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EFFECTS OF MULCHING MATERIALS ON THE GROWTH, DEVELOPMENT AND YIELD OF WHITE YAM

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ABSTRACT

Two similar experiments are described in which the effects of different mulching materials and staking on the growth, development and yield of white yam (*Dioscorea rotundata*) Minisetts were studied. One white yam cultivar TDR 131 was used and the treatments were: black and white embossed polyethylene plastic (Visqeen 38mu) with either black or white surface up; light weight black polyethylene plastic; rice straw; staking but no mulch, and no staking and no mulch. Each experiment was laid out in a randomised complete block design with four replications. Polyethylene plastic mulch with white surface up was superior to all other treatments. Total dry matter per plant and total fresh tuber yield were all consistently higher in plants grown under the white surface polyethylene plastic mulch. In 1985, mean tuber size was more than 34% larger than in the traditional staking system and nearly double the value obtained with no staking no mulch treatment. In 1986, mean tuber size was again larger with white surface plastic mulch but not significantly different from those of the staking and rice straw treatments. Plants in all treatments attained peak leaf area index (LAI) about 100 days after planting and those in the white surface plastic mulch maintained a higher LAI for most of the growing season. White surface polyethylene plastic mulch gave the larger Leaf Area Index and the greater Leaf Area Duration which ensured a high bulking rate over a comparatively longer period. It is suggested that under tropical conditions, farmers would obtain better seed yam yields through the use of white surface polyethylene plastic mulch.

***Key Words*: *Minisetts, Mucuna,* Polyethylene plastic, seed yam, transplanting**

RÉSUMÉ

Les effets de différentes matières de paillage et de tuteur sur la croissance, le développement et le rendement de l'igname blanche *Dioscorea rotundata* (Minisetts) ont été étudiés à travers deux expériences. Une variété d'igname, TDR 131 à été utilisée avec les traitements suivants une toile plastique polyéthylène (Visqueen 38 u) noir-blanc gaufrée, exposant suivant les conditions, le côté blanc ou noir; une toile plastique polyéthylène noire, légère, paille de riz, tuteur sans paillage et en l'absence de tuteur et de paillage. Chaque expérience a été répétée 4 fois. Les parcelles ensemencées ont été choisies purement au hasard. Toile plastique polyethyène avec surface blanche exposée était supérieure à tous les autres traitements. La matière sèche totale par plante et le rendement en tubercules fraiches étaient constament supérieur lorsque les plantes ont été cultivées dans les conditions précédentes. La longueur moyenne des tubercules en 1985 était 34% > à celle obtenue après usage de la méthode traditionnelle de pose de tuteur et double pratiquement celle obtenue en l'absence de

tuteur et de paillage. En 1986, la longueur moyenne des tubercules était encore plus élevée avec le traitement toile plastique surface blanche exposée et paillage mais pas de manière significative à celle obtenue avec tuteur et paillage avec pailles de riz. Tous les plants experimentaux ont atteint le maximum de (Leaf Area Index - LAI ou Index de surface foliaire) 100 jours après mise en terre mais ceux plantés avec toile plastique et surface blanche exposée et paillage avait le LAI le plus élevé toute la saison de culture. Toile plastique avec surface blanche exposée + paillage a généré le LAI et LAD (Leaf Area Duration) les plus élevés entrainant une augmentation de la taille sur une période de temps relativement longue. Il a été suggéré que dans les conditions tropicales, les paysans pourraient obtenir meilleurs rendements en semences d'igname en utilisant une toile plastique blanche et le paillage.

***Mots Clés*: Minisetts, *Mucuna*, plastique polyéthylène, semence d'igname, transplant**

INTRODUCTION

Traditionally, food yam (*Dioscorea rotundata* Poir) is propagated vegetatively by means of tubers. Whole tubers called 'seed' yam ranging form 100 to 1500 g, are used as planting materials. Alternatively, larger tubers are often cut into approximately 200 g pieces and used to establish the new crop (Onwueme, 1978; Okoli *et al.*, 1982). The practical implication of this is that the cost of planting material represents 38-45 percent of total cost of yam production. Accordingly, the availability of planting materials or 'seed' yam has been a major constraint to yam production.

