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Effect of conservation agriculture on soil moisture content and biomass water productivity: Case study of crop residues as soil cover

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Key words: Crop residue, Water use efficiency (WUE), Randomized, Biomass, Straw, Treatment

Abstract

One of the important principles of Conservation Agriculture is the permanent soil cover with crop residues which enhances soil and water productivity that leads to improved agricultural productivity. The effect of crop residues on soil moisture content, relative growth rate and biomass water productivity were examined in a completely randomized design at the University of Reading, Berkshire district, England. Straw treatment was significant on moisture content and water use efficiency at ($p< 0.01$) respectively while there is no significant difference on mean relative growth rate and dry final biomass weights. The study concluded that soil moisture content is conserved with increased use of crop residues as soil cover. The study therefore recommended that project based research on Conservation Agriculture should be carried out by governments and NGO's that will involve farmers; also they should provide support for the knowledge diffusion of Conservation Agriculture to local farmers since it will improve yield and productivity. Extension agents and other agencies that work with farmers should also be properly trained to be able to disseminate this technology to farmers.

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Introduction

Conservation Agriculture (CA) is a resource saving concept of agricultural production which aims to achieve acceptable profits and sustainable production levels while saving environmental costs (STOA, 2009). It is based on three basic principles which are minimum soil disturbance or zero tillage operations; permanent soil cover with crop residues or the use of cover crops; and diversification of crops through crop rotation, mainly the rotation of staple crops with legumes depending on farming systems (Dumanski *et al.*, 2006). One of the important principles of Conservation Agriculture is the permanent soil cover with crop residues which enhances soil and water productivity (Hobbs *et al.*, 2007), its water saving capacity through the reduction of evaporation, increased infiltration and run-off reduction has made it very important in improving agricultural productivity (Ling-ling *et al.*, 2011)

Soils under CA are expected to be 100% covered by crop residues and a minimum of 30% coverage is allowed under this system and anything below this is not regarded as Conservation Agriculture (Kassam *et al.*, 2009). Crop residues help in preventing erosion by intercepting rain drops and reducing its energy before hitting the soil, thereby preventing the clogging of soil micro pores and reducing the risk of runoff and erosion (Hobbs *et al.*, 2007); it was found to increase crop yields in Mexico, where zero till plots with residues resulted in higher yields than those without residues (Sayre and Hobbs, 2004); it reduces weed infestation by reducing light access to the weeds and also by the release of allelopatic chemicals that suppresses the growth of weeds by inhibition of surface weed seed germination (Hobbs *et al.,* 2007); it was found to reduce evaporation, soil temperature, increasing aggregate stability, soil porosity and improving water infiltration (Giller *et al.*, 2009); it was also found to reduce the risk of crop failure and drought due to a better water use efficiency in semi-arid regions (Scopel *et al.*, 2004; Bationo *et al.*, 2007; Parry *et al*, 2005). Water availability for crop use is often a major problem to crop production in the tropics (Muchow *et al.,* 1994) and improved use of crop residue can provide a more efficient management of water quality (Unger, 1994; Steiner, 1994). The effect of water conservation using crop residue may potentially lead to increase crop yields in tropical environments especially areas where there are potential risks of drought stress (Lal, 1998).

There have been studies on water conservation capacity of crop residues used as soil cover which is successfully done by the reduction of evaporation of soil moisture and the reduction of water loss through run-off and a reduction of wind and water pressure (Klocke *et al.*, 2004; Klocke *et al.,* 2006; Gicheru, 1994; Powell and Unger, 1997) but there are few studies on the effect of crop residues on water productivity. Therefore, this study examined the effect of conservation agriculture on soil moisture content and biomass water productivity: case study of crop residues as soil cover.
Hence, this study seeks to:

- Examine the effect of crop residues on soil moisture content;
- Examine the effect of crop residues on relative growth rate;
- Examine the effect of crop residues on water use efficiency; and
- Examine the effect of crop residues on biomass production.

