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Studies on impact of tillage and nutrient management practice on soybean (*Glycine max* L. (Merril.) under Vertisolic soil

PD Thakare, VM Bhale, MR Deshmukh, DT Dhule and JP Deshmukh

Abstract
Awareness towards soil health, productivity, and food quality has forced to find out a suitable and eco-friendly tillage and nutrient management practice of crop production. To study the impact of tillage and nutrient management on soybean under Vertisolic soil was studied at the Department of Agronomy, Dr. PDKV, Akola during 2018-19. The experiment was laid out in split plot design with five main plot and three sub plot treatments replicated for three times. The main plot treatments were constituted of five tillage practices *viz*., (1) Conservation tillage (CnT), Minimum tillage (MT), Subsoil tillage (ST), Roto Tillage (RT) and Conventional Tillage (CvT). Subplot treatments were comprised of three nutrient management i.e. 100% RDF (100 RDF), 75% RDF + 2 t ha^{-1} FYM +1.5 t ha^{-1} soybean straw (75RDF) and 50% RDF + 4 t ha^{-1} FYM + soybean straw + 1.5 t ha^{-1} soybean straw. The other cultural practices were kept common, as recommended. Results shows that, rainfed soybean grown on a clayey soil with Subsoil tillage exhibited better growth and yield attributes and recorded significantly higher seed yield. Nutrient management with 100% RDF (30:75:30 NPK kg/ha), being comparable to 75RDF, resulted in higher growth and yield attributes and seed yield of 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 subsoil tillage and integrated nutrient management practices of 75 RDF and 50RDF. Significantly higher gross monetary returns and net monetary returns along with maximum benefit: cost ratio were obtained with subsoil tillage. Application of 100% RDF recorded significantly higher gross monetary returns and net monetary returns along with maximum benefit: cost ratio.

Keywords: Tillage practice, nutrient management, conservation tillage, farm yard manure, mean weight diameter, porosity

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. Over the last few decades, there has been increasing interest in environmentally sound and sustainable soil management. The soils of Vidarbha region are mostly vertisol and dominated by clay and this soil 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 hard plough-pan beneath the soil surface.
Soybean (*Glycine max* L. Merril) 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 meal is a valuable ingredient in formulated feeds for poultry and fish. It is an excellent source of protein and oil besides it contains high level of amino acids such as lysine, Lucien, lecithin and large amount of phosphorous. The area covered under soybean in India was 116.285 lakh ha which produced 86.426 lakh MT with productivity of 781 kg ha^{-1} whereas, in Maharashtra the area under cultivation was 37.739 lakh ha which produced 27.835 lakh MT with productivity of 776 kg ha^{-1}. In Vidarbha, area under soybean was 18.726 lakh ha which produced 18.453 lakh MT with productivity of 973 kg ha^{-1} (SOPA, 2017). 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.

Tillage system can impact soil moisture status because tillage influences infiltration, runoff, evaporation, and soil water storage, with conventional tillage, weeds that competes with crops for moisture and other growth resources are mechanically removed. On the other hand, some tillage practices may promote drought stress through low residue cover, increased runoff and reduced water infiltration. Several workers have emphasized that the good soybean yields could achieved by reducing the cost of tillage through minimum tillage, i.e. just to till the land once with light harrow for providing easiness in sowing only. Therefore, for sustainability of any agricultural system and overall soil health, tillage and organic manure plays an important role and offer opportunities to restore the soil exhaustion of nutrients and soil moisture. Incorporation of FYM and other organic waste along with fertilizer or alone in any of the specific tillage system may improve the physicochemical properties of soil which simultaneously improve the productivity on sustainable basis and also economize the use of fertilizer.

In view of testing the various preparatory tillage implements either single or in combination on soils of Vidarbha region along with nutrient 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 nutrient management practice on soybean productivity, physical properties of soil, and economics of the treatment.