Recently, the National Root Crops Research Institute in Nigeria developed a system termed the 'minisett' technique which aims at overcoming the 'seed' yam problem. A 'minisett' is defined as a set less than one quarter of the minimum size (100 g) of yam set often planted (Okoli *et al.*, 1982). The technique involves cutting selected 'mother seed' yam into pieces 20–25 g each, treating them in a fungicide/insecticide suspension and sprouting them in moist sawdust in nursery beds. After three to four weeks, the sprouted minisetts are transplanted into the main fields on ridges (Otoo *et al.*, 1987).

The International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria carried out a wide range of experiments to examine various aspects of the minisett technology in order to improve the system. One aspect that was of particular interest to IITA was the use of polyethylene plastic mulch in the production of 'seed' yam. Many farmers were already using the plastic mulch in the production of seed yam and the observation was that the overall performance of the crop was better than that achieved without plastic mulch. However, quantitative evidence to support this view was lacking. Moreover, the relative effects of other mulching materials and the traditional staking system on the performance of crops from the minisetts had received little research attention. This paper describes two experiments in which the performance of the yam crop from the 'minisetts' was compared under different mulching materials and the traditional staking method.

MATERIALS AND METHODS

Experimental sites. The two experiments described here were identical in treatments and design and were carried out at the International Institute of Tropical Agriculture in Southern Nigeria (7°26' N 3°54' E) in the transitional zone between humid and subhumid tropics. The mean annual rainfall is approximately 1400 mm fairly well spread from April to November with occasional dry spells of 2–3 weeks in August. One experiment was carried out in the 1985 and the other in the 1986 growing seasons. The actual rainfall totals during these growing seasons were 1772 and 1252 mm, respectively. The 1985 growing season was unusually wet, the total rainfall received being nearly 40% higher than the mean annual rainfall over a 30-year period.

The soil of the area is derived from basement complex rocks with sandy loam surface texture overlying a layer of angular to sub-angular quartz gravel merging into an argillic horizon (Lal, 1974). The experimental sites were in a mucuna (*Mucuna utilis*)/ arable rotation. The two experiments were carried out in separate fields and each experiment followed mucuna. No fertilizer was applied. An improved, high yielding and early maturing white yam, TDr 131 was used.

Treatment and design. Two types of polyethylene plastic mulch were used: visqueen '38mu' white and black embossed type of approximately 26 m^2 per kg and a black, light weight type approximately

103 m² per kg. The full range of the treatments used was: White and black polyethylene—Black surface up (BP); White surface up (WP); Light weight black polyethylene (B); Staking, no mulch (NS); No mulch and no staking (NO); and Rice straw (R).

The land was ploughed, disc-harrowed and ridged (one metre between ridges). Polyethylene and rice straw were laid on the ridges just before transplanting the minisetts. Polyethylene mulches were anchored with lumps of soil located on either side of the ridges. Rice straw was applied at the rate of 6 t ha^{-1} (Lawson and Lal, 1977), and added periodically as it decomposed to ensure that the soil was covered throughout the season. Minisetts were prepared as described by Otoo *et al.* (1987). For all the treatments, minisetts were transplanted on ridge centres at 25 cm between plants giving a plant population of 40,000 plants ha^{-1}. Each plot was 10 x 10 m arranged in a Randomised Complete Block Design with four replicates. Minisetts were transplanted on 5 and 12 June in 1985 and 1986, respectively. For the staking treatment, plants were staked 42 and 56 days after transplanting (DAT) in 1985 and 1986, respectively.

Experimental measurements. Crop growth was monitored using the conventional growth analysis techniques. Sampling for dry matter and leaf area was carried out at 21 day intervals beginning 60 DAT. On each sampling date, eight plants were gently uprooted from each treatment to ensure that as much of the root system as possible was recovered.

