J. Soils and Crops 28 (1) 227-233, June 2018

ISSN 0971-2836
NAAS Rating - 4.46
Scientific Journal Impact Factor (2017) 4.338

EFFECT OF TILLAGE ON NUTRIENT UPTAKE AND WATER USE EFFICIENCY IN SOYBEAN

N.D.Parlawar[1], D.J.Jiotode[2], K.J.Kubde[3], Ajaykumar Meena[4] and A.R.Mohod[5]

ABSTRACT

A field experiment was conducted on the farm of Integrated Farming System Research Project, Dr. P.D.K.V., Akola during the *Kharif* season of 2016-2017. The experiment was laid out in randomized block design with six treatments and four replications. The tillage treatments constituted of T_1 (No-tillage - Sowing without cultivation and weed control by chemical), T_2 (Minimum tillage - 1 Harrowing + 1Hoeing at 15 DAS), T_3 (Conventional tillage --- 2 Harrowing + 2 Hoeing at 15 & 30 DAS), T_4 (Broad bed and furrow Sowing - 1 Harrowing + 2 Hoeing at 15 & 30 DAS), T_5 (Minimum tillage + Opening of furrow after every 3 rows) and T_6 (Minimum tillage + Opening of furrow after every 6 rows). Observations on traits related to nutrient uptake, water use efficiency, economic studies and benefit :cost ratio were recorded. Experimental results revealed that nutrient content (NPK) in seed and stover did not differ significantly due to various tillage practices but numerically highest nutrient (NPK) content in seed and stover was recorded with treatment broad bed and furrow (T_4) and conventional tillage (T_3) respectively. Significantly highest nutrient (NPK) uptake by the seed and stover was registered with treatment broad bed and furrow (T_4). The maximum water conservation was recorded with treatment broad bed and furrow (T_4) with the values of 35.10, 33.49, 31.29, 25.83, and 33.14% at 20, 40 60 , 80 DAS and at harvest respectively. Broad bed and furrow (T_4) practice of tillage and crop cultivation remarkably improved the water use efficiency by recording the highest value of 6.83 kg^{-1} mm^{-1} WUE. Maximum GMR, NMR and B:C ratio were found with treatment of broad bed and furrow (T_4) and proved as the most economic and remunerative tillage practices.

(Key words: Soybean, tillage, nutrient uptake, water use efficiency)

INTRODUCTION

Soybean (*Glycine max.* L.) is one of the important oilseed as well as a leguminous crop. Soybean is the most popular oilseed after groundnut and soybean oil is the largest produced oil in the country. Soybean as a miracle "Golden Bean" of the 21st century mainly due to its high protein (40%) and oil content (20%) and is now making headway in Indian Agriculture. In India, it is mainly grown as oilseed crop. The area covered under soybean in India was 109.10 lakh ha which produced 103.37 lakh MT with productivity of 951 kg ha^{-1} whereas, in Maharashtra the area under cultivation was 35.81 lakh ha which produced 39.45 lakh MT with productivity of 1102 kg ha^{-1}. In Vidarbha, area under soybean was 19.32 lakh ha which produced 14.76 lakh MT with productivity of 776 kg ha^{-1} (Annonymous, 2016).

Tillage is the mechanical manipulation of the soil and incorporation of plant residues to prepare an appropriate seedbed for crop planting, which have several advantages such as loosening soil, regulating the circulation of water and air within the soil, increasing the release of nutrient elements from the soil for crop growth, and controlling weeds by burying weed seeds and emerged seedlings (Reicosky and Allmaras, 2003).

Tillage options available to farmers have proliferated in recent years due to the availability of reliable chemical weed control, new tillage and planting equipment designs, desire to reduce production inputs and costs, and an increased emphasis on soil and water conservation. More than 30% of the soil surface covered with crop residue is one of the most effective and least costly methods of reducing soil erosion. Soil tillage, as a necessary practice in crop production, can affect the soil physical properties that are important for plant growth. Improvements of root penetration, water infiltration and soil moisture storage,

1. Associate Dean, College of Agriculture, Nagpur
2. Asstt.Professor, Agrometeorology, Agronomy Section, College of Agriculture, Nagpur 440 001
3. Assoc.Professor, Deptt. of Agronomy, Dr.P.D.K.V., Akola
4. P.G.Student, Deptt. of Agronomy, Dr.P.D.K.V., Akola
5. P.G. Student of Economics, BHU, Varanasi

weed control, and supply of nutrients from rapid decomposition of organic matter are considered the most beneficial contributions of tillage to crop production.