Materials and Methods

The fixed plot field experiment was carried out at the farm of Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola on vertisol under rainfed condition during *kharif* season of 2018-19. The experimental site is situated in the subtropical zone at latitude 200 42’ N and longitude 770 01’ E. The altitude of the place is 307.41 meters above mean sea level. 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 split plot design with 5 tillage management practices in main plot and 3 nutrient management practices in sub plot replicated three times. Tillage management constituted of conservation tillage (CnT)- one harrowing by tractor mounted disc harrow before sowing, minimum tillage(MT)- one tyne harrowing + one blade harrowing), subsoil tillage(ST)-one subsoiler + one tyne harrowing + one rotavator), roto tillage (RT) -one tyne harrowing + one rotavator and conventional tillage (CvT)- one ploughing + two tyne harrowing + one blade harrowing), Nutrient management practices were 100% RDF(100 RDF) [30:75:30 NPK kg/ha], 75% RDF + FYM 2 t/ha (75 RDF)and 50% RDF + FYM 4 t/ha (50 RDF)

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 80 DAS 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 moderate moisture stress condition. Soybean crop (Var. JS-335) was sown on 3rd July, 2018. Prior to sowing, all the tillage treatments were applied to the selected site of experiment. Simultaneously integrated nutrient management practices were also carried out. Crop was harvested on 4th October, 2018.

Result and Discussion

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

a. Soil physical properties
b. Soil Moisture content (%)

A perusal of Data in Table 1 showed that, tillage practices posed significant effects over mean moisture content at the depth of 0-15,15-30cm.The status of soil moisture(0-15cm) at sowing, 30, 60, 90 DAS and at harvest recorded in subsoil tillage (ST) 36.15%, 31.96%, 35.30%, 24.30% and 23.67%. However, the status of soil moisture (15-30 cm) at all periodical stages recorded in subsoil tillage (ST) 33.50%, 30.58%, 33.49%, 22.92% and 22.10% and was at par with the Conventional Tillage (CvT) and significantly superior over Minimum Tillage (MT) and Conservation Tillage (CnT) furthermore similar trends in status of soil moisture were observed at 15-30 cm depth. This improvement in higher water conservation with ST may attributed to loosening of soil to a higher depth coupled with increased porosity and higher mean weight diameter. Wesley *et al*. (1993) [32] also reported an improved moisture status resulting from subsoiling in soybean on clay soil as compared to other shallow tillage plots. Further Kailapan *et al*. (2001) [14], Karuma *et al*. (2014) [13] and Meidani (2014) [18] reported greater moisture conservation with deep and very deep tillage practices.

Nutrient Management treatment with 50 RDF significantly improved the status of soil moisture at all periodical stages and at par with 75 RDF. Significantly lowest moisture was recorded in 100 RDF at 0-15 cm and 15-30 cm depth. In case of maximum use of FYM there was highest porosity with minimum bulk density. Hence maximum soil moisture content was found in case of 50% RDF. This might be due to the aggregation of soil particles due to addition of organic fertilizer replacing the chemical fertilizer resulted in formation of good soil structure leading to high soil moisture content.

Interaction effect

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

Table 1: Effect of tillage and nutrient treatments on Soil Moisture (%) at 0-15cm and 15-30 cm depth in soybean.

Treatment	Soil Moisture (%) t 0-15cm depth					Soil Moisture (%) at 15-30 cm depth				
A) Tillage Management										
	At sowing	30 DAS	60 DAS	90 DAS	At Harvest	At sowing	30 DAS	60 DAS	90 DAS	At Harvest
CnT	31.72	26.96	29.36	19.07	19.32	29.51	24.57	29.50	18.68	17.74
MT	33.14	28.08	32.93	20.78	20.16	30.62	26.52	31.30	19.44	18.78
ST	35.85	31.96	35.30	24.30	23.67	33.50	30.58	33.49	22.92	22.10
RT	34.32	29.59	34.40	21.56	20.63	32.59	26.78	31.52	21.01	18.92
CvT	34.29	29.43	33.08	23.07	22.34	32.63	28.30	32.50	21.80	20.62
S.E(m)±	0.72	0.65	0.98	0.73	0.71	0.74	0.58	0.51	0.52	0.71
CD P= 5%	2.36	2.13	3.18	2.37	2.30	2.40	1.87	1.66	1.68	2.31
B) Nutrient Management										
100RDF	32.45	28.16	31.43	20.75	20.57	30.69	26.31	30.49	19.38	18.86
75 RDF	34.18	29.17	32.96	21.93	21.23	31.64	27.35	31.57	20.81	19.67
50RDF	35.16	30.27	34.65	22.58	21.87	32.99	28.39	32.92	22.13	20.37
S.E(m)±	0.71	0.56	0.53	0.42	0.20	0.60	0.51	0.65	0.29	0.19
CD P=5%	2.09	1.66	1.57	1.25	0.58	1.77	1.50	1.91	0.85	0.55
C) Interaction: Tillage x Nutrient Management										
S.E(m) ±	1.59	1.26	1.19	0.95	0.14	1.35	1.13	1.44	0.64	0.41
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Porosity (%) [P_t]