Materials and methods

Study Site

This experiment was carried out in the glass house of Agriculture department, University of Reading. The average temperature of the glass house was about 22.86°C with a maximum temperature of 47.13°C on hot days and a minimum of 11.87°C on cooler days. It also has an average relative humidity of about 54.03%RH with a maximum of 85.55%RH and a minimum of 16.73%RH. Recommended irrigation schedules were followed uniformly over all treatments within the experimentfor the first 3 weeks, after which treatments T5 –T8 of the maize crop and treatments T13 – T16 of cowpea with their replicates were made to undergo a drought treatment where no irrigation was applied for the remaining 3 weeks of the experiment, while the remaining treatment's irrigation schedule was maintained.

Experimental Design

The experimental layout of this study was arranged in a completely randomized design for the first week, but was re-arranged into a completely randomized block design of two crops (maize and cowpea) with four treatments and four replicates each (2x4x4) to eliminate the effects of the different positions of the pots in the glass house. The experiment consisted of 64 poly vynil pots, 7 inches in size which was filled three quarter (¾) way with slow fertilizer releasing compost in which the seeds (Maize, cowpea) were planted.

Table 1. Experimental Design.

Treatments	
T1-Maize +0% Soil Cover	T9 – Cowpea + 0% Soil Cover
T2-Maize +50% Soil Cover	T10 – Cowpea + 50% Soil Cover
T3-Maize +100% Soil Cover	T11 – Cowpea + 100% Soil Cover
T4-Maize +150% Soil Cover	T12 – Cowpea +150% Soil Cover
T5-Maize +0% Soil Cover + Drought	T13 – Cowpea + 0% Soil Cover+ Drought
T6-Maize +50% Soil Cover + Drought	T14 – Cowpea + 50% Soil Cover+ Drought
T7-Maize +100% Soil Cover + Drought	T15 – Cowpea + 100% Soil Cover+ Drought
T8-Maize +150% Soil Cover + Drought	T16 – Cowpea + 150% Soil Cover+ Drought

Table 2. Experimental pot layout

T16	T4	T3	T8	T4	T16	T15	T3
T5	T11	T7	T15	T10	T5	T1	T14
T10	T12	T13	T14	T8	T7	T9	T11
T2	T9	T6	T1	T2	T13	T6	T12
T9	T6	T8	T3	T4	T7	T3	T5
T10	T15	T12	T7	T14	T5	T11	T10
T1	T13	T2	T11	T2	T1	T6	T12
T5	T14	T4	T16	T8	T16	T13	T9

Seed and Straw Treatments

The seeds (cowpea and maize seeds) used for this experiment were gotten from the department of Agriculture, which was tested for viability in the seed laboratory according to the germination test procedures of the International seed testing association (ISTA, 2005) before the start of the experiment in the glass house. The straw used in this experiment is dry wheat straw gotten from the university farm in Sonning, the straw was already chopped into reasonable sizes and used as crop residue soil surface cover treatments in varying levels of soil coverage such as 0%, 50%, 100% and 150% as observed in Table 1 below. A 100% sample was represented by 9g of dry wheat straw, which was gotten from sampling and weighing the amount of straw that completely covered the soil surface.

Fig. 1. View of different straw treatments.

Data Collection and Analysis

The data and measurements taken during the experiment includes the rate of emergence (this was recorded immediately after planting by counting the number of plants that emerged above the soil and the time of emergence within the first few days of planting); tether probe readings (for soil velocity and volumetric soil moisture content reading); plant height (this was done on weekly basis except for the 5^{th} week where 3 measurements were taken within a week to emphasize the stagnant growth within the drought treatments compared to the wet treatments); soil core samples (this was taken at the end of the 6weeks experiments); and biomass harvests (this was harvested twice, the first biomass harvest was carried out at the 3^{rd} week and the second at the end of the experiments in week 6). The calculated parameters included the soil moisture content, relative growth rate from biomass and relative growth rate from plant height. Data from all parameters obtained were subjected to an Analysis of Variance (ANOVA) using Genstat computer software, although the final biomass harvest was analysed using an unbalanced Analysis of Variance (ANOVA) to mitigate the effects of the missing plots due to the first harvest done at the 3^{rd} week. Least Significant Difference test (LSD) was performed to separate mean values.

