Physical Properties of an Ultisol Under Plastic Film and No-Mulches and their Effect on the Yield of Maize

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Abstract: Film mulching is an important agricultural practices used to improve crop productivity .Field experiments were conducted using maize (*Zea mays L.*) to determine the effect of film mulching on soil physical properties and maize yield in 2006 and 2007 cropping seasons. The experiment was a randomized complete block design (RCBD) with four film treatments viz. Black film (BM), white film (WM), Black / white film (BWM) and no-treatment (NM). Seedling from three mulching treatments emerged 2days earlier than those from non-mulched treatments. Film mulching significantly ($P \leq 0.05$) increased soil temperature (taken at different times) and water retention relative to the un-mulched treatments. Results of the study show bulk density decrease of 9% (BWM), 4% (WM) and 17% (BM) at 45 DAP in the first season and 4% (BM), 1% (BWM) and 6% (WM) at 90 DAP in the second season compared to the un-mulched treatment. Yield increase of 55 – 78% (first season) and 108 – 142% (second season) were observed in film mulch treatment relative to the control. Film mulch can be used to increase crop production to meet the food need of the increasing human population.[Journal of American Science 2009; 5(5):25-30].(ISSN:1545-1003)

Key words: *Film mulch, crop productivity, physical properties, human population, agricultural practice.*

1. Introduction

Soil is a fundamental resource for agricultural production and the most important possession and input of farmers (Brady and Weil; 1999). Proper soil management is one key factor threatening sustainability (Smith *et al.* 1995). Intensive and sustainable crop production in tropical soils required soil management practices in order to prevent yield failures. The aim of proper land management could be to determine how best to utilize land resource in the rain fed agriculture, as such there is need to protect the soil and conserve it. Erosion causes fertility decline due to the removal of humus and clay fraction in the soil. The global economic loss due to accelerated erosion is very high (Pimentel *et al.* 1995). In order to stop the destructive force of water and wind it is necessary to cover the soil surface as much as possible. This can only be achieved by using mulch in agricultural (Beegle *et al.* 2000). According to Opara-Nnadi (1989) mulch helps to improve the soil environment for optimum crop growth and yield. Mulches are either organic (derived from plant and animal materials) or in organic (plastic film).The most frequently used organic materials include plant residues such as straw, hay, peanut hull, and compost; wood products such as saw dust, wood chips/shavings and animal wastes .However, natural mulch materials are often not available in adequate quantities for commercial operations or must be hauled to the place of use (McCraws and Motes, 2004). Again natural materials are not easily spread on growing crops and require considerable hand labour. Thus expense and logistic problems have generally restricted use of organic mulch to home gardeners and small market gardener with only limited use of a large commercial scale, (McCraws and Motes, 2004).Organic mulches properly utilized can perform all the benefits of any mulch with possible exception of early season soil warming .Similarly excessive use of unsorted organic wastes as mulches may likely lead to changes in soil physical and chemical characteristics .This can distort the inter-relationships among biophysical and chemical soil functions. It may also lead to loading of nitrates and heavy metals in the soil and ground water (Vousta *et al.* 1996) .In order to achieve sufficient food supply the primary requirement is not to research into new method but the increase application of techniques and practices that are already available and approved feasible. In the last three decades plastic film much cultivation has gradually become a great break through in agricultural production protected cultivation normally represented by plastic film mulching has greatly improved crop production Gu and Gu,2000 ;Liang *et al.* 1999). However, despite its numerous benefits and World-wide spread in tropical USA, Europe and China, its use in the Sub-Sahara Africa is at infant stage or not at all. This research is aimed at evaluating the changes in soil temperature, bulk density, total porosity, water retention, dispersion ratio, seed emergence / growth and yield of maize associated with the use of plastic film and no-mulch materials in an ultisol in Abakaliki- South Eastern Nigeria.