The noticeable differences were observed in Table 2, when effect of tillage was examined over porosity. At 0-15cm and 15-30 cm depth, P_t improved significantly with subsoil tillage (ST),to all other tillage treatment at all stages except at sowing and consistently recorded the figures ranging from 52.70% at sowing and 51.61% at harvest, (0-15cm depth)and 51.01% at sowing and 49.02% at harvest (15-30cm). It was pursued by conventional tillage CvT) and Roto tillage (RT) with reasonable decline. Performance of roto tillage and minimum tillage was almost similar with each other for P_t. Minimum tillage (CnT) noted lowest values of P_t, at 0-15 and 15-30 cm depth, it was in close proximity with minimum tillage and conservation tillage treated plots. It appears from the result analysis, that tillage had a distinct effect on P_t, reduction in bulk density, improvement in mean weight diameter, reduced soil strength with ST may casually enhanced soil physical properties including P_t.Similar findings were recorded earlier by Pagliani *et al.* (2004) [23], Ahmad *et al*. (2007) [2], Abdullah *et al*. (2008) [1], and Wang *et al*. (2014) [31].

Nutrient management treatments did not influence P_t to a level of significance. However long-term effect of root deposits, organic matter added throyh FYM and root channels by these treatments might affect the amount of macropores in the soil, as after decomposition of roots and organic matterit remain stays open at lower soil profile and results in higher Porosity (%) in 50RDF and 75 RDF as compared to the 100RDF at 0-15 and 15-30 cm depth.

Interaction Effect

Interaction between tillage practices adopted and nutrient management imposed was found absent when the experimental data was analyzed statistically.

Table 2: Effect of tillage and nutrient treatments on Soil Moisture (%) at 0-15cm and 15-30 cm depth in soybean.

Treatment	Soil Moisture (%) at 0-15cm depth					Soil Moisture (%) at 15-30 cm depth				
A) Tillage Management										
	At sowing	30 DAS	60 DAS	90 DAS	At Harvest	At sowing	30 DAS	60 DAS	90 DAS	At Harvest
CnT	51.07	49.98	49.81	49.94	49.39	49.26	48.27	48.18	47.85	47.50
MT	51.40	50.06	50.23	50.02	49.98	49.85	48.46	48.35	48.15	47.37
ST	52.70	51.87	51.99	51.53	51.61	51.01	50.13	50.12	49.45	49.02
RT	52.12	50.73	50.57	50.10	50.06	50.41	48.99	48.76	48.75	48.03
CvT	52.37	51.07	51.19	50.57	50.48	50.59	49.38	49.41	49.05	48.27
S.E(m)±	0.85	0.39	0.37	0.20	0.37	0.37	0.54	0.47	0.27	0.14
CD P= 5%	NS	1.28	1.19	0.65	1.22	1.23	1.62	1.43	0.85	0.46
B) Nutrient Management										
100RDF	51.77	50.36	50.62	50.24	50.49	49.85	48.75	48.15	48.05	48.08
75 RDF	51.85	50.94	50.77	50.49	50.16	50.18	49.12	49.25	48.89	47.97
50RDF	52.18	50.92	50.89	50.57	50.26	50.65	49.25	49.45	49.01	48.06
S.Em)±	0.39	0.15	0.17	0.11	0.23	0.44	0.15	0.12	0.11	0.09
CD P=5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C) Interaction: Tillage x Nutrient Management										
S.E(m) ±	0.94	0.31	0.36	0.25	0.51	0.98	0.34	0.38	0.25	0.20
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Mean weight Diameter [MWD](mm), Rate of infiltration [RI](cm hr^{-1}) and

