Comparative Effects of Organic and Plastic Mulches on the Environment, Growth and Yield of Okra in A Derived Savanna Zone of Nigeria

Aniekwe, N.L.

Department of Crop Production and Landscape Management, Faculty of Agriculture and Natural Resources Management, Ebonyi State University, Abakaliki, PMB 053, Ebonyi State, 480001, Nigeria

Abstract: ***The effectiveness of grass and black plastic mulches in modulating the environment, growth and yield of okra was compared in field experiments as the rainy season was winding up in Abakaliki, a derived savanna zone of Southeastern Nigeria. Black plastic mulch raised the soil daily temperature higher, promoted earliness in okra seed germination and flowering, prevented complete weed growth and influenced higher germination percentage than both grass and zero mulches while, grass mulch did better than the zero mulch treatment in all the parameters in 2009 than in 2008. There was 100% weed suppression on the black plastic mulched beds, while 54.9% weed suppression was achieved by grass mulch, and soil temperatures were significantly modulated for good crop growth by both mulches. The use of plastic mulch (plasticulture) is a veritable tool in promoting vegetable production in this zone as it promoted crop growth and yield, impacted on the environment especially weed control in comparison with organic mulch on an exotic okra variety "Clemson spineless" and hence, highly recommended in this zone.***

Keywords: Black plastic mulch; Grass mulch; Plasticulture; Rainy season; Clemson spineless

1. Introduction

Okra [*Abelmoschus esculentus* (L) Moench], which the Anglophone African countries know as ‘okro', a member of the plant family, Malvaceae with a diploid chromosome number (2n=72), is a fast growing common annual vegetable widely cultivated and consumed in Africa and is found in almost all her markets [20]. [19]-[20] reported that there are two okra species identified and cultivated throughout the tropics and subtropics in the rainforest and savanna zones of the northern Indian region where it is said to have originated, as well as in the temperate zones. These include the common okra [*Abelmoschus esculentus* (L) Moench] and the West African Okra [*Abelmoschus caillei* (A. Chev.) Stevels]. The common okra is much more day length - neutral than the West African okra although, both are highly polymorphic in character. Exotic varieties are now in common cultivation which are less mucilaginous, yet they produce higher number of pods with a smaller uniform plant forms which can be harvested within 3 months and sometimes as early as 6 weeks after planting. This is the class where the Clemson spineless, Lady’s finger, etc. belong.

Okra is an important multipurpose and versatile crop with edible leaves but essentially grown in Nigeria for its young fruits which have been found to possess a rich nutritional profile per 100g. The dry matter content of the young okra fruits is found to be 10.4 g, energy 31 Kcal, protein 1.8 g, calcium 90 mg, phosphorus 56 mg, magnesium 43 mg, iron 1.0 mg, carotene 0.l mg; thiamine 0.07 mg, riboflavin 0.08 mg, niacin 0.8 mg, vitamin C 18 mg, while the seed contains 20% lipids, 20-30% protein which compares favourably with those of poultry eggs and soybean, 6% ash and a good percentage of vitamin E [4], [7]-[9], [13]-[14]. The mucilaginous preparations can be used medicinally for curing ulcers, as a plasma replacement or blood volume expander and as a clarifying agent in sugarcane processing [19], [23]. The large vigorous and robust stems of West African okra are excellent sources of pulp for making paper [14], when dried it is used for making ropes, fish lines and hammocks [24]. Okra is also a good source of gum, while the ground pulp of *A. caillei* stems is used as a stabilizer when making "pita beer" in northern Ghana and the attractive okra flowers can be used to decorate homes [20].

Mulching practices have been a common activity in vegetable production for better growth and good yield of most horticultural crops. However, the importance of mulch is predicated on its effectiveness in the control of weed growth, soil runoff, conservation of moisture, reduction of soil compaction by rain drops and temperature regulation [18]. The degree, to which these factors are controlled, varies with different mulching materials used. [10], reported high yields with mulching technology while [6], reported rapid growth and heavy yields of tomato and sweet pepper with black plastic mulch than with grass mulch especially if the grass mulch contains mature weed seed. [25], observed that grass mulch increased crop yield but complete weed control was not achieved with grass mulch. [11] stated that plasticulture is a management tool that enables vegetable producers realize greater returns per unit of land, and maintains that such system may offer the following benefits, earlier crop production, higher yield/ha, cleaner and higher quality produce, more efficient use of water resources, reduced leaching of fertilizer inputs with fertigation technology, reduced soil and wind erosion, potential decrease in the incidence of disease, better management of certain insect pests, fewer weed problems, reduced soil compaction and elimination of root pruning and opportunity to double or triple-crop production in a cropping season with maximum efficiency.

