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Effect of Tillage and Millet Residue Mulch Rates on Water Use Efficiency of Cowpea [*Vigna unguiculata (L.)* Walp] in Maiduguri, Nigeria

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Abstract
A field experiment was conducted at the University of Maiduguri Teaching and Research Farm to determine the effect of tillage and millet crop residue mulch rates on water use efficiency of cowpea [Vigna unguiculata (L.) Walp]. Eight treatment combinations of 2-factor factorial experiment were laid out in randomized complete block design with no-till and tilled plots as factor A and residue rates (0, 2, 4, 6tha^{-1}) as factor B. A composite soil sample was collected from surface (0 – 15cm) and subsurface (15 – 30cm), a week before the commencement of the experiment for routine soil physico-chemical properties of the site following standard procedures. Soil moisture storage within 0 – 180cm depth was monitored at planting, 3, 6 and 9 weeks after planting (WAP) at depth of 20cm interval. Water use and water use efficiency (WUE) were determined alongside with yield parameters. The result showed a significant ($p < 0.05$) difference due to effect of treatments on WUE. All the yield parameters were significantly ($p < 0.05$) affected by treatments with the highest mean values under NTR_2 for grain yield, NTR_3 for chaff and total dry matter (TDM). Grain yield and yield components were higher under no-till as the residue amount increased. Water use efficiency (WUE) was higher in no-till and increased with increasing amount of applied residue compared to tilled plots. The highest value of grain yield WUE of 5.27kgmm^{-1} was recorded under NTR_1 while chaff yield had 1.22kgmm^{-1} and TDM WUE was 18.09kgmm^{-1} respectively under NTR_3. Generally, No-till and higher rates of 4 and 6tha^{-1} of residue rates is recommended for optimum water use efficiency and performance of cowpea in the study area.

Keyword: Tillage, surface mulch, water use, water use efficiency, cowpea yield, millet residue rate.

Introduction

Cowpea [*Vigna unguiculata (L)* Walp]; provides more than half of plant protein in human diets (IITA, 1987). In fact, it is a key staple food for the poorest sector of many developing countries of the tropics. As food, it is eaten in form of dry seeds, green pods, green seeds and tender green leaves (IITA, 1987).

The productivity of this crop in semi-arid areas of northeast Nigeria decreased over the last decades owing mainly to declining rainfall and poor structured soil condition (Hess and Grema, 1994). In this region, annual rainfall has declined by about 8mm per year between the periods (1961 – 90) (Hess and Grema, 1994). This decline has serious implications for the productivity of cowpea which is grown by majority of farmers in the region. The probability of dry spells for more than 10 days during the cowpea growing period is high (Sivakumar, 1992). Furthermore, most of the soils in which cowpea is grown in this region are not only poor in available nutrients but also retain little water and are very permeable. In these circumstances, crops grown on such soils often suffer water and nutrient stresses, which could result in yield decrease.

Tillage is a dynamic process that alters the nature of the soil surfaces, detaches and displaces soil aggregates and clods (Powell and Hemdon, 1987). Soil inversion and pulverization by repeated tillage operation accelerate decomposition of organic matter thus affecting soil physical, chemical and biological properties, the key attributes of soil quality (Cannel and Hawes, 1994). In light soils, where the surface structure is inherently weak, cultivation rapidly leads to surface degradation, reduced infiltration and the failure of the crops to emerge through the heavy crusts (Pala *et al*., 2000). Tillage pans occur in many sandy loam agricultural soils due to repeated tillage practices and hardening in no-till soils (Diazzorita, 2000). When such soils are cultivated dry, their poor structures render them very susceptible to wind erosion (Pala *et al*., 2000). Conservation tillage that buries plant materials or retain them on the surface conserves the soil against loses by wind erosion and improve soil fertility and soil physical conditions (Bieldders *et al*., 2002). In addition, crop residues are important in the formation of soil organic matter, buffers soil against the forces of raindrop impact and wind shear. Crop residue on the surface strongly influence radiation balance and energy fluxes and reduce the rate of evaporation from the soil.

