Effects of mulch on soil properties and on the performance of late season cassava (*Manihot esculenta* Crantz) on an acid ultisol in Southwestern Zaire.

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Keywords: Cassava — Late season — Mulching — Soil properties — Growth and development — Yield components.

Summary

Mulch effects on soil temperature, soil moisture content, soil chemical properties, growth and development, yield and yield components of late season cassava were investigated for three years on an acid ultisol in the tropical savanna zone of Southwestern Zaïre. Diurnal soil temperature and soil moisture content were recorded at 30-day intervals during the first 4 months of growth. Cassava growth and development were monitored at 3,6 and 9 months after planting while yield and yield components were noted at 12 months after planting. After each cropping year, changes in soil chemical constituents were recorded.

Mulching significantly reduced soil temperature by about 3.5°C and increased soil moisture content by 6.1% under late season cassava. Soil pH, soil organic carbon content, total nitrogen, soil available phosphorus and soil exchangeable cations (Ca, Mg, K) increased as a result of increase in organic matter with continuous application of mulch for 3 years. Plant height, leaf area, shoot and root dry weights of cassava plants given mulch were significantly increased as compared to the plants in unmulched plots. Cassava plants given mulch produced more and bigger storage roots than unmulched plants. Storage root yield increased by 16.7, 28.1 and 57.7% respectively in the first, the second and the third years of mulch application. The beneficial effect of mulching over no-mulching increased from year to year, irrespective of cassava cultivars.

Résumé

Les effets de paillis sur la température du sol, la teneur en eau du sol, les propriétés chimiques, la croissance et le développement, les composants de rendement et le rendement du manioc planté à la fin de la saison de plantation étaient mesurés durant trois ans sur un ultisol acide dans la zone de savane tropicale au sud-ouest du Zaïre.

La température diurne et l'humidité du sol étaient déterminées à intervalle de 30 jours durant les 4 premiers mois de croissance du manioc. La croissance et le développement des plants étaient mesurés à 3,6 et 9 mois après la plantation tandis que le rendement et ses composantes étaient enregistrés à 12 mois après la plantation. A la fin de chaque culture de manioc les changements en constituants chimiques du sol étaient quantifiés.

Le paillage avait réduit significativement la température du sol d'environ 3,5°C et avait accru de 6,1% la teneur en eau du sol sous le manioc planté à la fin de la saison de plantation. Le pH, la teneur en carbone organique, l'azote total, le phosphore disponible et les cations extractibles (Ca, Mg, K) avaient augmentés suite à l'augmentation de la matière organique en raison de l'application du paillis pendant 3 ans. Le paillis a favorisé la production de racines tubéreuses aussi bien en nombre qu'en taille. Le rendement en racines a augmenté de 16,7; 18,1 et 57,7% respectivement en première, deuxième et troisième année d'application de paillis. L'effet bénéfique du paillage par rapport au non paillage accroissait d'année en année quelques soient les variétés de manioc cultivées.

1. Introduction

Cassava (*Manihot esculenta* Crantz) is one of the main dietary root crops of the tropics and subtropics (14). It is planted throughout the rainy season and even towards the end of the rains. In the tropics, particularly in Zaïre where cassava leaves are frequently consumed as vegetable, late season cassava is fairly common. This late season is more adversely affected by moisture stress than earlier planting. Traditionally farmers, to reduce the problems of moisture stress at this time, clear their fields and leave the trash on soil surface as mulch without burning.

The primary effect of mulch seems to be physical since it is associated with moderate fluctuations in soil temperature, higher soil moisture, higher water infiltration capacity and lower evaporation (5,6,17). Okigbo (13) indicated that soil temperature and moisture regime as well radiation levels in the first three months of growth have a significant effect on cassava yield. It appears that high soil temperature in the surface layers can be a limiting factor in crop production in the tropics. Mulching could be one approach to overcome this limitation.

