

Effect of time of siam weed (*Chromolaena odorata*) mulch application on soil properties, growth and tuber yield of white yam

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Abstract: Experiments were conducted at two locations during the 2010/2011 cropping season for early yam production at Owo in the forest-savanna transition zone of southwest Nigeria to study the effect of time [December (D), January (J), February (F) and March (M) and a Control – no mulch (O)] of siam weed (*Chromolaena odorata*) mulch application on soil physical and chemical properties, growth and tuber yield of white yam. Mulch material in form of siam weed reduced soil temperature, bulk density, days to 50% sprouting and increased soil moisture content, SOM, N, P, K, Ca and Mg, vine length, leaf area and tuber yield of yam compared with the control. Mulch application in December (D) significantly produced higher ($p = 0.05$) SOM, N, P, K, Ca and Mg, vine length, leaf area and tuber yield of yam compared with mulch application in March (M). Mulch application in December (D) increased tuber yield of yam by 44.4% at site 1 and 47.4% at site 2 compared with the control (O). Similarly mulch application in December increased tuber yield of yam by 26.7% at site 1 and 23.2% at site 2 compared with March (M) application. However, because mulch application in December is statistically similar to January (J) applications in term of tuber yield, therefore either of the two is recommended for yam production.

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Introduction

Nigerian population is increasing day by day; this is likely going to pose a serious threat to food security. Tropical tuber crops are an important source of carbohydrate in developing nations, especially among the resource poor and rural populations. They are planted by millions of people in the tropics and are also identified to be the major source of food for the population of the world in the next decade (Scott *et al.*, 2000). Yam apart from being important as a source of energy in the diet of millions of people and livestock, it also has cultural and socio-economic significant (Agbede and Adekiya, 2012). However, most tropical tuber crops especially yams are not managed optimally, thus, resulting in low yield (Sangakkara *et al.*, 2004). The present trend on sustainable agriculture requires successful soil resource management geared toward better crop production. Among the most important factor affecting yield of yam, soil moisture and temperature are considered vital factors as they affect root development and hence could impose a significant impact on yields (Yamauchi *et al.*, 1996).

Mulching is a common practice recommended for tropical small holder farming system (Sangakkara *et al.*, 2004), due to its ability to conserve soil and moisture and moderate soil temperature. Mulching is a major aspect of yam production. Mulch-farming has been found an easy way to enhance natural soil-

nutrient build-up and soil quality protection. Inyang (2005) and Gbadebor (2006) revealed that mulch materials improve soil physico-chemical properties, suppress soil temperature, reduce evaporation and increase moisture thereby creating enabling soil micro-climatic condition for easy yam sprouting. Siam weed (*Chromolaena odorata*) has potential that sustain crop growth in all seasons. It is readily available to resource poor farmers; it grows luxuriantly and rejuvenates the soil of southwest Nigeria. The beneficial effect of mulching on soil moisture and temperature, growth and yam yield had been reported by various workers (Agbede *et al.*, 2013; Eruola *et al.*, 2012; IITA, 1995; Kutugi, 2002).

Since yams are planted between the period extending from the cessation of the rains in a given year to the time of onset in the succeeding year, it implies therefore that as soon as planting starts, soil moisture become critical, hence the need for effective soil moisture conservation strategy in other to optimize soil physical condition affecting crop yield (Eruola *et al.*, 2012). Farmers in southwest Nigeria mulch their yam plots at different times from immediately after planting through the dry period of cessation of rain to the month of March the succeeding year. Yams may react differently to different times of mulch application. Therefore this article sought to compare the time of application of

mulch on soil physico-chemical properties, growth and tuber yield of white yam.

Material and methods

Site description and treatments

Field experiments were carried out at Isuada (site 1 - latitude 7° 13'N and longitude 5° 35'E) and Obasooto village (site 2 - latitude 7° 12'N and longitude 5° 32'E), in Owo during the 2010/2011 early yam cropping season. Owo is located within the forest-savanna transition zone of southwest Nigeria. The soil at Owo is an Alfisol, and is classified as Oxic Tropudalf (USDA, 1999) or Luvisol (FAO, 1998) derived from quartzite, gneiss and schist (Agbede, 2006). The average rainfall varied from 1000 to 1240 mm. Owo has a bimodal rainfall pattern with first season commencing from March to July with dry spell in August followed by the second season, from September to November. The sites were manually cleared from 2-year old bush fallow after arable cropping. The experiment consisted of four different times [December (D), January (J), February (F) and March (M)] of mulch (Siam weed: *Chroolaena odorata*) applications to white yam (*Dioscorea rotundata* cv. Gambari) and a control (O) (no application of mulch). The 5 treatments were laid out in a randomised complete block design with 3 replications. Each block comprised 5 plots, each of which measured 6 x 5 m². Blocks were 1 m apart and plots were 0.5 m apart. The same treatment was allotted to each plot at the two sites.