Results

Effect of Crop Residues on Soil Moisture Content

The difference in moisture content between the wet and drought regimes was found to be significant at p<

0.01 with the wet treatment having about 54.87% higher moisture content than the drought treatment, the relationship between the moisture content and both the crops (maize and cowpea) planted and the straw treatments were also found to be significantly different at p=0.003 (p<0.05) and p= 0.004 (p<0.05) respectively where the cowpea was about 3.01% higher than the maize treatments in moisture content and the crop residue treatments 50%, 100% and 150% were 1.17%, 3.77% and 4.99% higher in moisture content than the 0% crop residue treatment [Fig.2 and 3].

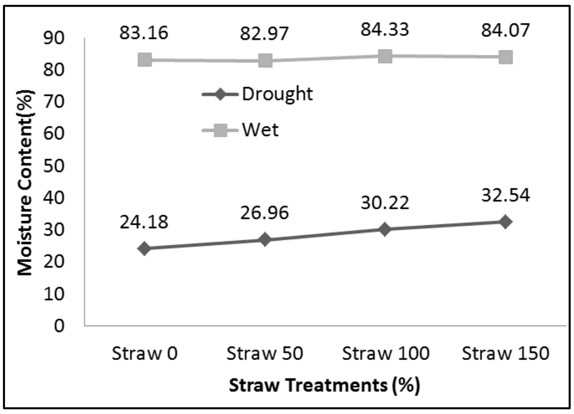

Fig. 2. Relationship between straw and moisture content.

Average least significant difference 3.940

Average standard error of difference 1.913

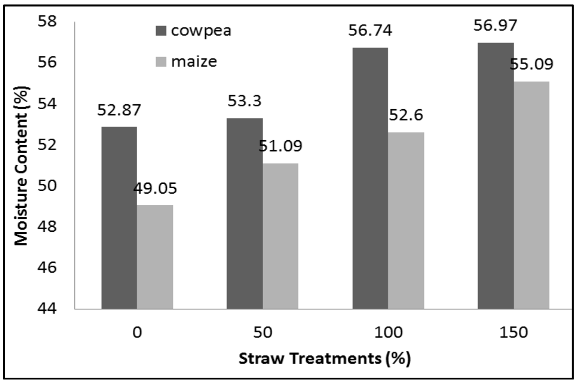

Fig. 3. Relationship between crops and moisture content.

Average least significant difference 3.892

Average standard error of difference 1.890

Effect of Crop Residues on Relative Growth Rate

The effect of crop residue (straw) on the mean relative growth rate was not statistically different, observations from the values gotten shows that some treatments with lower levels of crop residue (straw) inclusion have a higher mean relative growth rate.

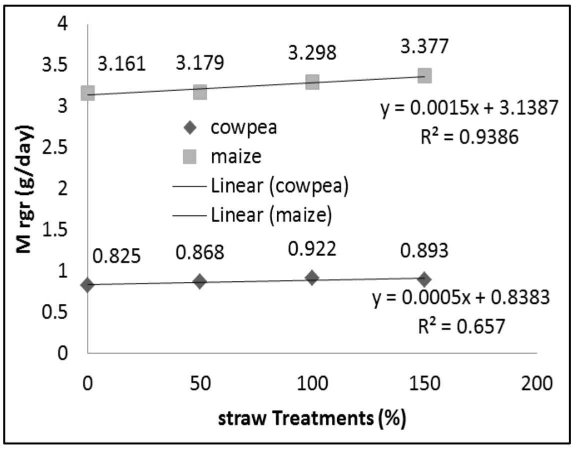

Fig. 4. Relationships between mean relative growth rate (Mrgr), Straw treatments and crops.