Lal (7) has indicated that crop residue mulch can prevent soil erosion, maintain soil organic matter content and sustain crop production. Juo and Lal (5) reported increases in organic carbon and total nitrogen content while Lal *et al* (9) found that exchangeable K and Bray – 1 P were significantly influenced by crop residue mulch. Yet, there is little information on changes in soil properties, of an ultisol, from year to year under field crops as a result of consecutive mulching.

Few studies have been reported on the effects of mulch on

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the performance of cassava (2,3,13) but research information on the wisdow or otherwise of proper mulching for late season cassava in the tropics is rather scanty.
This paper reports the effects of mulching on soil temperature, soil moisture content, soil chemical properties, growth and development, yield and yield components of late season cassava.

2. Materials and methods

The experiment was conducted for three consecutive late rainy season of 1981-82, 1982-83 and 1983-84 at M'vuazi station of the Programme National Manioc (PRONAM), Zaïre. The station is situated in the humid savanna zone at 05°27 South and 14°54 East, on the altitude of 450 m above sea level. The climate is characterised by AW climatic type of Koppen (18). The rain falls for about 7 to 8 months and has a bimodal distribution with peaks in April and November. The dry season starts from May and ends in September, covering a period of about 130 days. The soil, sandy loam in texture contained 1.56 in organic matter, 0.12% total N, 56.0 ppm available P (Bray's – 1 P), 0.22 ppm exchangeable K, 0.28 ppm exchangeable Ca and had a pH of 4.5 (1 soil: 2.5 water). The plot used had been fallowed for one year after a succession of two cassava crops.

There were two types of treatments: mulching (no mulch and mulch) and cassava cultivars (02864, 30085/28, 30555/3, 30122/2, 30010/10 and Mpelolongi). Mulching was applied to the same plots consecutively for 3 years while cassava cultivars were assigned randomly in the blocks.

The experiment design was a split-plot fitted into a randomized complete block with four replicates. The mulch treatment formed the main-plots and cassava cultivars subplots. Each plot size was 8m × 7m made up by eight rows of cassava planted at 1m × 1m to give a population of 10,000 plants/ha.

The soil was disc-plowed twice to an approximately 20 cm depth followed by harrowing. Cutting of 25 cm long from 12 months old plants were planted, in the month of May, at an angle of 45° with the lower two-thirds inside the soil. Immediately after planting, the available mulch consisting of rice (*Oriza sativa*) straw was applied at the rate of 5 tones/ha, where required. The dry season began 3 to 4 weeks after planting. Hand weeding was done at 3, 6 and 9 weeks after planting. Soil temperature was determined by means of bentstem soil thermometers which were installed in the plots at 10cm depth. Readings were done at 09:00, 12:00 and 15:00 hours at 30, 60, 90 and 120 days after planting (DAP). In order to estimate the soil moisture status in each plot at 30, 60, 90 and 120 days after planting, four soil samples from 0-10 cm depth were taken from each plot with a soil auger. The soil samples were weighed fresh, sun-dried and oven-dried at 105°C for 48 hours to standardize the dry-weight.

The dry and fresh weight of the sample were used to estimate the soil moisture percentage in each plot using the following equation (16):

$$\%\ \text{water weight} = \frac{\text{(Wet weight-oven dry weight)}}{\text{oven dry weight}} \times 100$$

At 3, 6 and 9 months after planting, two plants were sampled per plot, separated into roots and shoots and then weighed fresh before they were dried at 65°C for 48 hours for dry weight determination. Plant height and leaf area were also determined at 3, 6 and 9 months after planting.

The chemical effects of mulching treatments were estimated after each cassava harvest. Two soil samples from 0-15 depth were taken from each plot with a soil auger. Samples from the same treatments were bulked, air-dried and passed through a 2 mm sieve. Sub-samples for determination of organic carbon and total nitrogen were further ground and passed through 0.5 mm sieve. The prepared samples were analysed for percentage of organic carbon and total nitrogen, Bray – 1 P, exchangeable Ca, Mg and K as soil pH using the method outlining by IITA (4).