Planting of yam and application of mulch

After manual clearing, mounding was done manually at 1 m x 1 m spacing in November 2010. Each mound was approximately 1 m wide at the base and about 0.75 m high. Planting was done immediately after mound construction in November at Isuada (site 1) and Obasooto (site 2). One seedyam weighing about 0.4 kg of white yam (*Dioscorea rotundata* cv. Gambari) was planted per mound. One month after planting (10th of December, 2010), fresh siam weed was collected from nearby bush containing green tender stems and the leaves equivalent to 10 t/ha was applied (Agbede, *et al.*, 2013) to cover the mound for December treatment. Siam weed leaves and tender stems were also collected and applied on 10th January, 10th February and 10th March, 2011 at Isuada (site 1) and Obasooto (site 2) for January, February and March treatments, respectively. Staking was done after sprouting; weeding was done manually with a hoe four times throughout the cropping period at both sites.

Determination of soil properties

Prior to the commencement of the experiment in 2010, soil samples were taken from 0 to 15 cm depths of a pit located at each site. The samples were put in an oven set at 100°C for 24 h for determination of bulk density. The soil samples were also bulked, air-dried and sieved using a 2mm sieve and analysed for particle-size, soil organic matter, total N, available P, exchangeable K, Ca and Mg, and pH. At the end of the experiment (2011), soil samples were also taken for routine soil analysis on plot basis. Samples were analysed as described by Pansu and Gautheyrou (2006). Particle-size analysis was done using hydrometer method (Gee and Or, 2002). The organic matter was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996). Total N was determined by micro-Kjeldahl digestion method (Bremner, 1996), available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry (Frank *et al.*, 1998). Exchangeable K, Ca and Mg were extracted using ammonium acetate, K level was determined using a flame photometer, and Ca and Mg by the EDTA titration method.

From late March, determination of certain soil physical properties in all plots commenced and this was done at monthly interval on six occasions throughout the growing period. Five undisturbed core samples were collected at 0-15 cm depth from each plot on the top of yam mound using steel core samplers (4 cm diameter, 15 cm high) and were used for the determination of bulk density and gravimetric moisture content after oven drying of samples at 100°C for 24h. Soil temperature was determined at 15.00h with a soil thermometer inserted to 15 cm depth. Five readings were made per plot at each sampling time and the mean data were computed.

Growth and yield parameters

Ten plants were selected per plot for the determination of leaf area at 7 months after planting (MAP) using graphical method. Vine length was measured by meter rule at harvest (8 months after planting). Days to 50% sprouting was done by counting the number of days from planting to when 50% of the seedyam sprouted.

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) using the SPSS 16.0 and Microsoft Office Excel 2007 packages and treatment means were compared using the Duncan's multiple range test (DMRT).

Results

Initial soil fertility status of the experimental sites

Table 1 shows the results of the soil physical and chemical properties at site 1 (Isuada) and site 2 (Obasooto) before experimentation in 2010 and the critical values of soil nutrients in the ecological zone. The soils at both sites were slightly acidic, sandyloam

in texture with fairly high bulk densities. Based on the critical levels for soils in the ecological zone in Nigeria (Akinrinde and Obigbesan, 2000), the soils at both sites were generally low in organic matter and essential nutrients (except for N at site 1 and Mg at site 2, which were adequate).

