Research in: Agricultural & Veterinary Sciences
Vol.4, No.3, 2020, pp.96-103

EVALUATION OF TILLAGE SYSTEMS FOR SUSTAINABLE CROP PRODUCTION, LOW LAND AREA OF NORTH SHEWA, ETHIOPIA

Ayele Desalegn*, Tilahun Getachew, Getacher Kassa, Temesgen Yilma, Lisanu Getaneh

Debre Birhan Agricultural Research Centre, Debre Birhan, Ethiopia

Abstract. Tillage systems are sequences of operations that manipulate the soil in order to produce a crop it include tilling, planting, fertilization, pesticide application, harvesting, and residue chopping or shredding. Tillage has its own important, in other way it have drawback in the long run; due to the negative impact of tillage scholars reported the importance of conservation tillage. So this experiment was conducted to evaluate the effects of different tillage systems for sustainable crop production in Efratana Gidim, using sorghum and Mung bean as a test crop. (1) No tillage (NT) that is minimum disturbance for seed sowing, (2) tillage (T) which is 4 tillage operations before sowing, (3) No tillage with residue retention (NT+R) which is minimum disturbance during sowing and 30% residue retention on the filed during harvest and (4) tillage and residue incorporation (T+R) that is similar to treatment (3) except 30% residue incorporated during tillage. The result of the analysis of the two sorghum production years confirmed that the tillage with 30% residue incorporation could marginally gave statistically greater ($p<0.05$) yield. Even though it is not statistically different ($P<0.05$), the yield of mung bean was also numerically higher in tillage with 30% residue incorporation. The crop yield analysis confirmed that the conventional tillage with 30% residue incorporation could gave 3.94 % and 27.49% sorghum and mung bean yield advantage respectively compared to the tillage (conventional practice). Based on the result we conclude that the tillage integrated with 30% residue incorporation could have benefit for crop productivity.

Keywords: *no tillage, residue, Efratanagidim, Sorghum, Mung bean.*

***Corresponding Author:** *Ayele Desalegn, Debre Birhan Agricultural Research Centre, Po. Box 112, Debre Birhan, Ethiopia, e-mail: ayeledesalegn5@gmail.com*

Received: *24 September 2020;* ***Accepted:*** *19 November 2020;* ***Published:*** *16 December 2020.*

1. Background

Tillage systems are sequences of operations that manipulate the soil in order to produce a crop it include tilling, planting, fertilization, pesticide application, harvesting, and residue chopping or shredding. Tillage have several advantage, 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 & Allmaras, 2003). Conventional tillage practices, however, could cause rapid loss of soil organic matter, leading to a high potential for soil degradation and decline for environmental quality in the long run (Edralin & Sigua, 2016). Excessive or inappropriate tillage practices has been also reported to be the main cause of land degradation in Ethiopia by reducing vegetative cover and water infiltration (Araya *et al*., 2012).

Sorghum is the major growing staple cereal crops and highly adapted to the lowland agro-ecological zones including conditions marginal to the production of most of the other crops. Mung bean is early released and highly adapted pulse crop widely grown crop in the lowland areas of North Shewa. Mung bean is also coming to be the only alternative pulse crop used for rotation in the lowland areas of North Shewa Zone of Amhara region.

In the study area, sorghum field is ploughed 3–5 times depending on the soil type (based on local classification) and weed conditions. Due to this labor cost and oxen animals are required to finalize the plowing activities. complete removal of crop residues at harvest, aftermath overgrazing of livestock, frequent tillage, repeated occurrence of drought are also reported as the main causes for dry cropland degradation in Ethiopia (Araya *et al*., 2012). Our study area is located in North Shewa zone of Amhara region which is affected by moisture stress, loss of productivity and soil property depletion. Similarly in the study area; due to delay in plantation and the shortage of rainfall at the end of summer the crop mostly faces for moisture stress and finally it lost the productivity. With this circumstance, it is required to develop appropriate technologies.

As an important technology conservation agriculture has revealed to be a sustainable way to intensify crop production and sustain rural livelihoods in several African countries (FAO, 2010). Conservation agriculture is mainly used to keep the soil covered (>30% residue), to have minimal soil disturbance and to mix and rotate crops as well (Muminjanov, 2019). Different research result stated that the major reasons for the increase in yields are better moisture availability, improved soil fertility and better root growth as a result of conservation tillage application (Busari *et al.,* 2015). So the aims this study was to evaluate four tillage systems namely (1) no tillage (NT); no tillage and residue retention (NT+R); (3) tillage (T) which means 4 times plowing and (4) tillage and residue incorporation (T+R) for sustainably increase crop production in Efratana Gidim wereda of North Shewa zone.