At each harvest date (12 months after planting), 24 plants of cassava from center rows were uprooted. The number of storage roots as well as the length, the perimeter and the field fresh weight of storage roots were recorded. All plot yields were expressed on the basis of one hectare. Composite samples of storage roots from each plot were sliced to pieces and dried in an air-ventilated oven at 65°C for about 72 hours for dry weight determination. With the dry weight of the samples, the total dry weight of storage roots was estimated.

Data on soil temperature and soil moisture regimes from each growth stage of late season cassava were analysed by estimating error terms for testing mulch effects. Statistical analyses of the results of soil chemical constituents, growth and development, yield and yield components of cassava were done using the split-plot arrangement in a randomized complete block design with four replicates. Graphs and tables of means with associated standard errors (SE) or least significant differences (LSD) values were drawn to show treatment effects.

3. Results and discussion

3.1. Soil properties

3.3.1. Soil temperature. The effects of mulching on diurnal variations in soil temperature at 10 cm depth taken at 30, 60, 90 and 120 days after planting are illustrated in Figures 1 and 2.

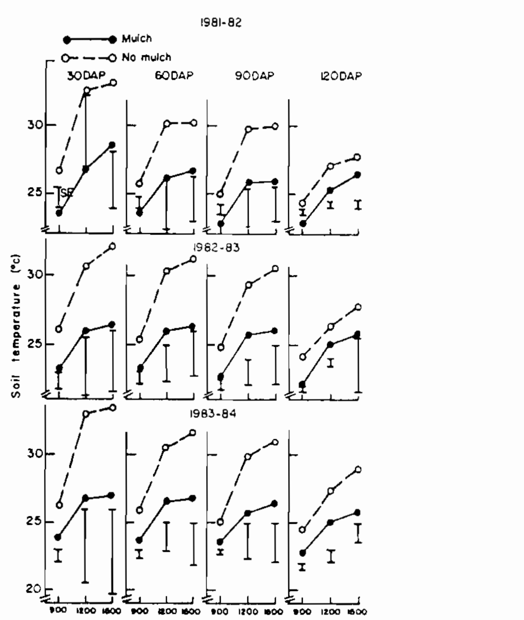

Figure 1 — Effect of mulching on diurnal soil temperature (0-10 cm depth) under late season cassava at 30, 60, 90 and 120 DAP in three cropping years.

Soil temperatures in mulched plots were lower than those in unmulched plots even as early as 9:00 hours. At 12:00 and 15:00 hours, soil temperatures increased as a result of solar radiation.

But the rate of increase was much higher in the unmulched plots (Fig. 1). At all stages of growth mulched plots had much lower temperature than unmulched ones. Soil temperature decreased with time from 30 to 120 days after planting but the rate of decrease was much higher on the unmulched plots than on the mulched ones. However the soil temperature in mulched plots varied but little as the season advanced as opposed to temperature in unmulched plots which droped drastically as cassava developed more leaf area (Fig. 2). Similar pattern has beneficial effect on soil temperature since it improves and moderates fluctuation in diurnal soil temperature.

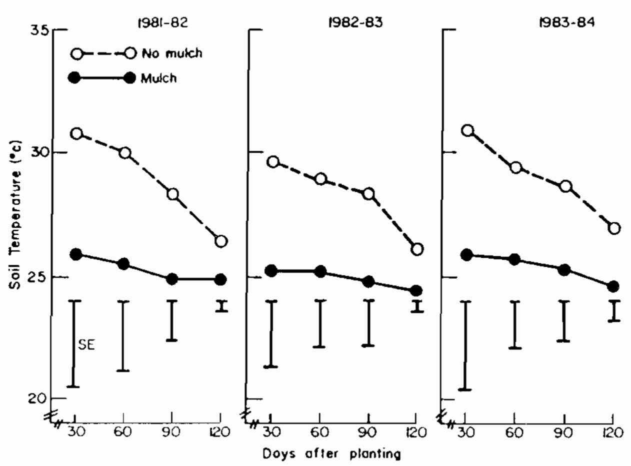

Figure 2 — Effect of mulching on soil temperature (0-10 cm depth) at various growth periods of late season cassava in three cropping years.

