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Full Length Research Paper

Effect of coloured polyethylene mulch and harvesting stage on growth and yield of industrial sugarcane in Nigeria

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Plastic mulch increases soil temperatures and accelerates plant growth and development. Field trials were conducted in 2010 and 2011 at the National Cereals Research Institute, Badeggi to assess the effect of mulching and harvesting time on the agronomic performance of a sugarcane variety named NCS 008. The treatments consisted of three-coloured polyethylene mulches (black, red, and green) with one treatment without mulch as a control and two harvesting stages (10 and 12 months after planting). The experiment was laid out as a randomized complete block design in a factorial arrangement and replicated three times per treatment. Sugarcane setts planted on plots mulched with black polyethylene sheet established significantly (P<0.05) faster than those planted on plots mulched with red and green coloured polyethylene sheet as well as those planted on plots without mulch. Plants in the control plots had the least performance for all parameters measured during the experiment. Coloured polyethylene significantly (P < 0.05) increased the stalk length, stalk girth, number of tillers, chewable stalk and yield of NCS 008 for the main, as well as, the ratoon crops. Harvesting stage significantly influenced the stalk length, stalk girth and yield. Plots harvested 12 months after planting performed better than plots harvested 10 months after planting.

Key word: Polyethylene colour (black, red and green), plastic mulch, harvesting stage, NCS 008.

INTRODUCTION

As early as the 1920s, researchers developed acceptable production practices with plastic or polythene mulches in vegetables and fruit production (Solaiman et al., 2008). Currently, plastic mulch is used on thousands of hectare of vegetables in the United States and mulching practices have increased in the production of a wide range of vegetable crops. Mulching is beneficial in sugarcane cultivation in dry months and during earthing up (Gana and Ogunremi, 2007). Polyethylene can be used in crop production as covers for greenhouses and low tunnels, or as direct covering of soil. Plastic film can be used to aid crop production in many ways (Arin and Ankara, 2001). Polyethylene and other materials can be formulated to control or utilize more effectively the heat and light energy from the sun, and also heat energy emitted from the soil (Arin and Ankara, 2001). These forms of energy are part of the electromagnetic spectrum and differ only in their wavelength. By using different polymers and additives, it is possible for films to transmit, absorb or reflect different wavelengths preferentially. It is possible therefore, to create a wide variety of microclimates by using different types of film, either as covers over crops or as a mulch on the soil surface (Arin and Ankara, 2001).The film entirely covers the crop and so has an influence on

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the total plant environment. The ideal properties of the films used for these very different growing systems in temperate regions are essentially the same (Gilby, 1990a). Polyethylene increased the yields of a number of crops and extended the growing period (Hancock, 1988).

Plastic covers raise soil and air temperatures compared to those in the open field, and protect crops from rain, hail, snow and wind. In addition to promoting earlier crops and providing protection against insect pests, they have other advantages including improvements in seed bed conditions, seed germination, higher yields and improved crop quality (Antill, 1988). Initially, plastic covers were used mainly by small-scale growers, but with improved mechanical methods of laying and lifting the film; their use is extending to large open fields. Developments in plastic technology have led to the availability of a greater variety of mulching materials (Gilby 1990a). In addition, plastic mulches have the advantage, in many situations, of retaining moisture in the soil. Plastic mulches mainly influence soil conditions and have a relatively small effect on the atmospheric environment of the crop. According to Antill (1988), polythene colour used for mulching should have the following requirements: visible light should be reflected back towards the crop by the film and so aid photosynthesis and the surface temperature of the mulch should not rise so high as to cause crop injury. Clear polyethylene film (15 to 50 microns) is used in Europe to warm up soil in early spring and enhance seed germination. This practice is most popular in the Mediterranean countries, but is gaining popularity in north-western Europe now that the process of laying plastic has been completely mechanized.