Much of the early university research before 1960 was conducted on the impact of colour) black or clear plastic film) on soil and air temperature, moisture retention and vegetable yields per film colour [3]. Plastic mulches directly affect the microclimate around the plant by modifying the radiation budget (absorbitivity versus reflectivity) of the surface and decreasing the soil water loss [12], [22]. Black plastic much, the predominant colour used in vegetable production, is an opaque blackbody absorber and radiator, which absorbs most ultraviolet (UV) visible and infrared wave lengths of incoming solar radiation and reradiates absorbed energy in the form of thermal radiation of long wavelength infrared radiation. Much of the solar energy absorbed by black plastic mulch can be reduced by ensuring a good contact between black plastic mulch and the soil surface [11].

For vegetable growers to remain competitive in today's market place, they must strive continually for high quality, superior yields and extended production cycles in the rainy and dry season crops which could be possible by the application of plasticulture. The usual annual okra glut in the season is no longer an acceptable economic experience considering the high cost of labour and farming inputs. One wise way of avoiding this situation is to spread okra supply by extending production out of season. Hence the main objective in carrying out this experiment was to determine the microclimate modifying potentials of organic (grass) mulch and black plastic mulch materials during the receding of the rainy season.

2. Materials and Methods

This experiment was carried out in 2008 and 2009 on the research farm of Faculty of Agriculture and Natural Resources Management (FARM), Ebonyi State University, Abakaliki, a derived savanna zone of Southeastern Nigeria, as rainy season was winding up. The research farm is lying on latitude 06^0 19´ 407´´ N and longitude 08^o 07´ 831´´ E at an altitude of about 447 m above sea level with a mean rainfall of between 1700 mm to 2060 mm spreading from April to October annually. The maximum mean daily temperature is between 27^o C to 31^o C with abundant sunshine and a high humidity all through the year except in the months of hamartan. The soil is shallow with unconsolidated parent materials (shale residuum) within 1m of the soil surface, described as *Eutric Leptosol* [5], [1]. The soil analysis of the Farm over the years has shown that the soil is slightly acidic with a pH of 5.5 and a very low percentage organic matter. The experiment was arranged in a randomized complete block design (RCBD) with four replications in l2 beds of 4 x 2 meters made one meter apart. The effect of black plastic mulch was compared with organic (grass) mulch, while unmulched beds served as a control on a single exotic okra variety Clemson spineless, a short early maturing crop plant. Immediately after bed making prior to application of mulches, a blanket application of NPK (15: l5:15) fertilizer was made at the rate of 400 kg/ha as suggested by [15]. The grass mulch (from a nearby mowed playing field) was applied to four beds, while a sheet of the black plastic mulch measuring 4.5 x 2.5 meters was placed over another four beds using the projections to fix it in the soil by heaps of soil on the four corners of the beds. Holes wide enough (10 cm^2) to admit seeds and rainfall were cut at a spacing of 60 x 45cm on the plastic mulch before seeds were sown, while the remaining four beds were used as control. Two okra seeds per hole were sown in all the l2 beds at a plant spacing of 60cm x 45cm. Four rows containing six plant stands per row, which at two seeds per stand, adds up to 48 plant stands per bed/plot of which two middle rows and four middle plant stands constituted the observational units from which data were collected. Weeds were manually removed every three weeks on the unmulched and grass mulched beds, and fresh and dry weed weights taken. Harvesting started six weeks after planting and continued for four weeks at regular intervals of 5 days. Growth and yield parameters measured included seed germination counts, plant height, pod weight, leaf number. Data analysis was done using the analysis of variance (ANOVA) procedures recommended by [21], while mean separation was carried out according to [2] as illustrated by [17].

3. Results and Discussion

3.1 Soil Temperature

Table 1 indicates that black plastic mulch had a high significant ($p<0.05$) effect on the morning (0700 GMT), evening (1600 GMT) and the daily average soil temperatures over the organic (grass) mulch. This is the most interesting result from experiments with plastic mulching techniques in addition to improvements on germination rates of seeds, general growth and yield parameters and complete weed suppression as collaborated by [6], [11]-[12].