3.1.2. Soil moisture. The soil moisture content at 0-10 cm depth as affected by mulching is shown in Figure 3. Mulching resulted in higher soil moisture content at various growth periods under the cassava planted in the late season. Soil moisture decreased with time as the dry season advanced but the rate of decrease was lower in the mulched plots than in unmulched plots. The average percent decreases for

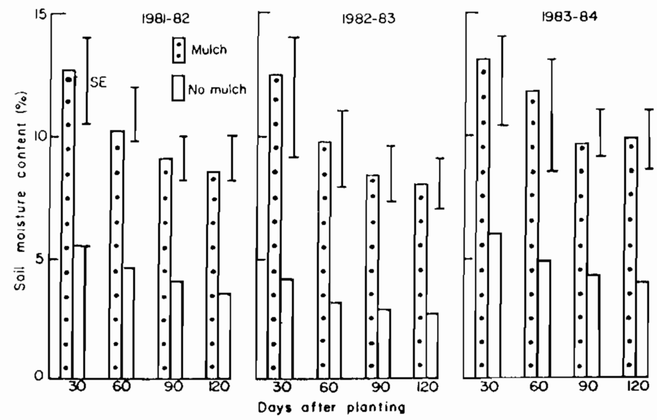

Figure 3 — Effect of mulching on percent soil moisture at 0-10 cm depth at various growth periods of late season cassava in three cropping years.

various growth periods were 16.5, 28.3 and 30.7 respectively for 60, 90 and 120 days after planting in the mulched plots whereas in unmulched plots the corresponding averages were 17.3, 30.7 and 34.6%. It appears that before complete closure of the canopy by the late season cassava, the unmulched plots were loosing more moisture than the mulched plots through evapotranspiration. Although no work has been reported on the effect of mulching on soil moisture under late season cassava, reports by Willis (19) and Lal (6) had earlier indicated that mulching indirectly influenced the soil moisture regime, the moisture holding capacity and moisture release characteristics of the soil through its effect on soil structure.

3.1.3. Soil chemical composition. Changes in soil chemical composition at 0-15 cm depth after each cropping year as affected by mulching are presented in Table 1.

(i) - *The soil pH* under mulched plots and unmulched plots did not differ very much after the first and the second cropping years while at the third year soil pH was higher under mulched than unmulched plot. The increase in soil pH observed after the third year under mulched plots was probably due to significant improvement in soil organic matter and exchangeable cations while the slight decrease of pH under unmulched plots could be attributed to erosion losses from

TABLE 1

Effect of mulching on soil chemical composition (0-15 cm depth) in three cropping years.

Treatments	Soil chemical composition						
	pH	% O.C.	% T.N.	Available P Bray-1 ppm	Exchangeable cations (meq/100 g)		
					Ca	Mg	K
1st-cropping year							
No mulch	4.5 a	1.39 a	0.119 a	43.2 a	0.26 a	0.13 a	0.18 a
Mulch	4.5 a	1.55 a	0.144 a	52.6 a	0.26 a	0.19 a	0.18 a
2nd-cropping year							
No mulch	4.4 a	1.39 b	0.125 a	41.3 b	0.16 b	0.12 b	0.14 b
Mulch	4.9 a	1.61 a	0.176 a	72.6 a	0.35 a	0.33 a	0.43 a
3rd cropping year							
No mulch	4.4 b	1.29 b	0.073 b	46.2 b	0.21 b	0.17 b	0.11 b
Mulch	5.1 a	1.64 a	0.175 a	75.0 a	1.17 a	0.63 a	0.54 a

Only means followed by different letter(s) within a column for each cropping year differ significantly at P ≦ 0.05.
% O.C. = % organic carbon   % T.N. = % total nitrogen

the topsoil. Leaching can also be another factor leading to the reduction in pH.