The effect of minimum tillage on the farmer's profit margin will occur in a number of ways. Soil quality is influenced by wind and water erosion. Valuable top soil on the surface is necessary for proper crop development. An increase in soil organic matter enhances nutrient availability for crop growth. Similarly, an increase in the moisture level in the soil has the potential to increase crop yields, which also increases the profit margin. Thus, there are number of reasons a producer would adopt minimum tillage practices.

Conventional tillage is defined as tillage that incorporates most of the previous crop's residue into the soil. Minimum tillage technology reduces the number of tillage operations before seeding a crop, thereby leaving the land less disturbed compared to conventional tillage. Minimum tillage also reduces the requirement for the land to be left fallow once every two to three years because of the need to preserve moisture. By leaving more of the previous crops residue on the surface of the land, more carbon is able to be sequestered; thereby reducing greenhouse gas emissions. An increased amount of residue on the soil surface significantly reduces the effects of wind and water erosion. Finally, the additional surface trash helps to maintain the soil moisture increasing the potential crop yield.

Keeping the above aspects in mind this was undertaken to study effect of tillage practices on nutrient uptake and water use efficiency in soybean.

MATERIALS AND METHODS

The experiment was laid out in randomized block design with six treatments; replicated four times having net plot size of 4.6 m x 2.7 m. The tillage treatments were:-

T_1 - NT	No tillage-Sowing without cultivation and weed control by chemical
T_2 - MT	Minimum tillage - 1 Harrowing + 1Hoeing at 15 DAS
T_3 - CvT	Conventional tillage --- 2 Harrowing + 2 Hoeing at 15 & 30 DAS
T_4 - BBF	BBF Sowing - 1 Harrowing + 2 Hoeing at 15 & 30 DAS
T_5 - MT+OFAE3R	T_2 + Opening of furrow after every 3 rows
T_6 - MT+OFAE6R	T_2 + Opening of furrow after every 6 rows

Soybean crop (Var. JS 335) was sown on 28th June, 2016. Prior to sowing, the six tillage treatments were applied to the selected site of field experimentation. Fertilizer dose to the crop was made as per recommended dose of fertilizer (NPK 30:75:30 kg ha^{-1}). Crop was harvested on 10th October, 2016. The row to row distance of 45 cm and plant to plant distance of 5 cm, as per treatments was maintained by gap filling and thinning so as to get expected plant stand. Observation on traits related to nutrient uptake, water use efficiency, economic studies and benefit : cost ratio were recorded as given below:

Estimation of nutrient uptake by seed and straw

The nutrient uptake by seed and straw after harvest were calculated in kg ha^{-1} and g ha^{-1} by using following formulae.

$$\text{Uptake by seed (kg ha}^{-1}) = \frac{\text{Nutrient content (\%) x Seed yield (kg ha}^{-1})}{100}$$

$$\text{Uptake by straw (kg ha}^{-1}) = \frac{\text{Nutrient content (\%) x Straw yield (kg ha}^{-1})}{100}$$

$$\text{Uptake by seed (g ha}^{-1}) = \frac{\text{Nutrient content (mg kg}^{-1}) \text{ x Seed yield (kg ha}^{-1})}{1000}$$

$$\text{Uptake by straw (g ha}^{-1}) = \frac{\text{Nutrient content (mg kg}^{-1}) \text{ x Straw yield (kg ha}^{-1})}{1000}$$

Estimation of nutrient content in seed and straw

Nitrogen content in seed and straw sample was estimated by Kjeldhal's method as describe by Jackson (1973). Phosphorus in seed and straw samples was estimated by Olsen's method (1973) and Potassium in seed and straw samples was estimated by using Flame photometer method as described by Jackson (1973).