Hydraulic Conductivity [HC] (cm hr^{-1})

A perusal of Data in Table 3 showed that, Mean weight diameter was found to be significantly improved with subsoil treatment (ST) ranging from 0.74 and 0.76mm and conventional tillage (CvT) ranging from0.75 and 0.72mm at sowing and at harvest of the crop, indicating improved soil aggregation status, indicating suitability of the tillage practice both for greater underground storage of moisture and improved aeration, that too under inadequate and excess rainfall situations. Rate of infiltration was found to be significantly highest with subsoil treatment (2.81 and 2.39cm hr^{-1}) followed by with conventional tillage treatment (2.67 and 2.33cm hr^{-1}) whereas in conservation tillage (2.04 and 1.82 cm hr^{-1}) when recorded at sowing and at crop harvest. Hydraulic conductivity of the soil under saturated condition was significantly improved with subsoil treatment (ST) and conventional tillage (CvT) assuring adequate moisture availability at the lower soil profile. Due to consistent lower bulk density with ST and CvT, it can be assumed that status of porosity (macropores) must have been improved, which ultimately metered the aeration, supporting greater multiplication of aerobic microorganisms within the soil layer causing stabilized aggregates of higher diameter. Hence, it can be stated that under vertisol with semi-arid climatic conditions, the intensive tillage with subsoiling significantly improves the water stable aggregates as compared to minimum tillage, which result in improvement in MWD, RI and HC deep tillage treatment as compared to shallow tillage treatment. These results are in conformity with those obtained by, Mikha and Rice (2004) [21], Pagliani *et al.* (2004) [23], Oswal (2007) [22] and Alvaro-Fuentes *et al*. (2008) [4].

Table 3: Effect of tillage and nutrient treatments on Mean weight Diameter, Rate of infiltration and hydraulic conductivity of soil as influenced by tillage and nutrient management practice.

Treatment	Mean Weight Diameter (mm)		Rate of Infiltration (cm hr^{-1})		Hydraulic conductivity (cmhr^{-1})	
	At sowing	At harvest	At sowing	At harvest	At sowing	At harvest
A) Tillage Management						
CnT	0.64	0.64	2.04	1.82	2.16	1.97
MT	0.66	0.69	2.20	1.96	2.43	2.31
ST	0.74	0.76	2.81	2.39	3.03	2.67
RT	0.68	0.70	2.57	2.31	2.87	2.50
CvT	0.73	0.75	2.67	2.33	2.90	2.57
S.E(m)±	0.00	0.02	0.04	0.03	0.07	0.07
CD P= 5%	0.01	0.05	0.11	0.11	0.22	0.23
B) Nutrient Management						
100RDF	0.68	0.71	2.46	2.15	2.67	2.39
75 RDF	0.69	0.71	2.46	2.16	2.68	2.40
50 RDF	0.69	0.71	2.46	2.17	2.68	2.41
S.E(m)±	0.00	0.00	0.00	0.00	0.00	0.00
CD P=5%	NS	NS	NS	0.01	0.00	0.01
C) Interaction: Tillage x Nutrient Management						
S.E(m) ±	0.01	0.01	0.01	0.01	0.00	0.01
CD at 5%	NS	NS	NS	NS	NS	NS
GM	0.69	0.71	2.46	2.16	2.68	2.40

Nutrient management treatments influenced Mean Weight Diameter, Rate of infiltration and Hydraulic conductivity non-significantly. When various nutrient management treatment were compared among each other, Higher values were recorded in treatments with 50 RDF, followed by 75 RDF for MWDRI and HC. It might have resulted from addition of organic matter added through FYM and soybean straw increase the soil aeration and the oxygen level due to decomposition of organic matter added by FYM and root channel formed due to deep rooted crops increase soil aeration and soil's ability to hold water, whereas 100%RDF treatments recorded less values for above said properties at sowing and at harvest. Considering other things constant, the inferior performance due to CnT could attribute to its failure to offset soil compaction.

Such a phenomenon was reported in their studies by Laddha and Totawat (1997) [16], Soltanabadi *et al.* (2008) [29], Rasmussen (1999) [24].