(ii) - *The organic carbon content* of the soil under mulched and unmulched plots remained unchanged until after the first cropping year. Thereafter it increased in mulched plots but decreased in unmulched plots. Apparently, the mulching material contributed to the organic carbon of the soil. It seems that in the first year, enough decomposition had not taken place to cause any noticeable effect, but later mulching material decomposed. Similar variations in soil organic carbon under traditional shifting cultivation have been observed in Zaire by Laudelot (10).

(iii) - *The total nitrogen* did not differ between mulched and unmulched plots after the first and the second cropping years while mulching significantly increased the soil total nitrogen after the third year. In general, total nitrogen increased with time under mulched plots due probably to the higher rate of nitrogen mineralization from the large quantities of organic material decomposed and released from mulch (15). The marked decline in total nitrogen after the third year on plots that did not receive mulch was apparently due to the higher rate of losses from volatilization, leaching, denitrification, erosion and crop removal (15).
Although, no much work has been reported in the monitoring of variations in total nitrogen during the growing season, Lal *et al.* (8) indicated that changes in total nitrogen followed a trend similar to that of soil organic carbon. However, under traditional shifting cultivation little changes in total nitrogen have been observed during cropping season (11).

(iv) - *The soil available phosphorus* under mulched and unmulched plots did not significantly differ the first cropping year. In the second and the third year, a significant increase in soil available P was noticed under plots given mulch. With time, there was a tendency for P to increase under mulch while an inconsistent decrease of P was observed in unmulched plots. A report by Lal *et al.* (8) has indicated that available phosphorus was significantly affected by mulching. The increase in available P in the mulched plots could be attributed to the increase in soil organic matter, since Sanchez (15) had mentioned that the importance of maintaining organic matter could affect the maintenance of organic phosphorus. However, the decline in available P in unmulched plots could probably be a result of plant uptake and P-fixation (15) without any replacement.

(v) - *Soil exchangeable cations* including calcium, magnesium and potassium, were not different under mulched and unmulched plots after the first cropping year. In the second and the third year, exchangeable cations increased in mulched plots while they decreased generally under plots without mulch. The rate of decrease differed with cations. for instance, under unmulched plots, calcium and magnesium decreased after the second year but tended to increase after the third year. The decline in exchangeable Ca, Mg, and K under unmulched plots could be attributed to removal through plant uptake and to losses through leaching. This observation agrees with earlier report by Obigbesan (12) indicating that cassava extract more K from the soil than N and P when equivalent amounts were applied to the soil. Another report by Sanchez (15) had suggested that under traditional cropping systems in Latin America Ca and Mg tended to leach faster than K. However, the increase of exchangeable Ca, Mg and K with time on plots given mulch could also be a result of the increase in organic matter derived from mulching. As indicated by Greenland and Dart (1) the organic matter supplies most of the cation exchange capacity (CEC) of acid soils and that the rapid decrease in organic matter results in sharp reduction in the CEC. Furthermore, Sanchez (15) had also mentioned that organic matter may form complexes with nutrients which prevent their leaching. It appears therefore, that under mulched plots, the increase in exchangeable cations could be a result of supplies through organic matter while under unmulched plots the decline in exchangeable cations could be attributed to crop removal and leaching.

3.2. Cassava growth characteristics

The effects of mulching on plant height at 3, 6 and 9 months after planting are illustrated in Figure 4. Mulching significantly increased plant height of late season cassava, irrespective of cultivars, except at 6 months after planting in the first cropping year. Cassava cultivars responded the same way to

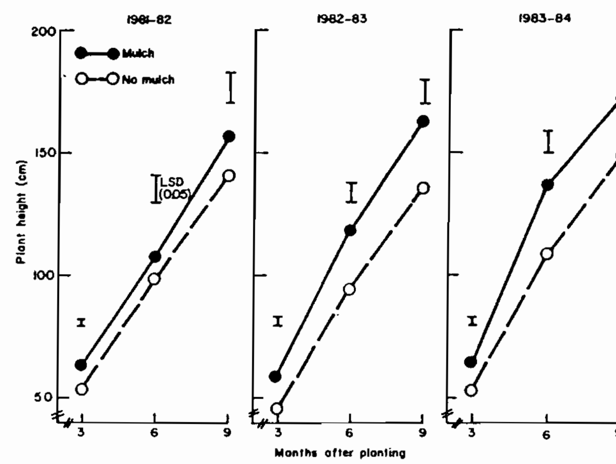

Figure 4 — Effect of mulching on plant height of late season cassava.