Estimation of available N, P and K in soil

Available N,P and K in soil was also estimated. Available Nitrogen (kg ha^{-1}) from soil was estimated by Alkaline Permanganate method described by Subbiah and Asija (1956). Available phosphorus from soil was estimated by Olsen's method. Available potassium from soil was determined by neutral normal ammonium acetate extract using flame photometer method (Jackson 1973).

Determination of soil moisture content (%)

Determination of moisture content in soil was calculated on oven dry basis (Piper, 1966) by using following formula.

$$PW = \frac{WS_1 - WS_2}{WS_2} \times 100$$

Where,

PW = Moisture percentage on oven dry basis

WS_1 = Fresh weight of sample

WS_2 = Dry weight of soil sample

Water use efficiency (WUE)

Water use efficiency for various treatments was calculated on the basis of seed yield and consumptive use of water in the given tillage treatment. It indicates the amount of seed yield produced per unit of water consumed per unit of land.

$$\text{WUE (kg ha}^{-1}\text{ mm}^{-1}) = \frac{\text{Yield (kg ha}^{-1})}{\text{Evapotranspiration (mm)}}$$

Where,

WUE = Water use efficiency (kg ha^{-1} mm^{-1})

Y = Economic yield (kg ha^{-1}) in a particular treatment

ET = Total evapotranspiration (mm) i.e. CU in the concerned treatment

Economic studies

The total value of produce i.e. seed and straw yield was calculated treatment wise as per the prevailing market rate and gross monetary return ha^{-1} was calculated. Net monetary return was calculated by subtracting the cost of cultivation from gross monetary return treatment wise.

Benefit : cost ratio

The benefit : cost ratio was calculated by dividing the gross monetary return with total cost of cultivation. This was calculated with following formula.

$$\text{Benefit cost ratio} = \frac{\text{Gross monetary return (Rs. ha}^{-1})}{\text{Cost of cultivation (Rs. ha}^{-1})}$$

The statistical analysis of data of the characters studied in the investigation was carried out through the procedure appropriate to the design of the experiment that is Randomized Block Design. The significance of difference was tested by the 'F' test (Panse and Sukhatme, 1985). Standard error of mean (SEm±) and critical difference (5%) were also calculated where ever found significant.

RESULTS AND DISCUSSION

NPK content in plant and its uptake

The data pertaining to effect of tillage in nutrient studies in soybean are presented in table 1.

The data on nitrogen uptake by seed, stover and total uptake by plant are presented in table 1. It is revealed from the data that, the average values of nitrogen content in seed and stover were 5.92 % and 0.46 %, respectively, while the total nitrogen uptake by soybean plant was 154.66 kg ha^{-1}.

The nitrogen content in seed and stover did not differ significantly due to various tillage practices. However, numerically highest nitrogen content in seed and stover was recorded with treatment broad bed and furrow (T_4) and conventional tillage (T_3), respectively. As far as nitrogen uptake is concerned, there were significant differences among various tillage practices. Significantly highest nitrogen uptake by the seed and stover was recorded with treatment broad bed and furrow (T_4). The corresponding figures were 174.59 and 14.93 kg ha^{-1}, respectively. Thus, this treatment also proved superior in total nitrogen uptake by recording nitrogen uptake value of 189.52 kg ha^{-1}. Whereas, significantly lowest nitrogen uptake in seed, stover and total was found with treatment no-tillage (T_1), where the total uptake was 108.35 kg ha^{-1}.The remaining tillage practices recorded moderate uptake of nitrogen. Maximum mobilization of nitrogen from soil to plant might have resulted from the greater availability of moisture and better soil physical status. It is evident due to broad bed and furrow (T_4) tillage practice with numerically highest total nitrogen content and its uptake. However, the lowest nitrogen content in seed, stover and it's uptake by plant was recorded in no-tillage (T_1) system might be due to less mobilization and uptake of N.