2. Materials and methods

Description of the study area

Field experiment was conducted Efratna Gidim wereda at Yimlowa farmers training center from 2017 to 2019 during main cropping seasons (July to September). Efratana Gidim is bordered on the south by Kewet, on the southwest by Menz Mama Midir, on the west by Menz Gera Midir, on the north by Antsokiyana Gemza, and on the east by the Oromia Zone. The area has an average annual rainfall of 1085 mm and annual mean minimum and maximum temperatures of 15.18^0C and 32.95^0C, respectively. Sorghum and Teff are the major cereal crops grown in Efratana Gidim. Ploughing frequency in Efratana Gidim depends on crop type, usually three times for Mung bean; there to five times for sorghum (Sorghum bicolor L.) and four to six times for teff (Eragrostistef). Repeated ploughing is expected to use as control of weeds and aeration of soil particles. The time of ploughing depends on the availability of oxen, type of crop and rainfall of the area.

Experimental Procedures

The experimental layout was a randomized complete block design (RCBD) with three replications. The plot size was 4.5m by 8m with a slope gradient of 3%. The tillage was practiced based on the traditional plowing system of oxen-drawn plow using local implement known as maresha. The first plowing started in mid-April based on the availability of moisture that helps for plowing at all experimental years. For tillage treatment, the farmer practice was applied. Sorghum seeds were sown after enough moisture was existed in the soil mostly at the start of July at Efratana Gidim. Seeds were sown by hand drilling seeds with 25 cm intra-row and 75 cm inter row spacing. For rotation after growing sorghum in the second production season (year) Mung bean seeds were sown at the end of July with 25 kg/ha seed rate.

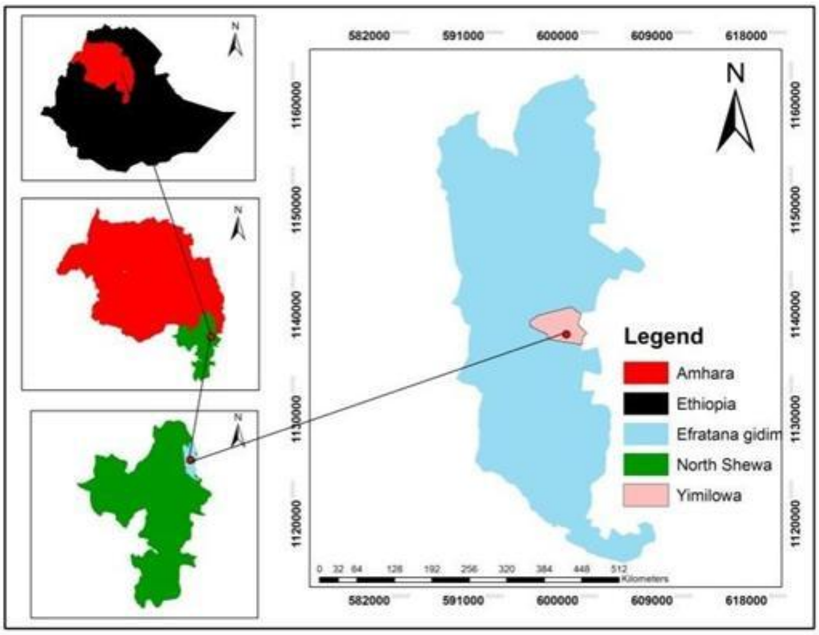

Figure 1. The location map of the study area

Treatments and experimental design

Two field operational management practices (No tillage and tillage) were used as treatments. No tillage; No tillage with 30% residue retention; tillage (4 plowing) and tillage (4 plowing) with 30% residue incorporation were the treatments used for this experiment. No tillage in this experiment means only sowing of crop with minimum disturbance. Residue retention in this experiment means retaining of 30% of residue during harvest. Residue incorporation means incorporating 30% retained residue during first plowing and tillage means the local practice applied by local cultivars,mainly4 times of plowing of farm land.