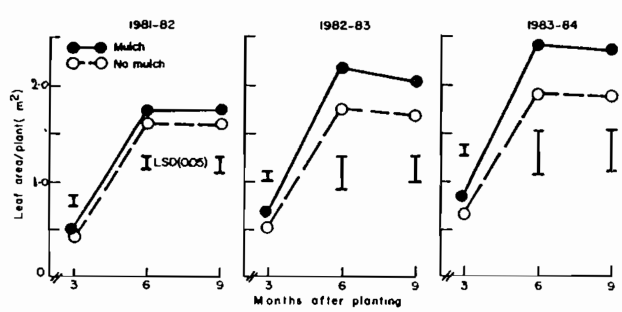

Figure 5 — Effect of mulching on leaf area of late season cassava.

mulching even though their individual heights differed. Cultivar 30010/10, 30122/2 and Mpelolongi were the tallest with average height of 179.8 cm, 175.7 cm and 172.0 cm. Leaf area per plant was not different in cassava plants from mulched and unmulched plots within 9 months after planting in the first year. But, in the following two years, higher leaf area was attained by plants from mulched plots than unmulched ones, irrespective of cassava cultivars (Fig. 5).

Higher shoot dry weight were produced by mulched cassava as compared to unmulched one at various growth stages (Fig. 6). All the cultivars had similar patterns of response to mulching although they differed in their shoot dry weights. Mpelolongi and 30555/3 produced shoots with higher dry weight. Their average weights per plant were 382.0 and 394.5 g/plant, respectively for mulched plots. The root dry weight of late season cassava at various growth stages as influenced by mulching is illustrated in Figure 7.

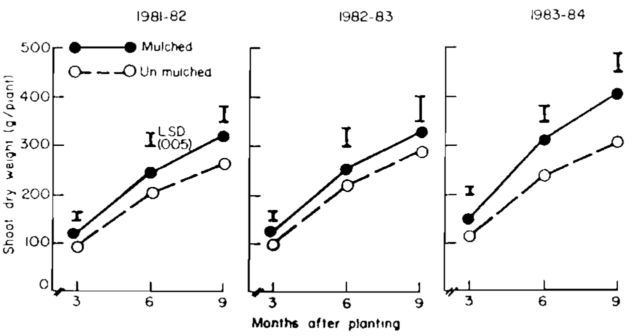

Figure 6 — Effect of mulching on shoot dry weight of late season cassava.

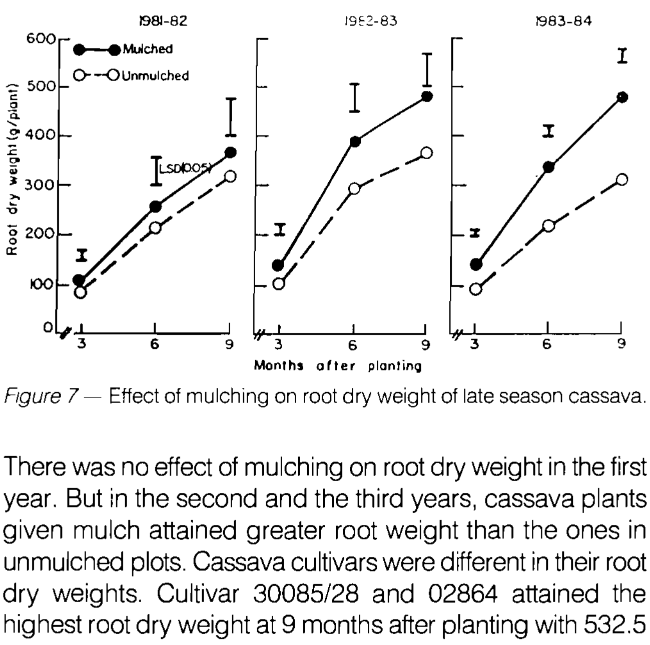

Figure 7 — Effect of mulching on root dry weight of late season cassava.