The data in table 1 depicts the values of phosphorus content and its uptake by the seed and stover of soybean. It is evident from the data that phosphorus content (%) did not differ significantly due to various tillage practices. However, numerically greater amount of phosphorus in seed and stover was recorded with broad bed and furrow (T_4) tillage treatment. Uptake of phosphorus by seed and stover was found to be significantly influenced by the various tillage practices. Significantly highest phosphorus uptake was found with treatment broad bed and furrow (T_4), where it increased to 13.72 kg ha^{-1}. However, this treatment was found statistically similar with treatment conventional tillage (T_3) by recording the respective values of 12.67 kg ha^{-1}. Significantly lowest phosphorus uptake (7.82 kg ha^{-1}) was recorded with treatment no-tillage (T_1). The other tillage practices helped to remove the phosphorus to a moderate extent. Better soil moisture and soil physical status with treatment broad bed and furrow (T_4), both under adequate and inadequate rainfall conditions, might have reflected in greater phosphorus uptake by the plants treated with broad bed and furrow (T_4) system of tillage.

The data in respect of potassium content and its uptake by seed and stover are presented in table 1. It is obvious from the values presented in table 1 that, the potassium content (%) in soybean seed and stover did not differed significantly due to various tillage practices. The general mean values recorded for potassium content in soybean seed and stover were 2.28 and 1.43 %, respectively. Uptake of potassium by soybean seed and stover was found to be differed significantly due to various tillage management practices. Significantly greatest amount of potassium uptake was recorded by the soybean seed and stover with treatment broad bed and furrow (T_4) with the respective values of 67.96 and 44.69 kg ha^{-1}, while significantly lowest potassium uptake by seed and stover was noted with treatment no-tillage (T_1) with the respective values of 36.43 and 22.32 kg ha^{-1}. As there was maximum content of potassium in seed and stover and as there was maximum seed and stover yield with treatment broad bed and furrow (T_4), this treatment performed satisfactory as compared to other tillage practices. Whereas, the yield performance of treatment no-tillage (T_1) was not much appreciable, thus there was huge reduction in potassium uptake with this treatment.

Available nitrogen, phosphorus and potassium (kg ha^{-1}) in the soil after harvest

The data in respect of available nitrogen, phosphorus and potassium in the soil after harvest of the crop as influenced by various tillage treatments are presented in table 2.

Data regarding effect of different tillage treatments on available nitrogen after harvest of the crop shows that the average available nitrogen status of the soil was 232.39 kg ha^{-1}. There was no significant difference between different tillage practices. However, numerically maximum nitrogen in the soil was recorded with treatment no-tillage (T_1) with the value of 243.41 kg ha^{-1}. Significantly lowest nitrogen in the soil was recorded with treatment broad bed and furrow (T_4) with the value of 216.38 kg ha^{-1}. Thus, the addition of nitrogen to soil as compared to initial status in treatment no-tillage (T_1) was about 41 kg ha^{-1} and in treatment broad bed and furrow (T_4) it was about 14 kg ha$^{-1.}$ The greater uptake of nitrogen in treatment broad bed and furrow (T_4) might have resulted in its lower availability at crop harvest stage.

Data regarding effect of different treatments on available phosphorus in the soil after harvest of the crop are presented in table 2. The average available phosphorus status of soil was 14.47 kg ha^{-1}. There was no significant difference between different tillage practices. However, numerically highest phosphorus in the soil was recorded with treatment no-tillage (T_1) with the value of 15.85 kg ha^{-1}, while the lowest phosphorus in the soil was recorded with treatment broad bed and furrow (T_4) with the value of 13.14 kg ha^{-1}. Thus, there was moderate addition of phosphorus to soil as compared to initial status in treatment no-tillage (T_1) about 1 kg ha^{-1}, while in the other tillage treatments the phosphorus level went down as compared to initial availability of phosphorus (15.20 kg ha^{-1}). The greater uptake of phosphorus in treatment broad bed and furrow (T_4) might have resulted in its lower availability at crop harvest stage.

Data regarding effect of different treatments on available potassium in the soil after harvest of the crop are presented in table 2. The average available potassium status of soil was 381.66 kg ha^{-1}. There was no significant difference between different tillage practices. However, numerically highest potassium in the soil was recorded with treatment no-tillage (T_1) with the value of 388.36 kg ha^{-1}. The lowest potassium in the soil was recorded with treatment broad bed and furrow (T_4) with the value of 372.25 kg ha^{-1}. Thus, the addition of potassium to soil as compared to initial status in treatment no-tillage (T_1) was about 46 kg ha^{-1} and in treatment broad bed and furrow (T_4) it was about 30 kg ha^{-1}. The greater uptake of potassium in treatment broad bed and furrow (T_4) might have resulted in its lower availability at crop harvest stage.