Further improvements are expected in combining mechanical laying of plastic mulch with other operations such as seeding, planting and the placing or irrigation pipes (Anonymous, 1990). Use of clear polythene and plastic present the potential advantage of soil solarisation (Schlesselma et al., 1985). Gana and Ogunremi (2007) observed that polythene mulches increased soil moisture and controlled weeds. Clear film is used to increase soil temperatures in temperate and Mediterranean countries whereas; black/white film with the white side uppermost may be useful in tropical countries to mitigate the effects of high soil temperatures. At the same time, weed growth would be suppressed and the exposed surface of the white film would remain relatively cool. Experiments are in progress in Britain with blue `thermic' mulching film. This reflects photosynthetically active light at the blue end of the spectrum which is believed to be beneficial for strawberry (Gilby, 1990a). Mulching soil surface with plastic shows positive effects on weed control, prevents soil drying and crusting, preserves soil moisture by preventing evaporation from surface, enhances soil vitality and increases uptake of nutrients by plants (Splittoesser, 1990).

MATERIALS AND METHODS

The experiment was conducted at the upland sugarcane experimental field of the National Cereals Research Institute Farm, Badeggi (latitude 9° 45' N, longitude 6° 07' E) in the Southern Guinea savanna ecological zone of Nigeria in 2010 to 2012 during the wet and dry seasons. The soil at the site of the trial has been classified as ultisol and sandy loam in texture with a bulk density of 1.459 m^{-1} (Ayotade and Fagade, 1993). The site has an average annual rainfall of 1124 mm and mean temperature ranging between 23 and 33°C. The industrial sugarcane variety NCS-008 was developed at the National Cereals Research Institute (NCRI), Badeggi and released in 2006. It has erect stools at maturity and exhibits a heavy stooling habit. It has an early maturing (9-11 months) and high yielding (on average 60 t/ha) characteristics. It is moderately resistant to smut and strives well in different soil types. The variety is also tolerant to stem borers and termites, tillers heavily and has good ratooning capacity.

Treatments, experimental design and plot size

The treatments consisted of three-coloured polyethylene mulches (black, red , and green) with 100 µm gauge thickness, one control unit without mulching, and two harvesting stages (10 months after planting and 12 months after planting). The treatment combinations therefore comprised the following: T_1 = Control + harvesting at 10 months, T_2 = control + harvesting at 12 months, T_3 = black colour + harvesting at 10 months, T_4 = Black colour + harvesting at 12 months, T_5 = red colour + harvesting at 10 months, T_6=red colour + harvesting at 12 months, T_7=green colour + harvesting at 10 months and T_8=green colour + harvesting at 12 months.

The experiment was laid out as a randomized complete block design and replicated four times per treatment. Each plot had the gross size of 2 m^2 (1 × 2 m) accommodating 4 rows of sugarcane setts and had a net plot size of 1 × 2 m (2 m^2). The distances between adjacent plots and blocks were 1.0 m each. Three setts of sugarcane were used per row at an inter row spacing of 1.0 m and intra row of 0.5 m. The total number of plots per replication was 8 giving a grand total of 32 plots. The total land area was 385 m^2. Three setts of sugarcane were planted per row during the experiment. Ratoon for this experiment was observed during the next cropping season of 2011. Parameters assessed included establishment count, number of tillers per plant, stalk length (cm), stalk girth (cm), and number of chewable stalk and yield (t ha^{-1}). All data collected were subjected to analysis of variance (ANOVA) to test treatment effects for significance using GENSTAT edition 11.3 statistical software package. The means were compared using F-LSD.

RESULTS AND DISCUSSION

Compared to plants grown in the unmulched (control) plots, plants mulched with polyethylene sheets had significantly lower establishment count for both the main and the ratoon crops. This may be attributed to the phenomenon that mulching conserves moisture, regulates extreme temperatures, and controls weeds thereby enhancing the survival and establishment of setts. The physio-chemical

Table 1. Physio-chemical characteristics of soil taken from experimental site before the establishment of the trial.

Soil property	0-25 cm depth
Physical properties	
Sand (%)	63.52
Silt (%)	6.48
Clay (%)	30.56
Textural class	Sandy clay loam
Chemical properties	
pH in water	5.8
Organic carbon (%)	1.26
Organic matter (%)	2.17
Total nitrogen (%)	0.06
Available phosphorus (ppm)	0.14
Exchangeable cation (C mol/kg^{-1})	
K	0.15
Mg	14.47
Ca	13.52
Na	0.70
CEC	28.88

characteristics of soil and soil temperature (°C) under different polythene treatment are presented in Tables 1 and 2 respectively. This result corroborated with Gutal et al. (1992) observed that the use of plastic mulches in agriculture helps to increases the production per unit area for all types of crops, coloured polyethylene mulch films increase soil temperature by 5 to 7°C, facilitating faster germination and better root proliferation while checking weed growth, preserving the soil structure and retaining soil moisture.