Table 1. Soil physical and chemical properties of the experimental sites before cropping in 2010 and the critical values of soil nutrients according to Akinrinde and Obigbesan (2000)

Property	Isuada (Site 1)	Obasooto (Site 2)	Critical values of soil nutrients according to Akinrinde and Obigbesan (2000)
Sand (%)	68	67	
Silt (%)	14	15	
Clay (%)	18	18	
Textural class	Sandyloam	Sandyloam	
Bulk density (Mg/m ³)	1.33	1.35	
Total porosity (%)	49.8	50.9	
pH (water)	5.8	5.9	
Organic matter (%)	2.85	2.55	3.0
Total N (%)	0.21	0.19	0.20
Available P (mg/kg)	5.6	6.2	10.0
Exchangeable K (cmol/kg)	0.12	0.11	0.15
Exchangeable Ca (cmol/kg)	1.15	1.51	2.0
Exchangeable Mg (cmol/kg)	0.39	0.50	0.40

Effect of time of siam mulch application on soil bulk density, moisture content and temperature

The effect of time of mulch application on soil bulk density, moisture content and temperature at site 1 (Isuada) and site 2 (Obasooto) are shown in Table 2, 3 and 4, respectively. Applications of mulch influenced bulk density significantly ($p = 0.05$) between mulched and unmulched plots (control). There were no significant differences in bulk densities between December, January, February and March mulch applications. Soil bulk density did not also change between the months of March and August (Table 2). Mulch applications also influenced soil moisture content significantly ($p = 0.05$) between mulched and unmulched plots with mulched plots

having higher values (Table 3). In all the months of data taken from March to August and the mean soil moisture content increased significantly with mulch application. However, there were no significant differences between December and January, and February and March applications (Table 3). Time of mulch application also influenced soil temperature significantly ($p = 0.05$) between mulched and unmulched plots. Mulched plots had significantly lower ($p = 0.05$) soil temperatures compared with unmulched plots (Table 4). Using the mean, there were no significant differences between mulch applied in December and January and between February and March, but there was a significant difference between mulch applied in December and March.

Table 2. Effect of time of siam weed mulch application on soil bulk density (Mg/m³) at site 1 and site 2 when averaged across six sampling periods

Treatment	March	April	May	June	July	August	Mean
No mulch/Control (O)	1.35a	1.35a	1.35a	1.35a	1.35a	1.35a	1.35a
Mulch applied in December(D)	1.20b	1.20b	1.20b	1.20b	1.20b	1.20b	1.20b
Mulch applied in January(J)	1.22b	1.22b	1.22b	1.22b	1.22b	1.22b	1.22b
Mulch applied in February(F)	1.24b	1.24b	1.24b	1.24b	1.24b	1.24b	1.24b
Mulch applied in March(M)	1.25b	1.25b	1.25b	1.25b	1.25b	1.25b	1.25b

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT)

Effect of time of siam weed mulch application on soil chemical properties

The effect of time of siam weed mulch application on soil chemical properties at site 1 and site 2 are shown in Table 5. Mulched plots significantly had

higher ($p = 0.05$) soil organic matter (SOM), N, P, K, Ca and Mg compared with unmulched plots. There were also significant differences between the times of mulch application with December having the highest values and March having the least. At both sites, the orders of decrease on soil chemical properties are:

December>January>February>March>Control. Therefore, mulch application in December increased the organic matter of the soil by 23.4% at site 1 and 34.9% at site 2 compared with mulch application in March.

Table 3. Effect of time of siam weed mulch application on soil moisture content (%) at site 1 and site 2 when averaged across six sampling periods

Treatment	March	April	May	June	July	August	Mean
No mulch/Control (O)	11.4e	12.6e	13.1e	13.3e	12.9e	11.7e	12.6c
Mulch applied in December(D)	14.8a	13.2d	14.2d	14.4d	13.9d	13.5d	14.0b
Mulch applied in January(J)	13.4ab	13.9cd	14.9cd	15.2cd	14.3cd	14.2cd	14.3b
Mulch applied in February(F)	12.6cd	14.9ab	15.9ab	16.3ab	15.2ab	15.6ab	15.1a
Mulch applied in March(M)	12.1d	15.3a	16.9a	17.1a	16.1a	16.8a	15.7a

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT)

Table 4. Effect of time of siam weed mulch application on soil temperature ($^{\circ}$ C) at site 1 and site 2 when averaged across six sampling periods

Treatment	March	April	May	June	July	August	Mean
No mulch/Control (O)	35.1a	33.5a	31.3a	30.1a	30.3a	31.6a	32.0a
Mulch applied in December(D)	31.5b	29.1b	28.9b	27.7b	27.9b	28.1b	28.8b
Mulch applied in January(J)	30.5b	28.6b	28.1b	27.1b	27.0b	27.8b	28.4b
Mulch applied in February(F)	29.1bc	27.3bc	27.5bc	26.0bc	26.2bc	27.2bc	27.2c
Mulch applied in March(M)	28.2c	26.1c	26.1c	25.1c	25.4c	26.1c	26.2c