Average least significant difference 0.3620

Average standard error of difference 0.1758

Effect of Crop Residues on Water Use Efficiency (WUE)

The effect of individual crops planted on water use efficiency was significant at p≤0.001 with maize crop being 0.0716 higher than the WUE value of cowpea, the straw treatments were also significantly different in their effect on the WUE at p≤0.030 and also having a trend of high WUE mean values with increasing crop residue (straw inclusion), with the 50%, 100% and 150% crop residue treatments having values of 0.0146, 0.02898 and 0.0353 higher than the 0% no crop residue treatment. [Fig. 5].

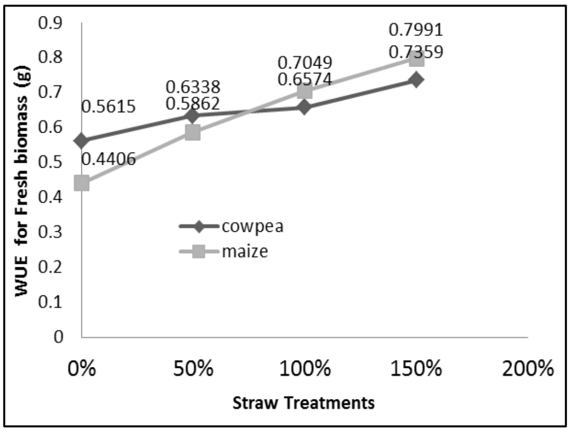

Fig. 5. Relationships between straw treatments, crops and WUE.

Average least significant difference 0.1104

Average standard error of difference 0.05109

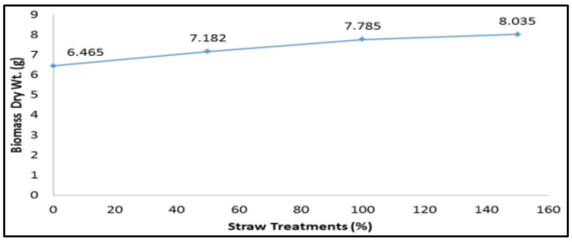

Fig. 6. Relationship between Final biomass dry wt. and Straw treatments.

Average least significant difference 1.200

Average standard error of difference 0.5555

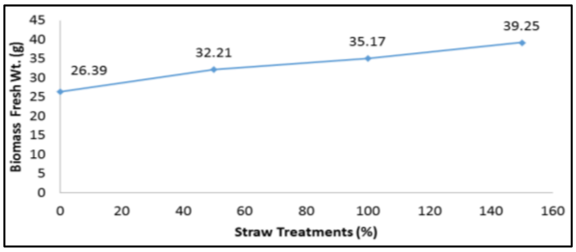

Fig. 7. Relationship between Final biomass fresh wt. and Straw treatments.

Average least significant difference 3.820

Average standard error of difference 1.768

Effect of Crop Residues on Biomass Production

The dry final biomass weights were not significantly different with regards to the straw treatments at $p<0.05$, however, a trend of increasing biomass weight was observed with an increase in straw level as soil cover as shown in Fig. 6 and 7.

On the other hand, effect of the crops were found to be significant at $p<0.001$ with maize crop having about 4.04% biomass dry matter higher than the cowpea treatments.

The difference in the biomass fresh weight was significant at $p<0.001$ for the straw treatments, with the 50%, 100% and 150% straw treatments having 5.86%, 8.78% and 12.86% higher means of biomass fresh weight than the 0% straw treatment respectively. However, the effects of the individual crops planted were not significantly different at $p < 0.05$ level, but the cowpea had a greater weight by 0.59% from the regression predictions.

Table 3. Mean effects of Crop residue (Straw) treatments on calculated parameters.