Soil moisture studies

Soil moisture status provides the ability of any tillage treatment to conserve the available moisture for its utilization by the crop. Therefore, it is necessary to study the periodical changes in soil moisture status under different tillage practices. The data in respect of soil moisture content at the depth of 0-30 cm as recorded from the experimental site are presented in table 2. It is obvious from the data that various tillage practices influenced the soil moisture status to a level of significance. At 20 DAS, as there was continuous rainfall, hence the treatment differences could not evident among various tillage practices. However, at 40 DAS, the maximum water conservation (33.49 %) was recorded with treatment broad bed and furrow (T_4). This treatment was statistically found at par with that of conventional tillage (T_3). The remaining tillage treatments, by recording somewhat lower values of moisture content, were found to be statistically similar among every other. At 60 DAS, though there was a short dry spell, the maximum conservation of water was noticed with treatment broad bed and furrow (T_4), by recording the value of 31.19 % which was found statistically similar with treatment minimum tillage + opening of furrow after every 3 row (T_5). At this stage, significantly lowest moisture content was recorded with treatment no-tillage (T_1) with the value of 24.71 %. At 80 DAS the same trend of observation was recorded. After this period, again there was constant rainfall of higher frequency with a record of 24 rainy days which reflected in getting the non-significant differences for moisture content among various tillage treatments, at harvest. Overall there was about 832.3 mm rainfall received during the investigational period. The crop also experienced a short dry spell between 40-80 DAS. Even under this condition, the maximum conservation of moisture with treatment broad bed and furrow (T_4) proved its superiority by keeping the rhizosphere with adequate water content. Greater sub soil compaction with treatment no-tillage (T_1) might have resulted in formation of lesser number of pore spaces, thus reflecting in reduced water conservation. Moreover, there might be greater surface runoff due to high intensity rains with treatment no-tillage (T_1), causing reduction in the rate of water infiltration.

Water use efficiency (kg ha^{-1} mm^{-1})

The value of water use efficiency denotes the production of economic yield unit^{-1} of water consumed through the process of evapotranspiration. The treatment differences are influenced by the ability of the crop to produce economic yield unit^{-1} of available water. The data in terms of WUE as derived from the investigational period are represented in table 2. It is observed from the data that maximum WUE i.e. 6.83 kg^{-1} ha^{-1} mm^{-1} was recorded with treatment broad bed and furrow (T_4) as compared to the lowest of 4.04 kg ha^{-1} mm^{-1} with treatment no-tillage (T_1). The second best treatment conventional tillage (T_3) recorded the respective value of 6.25 kg ha^{-1} mm^{-1}, which was followed by treatment minimum tillage + opening of furrow after every 3 row (T_5) with corresponding value of 6.01 kg ha^{-1} mm^{-1}.

Remaining tillage treatments i.e. minimum tillage + opening of furrow after every 6 row (T_6) and minimum tillage (T_2) were found to be moderate with the values of WUE to the tune of 5.68 and 5.27 kg ha^{-1} mm^{-1} respectively. The maximum seed production $unit^{-1}$ of consumptive use of water is the main cause to increase WUE with treatment broad bed and furrow (T_4). While the lower crop yield in spite of adequate water availability may be the reason for reduction in WUE with treatment no-tillage (T_1). Similar to this result Ram *et al.* (2010) reported that the permanent bed treatment in wheat recorded significantly higher water use efficiency than all conventional tillage (CT) and no-tillage (NT) treatments. Hari *et al.* (2013) observed that soybean and wheat planted on raised beds recorded about 17% and 23% highest WUE, respectively, than in flat layout. Choudhary *et al.* (2014) also reported that conventional tillage (CT) and paddy straw mulch (PSM), have registered 10% and 40% improvement of water use efficiency in pea (*Pisum sativum*). The findings clearly suggested that CT along with PSM registered improvement in water use efficiency.

