Modulating Effect of Black Plastic Mulch on the Environment, Growth and Yield of Cassava in a Derived Savanna Belt of Nigeria

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Summary

*The modulating effect of black plastic mulch on the crop growing environment, crop growth and yield of two improved cassava (*Manihot esculenta *Crantz) varieties (TMS 30572 and TMS 4(2) 1425) bred by International Institute of Tropical Agriculture (IITA) was studied in a soil described as Typic Paleustult at the Faculty farm of University of Nigeria, Nsukka, a derived savanna belt of Nigeria. The experimental design was a 2 x 2 factorial arranged in a randomized complete block design (RCBD) with four replications. Results show that black plastic mulch influenced a 100% weed control in the plots mulched and raised the morning (09.00 GMT) soil temperature to 46%. Moisture evaporation was effectively controlled as water vapour condensed beneath the plastic mulch and fell back as droplets into the soil. The fresh root tuber yield of the cassava varieties was increased to 40.7% (TMS 30572) and 48% (TMS 4(2) 1425) while the leaf area increased from 292.5 cm^2 to 572.8 cm^2 in TMS 30572 and from 266.9 cm^2 to 428.5 cm^2 in TMS 4(2) 1425 by the plastic mulch. Generally, all growth and yield parameters measured were significantly (P> 0.05) improved by the application of black plastic mulch.*

Résumé

Effet modérateur de la couverture du sol par du plastique noir sur l'environnement, la croissance et que le rendement du manioc dans une zone de savane dérivée au Nigeria

*L'effet modulateur de la couverture du sol par un film plastique noir a été évalué sur deux variétés de manioc (*Manihot esculenta *Crantz) (TMS 30572 et TMS 4(2)1425 améliorées par l'IITA (Institut International pour Agriculture Tropicale). L'essai a été réalisé sur un sol paleustult typique du champ expérimental de l'université du Nigeria situé dans une zone de savane dérivée. Le dispositif expérimental était des blocks aléatoires complètement randomisés avec 2 x 2 facteurs et quatre répétitions. Les variables étudiées étaient l'environnement de la plante, la croissance de la plante ainsi que le rendement. Les résultats obtenus montrent que la couverture du sol par du plastique noir permet un contrôle des adventices à 100% et permet une augmentation de la température matinale (9 h GMT) de 46%. L'évapotranspiration a été maîtrisée grâce à l'infiltration dans le sol des gouttes d'eau condensées sous le plastique. Le rendement en tubercules a augmenté respectivement de 40,7% pour la variété TMS 30572 et de 48% pour la variété TMS 4(2)1425 tandis que l'augmentation de la surface foliaire dû à la couverture du plastique était de 292,5 cm^2 à 572,8 cm^2 pour la variété TMS 30572 et de 266,9 cm^2 à 428,5 cm^2 pour la variété TMS 4(2)1425. D'une façon générale, en utilisant le plastique noir comme couverture, tous les paramètres de croissance et de rendements étudiés ont augmenté d'une manière significative (P> 0,05).*

Introduction

Cassava (*Manihot esculenta* Crantz) is regarded as one of the principal plants of use to man because of the important part it plays as a food in the regions of the world where there is hunger and starvation (23). Its food value lies in the high starch content (89% in the tuberised roots) and the nutritious leaves (protein content of 25%, glycoside 41%, lipids 6%, fibre 20%, ash 8% and dry matter 15%) that serve as an excellent complement to the tuberised roots (1, 23). Its outstanding features have been well reported in litera-

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ture, as a plant that tolerates extreme stress conditions, adapts suitably to diverse environment and farming systems, is biologically efficient in food energy production, has low production skill requirements and inputs, can stay in the ground for up to 24 months until required for consumption, is available throughout the year thereby helping to alleviate the famine situation in Africa and withstands drought for four to six months (10, 11, 13).