Straw treatments	Drought						
	Moisture content	Relative height rate	Moisture content	WUE dry	WUE fresh	Biomass dry	Biomass fresh
0%	51.13^{a}	2.188	27.37^{a}	0.1211^{a}	0.5011^{a}	6.465	26.39^{a}
50%	52.30^{ab}	2.193	27.82^{ab}	0.1357^{abc}	0.6100^{b}	7.182	32.21^{b}
100%	54.86^{bc}	2.183	28.87^{bc}	0.1500b^{c}	0.6812^{b}	7.785	35.17^{b}
150%	56.12^{c}	2.194	29.53^{c}	0.1564^{c}	0.7675^{c}	8.083	39.25^{c}
LSD	2.746	0.1789	1.244	0.02325	0.07836	1.183	3.82

Means within a column having the same superscript are not significantly different ($P<0.05$). WUE=Water use efficiency

Discussion

The result from the experiments implies that there is increasing soil moisture conservation with increased level of crop residues used as soil cover, and was significant at $p\leq 0.05$. Cover crop residues influence soil water content as this could help both natural precipitation and irrigation water to infiltrate in the soil where it can be utilized by plants. Which makes moisture available for efficient plant growth and biomass production, as this will help to improve agricultural productivity in the Arid and semi-arid regions. This is in line with the study carried out by Klocke*et al.*, (2006) where treatments with 100% crop residue soil cover was observed to have the highest moisture conservation capacity. The inclusion of crop residues as mulch were also found to conserve more moisture down the soil profile in two growing seasons within two years (Gicheru, 1994).

The relationship between the mean relative growth rate, straw treatments and crops is shown in Fig. 4, where treatments with the highest biomass outputs do not have the highest mean relative growth rate. This is similar to the results of Verhulst*et al.*, (2001), where treatments with zero tillage and crop residue retention had a slow initial growth but however, increased growth in the later stages making up for initial loss in growth rate.

The sample crops used in the study performed better in terms of growth and water use efficiency accordingly as evident in Fig.s 4 and 5 above. Biomass production increases with an increased soil cover which indicates that the availability of more moisture in the soil improved the biomass productivity as seen in Fig.s 6 and 7 above. This will give farmers the avenue to produce enough biomass to use as soil cover and also as feed their livestock.

The residues apart from conserving soil moisture, also increases soil fertility when the residues decay leading to improved biomass production. It has also been observed that the presence of these crop residues eventually reduces weeds on the farm thereby reducing the cost of farm management and Agricultural productivity in terms of herbicide use or cost of manual labour.

This implies that Conservation Agriculture (use of crop residue as soil cover) has the potential to increase crop yields, this is evident in that treatments with crop residue inclusion 50%, 100% and 150% have a better water use efficiency than the treatment with no crop residue (0%) and subsequently also having a higher biomass yield.

Conclusion

This study concluded that soil moisture content is conserved with increased use of crop residues as soil cover, and increase crop water productivity by improved biomass yield. Also, with the use of crop residues as soil cover, the risk of drought can be reduced. This study therefore recommends based on the findings that project based research should be carried out by governments and NGO's that involves farmers where farmer field schools and other extension tools can be used to both introduce the technology and also involve local knowledge in its refinement, since this study was carried out in a controlled greenhouse experiment. Government, social structures and NGO's should provide support for the knowledge diffusion of Conservation Agriculture which include soil cover as one of its principles especially to local farmers for improved rate of adoption. Also, extension agents and other agencies that work with farmers should be properly trained to be able to disseminate this technology to farmers.

References

Bationo A, Kihara J, Vanlauwe B, Waswa B, Kinetu J. 2007. Soil Organic Carbon Dynamics, Functions and Management in West African Agro-ecosystems. Agricultural Systems **94,**12-25.