Data collection

Agronomic data such as plant height (cm), head height (cm), number of pods per plant were recorded from 10 randomly taken plants and the averages were calculated. Yield of sorghum and Mung bean (kg) were recorded and adjusted with 12.5% and 10% seed moisture content respectively. The grain yields (kg) of both crops were converted to kg per hectare (kg/ha). Soil samples before sowing and after harvesting of the test crop were collected for the analysis of selected soil chemical properties. Bulk density and soil moisture content data were also collected in different time of experimentation.

Data analysis

The collected data were subjected to analysis of variance using R software version

3.6.1 to determine treatment effects. Wherever the difference among treatment means was compared using the Fisher's least significant difference test at 5% (P<0.05) level of significance.

3. Result and discussion

Effects of different farming systems on yield and yield components of sorghum

Table 1. Effects of different farming practices on grain, biomass and plant height of sorghum

	2019/20 cropping season			**2017/8 cropping season**		
Treatment	Grain yield (kg/ha)	Biomass (kg/ha)	Plant height(cm)	Grain yield (kg/ha)	Biomass (kg/ha)	Plant height(cm)
NT	4201.4b	17812.5b	182.4	3736.1	16271.5	202.7
T	5288.9a	22559.7a	195.4	3594.4	16272.6	196.7
NT+R	4213.9b	16857.6b	183.6	3952.1	14184.6	207
T+R	5483.3a	23572.9a	193.6	3750	13539.4	202.2
Mean	4796.9	20200.7	188.7	3758.2	15067	202.2
CV (%)	4.63	3.82	4.75	5.64	9.13	2.31
LSD	444	1541.7	ns	ns	ns	ns

In the first year of experimentation 2017/8 the grain and biomass yield of sorghum were not statistically different over treatments. The reason for insignificancy of the output of the statistical analysis might be due to uniform field management during the establishment of the experiment. Where as in the third year of experimentation statistically higher at (p<0.05) grain and biomass yield were obtained from tillage with 30% residue incorporation. Statistically higher sorghum yield which obtained from tillage with 30% residue incorporation was the result of improvement of essential plant nutrients from incorporated residues. A tillage system based on mulch-till by subsoiling is an indispensable element of modern intensive crop production on account of the benefit of improving the soil state and in maintaining the stability and reliability of cropping (Birkás *et al*., 2015). The results of research at China, the crop residue return significantly increased the average crop yield by 5.0% compared to no-straw treatments (Lu, 2020). The study in Pakistan also reported retention of crop residues significantly increased wheat grain and straw yield (Mohammad *et al*., 2012). The other study conducted at USA reported, residue retention rates had no effect on grain, crop residue yields, and nutrient uptake in either corn soybean/wheat or in continuous corn cropping systems (Govaerts *et al*., 2007). The plant height of sorghum at both experimental years was not statistically significant.

The result of Mung bean revealed that there was no statistical variation generated from treatments over all parameters (grain yield, straw yield; plant height and pod length). Even though it was not statistically significant (P<0.05); the result implied tillage with residue incorporation could result numerically better grain and straw yield. The vegetative performance of the Mung bean was also better in tillage with residue incorporation than the other treatments. So this implied the incorporated residue could improve the soil productivity and crop production, however it was not significant.

Table 2. Effects of farming systems on grain, straw and vegetative parameters of Mung bean in 2018/9 cropping seasons

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Plant height (cm)	Pod length (cm)
NT	740.2	2016	50.6	10.9
T	1002.2	2111.7	55.2	10.8
NT+R	1024	2018	54.6	11
T+R	1277.8	2563.4	56.6	11.1
CV (%)	20.2	37.8	7.4	7.4
LSD (0.05)	ns	Ns	ns	ns

Effects of conservation agriculture and other farming systems on soil properties

Table 3. The effects of conservation agriculture on soil chemical properties

Treatment	E.C(dS/m)	Exchangeable k(cmol(+)/kg of soil	PH (1:2.5)	Available .P (ppm)	SOC (%)	SOM (%)	Total N (%)
NT	0.106	3.316	7.3	32.2	1.836	3.167	0.149
T	0.119	3.378	7.2	34.8	1.822	3.143	0.149
NT+R	0.142	3.456	7.2	36.2	1.895	3.269	0.168
T+R	0.117	3.384	7.2	34.8	1.828	3.154	0.166

From the result we could conclude that no tillage with residue retention could preferably improve all soil chemical properties. The result of electrical conductivity (E.C ds/m) was dropped under similar range which is normal and free from salinity problem. The exchangeable potassium was increased with 2.3% in no tillage and residue retention compared to the tillage (conventional). Similarly the other studies revealed that the level of extractable K increase at the soil surface with no tillage as tillage intensity decrease and residue retention increase (Ismail *et al*., 1994).