Conservation tillage reduces soil disturbance and retains crop residues on the soil surface (Pittelkow *et al*., 2015). It can effectively reduce wind erosion (Young and Schillinger 2012), water erosion (Tan *et al*., 2015), and soil bulk density, and enhance soil total porosity and saturated water conductivity (Peng *et al*., 2018), thereby increasing rainfall infiltration and soil water holding capacity (Bascansa *et al*., 2006), reducing soil evaporation, and enhancing crop growth, yield, and WUE (Shao *et al*., 2016) . No-till with straw cover has been shown to improve grain yield by 13%, and WUE by 7.6% in winter wheat on the Loess Plateau of China (Su *et al*., 2007). No-till with straw cover has been shown to improve grain yield by 153%, and WUE by 46% in a wheat and maize *(Zea mays L.*) relay-planting system

Studies by (Payne *et al*., 1999) indicated that shallow tillage on a loose sandy soil of semi-arid West Africa conserves soil moisture and increases yield and water use efficiency. Other reports showed that tillage practices that retain crop residue on the surface of the coarse textured sandy loam soil conserves moisture (Wager and Denton, 1992), decreases supra-optimal soil temperatures and improves root growth (Gajri *et al*., 1994). Incorporation of crop residues in a loamy sand was found to increase soil water storage and enhance soil fertility status (Aggarwal *et al*., 1997).

Some studies have found that mulching can encourage crops to make full use of solar radiation energy, increase the surface and tillage soil temperature, and increase the effective cumulative temperature (Sun *et al*., 2018). Mulching has the functions of moisture conservation, evaporation suppression, rainwater collection, and precipitation infiltration, enabling the full and efficient utilization of natural precipitation, and it is of great practical significance to promote crop yield improvement in dry cropping areas (Onachela *et al*., 2020).
Previous research on applying land coverings to improve the growth of crops has demonstrated that applying surface covers can effectively suppress water transfer at the soil–gas interface, thereby providing a longer water retention time in the soil (Zong *et al*., 2021). This can significantly increase crop yields in dry-farming systems (Alothman *et al*., 2020).

The influence of tillage and residue management system on water use efficiency of millet in semi-arid regions of northeast Nigeria has been studied (Alhassan *et al*., 1998). However, there was no much research on tillage and rates of residue mulch application on cowpea production in Northeast Nigeria. It is on that note that this research was carried out to assess the effect of tillage and millet residue rates application on water use efficiency of cowpea in the area.