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT)

Table 5. Effect of time of siam weed mulch application on soil chemical properties

Treatment	SOM (%)		N (%)		P (mg/kg)		K (cmol/kg)		Ca (cmol/kg)		Mg (cmol/kg)	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
O	2.15e	2.45e	0.17e	0.19e	4.8e	5.1e	0.11e	0.10e	1.09e	1.11e	0.42e	0.36e
D	3.01a	3.40a	0.27a	0.28a	9.6a	9.8a	0.18a	0.17a	1.75a	1.86a	0.76a	0.66a
J	2.90b	3.10b	0.23b	0.25b	8.4b	8.6b	0.16b	0.15b	1.63b	1.70b	0.62b	0.54b
F	2.60c	2.79c	0.21c	0.23c	7.3c	7.0c	0.14c	0.13c	1.50c	1.58c	0.51c	0.43c
M	2.44d	2.52d	0.19d	0.21d	6.5d	5.9d	0.13d	0.12d	1.32d	1.37d	0.46d	0.31d

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT); O = control, no mulch application; D = December mulch application; J = January mulch application; F = February mulch application; M = March mulch application.

Effect of time of siam weed mulch application on growth and yield of yam

Data on the effect of time of siam weed mulch application on the growth and yield of yam are shown in Table 6. At both sites 1 and 2, application of mulch significantly increased ($p = 0.05$) vine length, leaf area and tuber yield of yam compared with unmulched plots. However, unmulched plots had higher days to 50% sprouting compared with mulched plots. Among times of mulch application, December produced higher vine length, leaf area, tuber yield of yam and least days to 50% emergence/sprouting compared with

January, February and March mulch applications, although the values of vine length, leaf area and tuber yield were not significantly different for December and January, and February and March mulch applications. The decreasing order of growth and yield of yam at both sites were $D > J > F > M > O$. Mulch application in December(D) increased tuber yield of yam by 44.4% at site 1 and 47.4% at site 2 compared with the control (O). Similarly mulch application in December increased tuber yield of yam by 26.7% at site 1 and 23.2% at site 2 compared with March (M) application.

Table 6. Effect of time of siam weed mulch application on the growth and yield of yam

Treatment	Days of 50% sprouting (DAP)		Vine length (m)		Leaf area (m ²)		Tuber yield (t/ha)	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
No mulch/Control (O)	135a	137a	2.90c	2.80c	1.90e	1.76e	24.3e	22.8d
Mulch applied in December(D)	72d	74d	3.80a	3.84a	3.59ab	3.28ab	35.1ab	33.6ab
Mulch applied in January(J)	83c	85c	3.70a	3.74a	3.41b	3.14b	34.8b	32.9b
Mulch applied in February(F)	112b	114b	3.21b	3.15b	2.78cd	2.50cd	29.2cd	27.8c
Mulch applied in March(M)	133a	135a	3.16b	3.01bc	2.59d	2.41d	27.7d	27.2c

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT); DAP= Days after planting

Discussion

Effect of time of siam weed mulch application on soil bulk density, moisture content and temperature

There was increased in soil moisture content, reduced bulk density and temperature in mulched plots compared with unmulched plots. The favourable temperature and moisture regime observed in mulched plots was similar to previous findings on mulching (Zaman and Choudhuri, 1995; Agele *et al.*, 1999 and Agbede *et al.*, 2013). This could be attributed to reduction of evaporation losses of the soil. In bare unmulched plots, there was increased soil moisture evaporation due to high soil temperature status. In a field study carried out to evaluate the effect of grass mulch on the soil and yield of maize and millet, Adeoye (1984), observed maximum temperature of 38-43°C at a soil depth of 5 cm in unmulched plots. Application of mulch at 5 t/ha reduced maximum temperature at 5 cm by 7°C and at 10 cm by 4°C. Mulches insulated and protected soil direct sunlight and prevented it from hard setting and toughness by controlling rates of evaporation (Tolk *et al.*, 1999). Therefore, the soil that was covered by mulch remain cooler as compared to non-mulched soil because of minimal temperature change. The reduction in soil bulk density observed in mulched plots compared with unmulched plots (control) was due to increase in soil organic matter resulted from the degraded mulch materials. The organic matter should have stabilized soil structure thereby reducing bulk density and increasing water content. Favourable effects of residue mulching on soil organic matter, water retention and stability of aggregates have been reported for surface layer (Havlin *et al.*, 1990 and Duiker and Lal, 1999). Therefore mulch increased soil moisture, organic matter contents leading to suitable environment for root penetration.