Interaction Effect

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

Yield Attributes of Soybean

Yield contributing characters i.e. no. of pods $plant^{-1}$, weight of pods $plant^{-1}$, no. of seed pod^{-1}, weight of seed $plant^{-1}$, test weight etc. designate 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 Physico-chemical properties of soil. The changes thus induced due to managerial involvement are precisely reflected in the yield attributes of the plant. 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 4.

Number of pods $plant^{-1}$, weight of pods $plant^{-1}$, weight of seed $plant^{-1}$, 33.76,8.19 g 6.25 g respectively was found significantly highest with subsoil tillage, except number of seed $pod^{-1}$and test weight (2.19 and 11.02 g). Whereas, in the conservation tillage treatment consisting of tillage with only one blade harrow (CnT) could not produce higher performance in yield attributes. Performance of both the shallow tillage i.e. Roto and Minimum tillage treated plot in respect yield attributes was found intermediary.

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 vertisols. The vertisol is mostly dominated by smectite and feldspar clay minerals. These soils swells when moistened and shrinks when dried. Most significant character of such soil is that it requires optimum conditions of moisture for improving its physical status, or otherwise physical properties improves under optimum moisture status, which in present investigation, might have been provided by way subsoil in treatment (ST) and CvT, resulting 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. Conversely, the physical status of soil was much inferior in MT and CnT than that of ST, causing unsatisfactory growth of plant. Kayombo (2000) [15], Singh and Sharma (2005) [28], Samra and Dhillon (2000) [25] also found the increased growth and yield attributes

Table 4: Yield attributes of soybean as influenced by different tillage and nutrient management treatments

Treatment	Yield attributes of soybean				
	No. of pods plant^{-1}	Wt. Of pods plant^{-1}(g)	No. of seeds pod^{-1}	Wt. Of seed plant^{-1}(g)	Test weight (g)
A) Tillage Management					
CnT	24.26	5.56	2.08	5.02	10.61
MT	24.56	5.80	2.11	5.17	10.72
ST	33.76	8.19	2.19	6.28	11.02
RT	25.07	6.17	2.12	5.48	10.70
CvT	26.57	6.70	2.15	5.83	10.89
S.E(m)±	2.08	0.48	0.35	0.10	0.09
CD P= 5%	6.23	1.44	NS	0.31	NS
B) Nutrient Management					
100RDF	27.53	7.16	2.23	5.98	10.80
75 RDF	23.43	6.70	2.11	5.56	10.83
50RDF	21.37	5.59	2.04	5.11	10.74
S.E(m)±	0.71	0.21	0.05	0.21	0.03
CD P=5%	2.15	0.64	0.16	0.62	NS
C) Interaction: Tillage x Nutrient Management					
S.E(m) ±	3.31	0.76	0.49	0.60	0.06
CD at 5%	9.95	2.27	1.47	1.79	NS
GM	26.84	6.48	2.13	5.56	10.79

Yield attributes mentioned above significantly influenced by different nutrient management treatments over 50RDF treatment except test weight. Nutrient regime of 100% RDF recorded significantly higher number of pods plant-1 (25.53), wt. of pod plant^{-1} (7.16 g), No. of seed pod^{-1} (2.23), wt. of seed plant^{-1} (5.98 g)and it was on par with the nutrient regime of 75RDF (26.04). Nutrient regime of 50RDF recorded the lowest values for yield attributes and being statistically equal to 75RDF. Under various nutrient management regimes the mean values of yield attributes were higher when the crop was fertilized with 100% RDF which could be attributed to higher vegetative attributes that led to higher accumulation of photosynthates for pod development indicating that the said nutrient management enabled the crop to express the inherent potential to the maximum.100% RDF proved statistically comparable to 75RDF. This is in line with the findings of Chaturvedi and Chandel (2005) [8], Deshmukh *et al.* (2005) [9], Maheshbabu *et al*. (2008) [17], Shivakumar and Ahlawat (2008) [26] and Hati *et al*. (2014) [11].

Seed, straw and biological yield (kg ha^{-1})

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 5.