The soil available P was improved by 4% on the treatments having residue retention than the control. This is due to decomposition of residues retained on the surface, since the available P generally has direct relation with surface placement of crop residues that leads to accumulation of SOC and microbial biomass near the surface. (Piegholdt *et al*., 2013) also reported 15% higher total P content in the top soil (0-5 cm) of zero tillage plots as compared to conventional tillage due to larger P addition from decomposition of residues retained on the soil surface.

SOC is also improved by 4% in no tillage and residue retention compared to tillage. The reason for the improvement of SOC under no tillage with residue retention is expected to be the presence of crop residue which protects the soil from erosion. Similar studies on comparative analysis of SOC under different medium and long term studies revealed that zero tillage accounted higher SOC in the tune of 3.86-31.0% over conventional tillage (Balota *et al*., 2004) and (Bram Govaerts *et al*., 2009). Many researchers also suggested that to achieve the beneficial effect of zero tillage in terms of higher SOC, its long term implementation is essential. Usually, a SOC change is directly proportional to the amount of crop residues returned to the soil.

The available soil nitrogen was improved by 13.1% in no tillage with residue retention compared to the conventional tillage. Comparably soil nitrogen was increased by 12% in tillage with residue incorporation compared to the conventional tillage. The improvement of soil nitrogen has direct relation with the availability of retained and incorporated residue. This implied that the retention and incorporation of crop residues could improve soil nitrogen and reducing nutrient loss through acting as protective layers and facilitating microbial activities in the soil. Solar heat and rainfall are the main causes of nutrient loss through volatilization and erosion so the incorporated and retained residue could also minimize the impacts of those events.

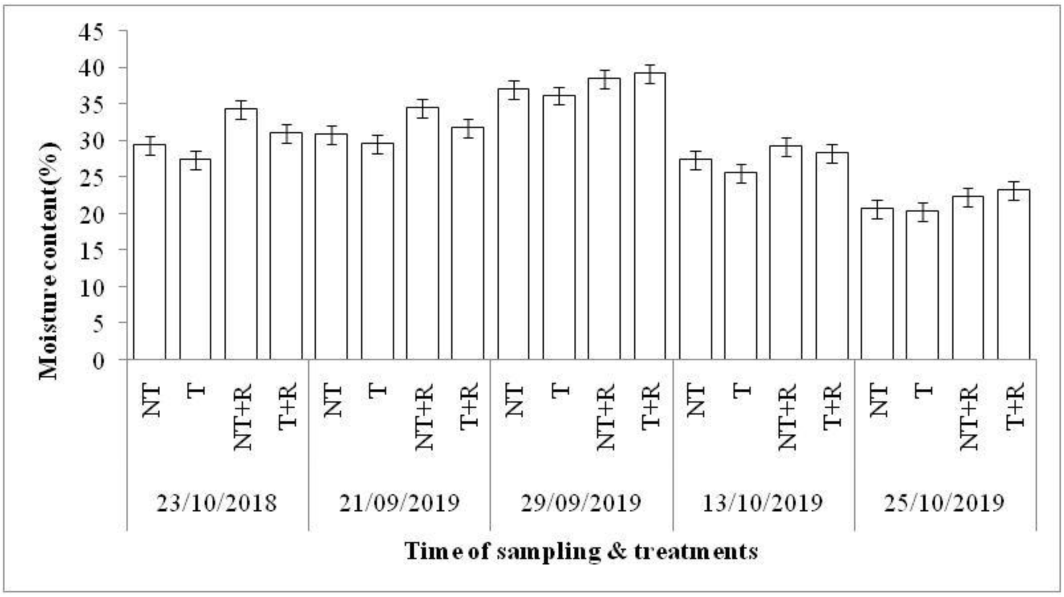

Figure 2. Effects of different farming systems on soil moisture content in different sampling time