There was no effect of mulching on root dry weight in the first year. But in the second and the third years, cassava plants given mulch attained greater root weight than the ones in unmulched plots. Cassava cultivars were different in their root dry weights. Cultivar 30085/28 and 02864 attained the highest root dry weight at 9 months after planting with 532.5 and 532.4 g/plant for mulched plots and 339.1 and 396 g/plant respectively for unmulched plots.

The results agree with earlier reports by Okigbo (13) indicating that mulching increased plant height, leaf number per plant and fresh and dry weight of roots and leaves. The increase in growth and development of late season cassava may be attributed to higher soil moisture, lower evapotranspiration rate and moderate fluctuation in soil temperature during the dry season as well as to the improvement in soil texture and an increase in soil nutrients when mulch was applied.

3.3. Yield and yield components

The effects of mulching on the number of storage roots per plant were produced by plants given mulch as compared to the unmulched ones. The beneficial effect of mulching over no-mulching increased from year to year. The response of cassava cultivars to mulching was the same although their individual storage root numbers varied. Cultivar 30010/10 produced the highest number of roots per plant.

The storage root length and perimeter of late season cassava affected by mulching are shown in Tables 3 and 4. Cassava plants given mulch produced longer and bigger roots in the three cropping years as compared to the ones that did not receive mulch. As regard root length and perimeter, the response of cultivars to mulching was the same although they differed in their average root length and perimeter.
Storage root yields of late season cassava as affected by mulching are illustrated in Tables 5 and 6. Fresh and dry root yields were not affected by mulching in the first cropping year while a very significant effect of mulching was observed in the second and the third years. Cassava plants given mulch outyielded the unmulched ones in all the cropping, irrespective of cultivars. The percents of increase on the fresh yield due to mulching over no-mulching were 16.7, 28.1 and 57.7 % for the first, the second and the third cropping year, respectively. However, the response of cassava cultivar to mulching was the same although cultivar 30085/28 and 02864 obtained the highest yield.

In regard to yield and yield components of late season cassava, the beneficial effect of mulching over no-mulching increased from year to year but was more pronounced in the second and the third year. The increase in storage root yield by mulching may be attributed to an improvement in soil temperature and soil moisture conditions and to a variety of resultant chemical (3) and biochemical factors associated with mulching.

TABLE 2

Effect of mulching on storage root number per plant of late season cassava.

Cultivars	Storage root number/plant					
	1981-82		1982-83		1983-84	
	Mulch	No Mulch	Mulch	No Mulch	Mulch	No Mulch
Mpelolongi	6.5	5.5	5.2	4.0	6.4	4.2
30085/28	6.5	5.8	5.6	4.1	6.5	3.7
02864	6.2	5.2	6.8	4.0	7.3	3.9
30122/2	6.3	5.7	6.4	6.5	7.6	5.5
30555/3	6.1	4.5	5.2	3.1	6.4	3.2
30010/10	8.2	7.5	6.3	6.0	7.6	4.9
Mean	6.6	5.7	5.9	4.6	6.9	4.3
LSD (0.05)						
-for same cultivars	2.5		2.6		1.5	
-for different cultivars	2.4		2.2		1.4	
-for mulch treatments	1.0		1.1		0.6	

TABLE 3

Effect of mulching on storage root length of late season cassava.