However, plastic mulch colour did not significantly influence the establishment count of the main crop but significantly (P<0.05) influenced the establishment count of the ratoon crop. Black and green colours resulted in the same mean value of 40.10% for the establishment of the main crop. However, mulching with the black-coloured polyethylene resulted in significantly higher establishment of the ratoon crop than mulching with the red and green polyethylene mulches. This may be attributed to less transpiration; soil been warmed up and increase in the availability of irrigated water. According to Lippert et al. (1994) who reported that black plastic mulch established plant faster and better because, it helps in warming up the soil and eliminating weeds, it reflects beneficial spectra of light back on to the plants.

Harvesting stage did not significantly affect the establishment of the main crop (Table 3).

Polyethylene mulch and harvesting stage did not interact to influences the establishment count of the main crop, but interacted to significantly influence the establishment count of the ratoon crop. Mulching with black polyethylene and harvesting 10 months after planting resulted in the highest establishment of the sugarcane sett (Table 3). This may be ascribed to the duration of time that the crops were on the field. Stalk length was significantly influenced by mulch colour both for the main and the ratoon crop. However, mulch colour interacted with harvesting stage to influence stalk length of the ratoon crop. The longest cane stalk for the main crop was recorded in response to mulching with black polyethylene, closely followed by the green one. The shortest cane stalk of the main crop was recorded for the control treatment. The longest cane stalk for the ratoon crop was recorded for plants mulched with black polyethylene and harvested 12 months after planting. The shortest cane stalk for the ratoon crop was recorded for unmulched plants which were harvested 10 days after planting.

Colour significantly increased the stalk length of sugarcane plant for plant and ratoon crops (Table 3). Black colour had the longest stalk length at harvest, hence black polyethylene mulch is significantly longer in stalk height than green, red and control. Control had the least stalk length. Ratoon crops stalk length is shorter than plant crops but the trend of the colour is the same. Harvesting at 12 month harvesting time gave the highest stalk length and was significantly higher than 10 MAP for plant and ratoon crops. The interaction was significant, that is, interaction between plastic mulch and harvesting stage for plant crops. There was also significant interaction of ratoon crops (Table 4). Interaction effect showed that the plants harvested at 12 MAP were significantly (P<0.05) higher than the plant harvested at 10 MAP for plant and ratoon crops.

Colour polythene significantly (P<0.05) increased the number of tillers for plant and ratoon crops. However, number of tillers differed significantly for both plant and ratoon crops (Table 3). Black colour produced the highest number of tillers, followed by red, green colour and the control had the least number of tillers, and ratoon crops were significant at 2, 4 and 6 MAP. There was no significant interaction effect on the treatments. Plastic mulch increased the size of stalk girth of sugar cane for plant crops and ratoon crops. Plant crops were more robust in size than ratoon crops. Plants that were mulched with polythene had a significant higher stalk girth than unmulched plant. Black polythene gave the highest stalk girth, which were significantly greater than mean values obtained from green and red plastic mulch. Control (unmulched) had the least stalk girth for plant and ratoon crops (Table 3). Harvesting stage had no significant effect. The interaction between polythene mulch × harvesting time on stalk girth was also not significant for plant and ratoon

Table 2. Soil temperature (°C) under different polythene treatment during the cultivation period.