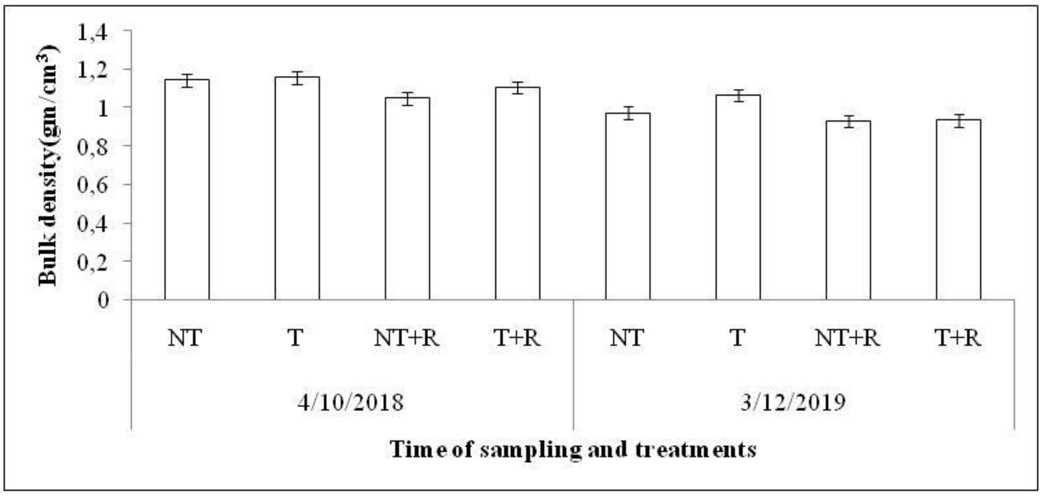

Figure 3. The effects of conservation tillage on soil bulk density (g/cm^3)

During the experimentation there was no shortage of rainfall or moisture in the study area. Due to this we could not catch the effects of conservation agriculture on moisture as visually on the crop stands and crop yield similarly. But based on the soil sample analysis we could see that no tillage with residue retention (NT+R) and conventional tillage with residue incorporation (T+R) can hold better moisture than the remaining farming systems as shown in the figure (Figure 2). Zero tillage systems which maintain residue retention over soil surface resulted in significant change in soil physical environment, especially in upper few centimeter of the soil (Anikwe & Ubochi, 2007).

The result of the analysis of bulk density (g/cm^3) stated that tillage with residue incorporation could minimize surface compaction and bulk density than other treatments in small extent. This is expected to be the fact that the incorporated crop residue can amend the soil organic carbon. The beneficial effect of conservation tillage in terms of better soil quality is reflects through improvement in physical soil properties like lower bulk density (BD), higher aggregate stability, enhanced water holding capacity and better soil structure (Yadav *et al.*, 2017). Reduction in intensity of tillage operations through adoption of conservation tillage practices would be expected to result in a progressive reduction in soil compaction over time (Kay & Vanden Bygaart, 2002). The higher organic matter and differential chemical composition of crop residues might result differential addition of SOC that may also leads to difference in soil Bulk density.

4. Conclusion and recommendation

The agronomic results from experiment confirmed that tillage with 30% residue incorporation could be beneficial for raising sorghum and mung bean grain and straw yields. Especially in sorghum production years, the statistical analysis result stated that the statistically greater ($P<0.05$) yield was obtained from tillage with 30% residue incorporation. The soil properties result of the experiment revealed that no tillage with 30% residue retention could preferably improve all physical and chemical properties than the other treatments. The tillage with 30% residue incorporation could improve some soil properties especially exchangeable potassium and total nitrogen. During the time of experimentation we seen highest weed infestation in the no tillage treatments than the tillage treatments, that might influenced to gain statistically lower sorghum yield from no tillage treatments. With 3 years of experimentation we could observed that, residue retention and incorporation provide benefit for soil health and better crop yield however the weed compete with the crops during nutrient uptake in the no tillage and residue retention. Finally to clearly show the impact of tillage systems on grain yield it is better to conduct this type of experiment for longer years in broad area is recommended.

Acknowledgement

The author dully acknowledge Debre Birhan Agricultural Research Center for financial and logistics support during the life time of this research.