The yield of cassava is highly skewed over the world. The world average yield is less than 9 $t.ha^{-1}$ and in nearly 25% of cassava producing-countries yields are less than 4 $t.ha^{-1}$ (5). Experimental plots under near-optimal edaphoclimatic conditions may yield more than 70 $t.ha^{-1}.yr^{-1}$ (6). Low productivity can be attributed to cultivation of marginal environments and sub-optimal soils and poor crop management practices (7). The observation of Watson (26) three decades ago is being confirmed that climate determines the crops that can be grown while weather determines the yield of crops grown. Therefore, a technology aimed at environmental management need to be sought and adopted for high crop production in areas where the combination of low yields and high population growth aggravates famine situations.

The discovery and development of polyethylene polymers in the late 1930s, and its subsequent introduction in the early 1950s in the form of plastic films, mulches, and drip-irrigation tubing and tape, revolutionized the commercial production of several vegetable crops which gave rise to a crop growing system known as plasticulture (14). Plasticulture has become since then a veritable management tool offering many benefits such as higher yields per hectare, cleaner and higher quality produce, more efficient use of water resources and fertilizer inputs, reduced leaching of fertilizer on light sandy soils, reduced soil and wind erosions, soil compaction, and root pruning, better management of certain insect pests, reduced disease incidence, and improved micro-climate by modifying the radiation budget (absorbitivity vs. reflectivity) of the surface, thereby enhancing earlier crop production and fewer weed problems (12, 14, 25).

Traditionally in the early 1960s, impact of colour (black or clear) plastic mulches have been found to be useful tools in modulating soil and air temperatures, moisture retention and energy, i.e. radiating behaviour of mulches depending on their degree of contact with the soil (thermal contact resistance). With air space in-between, soil warming is less effective (8, 9). It has been reported that clear plastic mulches were used in solarization (soil sterilization) and in the cooler regions of the United States such as the New England States. Placing a clear plastic mulch over a moist soil for about 30 days of sunny weather generates enough heat to kill nematodes 5 cm to 10 cm deep, making the soil free of living germs (17). Moreover, countries in the Middle East, North Africa, high elevations in Southern Africa and other areas of the world with extreme weather conditions use black plastic films to construct protected greenhouses whereas glass is used in Europe and America (22). Plasticulture system is finding a veritable use in crop production in the tropical regions (16, 19, 22). Therefore, the objective of this experiment was to determine the effect of black plastic mulch on the crop environment, growth and yield of some cassava varieties in the derived savanna belt of Nigeria.

Methodology

The study was conducted on the research farm of the Department of Crop Science, University of Nigeria, Nsukka, located at latitude 06^0 52' N, longitude 07^0 24' E, and an altitude of about 458.2 m above sea level. The soil type is a well-drained sandy clay loam tropical ultisol (Typic Paleustult) of the Nkpologwu series with a pH of 4.5. The annual rainfall is about 1600 mm spread between April and October.

Experimental design

The design of the experiment was a 2 x 2 factorial in randomized complete block design (RCBD) with four replications covering an area of 230 m^2. Factor A was the black plastic mulch at two levels (M_o= without mulch and M_1= with mulch), whereas factor B existed out of the two IITA (International Institute of Tropical Agriculture) improved cassava varieties (V_1= TMS 30572 and V_2= TMS 4(2) 1425), which gave rise to four treatment combinations. In all, 64 ridges of 4 m long were manually constructed with West African dwarf hoe, one meter apart to form 16 plots of 4 ridges each. Eight plots randomly selected received black plastic mulch while the other 8 plots had no plastic mulch. A 5 m x 4 m black plastic sheet was used to completely cover each plot while 0.5 m projections were buried in the soil around the plot to prevent the plastic sheets from been blown away by wind. Routinely, more soils were heaped as the need arises to strengthen the edges. Prior to planting the cassava stem cuttings, holes large enough to admit the cuttings and rainfall were made on the sheet at a spacing of 75 cm direct on the crest of the ridges. The plastic sheet was adequately made flat with the level of the ridges to prevent too many contours for water to collect on the plastic without reaching the soil through the holes. Stem cuttings of 20 cm long (4 nodes each) were planted at an angle of 45^0 to the surface of the mulch.