Economic studies

Economic studies provide the economic feasibility of the treatments tested in the experiment. It is the analysis of input cost incurred and the gross and net output obtained by cultivating the specific crop. The relevant data on cost of cultivation (COC), gross monetary returns (GMR), net monetary returns (NMR) and benefit cost ratio (B:C) as influenced by different treatments are shown in table 2. The data related to cost of cultivation are presented in table 2. The cost of cultivation for every treatment under study was derived through evaluating every input cost involved in cultivating the soybean crop. It indicated remarkable variation in the cost of cultivation with various treatments. General mean value of 24799 Rs ha^{-1}, is incurred towards soybean crop cultivation during a season. The highest cost of cultivation (26392 Rs ha^{-1}) was recorded with treatment broad bed and furrow (T_4), which was followed by other treatments under investigation, in reducing order of conventional tillage>no-tillage >minimum tillage + opening of furrow after every 3 row>minimum tillage + opening of furrow after every 6 row>minimum tillage. It was likely that the COC with no-tillage (T_1) may remain at the bottom, as compared to other tillage treatments; however, despite of no cost incurred towards cultivating the plots, the main reason for hike in the cost of cultivation with no-tillage (T_1) is an increase in the cost towards controlling the weeds, by means of herbicide application.

In the present investigation, the values of gross monetary returns differed significantly due to various tillage practices. Significantly highest gross monetary returns were recorded with treatment broad bed and furrow (T_4) with the value of 94525 Rs ha^{-1}. It was followed by treatment conventional tillage (T_3) with the value of 86771 Rs ha^{-1}. The values of GMR differed significantly among the various tillage treatments as per the descending order of minimum tillage + opening of furrow after every 3 row >minimum tillage opening of furrow after every 6 row>minimum tillage >no-tillage. Maximum GMR with treatment broad bed and furrow (T_4) is the result of higher crop production with this treatment, irrespective of greater COC value.

Data presented in table 2 indicate the pronounced treatment difference in obtaining net monetary returns due to various tillage practices. Net monetary returns were found significantly highest with treatment broad bed and furrow (T_4) with the value of 68133 Rs ha^{-1}. It was followed by treatment conventional tillage (T_3) with the value of 60566 Rs ha^{-1}. The treatment no-tillage (T_1) recorded lowest value (31245 Rs ha^{-1}) of NMR. The remaining treatments recorded intermediate values in the descending order of minimum tillage + opening of furrow after every 3 row>minimum tillage + opening of furrow after every 6 row>minimum tillage. As the NMR gives the net values of returns from the crop cultivation, it is considered as the best tool to compare the treatment differences on monetary basis. In the present investigation the significantly maximum NMR value obtained with treatment broad bed and furrow (T_4), is due to its ability to produce the seeds (economic product) up to the potential limit of the crop. With this treatment all the plant growth and yield contributing characters were consistently greater, it has very specifically reflected in obtaining the greater NMR.

Similar to these results Monsefi and Bhera (2014) reported highest net returns of 30,614 under conventional tillage raised bed planting, closely followed by zero tillage raised bed (29,674). The cost of cultivation varied for different tillage and crop-establishment practices from 16.674 in zero tillage raised-bed to 18,374 in conventional tillage raised-bed in soybean. Visalakshi and Sireesha (2015) reported that the cost of maize cultivation was highest in ridge sowing (Rs. 2,333 ha^{-1}) and lowest in zero tillage sowing (Rs. 23,000 ha^{-1}). The comparative economics of maize sowing methods indicated the net income of Rs.58.337 ha^{-1} with zero tillage sowing, Rs. 48,752 ha^{-1} with conventional line sowing and Rs. 45,840 ha^{-1} with broadcast sowing which clearly indicated that zero tillage is economically profitable method of maize cultivation.