2. Materials and Methods

The study was conducted in 2006 and 2007 growing seasons at the Teaching and Research Farm of Faculty of Agriculture and Natural Resource Management, Ebonyi State University, Abakaliki. The area is located at latitude $06^o\ 4^1$ N and longitude $08^o\ 65^1$ E in the derived Savannah of the South East agro-ecological zone.

According to Ofomata (1995) the minimum and maximum temperature of the area are 27°C and 31°C, respectively. The area experiences bimodal patterns of rainfall (April – July) and (September – November) with short spell in August. The total annual mean rainfall ranges between 1700 to 2000 mm. The soil belongs to the order ultisol (FDALR, 1985) and classified as Tyic- Haplustult.

2.1 Experimental Layout and Management

The experiments were carried out in 2006 and 2007 growing seasons. It was laid out in Randomized Complete Block Design (RCBD) with plot sizes measuring 3m x 3m replicated four times. A land area measuring $199.5m^2$ (equivalent to 0.01975, ha) was marked out, slashed and cleared of grasses. The field was divided into four blocks with each block having five experimental units giving a total of 20 plots. The experimental units were demarcated by 1m alleys.

A maize variety (Oba – super 11) was planted at a spacing of 0.5m x 0.5m inter and intra-row at two maize plants per hill. The treatments were black plastic film mulch (BM), white plastic film mulch (WM), black / white (BWM) plastic film and no mulch (NM). Before sowing the black, black/white and white plastic film mulch (3x3 cm, wide and 0.0075m thick) were applied on soil surface with the edges tied tightly under the soil. There were six rows of plant in each plot. Among the six rows three were taken for routine sampling area, the others were left for crop yield assessment. Thinning was carried out two weeks after germination to one plant per hole, to give 36 stands/plot equivalent to 53,000 plants/ha. The no-mulched plots were kept relatively weed free by removing the weeds. At the end of the experiment in 2006 the plastic film were removed. The same procedure as described above was repeated in the 2007 planting season.

2.2 Sampling and analysis:

The following soil properties were determined. Particle size distribution was determined by the hydrometer method (Gee and Bauder, 1986). Undisturbed soil core samples we collected from each plot at 45 and 90 days after planting (DAP). The core samples were used to determine the dry bulk density using, the core method as outlined by Blake and Hartge (1986) . Total porosity was calculated from bulk density data using the formula;

$Tp = (1-^{bd}/pd) \times 100$ where

Pd = Particle density (assumed to be $2.65gcm^{-3}$)

Bd =Bulk density.

Volumetric water content of the soil was determined as described by Klute (1986), while dispersion ration was determined using the techniques of Nkidi-kizza *et al.* (1984). Maize emergence was counted at ten days after planting while soil temperature was taken at two points in each plot between 12-1pm at a depth of 5cm using soil thermometer at 14, 40 and 75 DAP. At maturity plant height was taken using meter rule. Similarly maize was harvested and the grain air dried, weighed and expressed on a 12.5% content.

Data collected from the study was analyzed using analysis of variance test based on RCBD according to the procedures outlined by Steel and Torrie (1980).

3 Results:

The particle size analysis (Table 1) showed that the texture of the soil is sandy clay loam.

Table 2 show that plastic film mulching significantly ($p < 0.05$) increased soil temperature in both seasons. In both cropping seasons WM gave the highest soil temperature values at the different periods of measurements.

Table 1: Soil Particle size distribution

Particle size distribution	Values%
Sand	69
Silt	6
Clay	25
Texture	Sandy clay loam

Table 2: Effects on Soil temperature taken on 14, 40 and 75 DAP

	2006			2007		
DAP	14	40	75	14	40	75
BWM	27.6	28.6	29.78	28.0	29.0	29.6
WM	28.1	28.8	30.2	29.0	30.1	30.3
BM	26.0	26.4	27.2	27.0	28.3	29.6
NM	25.0	26.0	26.8	26.6	28.0	28.9
$LSD_{0.05}$	0.345	0.460	0.399	0.131	0.103	0.140

BM = Black film, mulch, WM = White film Mulch, BWM = Black/White Mulch, NM = No Mulch.