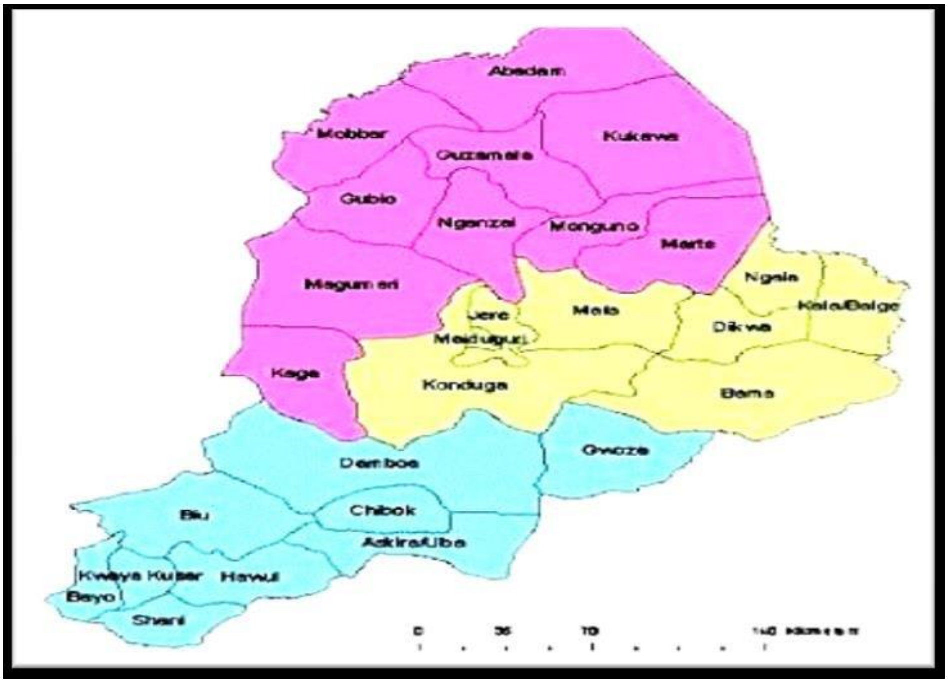

Figure 1: The Study Area

Materials and Methods

Experimental Site and Soil Characteristics

A field experiment on the effect of tillage and residue mulch rates was conducted on the University of Maiduguri Teaching and Research Farm (Lat 13^0 5'N and Lon $11^0$5'). The mean annual ranges of rainfall and temperature were 440 – 800mm and 28.5 – 32.8^0c respectively. The soils of the experimental site were classified as typic ustipsamment (Rayar, 1983), being predominantly sandy with low water holding capacity and organic matter content.

Experimental Treatments, Design and Crop Husbandry

Treatments

The details of the treatments used were as follows;

1. No-till + No residue (NTR_0)
2. No-till + residue rate of $2tha^{-1}$ (NTR_1)
3. No-till + residue rate of $4tha^{-1}$ (NTR_2)
4. No-till + residue rate of $6tha^{-1}$ (NTR_3)
5. Till + No residue (TR_0)
6. Till + residue rate of $2tha^{-1}$ (TR_1)
7. Till + residue rate of $4tha^{-1}$ (TR_2)
8. Till + residue rate of $6tha^{-1}$ (TR_3)

Experimental design

The experimental design was a two-factor factorial experiment in a randomized complete block design with two tillage types as the first factor and four residue rates as the second factor. There were three replications.

Crop husbandry

The experimental site was under continuous millet cropping for over ten (10) years. The land was harrowed once to 20cm depth in the tilled plots while in no-till plots, herbicides ***(Paraquat) was applied at 276g/l. Plots of 8m by 4m laid with alleys of 1m width***. Millet crop residue was applied manually at 0, 2, 4 and 6tonnes per hectares two weeks before planting.

Seed of cowpea [Vigna anguilata (L) Walp] var Borno Red was obtained from Borno State Agricultural Development Programme (BOSADP) and treated with a fungicide (Apron plus) at the rate of 3kg seeds per 10kg sachet. The seeds were planted manually at 1m x 1m at both intra and inter row spacing giving a total of 32 stands per plot. The seedlings were thinned to two plants per stand 10 days after planting giving a total plant population of 29,000 plants per hectare. Weeding was done manually at weekly interval. 40kgP_2O_2/ha [single super phosphate (SSP)] fertilizer was applied at seedbed preparation by broadcasting evenly on the surface. At flower setting, Corchem (Monocrotophosat 400gms/litre) was applied against insects.

Determination of moisture content

Soil moisture was determined by gravimetric method at planting, 3, 6 and 9WAP when the soil was fully covered by plant canopy. Soil samples were collected at 20cm intervals down to 180cm. Samples collected were weighed, oven dried and weighed again to determine the mass of water. Values obtained were expressed on volume basis.

Water Balance Calculations

Water use efficiency (WUE), was determined as a function of cowpea grain yield calculated as a ratio between grain yield and total water depth used in each treatment (Souza *et al*., 2011). This was estimated using the equation developed by Power (1983).

$$WUE = Y/ET \qquad (1)$$

Where; WUE is the water use efficiency, Y is the economic yield per given area during the growing season and ET is the evapo-transpiration. Water use efficiency can be expressed on weight per volume basis. Water use efficiency was expressed as yield produced per unit volume of water (Kgm^{-3}).

Evapo-transpiration was estimated using the general water balance equation (Michael, 1978).

$$ET = R_f + I - R_0 - Dr + \text{or} - Ds \qquad (2)$$

Where R_f is the rainfall, I is irrigation, R_0 is surface runoff, Dr is deep drainage and Ds is the change in soil water storage.

Since the crop is grown under rainfed conditions and irrigation was not practiced, therefore I, was zero, surface runoff was negligible considering the fact that edges of the plots were raised to prevent it, therefore, R_0 was zero. The ET was restricted to the water removed from the soil by evaporation and transpiration excluding that lost via deep drainage and surface runoff (Power, 1983).

Crop measurement

Yield and yield components

Harvesting of crops was done 12WAP. The pods were handpicked and throne into back sacks. This was later sun dried by exposing to solar radiation and threshed. The grain, chaff and stover were weighed with a 10kg top loaded and hanging balance.