The plants were separated into leaves, stem (vine) and petioles, tubers and fine roots. Leaf area was determined from a sub-sample of leaves using a portable leaf area meter (L1-3000). All plant parts were then dried to a constant weight in a forced drought oven at 65°C for 48 hr before weighing. Soil temperature was measured twice daily at 0800 and 1500 hours using a bent stem thermometer set at 5 cm depths within each treatment.

Net Assimilation Rate (NAR), Crop Growth Rate (C) and Leaf Area Duration (LAD) were estimated for each treatment as described by Hunt (1978). The final harvest was carried out on the 12 and 21 December in 1985 and 1986, respectively. For each treatment, plants from a net plot size of 5 x 8 m were harvested to estimate the number of tubers ha^{-1}, mean tuber size and the total fresh tuber yield ha^{-1}.

RESULTS

Soil temperature and crop establishment. Soil temperature measurements were made only in 1985 during the main growth period which covered the months of July, August, September and October. However, for the purpose of this paper, only weekly means for July and October are presented in Table 1. These months also coincided with the early and late growth stages of the crop, respectively.

TABLE 1. Weekly mean soil temperature (°C) in yam minisetts grown under different mulching materials at 0800 and 1500 hr

July	Week I		Week II		Week III		Week IV		Means.	
	800	1500	800	1500	800	1500	800	1500	800	1500
a. Black surface up	25.7	33.7	24.4	31.87	25.1	30.9	25.5	36.1	25.2	33.1
b. White surface up	24.5	31.0	24.1	29.1	24.2	30.1	24.3	33.2	24.3	30.9
c. Light weight black plastic	24.9	31.7	24.2	30.2	24.2	30.7	24.5	35.4	24.5	32.0
d. Staking no mulch	24.3	30.6	23.3	29.7	23.4	29.8	23.1	36.1	23.5	31.6
e. Rice straw	24.2	28.3	23.9	26.8	24.1	27.9	23.9	29.8	24.0	28.2
f. BARE	24.4	32.6	23.5	30.1	23.5	30.4	23.9	36.8	23.8	32.5
October										
a. Black surface up	26.9	34.4	27.0	33.7	25.8	31.3	27.7	36.7	26.8	34.0
b. White surface up	24.6	29.5	24.9	31.8	24.0	30.3	25.8	33.7	24.9	31.3
c. Light weight black plastic	25.9	32.2	26.4	33.5	25.2	31.1	27.3	35.9	26.2	33.2
d. Staking no mulch	24.4	34.7	26.2	35.4	23.9	32.6	26.2	33.3	25.2	34.0
e. Rice straw	24.8	28.1	25.3	28.8	25.2	27.2	26.4	30.5	25.4	28.7
f. BARE	27.4	35.7	26.7	36.4	24.9	33.5	27.2	37.3	26.5	35.7

Differences in soil temperatures between treatments were large, particularly in the afternoons (Table 1). Compared to other mulching materials and bare soil, rice straw tended to decrease afternoon soil temperature whereas black polyethylene plastic mulch and bare soil increased it, with many values exceeding 30°C (supra-optimal). These observations are generally in agreement with those reported by Maurya and Lal (1981). The high soil temperature under the black polyethylene plastic mulch may have affected crop development particularly during the early growth stages.

During July, afternoon soil temperature under the black polyethylene plastic mulch were slightly higher than those under bare soil whereas the reverse occurred during October, most probably because of increased canopy cover. Soil temperatures under the white polyethylene plastic mulch were intermediate between those under the black polyethylene mulch and bare soil on the one hand and those under rice straw on the other. However, like in the rice straw mulch, soil temperatures under the white polyethylene mulch were relatively stable compared to those recorded from other treatments and bare soil.

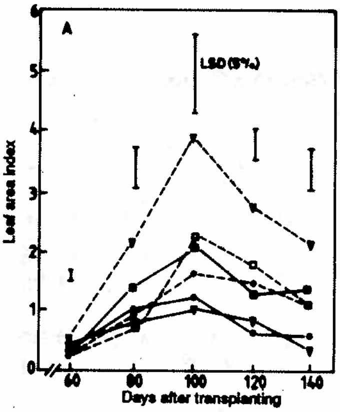
Plant counts were made 3, 6 and 9 weeks after transplanting in both seasons to monitor the establishment (survival) of the minisetts (Table 2). Plants with well developed vines consisting of at least three leaves were considered established. In general, establishment was slow though considerably better during 1986 season. It was also better under mulch than without mulch. In both seasons the mulched treatments achieved more than 80% establishment about 42 DAT whereas the staking and no staking, no mulch treatments attained similar establishment percentage 63 DAT. Among the mulched treatments, establishment percentage was consistently higher under white surface plastic in both seasons though not significantly different from other treatments.