The observed soil temperature values in the WM plots were 28.1°C, 28.8°C and 30.2°C at 14, 40 and 75 DAP in the first season. At 14 DAP the values were 2%, 8% and 12% higher than BMW, BM and non-mulched (NM) plots, respectively. Similarly, soil temperature values in the mulched plots were increased by 9, 2 and 5% relative to the control for WM ,BWM ,BM and BM, respectively at 14 DAP in the second season. The order of soil temperature increase at 75 DAP in the second season was WM>WBM=BM>NM. Table 3 show higher bulk density values of 1.25 and 1.40gcm^{-3} at 45 and 90 DAP respectively, in the non-mulched plot in the first season. At 45 DAP in the first season bulk density values were smaller in the mulched plots relative to the control by 9% (WBM), 4% (WM) and 17% (BM). Similarly lower bulk density values of 1.34gcm^{-3} (BM), 1.40 gcm^{-3}(WM) and 1.34 gcm^{-3} (BWM) were observed in plastic film mulched plots relative to 1.42gcm^{-3} observed in no-mulched plots at 90 DAP in the second season.

Table 3: Effect on Bulk density (gcm^{-3}) and total porosity (%).

	2006				2007			
	BD		TP		BD		TP	
Treatment	45	90	45	90	45	90	45	90
BM	1.04	1. 61	61	49	1.15	1.34	57	49
WM	1.20	1.34	55	49	1.16	1.40	56	47
BWM	1.14	1.37	67	48	1.10	1.34	58	49
NM	1.25	1.40	57	47	1.24	1.42	53	46
LSD $_{0.05}$	0.076	0.032	0.779	1.06	0.030	0.015	0.174	1.03

BM = Black film, mulch, WM = White film Mulch,
BWM = Black/White Mulch, NM = No Mulch.

Table 3 also show that plastic film mulches increased the total porosity of the soil relative to the control. At both growing seasons the lowest porosity values were observed in non-mulched plots. At 45 and 90 DAP the order of porosity increase were BWM > BM > WM > NM in the first season.

Result of the study on table 4 show that plastic film mulches significantly (P = 0.05) increased soil moisture retention relative to the no-mulched plots in both seasons. In the first season moisture retained at BWM plots (30.2) was higher than WM, BM and NM plots by 11, 5 and 45%, respectively. Similarly higher moisture retention values of 50.1% (BWM), 48.7% (WM) and 43.0 %(BM) were observed in plastic film mulched plots relative to lower value of 40.0% (NM) observed in the control or no-mulched plot. In both seasons the effects of plastic film mulches on dispersion ratio were non-significant (Table 4).

Table 4: Effect on Water retention and Dispersion ratio

	2006		2007	
Treatment	WR	DR	WR	DR
BM	28.7	0.88	43.0	0.89
WM	27.2	0.95	48.7	0.90
BWM	30.2	0.89	50.	0.90
NM	20.8	0.88	40.0	0.87
LSD $_{0.05}$	0.596	NS	0.371	NS

BM = Black film, mulch, WM = White film Mulch,
BWM = Black/White Mulch, NM = Not Mulch.

Plastic film mulching gave significantly higher plant height relative to the non-mulched plots (Table 5). The tallest plants (126.6 and 130.46cm) were observed in BM and BWM plots, respectively, in the first and second seasons. The order of plant height increase in the first season was BM > WM > BWM > NM. In the second season plant height in the no-mulched plot showed 125, 91 and 71% decrease compared to BM, WM and BWM in mulched plots respectively.

Table 5 also show significantly higher yield in plastic film mulched plots relative to the no-mulched plots in both seasons. Yield increase was the highest in WM (2.32) in the first season. The observed values (2.32 t ha^{-1}) in WM plots was 5%, 19% and 78% higher than yield values observed in BWM, BM and no-mulched plots respectively. The order of yield increase was BWM > WM > BM > NM in the second season.