Month	Year	Treatment							
		T1	T2	T3	T4	T5	T6	T7	T8
Jan	2010	36.0	36.0	45.0	45.0	41.0	41.0	36.0	36.0
	2011	37.0	37.5	43.0	44.0	39.0	39.0	35.0	36.0
Feb	2010	33.0	35.0	44.0	39.0	41.0	39.0	36.0	37.5
	2011	38.0	37.0	45.0	45.0	41.0	41.0	39.0	38.0
Mar	2010	34.0	36.0	42.0	43.0	42.0	41.0	39.0	38.0
	2011	25.0	28.0	36.0	37.0	32.0	33.0	28.0	32.0
April	2010	23.0	25.0	33.0	28.0	32.0	32.5	37.5	34.0
	2011	25.0	25.0	36.0	35.0	30.0	31.0	27.0	29.0
May	2010	26.0	27.0	32.0	31.0	30.0	32.0	37.5	34.0
	2011	25.0	25.0	35.0	35.0	30.0	30.0	27.0	28.0
June	2010	25.0	25.0	31.2	32.0	28.0	31.0	37.5	37.5
	2011	25.0	25.0	34.0	34.0	31.0	31.0	29.0	30.0
July	2010	25.0	25.0	34.0	34.0	31.0	31.0	29.0	29.0
	2011	24.0	25.0	35.1	31.2	32.0	28.0	36.0	32.5
Aug	2010	25.0	25.0	34.3	34.1	31.0	31.0	29.0	29.0
	2011	26.0	27.0	34.0	34.0	31.0	31.0	32.5	29.0
Sept	2010	26.0	27.0	34.8	35.1	31.2	32.0	30.0	30.0
	2011	26.0	25.0	34.0	34.0	31.0	31.0	29.0	34.0
Oct	2010	27.0	29.0	39.0	38.0	33.0	34.0	31.0	32.5
	2011	26.0	25.0	39.6	39.5	34.0	36.0	36.0	32.5
Nov	2010	30.5	30.0	39.6	39.5	34.0	36.0	32.5	33.0
	2011	31.0	36.0	41.0	41.0	32.5	37.5	37.5	36.0
Dec	2010	31.0	31.0	41.0	42.0	37.0	37.0	34.0	34.5
	2011	34.0	36.0	41.0	40.0	36.0	38.0	32.5	34.0

T_1, control + harvesting at 10 months; T_2, control + harvesting at 12 months; T_3, black color + harvesting at 10 months; T_4, black color + harvesting at 12 months; T_5, red color + harvesting at 10 months; T_6, red color + harvesting at 12 months; T_7, green color + harvesting at 10 months; T_8, green color + harvesting at 12 months.

Table 3. The effect of polythene, time of harvest and interaction on the establishment count, tillers count, stalk length, stalk girth, chewable stalk and yield (t ha^{-1}) of sugarcane for plant and ratoon crops.

Treatment	Establishment count		Tiller count		Stalk length (cm)		Stalk girth (cm)		Chewable stalk		Yield (t ha^{-1})	
	PC	RC	PC	RC	PC	RC	PC	RC	PC	RC	PC	RC
Plastic mulch												
Control	27.2	48.00	10.00	7.00	159.83	152.33	2.62	1.82	25.17	28.00	24.65	26.10
Black	40.1	73.50	23.17	9.00	274.67	194.50	4.97	5.15	45.50	53.00	45.40	44.33
Green	40.1	62.33	17.00	6.17	204.50	183.33	3.10	3.25	37.33	40.83	35.52	37.93
Red	32.1	57.67	19.83	4.83	175.50	166.50	2.38	3.57	29.17	34.33	30.93	28.97
F-LSD (0.05)	NS	1.61	0.88	1.13	4.62	3.03	0.31	0.20	2.48	1.92	2.62	0.99
Harvesting stage (month)												
10	36.7	64.42	17.25	6.17	209.50	166.67	3.04	3.28	33.83	35.92	27.56	27.73
12	33.0	56.33	17.75	7.33	197.75	181.67	2.96	3.62	34.75	42.17	40.69	40.94
F-LSD (0.05)	NS	2.28	NS	0.80	3.26	2.14	NS	0.14	NS	1.36	1.85	0.70
Interaction	NS	3.23	NS	NS	NS	4.28	NS	NS	NS	NS	3.71	1.39

PC, plant crop; RC, ratoon crop; F-LSD, Fisher's least significantly different at 5% level of probability and NS, not significant.

Table 4. Interaction effect of polythene mulches and time of harvest on the establishment count, stalk length, and yield (t ha^{-1}) of ratoon crop.