Statistical Analysis

ANOVA was carried out on the collected data following two-factor factorial experiment in a Randomized Complete Block Design (RCBD) procedure outlined by Gomez and Gomez (1984). Mean values which showed significant difference were compared using Ducan Multiple Range Test (DMRT) at 1 and 5% levels of probability (Gomez and Gomez, 1984).

Results

Table 1: Physico-chemical properties of the soil of the experimental site

	0 – 15cm	15 – 30cm
pH in H_2O	6.82	6.10
pH in KCl	5.79	5.41
EC in $dScm^{-1}$	0.04	0.03
N(g/kg)	56	65
P (mgkg-1)	2.80	2.40
K(Cmolkg-1)	0.69	0.49
Ca (Cmolkg-1)	4.80	6.40
Mg (Cmolkg-1)	4.00	4.80
Na (Cmolkg-1)	0.78	0.79
O.C (g/kg)	70	30
Base Saturation (%)	98	96.89
C.N Ratio	4.80	4.60
Bulk Density ($mgcm^{-3}$)	4.48	4.92
Clay (g/kg)	14.75	16.31
Silt (g/kg)	16.60	20.74
Sand (g/kg)	68.65	62.95
Texture	Sandy loam	Sandy loam

Table 2: Effect of Tillage and Millet Residue Mulch Rates on Water Use (mm)

		Mulch residue rates (tha^{-1})			
Dates	Tillage	0tha^{-1} (R_0)	2tha^{-1} (R_1)	4tha^{-1} (R_2)	6tha^{-1}(R_3)
3 WAP	No-til (NT)	$274.27^{bc\beta}$	329.76^{b}	312.43^{b}	296.73^{bc}
	Tilled (T)	412.89^{a}	421.85^{a}	341.83^{b}	302.80^{a}
	Difference	-138.62	92.09	29.40	6.07
6 WAP	No-till (NT)	312.15^{d}	365.34^{b}	329.85^{c}	322.56^{c}
	Tilled (T)	423.93^{a}	375.01^{b}	382.25^{b}	332.62^{c}
	Difference	111.78	9.67	52.40	10.05
9WAP	No-till (NT)	267.02^{b}	296.92^{a}	256.10^{c}	254.26^{c}
	Tilled (T)	341.73^{a}	338.33^{d}	273.45^{b}	288.45^{a}
	Difference	74.71	41.41	17.35	34.19

Mean value followed by similar letters on the same rows are not significantly different at 1% percent level of probability (DMRT)
β = mean of three replications

Table 3: Effect of Tillage and Millet Residue Mulch Rates on Yield ($kgha^{-1}$)

		Mulch residue rates (tha^{-1})			
Yield components	Tillage	0tha^{-1} (R_0)	2tha^{-1} (R_1)	4tha^{-1} (R_2)	6tha^{-1}(R_3)
Grain yield ($kgha^{-1}$)	No-til (NT)	$1055.34^{b\beta}$	1185.43^{ab}	1350.67^{a}	1185.83^{d}
	Tilled (T)	920.42^{cb}	814.29^{d}	931.40^{cd}	1040.50^{b}
	Difference	134.92**	371.14*	419.27*	145.33**
TDM($kgha^{-1}$)	No-till (NT)	2754.70^{cd}	2560.00^{bc}	4100.00^{a}	4426.70^{ab}
	Tilled (T)	2730.00^{d}	3873.30^{cd}	3254.60^{cd}	3625.00^{bc}
	Difference	24.70^{NS}	-1313.3^{NS}	845.40*	801.70*
Haulm yield ($kgha^{-1}$)	No-till (NT)	310.41^{a}	280.10^{b}	250.25^{a}	310.53^{a}
	Tilled (T)	120.72^{c}	180.29^{d}	181.56^{cd}	171.25^{c}
	Difference	189.69*	99.81**	68.69**	139.28*

Mean value followed by similar letters within a Column are not significantly different at 5% percent level of probability according to (DMRT)
NS = Not-significant at 5% level of probability
β = mean of three replications
* = mean values are significant at 5% level of probability.
** = Mean values significant at 1% level of significant.