Dumanski J, Peiretti R, Benetis J, McGarry D, Pieri C. 2006. The paradigm of conservation tillage. In: Proceedings of the World Association of Soil and Water Conservation P1-7, pp. 58–65. Beijing, P.R. China.

Gicheru PT. 1994. Effects of residue mulch and tillage on soil moisture conservation. SoilTechnology **7(3),** 209-220.

Giller KE, Witter E, Corbeels M, Tittonell P. 2009. Conservation Agriculture and Small Holder Farming in Africa: The heretics view. Field Crops Research **144(1),** 23-34

Hobbs PR, Sayre K, Gupta R. 2007. The role of conservation agriculture in sustainable agriculture. Phil. Trans. The Royal Society B. **363(1491),** 543-555.

International Seed Testing Association. 2005. Germination Test. International rules for seed testing. The Seed Testing Association, Bassersdorf, CH-Switzerland.

Kassam A, Friedrich T, Shaxson F, Pretty J. 2009. The Spread of Conservation Agriculture: Justification, Sustainability and Uptake. International Journal of Agricultural Sustainability **7(4)**, 292-320. DOI: 10.3763/ijas.2009.0477

Klocke NL, Currie RS, Dumler TJ. 2006. The effects of crop residue on sprinkler irrigation management. In: Colby, K.S., (Edt) Central plains irrigation conference and exposition proceedings pp. 115-121.

Klocke NL, Schneekloth JP, Melvin SR, Clark RT, Payero JO. 2004. Field Scale Limited Irrigation Scenarios for Water Policy Strategies. J. of App. Eng. in Agric **20(5),** 623-631.

Lal R. 1998. Mulching effects on runoff, soil erosion and crop response on alfisols in western Nigeria, Journal of Sustainable Agriculture **11,** 135-154.

Ling-ling LI, Gao-bao H, Ren-zhi Z, Belloti B, Li G, Chan KY. 2011. Benefits of conservation agriculture on soil and water conservation and its progress in China. Agricultural Sciences in China **10(6),** 850-859.

Muchow RC, Hammer GL, Vanderlip RL. 1994. Assessing climatic risk to sorghum production in water-limited subtropical environments II Effects of planting date, soil water at planting and cultivar phenology. Field Crop Research **36,** 235-246.

Parry MAJ, Flexas J, Medrano H. 2005. Prospects for crop production under drought: research priorities and future directions. Annuals for Applied Biology **147,** 211-226.

Powell JM, Unger PW. 1997. Alternatives to Crop Residues for SoilAmendment. In: Renard, C., (Edtr.) Crop Residue in sustainable Mixed Crop/Livestock Farming System. CAB international. Wallingford Oxon OX 10 8DE UK.

Sayre KD, Hobbs PR. 2004. The Raised-bed System of Cultivation for Irrigated Production Conditions. In: Lal, R., Hobbs, P., Uphoff, N. and Hansen, D.O., (Eds) Sustainable agriculture and rice-wheat system. Paper 20 2004 pp.337-355. Columbus, OH: Ohio State University.

Scopel E, Triomph B, Seguy L, dos Santos Ribeiro MF, Denardin JE, Kochhan RA. 2004. Direct Seeding Mulch-Based Cropping Systems (DMC) in Latin America. Communication presented at the 4th International crop science congress Brisbane, Australia. 26th September to 1st October 2004.

STOA. 2009. Conservation Agriculture: Final Report, Agricultural Technologies for Developing Countries, STOA project "Agricultural technologies for developing countries" April 2009. European Technology Assessment Group (ETAG). ITAS. DBT. Viwta. POST. Rathenau.

Verhulst N, Govaets B, Nelissen V, Sayre KD, Crossa J, Raes D, Deckers J. 2011. The Effect of Tillage, Crop Rotation and Residue Management on Maize and Wheat Growth and Development Evaluated with Optical Sensor. Field Crops Research **120(1),** 58-67.
DOI:10.1016/j.fcr.2010.08.012.