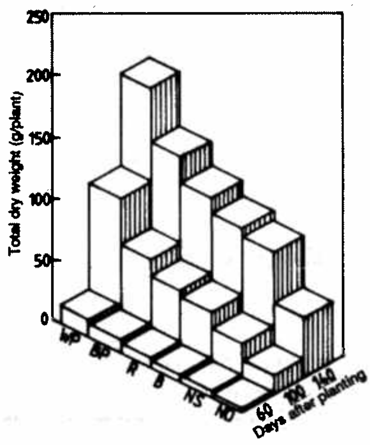
Canopy development. Five samples were taken from each treatment for leaf area and dry matter determination in 1985 but only three could be taken in 1986 season. Leaf area indices (LAI) are presented in Figure 1. In 1985, canopy development was slow during the early growth phase. By the first sampling date (60 DAT), LAI were still very low (less than 0.5 for all the treatments) and no significant differences among treatments were observed. In contrast, canopy development was faster in 1986 and some treatments had reached LAIs above one by the first sampling. Differences in the rate of canopy development between the two seasons were probably due to differences in the rate of establishment, which was higher in 1986 than in 1985. Subsequently, however, LAI increased rapidly and by the second sampling date in 1985, some treatments had more than 70% ground cover and differences between some treatments were large and significant (P = 0.05). These differences were largely maintained for the rest of the growth period.

Plants grown under the white surface mulch produced the highest LAI, achieving the maximum LAI of about 3.7 at 100 DAT. The no staking no mulch treatments consistently produced the lowest LAI. In other treatments maximum LAI was reached at 100 DAT and thereafter there was a sharp decline. This decline was largely due to leaf

TABLE 2. Percentage establishment of transplanted white yam minisetts as affected by different mulching materials and staking

	1985			1986		
	Days after transplanting			Days after transplanting		
Treatments	21	42	63	21	42	63
a. Black surface up	65.7	84.4	90.1	72.1	89.1	94.5
b. White surface up	71.1	88.6	93.4	78.8	93.2	99.0
c. Light weight black plastic	64.2	85.4	90.2	70.3	88.5	96.4
d. Staking no mulch	53.4	74.0	82.8	60.5	79.5	89.3
e. No staking, no mulch	51.0	70.8	85.8	58.3	76.0	86.4
f. Rice straw	69.4	84.9	89.3	74.0	89.4	96.7
LSD (P = 0.05)	25.09	21.47	11.21	23.90	19.97	14.55





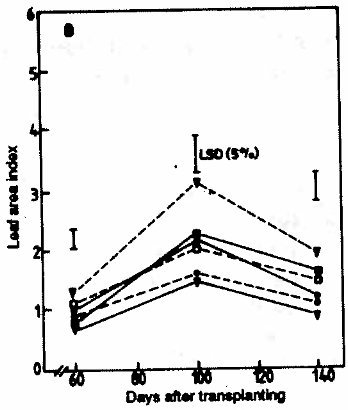


Figure 1. Effects of different mulching materials on the development of leaf area index (LAI) in white yam (*Dioscora rotundata*) minisetts in (A) 1985, and (B) 1986: Bp ( ); Wp ( ); B ( ); No. ( ); and R ( ).

Figure 2. Effects of different mulching materials on dry matter production in white yam (*Dioscora rotundata*) minisetts, 1985.

fall and leaf senescence which became more pronounced as the weather became dryer towards the end of the growing season and plants approached maturity. In 1986, LAI for the various treatments followed a similar pattern except that they were lower.