Table 5: Effect on maize growth (cm) and yield (tha^{1})

	2006		2007	
Treatment	Growth	Yield	Growth	Yield
BM	126.60	2.02	110.28	2.50
WM	107.04	2.32	73.32	2.62
BMW	96.30	2.20	130.46	1.90
NM	56.20	1.30	50.38	1.20
LSD $_{(0.05)}$	1.852	0.163	0.794	0.078

BM = Black film, mulch, WM = White film Mulch,
BWM = Black/White Mulch, NM = No Mulch.

Germination count taken at 7DAP-show 95 and 98% seedling emergence on plastic film mulched plots and 78 and 80% in no-mulched plots in the first and second seasons, respectively. Generally, seedling emergence was 2 days earlier inplastic film mulched plots relative to the no-mulched plots.

4. Discussions:

Plastic film mulch increased the soil temperature due to its ability to intercept sunlight which warms the soil. At the different times of reading WM gave the highest soil temperature values in both seasons due to its thermal properties of reflection, absorption and transmission. Study by Larment (1999) showed that white plastic mulch absorbs little solar radiation but transmits 90-95% (depending on the degree and it opacity), while black film mulches absorbs ultraviolet, visible and infrared wavelengths of incoming solar-radiation and re-radiates absorbed energy in the form of thermal radiation or long-wavelength infra-red radiation. Due to higher thermal conductivity in soil relative to that of the air, black plastic transfers much of its absorbed energy to the soil by conduction. According to Schales and Sheldrake (1967) black plastic film mulches losses much of solar energy

through radiation and forced convection thus resulting to lower temperature readings relative to white plastic film. The results of this study conforms with the observation of Anikwe *et al.* (2007) when they evaluated the effects of tillage and plastic mulching on soil properties and yield of cocoyam on an ultisol in Southern Eastern Nigeria.
Katan (1976) showed that using plastic film mulch to achieve high soil temperature helps to destroy soil pathogenic weeds nematodes. The increased soil moisture observed in plastic film mulched plots may be attributed to its ability to prevent soil water loss during dry times and shedding of excessive water from crop root zone during dry excessive rainfall. The observed increased soil temperature and moisture retention resulted to seeding emergence 2 days earlier in plastic – film mulched plots than in the no – mulched plots. Studies by Li *et al.* (1999) and Gan and Stottle (1996) showed earlier seedling emergence in plastic film mulched plats relative to no-mulched plots. The early seedling emergence is crucial for initial dry matter production and growth of crops Gan and Stottle (1996). According to Loy *et al.* (1998) the early growth response of crops on plastic film mulches is due to reflection of PAR into plant canopy, increased photosynthesis and biomass accumulation. The increased growth and yield observed in plastic film mulched plots could be attributed to its ability to increase soil temperature, water retention, soil porosity and decrease soil bulk density. Guo and Gu (2000) and Han and Wan (1993) showed that plastic film mulches raises soil temperature there by promoting faster crop development and increased yields. Bulk density is a soil parameter that is used to quantify soil compactness. Soil compaction increases bulk density and decreases pore volume (Koistra and Tovey, 1994). Mbah *et al.* (2004) reported that high bulk density results in reduced water infiltration into the soil, reduced aeration and poor root penetration, resulting in reduction in crop yield. The increase porosity and decreased compaction (due to decreased soil bulk density) in plastic film mulched plots may have enhanced aeration and microbial activities in the soil thus resulting to increased root penetration and cumulative feeding area leading to increased plant growth and yield in line with the observations of (Mbah *et al.* (2004),Obi and Ebo, (1995) and Mbah *et al* .(2001).

Conclusion:
Results from the study showed that plastic film mulches improved the soil physical properties such as the soil water content and the temperature in top soil layers, prompting emergence of seedling and greater root distribution in soil. The improved soil physical properties lead to increased plant growth and yield. Film mulch practice had much more room for supporting food to support population. Similarly if utilized by farmers, more fragile and marginal land, can be utilized for crop production.

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