Benefit : cost ratio

The data presented in table 2 resulted that the highest B:C ratio of 3.58 was noted with treatment broad bed and furrow (T_4). The second best treatment in this regard was that of minimum tillage + opening of furrow after every 3 row (T_5) with respective value of 3.45. However, irrespective of comparatively lower cost of cultivation with treatment no-tillage (T_1) recorded the lowest B:C ratio of 2.25. The remaining tillage treatments proved to be economical by recording the B:C values over 3.14. The significance of raised bed cultivation is emphasised during the present investigation, as treatment broad bed and furrow (T_4) proved to be most economical and highly remunerating treatment. The least B:C ratio with treatment no-tillage (T_1) signifies the non-suitability of no tillage practices under vertisol conditions. Overall economic study indicated that,

Table 1. Effect of tillage on nutrient content and nutrient uptake in soybean

Treatments	Nitrogen content (%)		Nitrogen uptake (kg ha^{-1})			Phosphorus content (%)		Phosphorus uptake (kg ha^{-1})			Potassium content (%)		Potassium uptake (kg ha^{-1})		
	Seed	Straw	Seed	Straw	Total	Seed	Straw	Seed	Straw	Total	Seed	Straw	Seed	Straw	Total
$_1$ – No tillage	5.86	0.43	100.24	8.11	108.35	0.37	0.08	6.25	1.57	7.82	2.13	1.17	36.43	22.32	58.75
T_2 - Minimum tillage	5.83	0.42	130.32	10.22	140.54	0.35	0.07	7.83	1.58	9.41	2.19	1.45	48.87	35.29	84.15
T_3 – Conventional tillage	5.96	0.49	157.71	13.39	171.10	0.38	0.09	10.07	2.60	12.67	2.27	1.48	60.19	42.48	102.67
T_4 - Broad bed and furrow	6.03	0.49	174.59	14.93	189.52	0.38	0.10	10.84	2.88	13.72	2.39	1.48	67.96	44.69	112.66
T_5 – Minimum tillage + opening of furrow after every 3 row	5.93	0.46	150.71	12.79	163.50	0.38	0.10	9.72	2.70	12.42	2.34	1.48	59.53	40.80	100.33
T_6 - Minimum tillage + opening of furrow after every 6 row	5.92	0.48	142.45	12.52	154.97	0.39	0.10	9.34	2.61	11.94	2.35	1.55	57.46	40.52	97.97
	-	-	**2.200**	**0.500**	**2.271**	-	-	**0.523**	**0.210**	**0.397**	-	-	**1.694**	**2.925**	**3.520**
CD at 5 %	-	-	**6.600**	**1.500**	**6.845**	-	-	**1.577**	**0.630**	**1.198**	-	-	**5.107**	**8.815**	**10.610**
GM	5.92	0.46	142.66	11.99	154.66	0.37	0.09	9.00	2.32	11.32	2.28	1.43	55.07	37.68	92.75

Table 2. Effect of tillage on nutrient available in soil, soil moisture content, seed yield, water use efficiency and economic traits in soybean

Treatments	Available in soil			Soil Moisture Content (%)					Seed yield (kgha^{-1})	WUE (kg ha^{-1} mm^{-1})	COC (Rs.ha^{-1})	GMR (Rs.ha^{-1})	NMR (Rs.ha^{-1})	B:C ratio
	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	20 DAS	40 DAS	60 DAS	80 DAS	At harvest						
T_1 – No tillage	243.41	15.85	388.36	35.20	30.13	24.71	20.24	32.56	1711	4.04	24950	56195	31245	2.25
T_2 - Minimum tillage	243.34	15.64	385.53	35.40	30.55	26.52	21.59	32.60	2235	5.27	23277	73229	49952	3.14
T_3 – Conventional tillage	219.52	13.18	378.45	35.01	31.31	29.32	23.85	32.95	2648	6.25	26205	86771	60566	3.31
T_4 - Broad bed and furrow	216.38	13.14	372.25	35.10	33.49	31.19	25.83	33.14	2896	6.83	26392	94525	68133	3.58
T_5 – Minimum tillage + opening of furrow after every 3 row	235.84	14.20	380.41	35.29	31.12	30.58	24.09	33.04	2542	6.01	24141	83296	59155	3.45
T_6 - Minimum tillage + opening of furrow after every 6 row	235.84	14.86	383.97	35.31	31.08	28.54	23.45	32.89	2407	5.68	23839	78842	55013	3.30
SE (m)±	-	-	-	-	**0.84**	**1.236**	**1.354**	-	**41.62**		-	**1264**	**1264**	-
CD at 5 %	-	-	-	-	**2.52**	**3.708**	**4.062**	-	**125.42**		-	**3810**	**3810**	-
GM	232.39	14.47	381.66	35.22	31.28	28.48	23.18	32.86	2406		24799	78810	54011	3.17
Initial values	202.00	15.20	342.33											