Polythene colour	Harvesting Time	Establishment count (RC)	Stalk length (RC)	Yield (t ha^{-1})	
				PC	RC
Control	10	52.33	145.33	18.30	19.10
	12	43.67	159.33	31.00	33.10
Black	10	81.00	181.33	35.30	34.83
	12	66.00	207.67	55.50	53.83
Green	10	63.67	178.33	30.93	33.13
	12	61.00	188.33	40.10	42.73
Red	10	60.67	161.67	25.70	23.83
	12	54.67	171.33	36.17	34.10
F-LSD		3.23	4.28	3.71	1.39

PC, plant crop; RC, ratoon crop; F-LSD, Fisher's least significantly different at 5% level of probability.

crops (Table 4). Polythene mulch significantly increased the number of chewable stalks for plant and ratoon crops (Table 3). Black polythene mulch material gave the highest number of chewable stalk for plant and ratoon crops. Black colour significantly increased the number of chewable stalk than green and red colour. The number of chewable stalk for black, green, red and control (unmulched) increased. Control had the least mean value for plant and ratoon crops. Ratoon crops produced more number of chewable stalks than plant crops. However, harvesting time had no significant effect on the number of chewable stalks and the interaction (Table 3). Polythene significantly increased the yield of sugarcane for plant and ratoon crops. Black colour significantly had the highest yield (t/ha) of sugarcane for plant and ratoon crops, and green coloured yield was higher than the red coloured (Table 3). However, harvesting stage were significant ($P<0.05$). There was significant difference between 10 and 12 MAP, and also there was significant interaction between plastic mulch and harvesting stage (Table 4). There was significant increase from plot covered with polyethylene mulch on stalk length, stalk girth, number of tillers, numbers of chewable stalk and yield.

The fast germination of black colour polythene mulch could be attributed to high temperature of the soil from Table 2 when compared with other colours. This result agrees with that of Kemble (2000) who stated that clear polyethylene film (15 to 50 microns) used in Europe warm up soil in early spring and enhance seed germination. At the same time, weed growth would be suppressed and the exposed surface of the white film would remain relatively cool. Experiments are in progress in Britain with blue `thermic' mulching film. The significant increased on the crop development could be as a result of low evapotranspiration, availability of water and mulching of the soil. According to Arin and Ankara (2001) who reported that polyethylene mulch are useful for encouraging crop development during initial stage of plant, early harvest and high total yield. plastic mulches effectively shut off vapour transport, soil would be warm up and increased availability of irrigated water. Lippert et al. (1994) and Waggoner et al. (1996) reported that moisture distribution in upper soil layers in mulched is more uniform compared to unmulched soil, and root development is better in the upper soil layer, which usually is rich in nutrients and useful microorganisms. Likewise, the increase in stalk height and girth of coloured mulch over unmulched plants may be as a result of soil temperature, which is in agreement with the results of Tressen (1993) who reported that critical soil temperature increases the height and diameter of tomato plant. Gerber et al. (1988) reported that the pepper crop development increases by increase in soil temperature due to tunnel effect. Salman et al. (1992) pointed out that mulching and tunnelling application increases the soil temperature so that vegetative development and fruit yield of tomatoes increases in the conditions of unheated soil. The coloured mulched plot encourages vegetative growth and development over the unmulched plot.

The yield (t/ha) was higher for black polyethylene mulch than red and green polyethylene mulched because much heat were generated for the crop growth and development. Sugarcane is a C4 plant with a high rate of photosynthesis (Busari, 2004). The result obtained on increased in yield of polyethylene mulched plots is similar to that of Pimpini et al. (1987) in which, mulch and tunnel increased the fruit weight. Gerber et al. (1988) observed that tunnelling increases the fruit yield and quality of pepper. Gilby (1990a) recorded increase in yield of pepper, eggplant, melon and water melon by mulch application.

Conclusion

The results of this study clearly indicate that better sugarcane yield (t ha^{-1}) could be obtained by polyethylene mulching. Therefore, the use of polyethylene colour for industrial sugarcane should be encouraged in estate especially in areas where the annual rainfall duration is short to enable the crop to maximise the water available.

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