Dry matter production and crop growth parameters. The pattern of dry matter production was very similar during the two seasons and so only the results for 1985 are presented in Figure 2. The white surface mulch produced the highest dry matter per plant followed by the black surface plastic. The no staking, no mulch treatment produced the lowest dry matter. These differences were noticeable by the first sampling date and remained so throughout the growth cycle.

Leaf Area Duration (LAD), Net Assimilation Rate (NAR) and Crop Growth Rate (C) were calculated using the 1985 data and the values are presented in Table 3. LAD was significantly higher in the white surface polyethylene plastic mulch followed by the black surface polyethylene plastic and rice straw mulch in that order. The average NAR calculated for the whole season ranged between 0.32 gm dm^{-2} week^{-1} in the white polyethylene plastic mulch to 1.49 gm dm^{-1} week^{-1} in the staking, no mulch treatment. These values are considerably higher than those reported by Sabulo (1972) and Chapman (1965) for the main yam. All treatments achieved the highest NAR during the early stages of crop growth most probably because at this stage there was little or no mutual shading of leaves. As the season progressed, all treatments showed decreasing values of NAR except for the staking treatment which maintained very high values for most of the season.

Despite the low NAR achieved in the white surface polyethylene mulch the mean C was highest; an effect which resulted mainly from the higher LAI and greater LAD achieved in this treatment. The lowest C occurred in the no staking, no mulch treatment.

Tuber yield and yield components. Fresh tuber yield and yield components are presented in Table 4. The number of tubers ha^{-1} varied only slightly

TABLE 3. Leaf Area Duration (LAD), Net Assimilation Rat (NAR) and Crop Growth Rate (C) of yam minisetts as affected by different mulching materials and staking, 1985

		NAR (g Dm^{-2} Week^{-1})					C (g^{m-2} Week^{-1})				
		Week					Week				
	LAD	11th	14th	17th	20th	Mean	11th	14th	17th	20th	Mean
a. Black surface up	68	0.42	0.27	0.32	0.37	0.35	37.4	47.6	38.9	66.0	47.48
b. White surface up	96	0.57	0.29	0.15	0.25	0.32	65.4	67.0	52.6	51.1	59.03
c. Light weight black plastic	50	0.54	0.36	0.28	0.22	0.35	27.9	46.9	39.9	36.9	37.90
d. Staking no mulch	34	0.62	0.23	0.56	0.55	0.49	43.2	19.3	53.9	34.7	37.78
e. No staking, no mulch	29	0.45	0.29	0.39	0.19	0.33	23.4	27.6	35.4	3.7	22.53
f. Rice straw	58	0.44	0.34	0.46	0.098	0.33	24.1	46.8	70.8	34.4	44.03
LSD (P = 0.05)	21	0.09	0.03	0.05	0.11		18.2	17.4	16.2	13.9	

TABLE 4. Effects of different mulching materials on tuber yield and yield components of white yam minisetts

	1985			1986		
	No. of tubers ha^{-1}	Weight per tuber (g)	Tuber yield (t ha^{-1})	No. of tubers ha^{-1}	Weight per tuber (g)	Tuber yield (t ha^{-1})
a. Black surface up	36,045	424.9	15.5	42,968	487.0	21.1
b. White surface up	37,325	605.8	22.2	45,000	587.2	26.5
c. Light weight black plastic	33,788	415.5	14.2	41,250	412.3	16.9
d. Staking no mulch	37,163	399.9	14.9	42,969	549.2	23.8
e. No staking, no mulch	34,150	312.9	10.7	40,781	396.3	16.2
f. Rice straw	34,300	517.8	17.9	42,813	497.6	21.3
LSD (P = 0.05)	12,792	101.6	3.9	4,754	95.3	4.5

between treatments and there were no significant differences in both seasons. The white surface mulch produced significantly higher fresh tuber yield and larger mean tuber size (P = 0.05). In 1985, the mean tuber size was 34% larger than in the traditional staking system and nearly double the value obtained from the no staking, no mulch treatment. The rice straw produced the second highest fresh tuber yield though not significantly better than those in the black surface mulch and the staking treatment. In 1986, mean tuber size was again larger with white surface plastic mulch though not significantly different from those of the staking and rice straw treatments.