Table 4: Effect of Tillage and Millet Residue Mulch Rates on Water Use Efficiency ($kgmm^{-1}$)

WUE of yield		Mulch residue rates (tha^{-1})			
Components($kgmm^{-1}$)	Tillage	0tha^{-1} (R_0)	2tha^{-1} (R_1)	4tha^{-1} (R_2)	6tha^{-1}(R_3)
Grain yield ($kgmm^{-1}$)	No-till (NT)	3.95bβ	3.99cd	5.27a	4.44d
	Tilled (T)	2.69d	2.4c	4.41b	3.61b
	Difference	1.26*	1.58*	1.88*	1.05*
TDM($kgmm^{-1}$)	No-till (NT)	13.59g	14.15b	10.07c	18.09a
	Tilled (T)	8.14e	10.22d	11.91b	13.45c
	Difference	5.45*	3.93*	-1.84^{NS}	4.64*
Haulm yield ($kgmm^{-1}$)	No-till (NT)	0.96ab	0.97ab	1.00ab	1.22a
	Tilled (T)	0.35b	0.52b	0.66b	0.59b
	Difference	0.81*	0.38*	0.34*	0.63

Mean value followed by similar letters on the same rows are not significantly different at 1% percent level of probability (DMRT)
NS = Not-significant at 5% level of probability
β = mean of three replications
* = mean values are significant at 5% level of probability.

** = Mean values significant at 1% level of significant.

Discussion

The result of the effect of treatments on grain yield and yield components is presented in Table 3. Generally, yield and yield components were significantly ($p < 0.05$) higher in no-till plots compared to till plots. The highest mean value of grain yield of 1350.67kgha^{-1} was recorded under NTR_2 while TDM and chaff yield had the highest mean value of 4426.76kgha^{-1} and 310.53kgha^{-1} respectively under NTR_3. Similarly, the least value of grain yield, chaff and TDM weight of 814.29kgha^{-1}, 171.25kgha^{-1} and 2560.00kha^{-1} were recorded under TR_1, TR_3 and NTR_1 respectively. The crop water use efficiency (WUE) of grain, total dry matter (TDM) and chaff weight was presented in Table 4: The table showed significant ($p<0.05$) difference due to effect of treatments on WUE of grain yield and yield components. The higher mean value of WUE of grain yield of (27kgmm^{-1}), TDM (18.0kgmm^{-1}) and chaff (1.22kgmm^{-1}) were recorded under NTR_2, NTR_3, NTR_2 respectively whereas the least mean value of WUE of 2.41kgmm^{-1} for yield, 8.18kgmm^{-1} for TDM and 0.35kgmm^{-1} for chaff were recorded under TR_0. Also significant ($p < 0.05$) difference was observed among tillage practices (No-till and tilled) irrespective of rates of application.

The higher values of grain yield and TDM WUE of cowpea under residue application of rate 4 and 6tha^{-1} respectively were probably due to the decomposition of the millet crop residue on the surface that improved soil physico-chemical properties. This result was supported by the work of Zaongo, *et al*., (1997), who opined that more soil water and nutrient uptake improve grain production. In addition, it could be probably due to the crop residues that have minimized evaporation while at the same time optimizing transpiration that increased the efficiency of water utilization by the crop. A similar observation was made by Iwuafor *et al*., (1998) who reported that the growth of cereal crops like millet and sorghum was directly related to the amount of water they transpired. Sun *et al*., (2018) also held similar view in their assertion that mulching has the functions of moisture conservation, evaporation suppression, rainwater collection, and precipitation infiltration, enabling the full and efficient utilization of natural precipitation, and it is of great practical significance to promote crop yield improvement in dry cropping areas. The higher WUE in the no-till may have been as a result of little or no soil surface disturbance. This result is supported by (Zarea, 2011) who argued that conservation tillage is a component of conservation agriculture (CA). Hatfield *et al*., (2001), propended that conservation tillage system can increase water use efficiency by 25-40%.

Conclusion

Water use efficiency was generally higher in the no-till plots and increased with increasing amount of applied residue compared to till plots. Treatments with residue application at higher rate seemed to have favored more WUE and rapid growth than lower rate. Under limited rainfall as in the case of semi-arid environment, tillage alone may be as good as no-till with residue application of 4tha^{-1} and above. Higher rate of residue application irrespective of tillage is better in improving soil condition and consequently increase yield and yield components of cowpea.