Measurements and data analysis

Three weeding schedules were made on the unmulched plots before the cassava was harvested. Before each weeding, a quadrant was thrown in each plot and the weeds harvested from it were weighed fresh and dry. A month after planting, soil temperature measurements were taken daily during one month at two depths (15 cm and 30 cm) in the mornings (09.00 GMT) and in the evenings (15.00 GMT) in both plots (with or without plastic mulch). Each plot contained 24 plant stands and the innermost four stands from the innermost two ridges were used for data collection. In the experimental plots, harvesting was done between ten and eleven months after planting. The data collected were statistically analyzed using the analysis of variance (ANOVA) procedure while mean separation for detecting significant differences between means was performed using Fisher's least significant difference (F -LSD) according to Carmer and Swanson (2).

Results and discussion

Soil temperature

Table 1 shows that the morning (09.00 GMT) soil temperature was significantly (P> 0.05) improved by the application of black plastic mulch.

Table 1

Measurement of soil temperature (^{0}C) modulated by black plastic mulch (15 cm and 30 cm depths)

Plastic mulch	Morning (09.00 GMT)		Evening (15.00 GMT)		Daily Average
	Depth				
	15 cm	30 cm	15 cm	30 cm	
With mulch	27.2	27.0	29.6	29.4	28.3
Without mulch	26.1	25.6	29.3	29.0	27.5
F- LSD(P= 0.05)	0.5	0.5	ns	ns	0.5

ns= not significant

Such improvement as influenced by black plastic mulch is highly reported in literature by scientists like Otoo (21), Mbagwu (16) and Onwueme and Sinha (18). Otoo (21) reported that in addition to raising the soil temperature, it conserved soil moisture and soil nutrients, protected soil structure, and prevented soil erosion. Onwueme and Sinha (18) reiterated that plastic mulch was used to raise the soil temperature where low soil temperature would have adversely affected on plant growth. Use of black plastic mulch is highly recommended for places experiencing low soil temperature to save crops from cold injury (22).

Weed growth control

The data obtained about the environment during the experiment shows that there was a complete and effective suppression of weed growth by the application of black plastic mulch. In table 2, the mean fresh weight and dry weight of weeds from the three weeding periods (g.m^{-2}) proved black plastic mulch an effective technology for weed control in crop production.

Table 2

Weights of weed growth from three weeding schedules in the unmulched plots (g.m^{-2}) of cassava

Schedule	Fresh weight	Dry weight
6 WAP	108.64	20.40
15 WAP	277.93	43.08
31 WAP	428.06	104.14
Mean	271.54	55.87

WAP= Weeks After Planting

Okeke (19) reported the same complete weed control and about 100% yield increase in cassava root tubers by the application of plastic sheet as mulch. The importance of this observation is predicated on the reduced labour cost that would have been expended for weeding especially these days of jumping labour cost in most developing countries. The third triennial symposium of the International Society for Tropical Root Crops (African branch) recommended among other things that current and future research should focus on the development of technologies for reducing production costs for our staple root crops (1). Also, since by this technique, weed control can be naturally achieved, it can easily be adopted into the organiculture system and the need for sustainable farming system research in the fragile soils of this region. The technology is environmentally friendly in its function except its disposal problem, which can be overcome with the use of biodegradable types of plastic film now being developed.

Plant growth

The growth parameters of cassava (leaf number, leaf area, leaf area index, stem number and height at first branching) were significantly (P> 0.05) improved by the application of black plastic mulch (Tables 3, 4 and 6).

Table 3

Effect of black plastic mulch on leaf number of two cassava varieties six months after planting

Month	Treatments				Mean
	M_0V_1	M_0V_0	M_1V_1	M_1V_2	
1	17	19	18	21	18.8
2	48	46	70	69	58.3
3	80	85	149	155	117.3
4	102	100	196	182	145
5	113	98	222	149	146
6	125	63	302	91*	145
Mean	81	69	160	111	

F - LSD (P= 0.05)= 29 for comparing two monthly means
F - LSD (P= 0.05)= 21 for comparing two varietal means
F - LSD (P= 0.05)= 41 for comparing monthly x mulch interaction means