The significant difference of moisture content and temperature between December (D) and March (M) mulch applications could be adduced to the surface sealing of soils in March treatments due to long exposure before mulch application which caused reduction of rain infiltration (Adeoye, 1990). Thus a mulch layer increases soil moisture content and reduced temperature by increasing the capture of rain

water and by conserving the water which has been captured.

Effect of time of siam weed mulch application on soil chemical properties

Application of siam weed mulch to the soil at site 1 and site 2 increased SOM, N, P, K Ca and Mg compared with no application of mulch. The increase in soil SOM and nutrients attributed to siam weed mulch affirmed that these nutrients were released into the soil by decomposed mulch. Other workers (Akanbi and Ojeniyi, 2007; Awodun and Ojeniyi, 1998; Agbede *et al.*, 2013) also proved that siam weed residue decomposed to enhance soil organic matter and nutrients. The increase in soil SOM and nutrients in mulched plots could also be adduced to possible reduction of nutrient losses by surface erosion and leaching to mulch application. The mulch material also helps to control weeds thereby reducing competition for nutrients. The difference in soil nutrient composition between December and March mulch applications could be due to total decomposition of mulch material (siam weed) to release nutrients in case of December application and partial decomposition in case of March application. Opara-Nadi and Lal (1987) reported that fresh shoots of siam weed mulch improved soil nutrient availability.

Effect of time of siam weed mulch application on growth and yield of yam

The significant influence of vine length, leaf area and tuber yield to siam weed mulch compared with no application could be due to reduced temperature and bulk density and increased availability of SOM, N, P, K Ca and Mg due to the mulch (Agbede *et al.*, 2013) and increased availability of moisture. The improved soil moisture and reduced temperature could have enhanced root development possibly through greater soil moisture and nutrient uptake, which favoured vine length and leaf area development in mulched plots. Improved leaf area development could reduce evaporative loss and increase infiltration probably due to increased soil biological activities as a result of lower soil temperature were reported by Olaniran (1988) and Zaman and Choudhuri (1995). The mulched plots attained earlier days to 50% sprouting

compared with the unmulched plots. This could be attributed to the favourable soil moisture and temperature regimes available to the mulched plots during the critical period of rains cessation. Inyang (2005) and Gbadebor (2006) revealed that mulch materials improved the soil physico-chemical properties, suppressed soil temperature, reduced evaporation and increased the soil moisture, thereby creating enabling soil microclimatic conditions for early sprouting of yams. Other workers (Odjugo, 2008 and Olsantan, 1999) had earlier reported that the emergence and growth rate of yam seedlings were observed to be significantly earlier in mulched plots than unmulched plots.

The findings that December and January mulch applications produced better growth and yield compared to February and March mulch applications could be added to better release of SOM, N, P, K Ca and Mg by these treatments which are due to complete decomposition of the mulch materials compared with February and March applications. The higher yield produced by December and January mulch application could also be as a result of better soil and microclimatic conditions that brings about early sprouting (emergence) and early development of yam plot (Odjugo, 2008). The December and January mulch was now well decayed during the period of tuber formation thus allowing solar radiation to reach the mound and increase the soil temperature, a condition needed for the development of long and big yam tubers (Madu, 2003). Whereas, in the February and March applications, mulch was still on the mound surface preventing solar radiation from reaching the soil and preventing the needed microclimate for tuberization. Madu (2003) reported that most traditional farmers in West Africa normally remove mulch materials during tuber formation stage in yams.

Conclusion

Results showed that mulch material in form of siam weed reduced soil temperature, bulk density, days to 50% sprouting and increased soil moisture content, SOM, N, P, K Ca and Mg, vine length, leaf area and tuber yield of yam compared with the control. Mulch application in December (D) also produced significantly higher tuber yield (average of 25% from both sites) compared with mulch application in March (M). Because mulch application in December is statistically similar to January (J) application in term of tuber yield, therefore either of the two is recommended for yam production.

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