Cultivars	Storage root length (cm)					
	1981-82		1982-83		1983-84	
	Mulch	No Mulch	Mulch	No Mulch	Mulch	No Mulch
Mpelolongi	24.2	21.0	27.2	20.0	26.7	21.0
30085/28	22.0	20.6	25.0	16.2	21.5	20.7
02864	20.9	17.5	26.5	15.0	24.7	20.0
30122/2	18.9	16.4	21.5	16.5	22.2	20.0
30555/3	22.8	19.2	26.5	15.7	26.2	19.7
30010/10	17.7	15.3	20.5	15.0	22.2	19.5
Means	21.1	18.3	24.4	16.4	23.9	20.2
LSD (0.05)						
-for same cultivars	4.1		3.4		4.1	
-for different cultivars	4.0		4.9		3.6	
-for mulch treatments	1.7		1.4		1.7	

TABLE 4

Effect of mulching on storage root perimeter of late season cassava.

Cultivars	Storage root perimeter (cm)					
	1981-82		1982-83		1983-84	
	Mulch	No Mulch	Mulch	No Mulch	Mulch	No Mulch
Mpelolongi	13.2	10.7	19.2	17.0	16.0	12.2
30085/28	15.1	12.4	20.2	16.5	16.5	12.5
02864	14.2	10.5	20.5	15.2	17.0	13.2
30122/2	12.5	9.5	18.0	14.0	15.2	12.2
30555/3	13.2	11.8	19.0	15.7	16.5	16.0
30010/10	10.7	10.4	17.5	12.2	17.5	13.0
Means	13.2	10.9	19.1	15.1	16.4	13.2
LSD (0.05)						
-for same cultivars	2.5		4.1		3.1	
-for different cultivars	3.3		4.4		2.9	
-for mulch treatments	1.0		1.7		1.2	

TABLE 5

Effect of mulching on fresh storage root yield of late season cassava.

Cultivars	Fresh storage root yield (t/ha)					
	1981-82		1982-83		1983-84	
	Mulch	No Mulch	Mulch	No Mulch	Mulch	No Mulch
Mpelolongi	14.4	12.1	18.5	14.2	18.3	10.1
30085/28	15.2	12.6	19.3	15.4	19.9	13.6
02864	14.3	12.3	20.6	15.3	18.9	12.8
30122/2	11.3	10.9	13.7	12.2	13.6	9.0
30555/3	10.7	9.0	14.6	10.3	14.3	9.2
30010/10	11.7	11.2	11.8	9.4	12.6	8.0
Means	12.9	11.3	16.4	12.8	16.3	10.5
LSD (0.05)						
-for same cultivars	6.1		5.6		2.1	
-for different cultivars	6.5		5.4		2.4	
-for mulch treatments	2.5		2.3		0.8	

TABLE 6

Effect of mulching on dry storage yield of late season cassava.

Cultivars	Dry storage root yield (t/ha)					
	1981-82		1982-83		1983-84	
	Mulch	No Mulch	Mulch	No Mulch	Mulch	No Mulch
Mpelolongi	4.7	4.0	6.2	4.7	6.1	3.4
30085/28	5.3	4.4	6.7	5.0	6.8	4.7
02864	4.8	4.2	7.1	5.2	6.8	4.5
30122/2	3.7	3.6	4.5	3.9	4.7	3.1
30555/3	3.7	3.2	5.2	3.7	4.9	3.2
30010/10	3.4	3.7	4.0	3.1	4.4	2.8
Means	4.3	3.8	5.6	4.3	5.6	3.6
LSD (0.05)						
-for same cultivars	2.1		1.9		0.7	
-for different cultivars	2.2		1.8		0.8	
-for mulch treatments	0.8		0.8		0.3	

4. Conclusion

Mulching reduced the soil temperature at 10 cm depth and increased the soil moisture content under late season cassava. With continuous application of mulch for 3 years, soil pH, organic carbon content, total nitrogen, soil available phosphorus and soil exchangeable cations (Ca, Mg, K) increased probably as a result of increase in organic matter derived from mulching. Growth, development and yield of late season cassava increased with mulch application. It appears that, the agronomic importance of yield increase in late season cassava by mulching is significant on the acid ultisol. Therefore, easy and cheap practical means of procuring and applying mulch materials should be developed in order not to limit its use.

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