References

Aggarwal, R.K., Praveen – Kumar, and Power, J.F. (1997). Use of Crop Residue and Manure to Conserve Water and Enhance Nutrient Availability and Pear Millet Yields in an Arid Tropical Region. *Soil and Tillage Research.* 41: 43-51.

Alhassan, A.B., Kundiri, A.M and Folorunso, O.A. (1998). Water Use Efficiency of Millet as Influenced by Different Tillage Residue Management Practices in Semi-Arid Northeast, Nigeria. *Journal Arid Agriculture;* 8: 45-50.

Alothman, A.A.; Mattar, M.A.; Alsamhan, M.A. (2020). Effect of mulching and subsurface drip irrigation on soil water status under arid environment. *Span. J. Agric. Res*. **18**,

Bescansa, P.; Imaz, M.J.; Virto, I.; Enrique, A.; Hoogmoed, W.B. (2006). Soil water retention as affected by tillage and residue management in semiarid Spain. *Soil Tillage Res*. **87**, 19–27.

Bielders, C.L., Michels, K. and Batiano, A (2002). On-farm Evaluation of Ridging and Residue Management Options in a Sahelian Millet – Cowpea Intercrop. 1. Soil Quality Changes. Soil Analysis Part 1. Second ed. Agron. Monograph 9. A.S.A and SSA Madison W.I. P. 825 – 844.

Cannell, R. Q and Hawes, J.D. (1994). Trends in Tillage Practices in Relation to Sustainable Crop Production with Special Reference to Temperate Climates. *Soil Tillage Research*. 30: 245 – 282.

Diazzorita, M. (2000). Effect of Deep Tillage and Nitrogen Fertilization Interaction on Dry Land Corn (Zea mays L.) Productivity. *Soil Tillage Research*. 54: 11-19.

Gajri, P.R., Arora, V.K and Chaudhay, M.R. (1994). Maize Growth Responses to Deep Tillage, Straw Mulching and Farm Yard Manure in a Coarse Textured Soil of NE India. *Soil Use and Management*. 10: 15 – 20.

Gomez, K.A. and Gomez, (1984). *Statistical Procedures for Agricultural Research.* Second Edition. John Wiley and Sons Inc. p 20-29.

Hatfield, J.L., T. J. Sauer, and J. H. Prueger, (2001). "Managing Soils to Achieve Greater Water Use Efficiency : A Review Managing Soils to Achieve Greater Water Use Efficiency : A Review," *Agron. J.*, 93; 271–280.

Hess, T.M and Grema, A.K. (1994). The Impact of Changing Rainfall Patterns on the Efficiency of Rainfall Utilization in Pear Millet – Cowpea Intercropping System in Northeast Nigeria. *Aspects of Applied Biology*. 38: 231-238.

International Institute of Tropical Agriculture (IITA) (1987). In S.R Singh and K.O. Rachie (ed). *Report on Cowpea Production and Utilization.* Ibadan, John Willey & Sons,

Iwuafor, E.N.O., Kang, B.T. Nnandi, L.A and Ike, I.F. (1998). Sorghum Performance under Different Tillage and Crop Residue Management System in the Nigerian Guinea Savanna. National Farming Systems. *Research Network Proc.*, 233 – 251.

Michael, A.M., (1978). *Irrigation Theory and Practice.* New Delhi. India, Vikas Publication House., pp. 686 – 739.

Onachela, S.; López, J.C.; Hernández, J.; Granados, M.R.; Magán, J.J.; Cabrera-Corral, F.J.; Bonachela-Guhmann, P.; Baille, A. (2020). How mulching and canopy architecture interact in trapping solar radiation inside a Mediterranean greenhouse. *Agric. For. Meteorol.* 294,

Pala, M., Harris, H.C., Ryan, J., Makboul, R., and Dozom, S. (2000). Tillage Systems and Stubble Management in a Mediterranean Type Environment in Relation to Crop Yield and Soil Moisture, *Experimental Agriculture;* 35: 223-242.