Different tillage management had a significant influence on the seed yield and straw yield of soybean. From the data, it revealed that subsoil tillage (ST) recorded significantly higher seed yield (2219 kg ha^{-1}), straw yield (2465 kg ha^{-1}) and biological yield (4684 kg ha^{-1}) which was statistically at par with conventional tillage (CvT)for seed yield (2106 kg ha^{-1}) and straw yield (2348 kg ha^{-1}) and biological yield (4454 kg ha^{-1}). Seed yield and straw yield recorded under conventional tillage (CvT) and roto tillage (RT) was comparable. Lowest seed yield, straw yield and biological yield was recorded with conservation tillage (1709, 2085 and 3794 kg ha^{-1}) which was statistically comparable to minimum tillage treatment (1790, 2142 and 3932 kg ha^{-1}). Harvest index was also highest in ST (47.37%) followed by CvT (47.29%), RT (46.14%), MT (45.53%) and CnT (45.04%).

Superior yield level with subsoil tillage and conventional tillage was due to better expression 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. It indicates that plant did not respond well to shallow tillage which might be due to non-improvement of soil physical status with shallow tillage operation. This is also in accordance with the findings of Choudhary (2014) [7], Monsefi *et al*. (2014) [19], Alizadeh and Allameh (2015) [3], Ferhat Ozturk and Tahsin Sogut (2016) [10]; and Mourtzinis *et al.* (2017) [20], 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 and biological yield (kg ha^{-1}) of soybean as influenced by different tillage and nutrient management treatments

Treatment	Soybean yield(kg ha^{-1})			Harvest Index (%)
	Seed	Straw	Biological	
A) Tillage Management				
CnT	1709	2085	3794	45.04
MT	1790	2142	3932	45.53
ST	2219	2465	4684	47.37
RT	1935	2259	4194	46.14
CvT	2106	2348	4454	47.29
S.E(m)±	61	67	140	--
CD P= 5%	184	202	418	--
B) Nutrient Management				
100RDF	2163	2290	4453	48.57
75 RDF	2042	2212	4254	48.00
50RDF	1818	2075	3893	46.69
S.E(m)±	54	65	133	--
CD P=5%	163	194	397	--
C) Interaction: Tillage x Nutrient Management				
S.E(m) ±	106	120	192	--
CD at 5%	318	NS	NS	--

Seed yield and straw yield of soybean was significantly influenced by varying nutrient management regime. From the pooled data it was apperant that Nutrient management regime of 100% RDF (30:75:30 NPK kg/ha) was significantly superior over application of 50 RDF and on par with 75 RDF. The increase in seed yield was to the extent of 11.50%, in 100 RDF and 75 RDF compared to 50RDF. Harvest index was also highest in 100RDF followed by 75 RDF and 50 RDF. Significant increase in seed yield, straw yield biological yield with 100% RDF could be due to fact that this nutrient management regime initiated better vegetative growth in terms of plant height, branches, leaf area, which produced more photosynthates and that had reflected in higher dry matter, number of pods and seed weight/plant and ultimately higher seed yield. In application of 75% RDF+ 2 t FYM ha^{-1} similarly proved comparable.

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 6.

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. 33750 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). It was followed by subsoil tillage (Rs. 32050 ha^{-1}) and Roto tillage (31525. Minimum Tillage & Conservation tillage treatment showed the minimum cost of cultivation (Rs. 31175 ha^{-1}) and (Rs. 30150 ha^{-1}) due to only 1 tyne harrowing+ 1 blade harrowing and 1 disc harrowing respectively. Fortuitous rise in cost of cultivation (Rs. 31175 ha-1) and (Rs. 30150 ha-1) with minimum tillage practice (MT) and conservation tillage (CnT) likely due to an extra expenditure incurred towards controlling the weeds in those plots by way using herbicides and additional hand weeding and hoeing operation with MT and CnT. Blaise *et al*., (2005) [6] also reported that herbicide is the single most costly input.

Higher cultivation cost was noted with 50 RDF (Rs. 37729/ha) followed by treatment 75 RDF (Rs. 29227/ha) and 100% RDF (Rs. 27463/ha).

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.