Table 1: Daily soil temperature (^{o}C) measurements under grass and plastic mulches in Abakaliki

Mulch type	Morning (0700 GMT)		Evening (1600 GMT)		Daily average	
			Depth		Year	
	15cm	30cm	15cm	30cm	2008	2009
Black plastic mulch	27	27.5 (28.1)	28.3	29.3 (30.2)	28	28.4
Grass mulch	26.8	26.8 (27.3)	27.8	28.0 (29.3)	27.4	27.8
Zero mulch	27.5 (27.6)	26.5	27.8 (28.3)	28	27.5	27.6
F-LSD (P=0.05)	0.5	0.5	0.5	0.5	0.5	0.5

The average daily temperature under black plastic mulch in 2008 (28.0^{o}C) and 2009 (28.4^{o}C) were the highest in comparison with grass mulch which in turn was higher on the unmulched plots. Black plastic mulched plots also consistently influenced higher soil temperatures at 15cm and 30cm depths in both morning and evening measurements. At the 30cm depth, black plastic mulch raised the soil temperature higher than it did at 15cm deep in the morning and evening periods. This observation is in consonance with the notable properties of black bodies as good heat emitters as well as good heat absorbers. The heat radiated from the sun during the day is absorbed by the black plastic mulch and emitted to the soil surface which was transmitted through the soil in proportion to the heat received. Bare soil surfaces absorb heat radiated from the sun during the day and radiates it at night to the air outside, thus the ground is cooler at night. Whereas, the effect of black plastic mulch on the microclimate is celebrated, it is worthy of note that the organic (grass) mulch was equally significant compared to the control, especially at this period of the season when the rains were scanty.

3.2 Germination Rate

In Table 2, the good temperature modulation by the black plastic mulch resulted in the high percentage germination rate observed on such mulched plots in both years (90% in 2008 and 86% in 2009). This shows that the microclimate of the seed environment was adequately modified as documented by [1I] that plasticulture enabled early and high seed germination which caused the seeds to attain the (90%) germination percentage four days after planting as indicated on the seed sachet by the seed producers (Premier Seeds Nigeria Limited).

Table 2: Effects of grass and plastic mulches on mean germination rate of Clemson spineless variety of Okra seeds

Mulch	Mean germination	% germination
	2008	
Black Plastic mulch	43.2	90
Grass mulch	21.6	45
Zero mulch	10.9	22.8
F-LSD (P= 0.05)	0.95	
	2009	
Black Plastic mulch	41.3	86
Grass mulch	32.6	68
Zero mulch	16.8	35
F-LSD (P= 0.05)	0.95	

The lower germination rates (45% in 2008 and 68% in 2009) and the lower percentage germination (22.8% in 2008 and 35% in 2009) obtained from the grass mulch in comparison with that of black plastic mulch was still significantly ($p<0.05$) higher that what was obtained from the unmulched plots (control). When this result is viewed from the angle of significance, the importance of black plastic mulch becomes more obvious as seed germination under plastic mulched beds was 90% four days after planting while, the hook was just peeping in the grass mulched beds and nothing showed up on the unmulched beds in 2008. In 2008, seven days after sowing, plants on the black plastic mulched beds produced three leaves while, 45% germinated on grass mulched beds and 22.9% germinated on the unmulched beds. [18] reported that rapid cassava stem production was achieved under black plastic mulch which raised the soil temperature, in addition to conservation of soil moisture and soil nutrients, protection of soil structure and prevention of soil erosion. Truly, vegetable production can be increased by the use of black plastic mulch in this agro-ecological zone of Nigeria as well as with other mulching materials like organic materials. Subsequently, it is very possible that the soil property under the grass mulch would improve significantly following its decomposition, in terms of soil fertility and physical soil properties, as added advantage for using grass as mulch. This aspect could be investigated in future study.

3.3 Weed Growth Control

The data on weed growth shown in Table 3 indicates that the weed control property of black plastic mulch is superb as there was complete and effective 100% suppression of weed growth by its application. On the other hand, organic (grass) mulch had fair complete weed growth control than the un-mulched beds. [16], emphasized weed control was a daily problem for the vegetable growers in the Tropics, even more than in temperate or Mediterranean climate; stating that in West Indies, one month weed-free periods are recommended for bean, tomato and sweet potato and up to 10 weeks for pigeon pea, and a whole growing periods for staked yam and *Allium spp*.