Peng, Z.; Li, L.; Xie, J.; Kang, C.; Essel, E.; Wang, J.; Xie, J. (2018). Shen, J. Effects of conservational tillage on water characteristics in dryland farm of central Gansu, Northwest China. *Chin. J. Appl. Ecol*. **29**, 4022–4028.

Pittelkow, C.M.; Liang, X.Q.; Linquist, B.A.; Groenigen, K.J.; Lee, J.; Lundy, M.E.; Gestel, N.; Johan, S.; Venterea, R.T.; Kessel, C. (2015). Productivity limits and potentials of the principles of conservation agriculture. *Nature* **517**, 365–368.

Power, J.F., (1983). Soil Management for Efficient Water Use. Soil Fertility. In. Jordan et al., (eds), *Limitation to Efficient Water Use in Crop Production.* Pub, ASA CSSA and Madison, USA. Pp. 461-470.

Powell, G.M and Herndon, L.P. (1987). Maintenance of Field Conservation Structures. In *Optimum Erosion Control at least Cost. Proceedings of a National Symposium on Conservation System.* American Society of Agricultural Engineers, St. Joseph-MI, pp. 374-383.

Payne, W.A., Wendt, C.W., and Lascanno, R.J., (1990). Root Zone, Water Balance of three Low Input Fields in Niger. *Agronomy Journal*. **82**: 813-819.

Rayar, A.J. (1983). Response of Groundnut to Application of FYM and N and P on Light Sandy Loam Savanna Soil of Northern Nigeria, *Intern J. Trop.* 4 (1) 46 – 54.

Shao, Y.; Xie, Y.; Wang, C.; Yue, J.; Yao, Y.; Li, X.; Liu, W.; Zhu, Y.; Guo, T. (2016). Effects of different soil conservation tillage approaches on soil nutrients, water use and wheat-maize yield in rainfed dry-land regions of North China. *Eur. J. Agron*. **81**, 37–45.

Sivakumar, M.V.K. (1992). Empirical Analysis of Dry Spells for Agricultural Application in West Africa *J. Clim.*, **5**; 532 – 539.

Souza, L.S.B Moura, M.S.E. Sadiyana, G.C., Silva, T.G.F. (2011). Eficiencia do uso do agua das culturas do milho e do feigas-caupi sab sistemas de plantio exclusive e conseciado no semarido, brasilero, Bragantia; 70. P. 715-721.

Sun, T.; Li, G.; Ning, T.Y.; Zhang, Z.M.; Mi, Q.H.; Lal, R. (2018). Suitability of mulching with biodegradable film to moderate soil temperature and moisture and to increase photosynthesis and yield in peanut. *Agric. Water Manag*. **208**, 214–223

Su, Z.; Zhang, J.; Wu, W.; Cai, D.; Lv, J.; Jiang, G.; Huang, J.; Gao, J.; Hartmann, R.; Gabriels, D. (2007). Effects of conservation tillage practices on winter wheat water-use efficiency and crop yield on the Loess Plateau, China. Agric. *Water Manag*. **87**, 307–314.

Tan, C.; Cao, X.; Yuan, S.; Wang, W.; Feng, Y. (2015). Effects of Long-term Conservation Tillage on Soil Nutrients in Sloping Fields in Regions Characterized by Water and Wind Erosion. *Sci. Rep*. **5**.

Wagger, M.G. and Mullen, R.W., Thomason, W.E and Rann, W.R., (2001). Estimated Land Area Increase of Agricultural Ecosystems to Sesquester Excess Atmospheric Carbon dioxide Common. *Soil Science, Plant Anal* 32.

Young, D.L.; Schillinger, W.F. (2012). Wheat farmers adopt the undercutter fallow method to reduce wind erosion and sustain profitability. *Soil Tillage Res*: **124**, 240–244.

Zaongo, C.G.L., Wendt, C.W., Lascano, R.J., and Juo, A.S.R., (1997). Interaction of Water, Mulch and Nitrogen on Sorghum in Niger. Plant and Soil.**197**; 119 – 126.

Zarea, M.J. (2011). Biodiversity, Biofuels, *Agroforestry and Conservation Agriculture*, **vol. 5**.

Zong, R.; Han, H.; Li, Q. (2021). Grain yield and water-use efficiency of summer maize in response to mulching with different plastic films in the North China Plain. *Exp. Agric*. ***57***, 33–44.