Treatment	COC (Rs ha^{-1})	GMR (Rs ha^{-1})	NMR (Rs ha^{-1})	B:C
A) Tillage Management				
CnT	30150	61545	30722	2.04
MT	31175	61897	31395	1.99
ST	32050	75581	43531	2.36
RT	31525	66279	34754	2.10
CvT	33750	74299	40550	2.20
S.E(m)±	--	1311	1311	--
CD P= 5%	--	4275	4275	--
B) Nutrient Management				
100RDF	27463	71901	44438	2.61
75 RDF	29997	67156	37159	2.24
50RDF	37729	64703	26974	1.71
S.E(m)±	-	806	806	-
CD at 5%	-	2376	2376	-
C) Interaction: Tillage x Nutrient Management				
S.E(m) ±	-	1801	1801	-
CD at 5%	-	NS	NS	-

Differences in cost of cultivation with various nutrient management treatments were due to variations in the application rate of chemical fertilizers and FYM.

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

Among tillage management practices, gross monetary returns was maximum with ST-Subsoil tillage (Rs. 75581 ha^{-1}) which was at par with CvT-Conventional tillage (Rs.74299 ha^{-1}) and significantly superior over rest of the tillage treatments. Tillage Treatment CvT statistically significant to roto tillage (Rs. 66279 ha-1). Conservation tillage (CnT) and MT-minimum tillage are at par to each other recorded the lowest GMR (Rs. 61545 ha^{-1}) on par with (Rs. 61897 ha^{-1}) respectively. Deep tillage treatments of subsoil and 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) [30], Heatherly and Spurlock (2001) [12], Singh *et al*. (2008) [27] also reported an increase in GMR with greater intensity of tillage in cotton.

In case of nutrient management treatment, GMR was significantly influenced, application of 100% RDF recorded significantly higher GMR (Rs. 71901ha^{-1}) which was significantly superior over the treatment of 75% RDF+ 2 t FYM ha^{-1} (Rs. 67156 ha^{-1}) and 50% RDF+ 4 t FYM ha^{-1} (Rs. 64703 ha^{-1}). The latter two treatments were statistically at par. Higher yield output under 100% RDF and 75RDF resulted in higher gross monetary returns.

Net Monetary Return (Rs. ha-1)

Subsoil tillage (ST) with NMR Rs.43531 ha^{-1}) was statistically equal with Conventional tillage (CvT) with NMR

Rs.40550 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 lowest NMR (Rs.30722 ha^{-1}) at par with Conservtion tillage (Rs. 31395 ha^{-1}).

Nutrient management practices significantly influenced net monetary return. Application of 100% RDF recorded significantly highest NMR Rs. 44438ha^{-1}) than treatment of 75 RDF (Rs. 37159 ha^{-1} and 50 RDF (Rs. 26974 ha^{-1}). Higher yield output with 100% RDF and 75RDF resulted in higher net monetary returns.

Interaction

The interaction effect due to tillage with any of nutrient management treatment could not be obtained significantly for GMR and NMR.

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 2.13.

Difference in tillage management resulted in variation of B:C ratio. Maximum benefit cost ratio 2.36 was observed with subsoil tillage (ST) followed by Conventional tillage 2.20, Roto tillage 2.10. Comparatively, shallow tillage practices minimum tillage (1.99), conservation tillage recorded 1.99 and 2.04 B:C ratio respectively. Singh *et al*. (2008) [27] also found greater benefit to the cost ratio of various crops grown with greater tillage intensity.

Nutrient management with application of 100% RDF recorded the maximum B:C ratio (2.61) followed by treatment of 75% RDF+ 2 t FYM ha^{-1} (2.24) and the lowest with application 50% RDF+ 4 t FYM ha^{-1} (1.71).

Conclusions

According to finding of this study, rainfed soybean with subsoil tillage (one subsoil + one tyne harrowing + one rotavator) exhibited better growth and yield attributes and recorded significantly higher seed yield and at par with Conventional Tillage (one ploughing + two tyne harrowing + one blade harrow). Nutrient management with 100% RDF (30:75:30 NPK kgha^{-1}), being comparable to 75% RDF+FYM 2t ha^{-1}, resulted in higher growth and yield attributes and seed yield of 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 subsoil tillage (one subsoiler + one tyne harrow + one rotavator) and integrated nutrient management practices of 75% RDF+ 2 t FYM ha^{-1} and 50% RDF+ FYM 4 t ha^{-1}. Significantly higher gross monetary returns and net monetary returns along with maximum benefit: cost ratio were obtained with subsoil tillage and 100% RDF nutrient management.

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