References

Anikwe, M.A.N., Ubochi, J.N. (2007). Short-term changes in soil properties under tillage systems and their effect on sweet potato (Ipomea batatas L.) growth and yield in an Ultisol in south-eastern Nigeria. *Australian Journal of Soil Research, 45*(5). https://doi.org/10.1071/SR07035

Araya, T., Cornelis, W. M., Nyssen, J., Govaerts, B., Getnet, F., Bauer, H., …& Deckers, J. (2012). Mediumterm effects of conservation agriculture based cropping systems for sustainable soil and water management and crop productivity in the Ethiopian highlands. *Field Crops Research*, 132, 53–62.

Balota, E.L., Filho, A.C., Andrade, D.S., & Dick, R.P. (2004). Long-term tillage and crop rotation effects on microbial biomass and C and N mineralization in a Brazilian Oxisol. *Soil and Tillage Research, 77*(2). https://doi.org/10.1016/j.still.2003.12.003

Birkás, M., Mesić, M., & Smutný, V. (2015). Soil conservation tillage in crop production. *Contemporary Agriculture*, 64, 3-4.

Busari, M.A., Kukal, S.S., Kaur, A., Bhatt, R., & Dulazi, A.A. (2015). Conservation tillage impacts on soil, crop and the environment. *International Soil and Water Conservation Research, 3*(2), 119–129. https://doi.org/10.1016/j.iswcr.2015.05.002

Edralin, D. I., Sigua, G.C., & Reyes, M.R. (2016). Dynamics of soil carbon, nitrogen and soil respiration in farmer’s field with conservation agriculture, Siem Reap. *Cambodia. Int. J. Plant Soil Sci., 11*(1), 1-13.

FAO. (2010). Conservation Agriculture and Sustainable Crop Intensification in Lesotho. *Integrated Crop Management*, 10, 1–66.

Govaerts, B., Sayre, K. D., Lichter, K., Dendooven, L., & Deckers, J. (2007). Influence of permanent raised bed planting and residue management on physical and chemical soil quality in rain fed maize/wheat systems. *Plant and Soil, 291*(1–2). https://doi.org/10.1007/s11104-006-9172-6

Govaerts, B., Sayre, K. D., Goudeseune, B., De Corte, P., Lichter, K., Dendooven, L., & Deckers, J. (2009). Conservation agriculture as a sustainable option for the central Mexican highlands. *Soil and Tillage Research, 103*(2), 222-230.

Ismail, I., Blevins, R.L., & Frye, W.W. (1994). Long-Term No-tillage Effects on Soil Properties and Continuous Corn Yields. *Soil Science Society of America Journal, 58*(1). https://doi.org/10.2136/sssaj1994.03615995005800010028x

Kay, B.D., & Vanden Bygaart, A.J. (2002). Conservation tillage and depth stratification of porosity and soil organic matter. *Soil and Tillage Research, 66*(2). https://doi.org/10.1016/S0167-1987(02)00019-3

Lu, X. (2020). A meta-analysis of the effects of crop residue return on crop yields and water use efficiency. *Plos One, 15*(4), e0231740.

Muminjanov, S.C. (2019). Conservation Agriculture: Training guide for extension agents and farmers in Eastern Europe and Central Asia. In *Conservation Agriculture*. https://doi.org/10.1007/978-3-319-11620-4

Mohammad, W., Shah, S.M., Shehzadi, S., & Shah, S.A. (2012). Effect of tillage, rotation and crop residues on wheat crop productivity, fertilizer nitrogen and water use efficiency and soil organic carbon status in dry area (rainfed) of north-west Pakistan. *Journal of Soil Science and Plant Nutrition, 12*(4), 715-727.

Piegholdt, C., Geisseler, D., Koch, H. J., & Ludwig, B. (2013). Long-term tillage effects on the distribution of phosphorus fractions of loess soils in Germany. *Journal of Plant Nutrition and Soil Science, 176*(2). https://doi.org/10.1002/jpln.201200393

Reicosky, D.C., Allmaras, R.R. (2003). Advanced tillage in north american cropping system. *Journal of Crop Production*, 8.

Yadav, M.R., Parihar, C.M., Kumar, R., Yadav, R.K., Jat, S.L., Singh, A.K., ... & Yadav, N. (2017). Conservation agriculture and soil quality - An overview. *Int. J. Curr. Microbiol. Appl. Sci., 6*(2), 1-28.