Table 3: Effects of grass and plastic mulches on the fresh and dry weed weights (kg/plot) in Abakaliki

Mulch	Fresh weight	Dry weight	% weed suppression
	2008		
Black plastic mulch	-	-	100 % suppression
Grass mulch	412.0	86.0	54.9 %
Zero mulch	750.0	156.0	No suppression
2009			
Black plastic mulch	-	-	100% suppression
Grass mulch	312.25	46.0	40.6 %
Zero mulch	768.7	220.0	No suppression

Different crops suffer or resist the competitive effects of weeds with varying degrees of success, in the different weeding methods practiced were intended to prevent. Mulching with organic wastes or with opaque, black, smoke grey or green plastic sheets achieves a very much better results [16] as implicated in this experiment. While 100% weed suppression was achieved in both years on the black plastic mulched plots, 54.9% weed suppression was achieved by the grass organic mulch in 2008 and 40.6% in 2009 as against the fresh weed weight of 750.0 kg/plot and dry weight of 156.0 kg/plot in 2008 and 768.7 kg/plot fresh weight and 220.0 kg/plot dry weight in 2009 from the unmulched plots. Since by the application of black plastic mulch, natural weed control can be achieved, this can easily be adopted into the organicultural system and for sustainable farming system research in the fragile soils of the region. The plasticulture technique is essentially environmentally friendly in its function despite its disposal problem which can be overcome by the use of biodegradable films now being developed.

3.4 Crop growth and yield

More than its microclimate and growing environmental modification, the growth and yield parameters were significantly ($p<0.05$) improved by the application of black plastic mulch in comparison with that of grass mulch and the control. In Table 4, the effect of the two mulching materials on the growth and yield of okra variety (Clemson spineless) was displayed showing that black plastic mulch significantly ($P<0.05$) improved the yield (pod weight), plant height and leaf production much more than the organic mulch and the control in both years.

Table 4: Effects of grass and plastic mulches on the pod weight, plant height and number of leaves of Clemson spineless variety of okra in Abakaliki

Mulch type	*Pod weight (g)*	*Plant height (cm)*	*Number of leaves*
	2008		
Black Plastic mulch	23.8	20.2	12
Grass mulch	19.2	13.0	8

Zero mulch	5.0	8.2	5
F-LSD (P= 0.05)	3.2	3.6	1.5
		2009	
Black Plastic mulch	29.05	58.47	22
Grass mulch	22.78	47.17	20
Zero mulch	17.92	34.13	15
F-LSD (P= 0.05)	8.51	20.13	3.51

Plant height attained 20cm on the black plastic mulched beds, l3cm from the grass mulched beds and 8cm from the control six weeks after planting. Six weeks after planting, the first harvest was made with 23.8g/plot fresh pods from plastic mulch, 19.2g from grass mulch and 0g from the control in 2008. The advantage of organic mulch over the plastic mulch played out on the yield and growth parameters in year two as heavier pod weight (22.78 g) was achieved in 2009 than in 2008 (19.2 g) on the grass mulched beds, though year two was generally better than year one. Also, taller plants (47.17 cm) and more number of leaves (20) were observed in 2009 than in 2008 (20.2 cm and 8) on the grass mulched beds. However, black plastic mulch was more effective in influencing the growth and yield parameters in both years than grass mulched beds and the control. This result agrees with the findings of [10] who reported high yields of okra from mulching, while [6] reported rapid growth and heavy yields of tomato and sweet pepper. [11], also observed that earlier crop production, higher yields per unit area, cleaner and higher quality produce, and opportunity for double or triple-crop production with maximum efficiency are all possible with plastic mulching technology.

4. Conclusion

For vegetable growers to remain competitive in today's market place, they must strive continually for higher quality, superior yield and extended production cycles in both rainy and dry season crops. This has been proved to be a possibility by the results of this study on the comparative effects of the application of organic (grass) and plastic (black plastic films) mulching materials on okra production in a derived savanna environment of Nigeria. Moreover, for the fact that vegetable seed producers must ensure that they bring to the farmers seeds with high yield and growth potentials makes it a necessity that the best production techniques should be employed in its production. It is high time the use of plasticulture technology be effectively intensified for making vegetables available throughout the year as evidenced in this experiment at no extra cost or labour. Comparatively, black plastic mulch overshadowed grass mulch in okra yield, in maintaining microclimate conditions, in suppressing weed growth and in general plant growth in both years. The global climate change pervading the crop growing environment should be critically looked into and encourage people especially the smallholder farmers to 'think outside the box' of their current practices and capitalize upon certain technologies that exist within their present crops and within the soil systems in which these crops grow. One major constraint with the use of plastic mulch has to do with the difficulty to reuse it and its disposal problem at the end of a growing season. However, the development and employment of decomposable types can solve the disposal problem and more interest of the smallholder farmers will be attracted, while higher crop yields and higher quality crops are achieved.

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