rs.77399 ha^{-1}) which was at par with Minimum tillage (Rs.66145 ha^{-1}) and significantly lowest was recorded with zero tillage (Rs.49349 ha^{-1}) treatment. Deep tillage conventional tillage resulted in better growth and yield attributes and consequently higher yield output and in turn higher gross monetary returns. Usman *et al*. (2013) [37], Heatherly and Spurlock (2001) [12], Singh *et al*. (2008) [35], Monsefi and Bhera (2014) [26], and SY Dhale *et al*. (2021) [8] also reported an increase in GMR with greater intensity of tillage in cotton and soybean.

In case of weed management treatment, GMR was significantly influenced by weed management practices. Weed free (W4) WF (2H at 15 & 30 DAS + 1HW at 20DAS treatment recorded significantly higher GMR value (Rs.96489ha^{-1}) which was significantly superior over the treatment (W2) (Rs. 70622ha^{-1}) i.e. PoE Propaquizafop + Imazethapyr @ 0.125kg a.i./ha at 20DAS, treatment $W1_1$ PE application of Diclosulam @ 0.0030kg a.i./ha(Rs. 55958 ha^{-1}) and W5 weedy check(Rs. 39510ha^{-1}).Whereas, treatment W4 and W3 was at par with each other (Rs.92326 ha^{-1}) higher yield output under weed free treatment resulted in higher gross monetary returns.

Net Monetary Return (Rs. ha^{-1})

Conventional tillage (CvT)) with NMR Rs. 58441 ha^{-1}) was statistically equal with Reduced tillage (RT) with NMR Rs. 48223 ha^{-1} are significantly superior over rest of the tillage treatments. Tillage practices where tillage intensity was kept to the minimum extent did not improve NMR as Minimum tillage (MT) recorded the NMR (Rs. 38597 ha^{-1}). Significantly lowest NMR was recorded with zero tillage treatment (Rs.24506 ha-1).This result are in confirmation with SY Dhale et al. (2021) [8].

Weed management practices significantly influenced net monetary return. The highest net monetary return (Rs 61819ha^{-1}) was recorded with the herbicidal treatment (W3) Diclosulam @ 0.030 kg a.i./ha PE fb Prop + Imazethapyr @ 0.125Kg a.i./ha POE was recorded highest net monetary return however it was at on par with treat weed free (W4) (Rs 61653 ha^{-1}). While among the other herbicidal treatments Diclosulam @ 0.030 kg a.i./ha PE fb Propaquizafop + Imazethapyr @ 0.125Kg a.i./ha POE (W2) (Rs 42706 ha^{-1}) was recorded highest net monetary return(62831 Rs ha^{-1}) over treatment Diclo@0.030 kg a.i./ha PE (W1). Lowest net monetary return (Rs16230 ha^{-1}) was observed in weedy check (W5).Result are in confirmation with Navell Chander *et al*.(2014) [29].

Interaction

The interaction effect due to tillage and weed management was found to be significant with GMR and NMR.

Table 7: Pooled means of NMR of soybean (Rs./ha) as influenced by interaction of tillage and weed management practices during kharif season of 2018-19

Treatments	W1	W2	W3	W4	W5 WC
T1 CvT 1Plou.+ 2Culti.+1 Bl. harrow	53263	68021	88068	88124	34020
T2 RT Culti. + 1 Roto Till	39679	54392	74549	74259	20590
T3 MT 1 Roto Till	31505	44106	66540	67130	14788
T4 ZT Zero Till	13882	27585	47902	48183	9125
SE(m)±	1304				
CD at 5%	3807				

There is significant effect of tillage and weed management practices on NMR (Rs./ha). Treatment combination conventional tillage and weed free treatment was recorded maximum NMR (Rs.88124/ha) but this treatment combination was at par with conventional tillage and (W3) application of diclosulam @ 0.030 kg per ha as a PE + POE application of propaquizafop + imazethapyr 0.125 kg per ha at 20 DAS (Rs. 88068/ha). The next better treatment combination which recorded higher NMR (Rs./ha) was reduced tillage and W3 i.e. application of diclosulam @ 0.0030 kg per ha as a PE + POE application of propaquizafop + imazethapyr 0.125 kg per ha at 20 DAS. Significantly the lowest NMR (Rs./ha) was recorded by treatment combination Zero tillage (ZT) and W5 i.e. weedy check. Similar kind of result was recorded by DD Meshram *et al*.(2019) [22].

B: C ratio

Benefit: cost ratio (B:C ratio) as influenced by different treatments are presented in Table 6. It is evident from the data that as compared to the cost incurred towards cultivation of crop, almost two fold or more than that benefit was noticed as the mean value of B: C ratio was 2.40.

Difference in tillage management performed in variation of B:C ratio. Maximum benefit cost ratio 2.75 was observed with conventional tillage (CvT) followed by Reduced tillage (RT) 2.60, Minimum tillage (MT) 2.33 and zero tillage (1.92), B: C ratio, respectively. Singh *et al*. (2008) [35] also found greater benefit to the cost ratio of various crops grown with greater tillage intensity.

Conclusions

According to finding of this study, In soybean, among the tillage management practices, conventional tillage management practice i.e. one ploughing + two harrowing by tyne cultivator + one harrowing by blade harrow was found significantly superior over other tillage management practices and found significantly maximum in growth and yield attributes with highest in seed, straw and biological yield, harvest index, GMR, NMR and B:C ratio.

The soil physical properties improved in conventional tillage with higher soil moisture content, porosity, infiltration rate, hydraulic conductivity, better soil aggregates and lowers bulk density.

Significantly higher gross monetary returns and net monetary returns along with maximum Benefit: Cost ratios were obtained with conventional tillage and application of diclosulam @ 0.030 kg per ha as PE + POE application of propaquizafop + imazethapyr 0.125 kg per ha at 20 DAS.

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