DISCUSSION

These experiments show that plants in the white surface polyethylene plastic mulch were superior to those in all other treatments. Leaf area indices, total dry matter per plant, mean tuber size and total fresh tuber weight were all consistently higher in plants grown under white surface polyethylene plastic.

Plants grown under the white surface polyethylene plastic mulch had high LAI because they produced more leaves (data not presented) and retained them much longer than did other treatments. This effect could have occurred because of the relatively high but stable soil temperature in the white surface polyethylene plastic which seemed ideal for leaf area development. The supra optimal temperatures (above 30°C) such as those observed in the black polyethylene plastic mulch are likely to have negative effects on leaf area development (Maurya and Lal, 1981). In studies involving other crops, soil temperatures have been found to markedly influence the rate of leaf appearance and leaf extension (Hay and Tunnicliffe Wilson, 1982).

The amount of leaf area available during tuber bulking period largely determines tuber yield in yam (Chapman, 1965; Enyi, 1972a,b). The higher yield from the white surface plastic mulch, therefore, relates to the higher LAI and longer LAD which ensured higher bulking rate for a longer period. In Table 3 it can be seen that LAD was greater with the white surface plastic mulch than in any other treatments, confirming that this was the main reason for the high yield. The no staking, no mulch treatment had the lowest LAD and it also achieved the lowest fresh tuber yield.

White surfaces (as of the plastic mulch in this experiment) reflect light. This could have improved the light interception pattern in plants grown with the white surface plastic mulch. Evidence from the literature indicate that both the rate of dry matter accumulation and total yield can be improved through the use of reflective mulches (Doud and Ferre, 1980; Dufault and Wiggans, 1981; Kwon, 1988). In the present experiments, it is likely that the beneficial effects of improved light interception occurred only during the early stages of crop growth since such effects would diminish as soon as a good canopy cover was achieved. An important indication for this is the pattern of NAR in the white surface polyethylene plastic mulch which shows very high values during the early stages of growth and rather low values as the season progressed.

NAR was consistently high in the staking, no mulch treatment compared to other treatments. This is perhaps not surprising because staking ensures that the leaves are well exposed to solar radiation and mutual shading is considerably minimised. Thus these experiments support the view that staking is particularly desirable in situations where radiation is low. For example, in the yam zone of Nigeria, yam plants are often staked up to 4 m in the forest belt where conditions are very wet and cloudy whereas in the savannah area there is virtually no staking. In other words, the benefit of staking decreases with improved solar radiation (Okigbo 1973; Hahn *et al.*, 1988).

Overall, the LAI's obtained in these treatments were low compared with those obtained in many yam cultivars. The probable explanation for this is that intraplant competition between the developing tuber and shoot for assimilates must have restricted leaf area development. This is suggested because in all the treatments tuber initiation occurred early (6-7 weeks after transplanting). In the main yam planted from larger setts, tuber initiation often occurs 12-13 weeks after emergence (Sabulo, 1972; Onwueme, 1978) thus allowing for sufficient leaf area development before tuber bulking begins.

The use of polyethylene plastic mulch is well known particularly in some temperate countries such as Japan and Korea where the growing season is limited by cold weather. Various types of plastic mulches are used to improve soil temperature in the early part of the season. However, evidence presented in these experiments and elsewhere (Maurya and Lal, 1981) indicate that under the tropical heat, black polyethylene tend to give rise to higher soil temperatures and that the most ideal type is the white surface plastic.

Using plastic mulch will considerably improve the production of seed yam because it eliminates the need for staking and checks weed growth. A survey carried out in Nigeria showed tremendous increase in the adoption of the technology and thus a clear promise for a future boom in the supply of seed yam (IITA, 1985). Future trends in the seed yam farming will probably follow one of the two directions; it may be largely used by small scale ware yam growers to meet their own demands for planting materials or a few large scale producers may specialize in the production of seed yam for sale to ware yam producers. Either way, wide adoption of the technology will improve both the availability of planting materials and the overall farm income.

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