* Termite attack affected the leaf number produced

Table 4

Effect of black plastic mulch on the growth and yield parameters of cassava

Mulch	Stem number per plant	Height at first branching	Leaf number (cm)	Leaf area (cm^2)	LAI	Number of root tubers	Weight of root tuber yield kg per plant	Harvest index
Without	3.0	84.7	79.0	279.7	3.5	9.0	2.6	0.65
With	4.0	102.2	143.3	500.6	6.3	14.0	3.8	0.56
F-LSD (P= 0.05)	1.0	9.6	19.2	114.6	1.4	2.0	0.6	0.05

Table 5

Variety x plastic mulch interaction on the weight of root tuber yield ($kg.plant^{-1}$) of cassava

Variety	Mulch		
	Without mulch	With mulch	Means
TMS 30572	2.7	3.8	3.3
TMS 4(2) 1425	2.5	3.7	3.1
Means	2.6		

F- LSD (P= 0.05)= 0.6 for comparing two variety means
F- LSD (P= 0.05)= 0.6 for comparing two mulch means
F- LSD (P= 0.05)= 0.8 for comparing variety x mulch interaction means

Table 6

Variety x plastic mulch interaction on the leaf area (cm^{-2}) of cassava

Variety	Mulch		
	Without mulch	With mulch	Means
TMS 30572	292.5	572.8	432.7
TMS 4(2) 1425	266.9	428.5	347.7
Means	279	500.7	

F- LSD (P= 0.05)= 114.6 for comparing two variety means
F- LSD (P= 0.05)= 114.6 for comparing two mulch means
F- LSD (P= 0.05)= 162.1 for comparing variety x mulch interaction means

Leaf count on monthly basis (from sprouting to six months after planting) (Table 3) shows that the rate of leaf production of the two varieties in response to plastic mulch treatment was higher than the unmulched plots. The number of leaves increased consistently with months except in V_2 (TMS 4(2) 1425) by the fifth month when termite attack affected some stands. In table 6, with black plastic mulch, leaf area reached between 572.8 cm^2 (TMS 30572) and 428.5 cm^2 (TMS 4(2) 1425) though CIAT (3) indicated that large leaf area above 500 cm^2 per plant has little advantage and can encourage mutual shading and shorter leaf life at the base of the canopy. Otoo (21) also reported this general improvement in the growth parameters by the modulating influence of black plastic mulch on the environment.

Crop yield

Black plastic mulch enhanced the entire cassava yield parameters (number of storage roots per plant, storage root tuber weight and harvest index) measured in this experiment (Tables 4 and 5). The storage root tuber weight was significantly (P> 0.05) increased by 46% but the corresponding increase in leaf area depressed the harvest index (Table 4). This agrees with the work of Cock (4) who pointed out that harvest index would generally be low under high plant population in crops that exhibit partitioning of dry matter in phases especially root and tuber crops. Harrison-Murray and Lal (12) observed that black plastic mulch increases root tuber yield and CIAT (3) pointed out that large leaf area might unnecessarily overtax the dry matter accumulation to the detriment of the storage root tuber yield. Increase in root tuber yield by black plastic mulch is well reported in literature. Otoo (21) observed that yield parameters were improved, while Okeke (19) reported a 100% increase in the yield of root tubers. A crop production technology that has such reputation for yield increase may easily be accepted by farmers in cassava growing countries to enhance their strength in their war against famine especially if the plasticulture technology is cheap and affordable. In table 5, it may not be superfluous to stress that the response of the two varieties (TMS 30572 and TMS 4(2) 1425) with 41% and 44% increase respectively was very impressive.

Conclusion

From literature and from the observations made in this experiment, it is strongly established that black plastic mulching, as an improvement technique is both environmentally friendly and a very effective means of modulating crop environment. Considering all the advantages of this technique, we do not hesitate to recommend its further trial and use in other crops to increase crop production. However, the only snag about this report is that the plastic mulch used is non-biodegradable which presents disposal problem in the farm at the end of the crop growth. When biodegradable types become common and affordable, its use is expected to increase.

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