raised bed cultivation practice in vertisol provides not only greater crop yield, but also assures economic security under both excessive and moderate stress condition in vertisol. Similar to this result Birendra Kumar and Karmakar (2015) observed that zero tillage recorded highest B:C ratio (2.5) over minimal and conventional tillage in forage oat. Visalakshi and Sireesha (2015) also reported that in maize B:C ratio of 2.5with zero tillage sowing, 1.78 with ridge sowing, 1.89 with conventional line sowing and 1.83 with broadcast which clearly showed that zero tillage is economically profitable method of maize cultivation,

In conclusion of this experiment it is observed that significantly highest nutrient (NPK) uptake by the seed and stover was registered with treatment broad bed and furrow (T_4). The maximum water conservation was recorded with treatment broad bed and furrow (T_4) with the values of 35.10, 33.49, 31.29, 25.83 and 33.14% at 20, 40, 60, 80 DAS and at harvest, respectively. Broad bed and furrow (T_4) practice of tillage and crop cultivation remarkably improved that water use efficiency by recording the highest value of 6.83 kg^{-1} mm^{-1} WUE. Maximum GMR, NMR and B:C ratio were found with treatment of broad bed and furrow (T_4) and proved as the most economic and remunerative tillage practices.

REFERENCES

Ali, M. 2014. Tillage and weed management for improving productivity and nutrient uptake of soybean". Indian J. Weed Sci. **46**(2): 184–186, Indian Agriculture Research Institute, New Delhi, India

Anonymous 2016. Soybean Processors Association of India

Birendra Kumar and S. Karmakar, 2015. Effect of tillage and nutrient management on fodder yield, economics and energetics of oat (*Avena Sativa* L.) Forage Res. **41** (1): 19-22.

Choudhary, V. K. 2014. Tillage and mulch effects on productivity and water use of pea and soil carbon stocks. Archives of Agronomy and Soil Sci. **61**(7):1013–1027.

Hari, R., K. Kumar, D. S. Kler and Y.Singh, 2010. Effect of permanent bed planting and tillage options on microenvironment, crop productivity, water use efficiency, and soil properties under soybean (*Glycine Max* L.) -wheat (*Triticum aestivum* L.) cropping system. Punjab Agricultural University, Ludhiana 141 004.

Jackson, M.L. 1973.Soil Chemical Analysis (Edn. 2) Prentice Hall of India Pvt ltd New Delhi. 69-182.

MonsefI Ali and U. K. Behera, 2014. Effect of tillage and weed-management options on productivity, energy-use efficiency and economics of soybean (*Glycine max*) Indian J. Agron. **59** (3): 481- 484.

Namrata, J., J. S. Mishra, M. L. Kewat and V. Jain, 2007. Effect of tillage and herbicides on grain yield and nutrient uptake by wheat (*Triticum aestivum*) and weeds. Indian J. Agron. **52** (2): 131-134.

Pankaj, C. and N. N. Angiras, 2007. Effect of tillage and weed management on productivity and nutrient uptake of maize (*Zea mays*). Indian J. Agron. **53**(1): 66-6.9

Panse, V.G. and P.V. Sukhatme, 1985. Statistical methods for Agricultural Workers. ICAR New Dehli.

Ram, L. L., D. S. Kler, Y. Singh and K. Kumar, 2010. Productivity of maize (*Zea mays*) wheat (*Triticum aestivum*) system under different tillage and crop establishment practice. Indian J. Agron. **55**(2): 185-190.

Reicosky, D.C. and R. Allmaras, 2003. Advances in tillage research in north American cropping systems. J. Crop Prod. **8**: 75-125.

Subbiah, B.V. and G.L. Asija, 1956. A rapid procedure for the estimation of available nitrogen in soils. Curr. Sci. **25**: 259-260.

Visalakshi, M and A. Sireesha, 2015. Study on influence of tillage methods on productivity of maize. Indian J. Agric. Res. **49** (5): 452-455.

Rec. on 10.06.2017 & Acc. on 25.06.2017