# Soil Microclimate and Crop Yield of *Zea mays* (L.) As Affected by Mulching and Nitrogen Application

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## Abstract
*The experiment was conducted in the Teaching and Research Farm unit of the Department of Agricultural Science Education, Delta State University, Abraka, (latitude $5^0$ 46'N and longitude $6^0$ 5'E) Nigeria during the 2011 and 2012 cropping seasons. The study was aimed at evaluating the comparative effects of organic mulches and mineral nitrogen application on soil moisture, soil temperature and yield and yield components of maize. Eight treatments arranged in a randomized complete block design were used. The treatments were: control, three nitrogen levels applied at 40, 80 and 120kgN/ha and four weed-based mulch supplemented with 40kgN/ha. Results showed increased soil moisture and reduced temperature with use of organic mulch. Guinea grass had the highest prime effect (-2.4) and longer duration effect of 85 days, while tropical kudzu had the lowest prime effect (-1.4) and shorter duration effect (33 days). Increasing nitrogen increased the components of yield and yield with maximum grain yield of 1292.6 kg/ha 120N. In mulch supplemented with nitrogen, tropical kudzu and stylo gave higher grain yield of 968.5 kg/ha and 946.3 kg/ha respectively compared to the grasses which recorded 872.8 kg/ha (guinea grass) and 890.6kg/ha (goose grass). The study showed that leguminous mulch has more potential of contributing to direct effect on the crop in terms of higher yield compared to grass weeds, while the grass mulch have more indirect effects in regulating soil microclimate.*

**Keywords:** Mulch, soil moisture, temperature, maize, grain yield

## INTRODUCTION
In the humid tropics, unfavourable conditions for crop growth and yield are created by the extreme climatic regimes and highly degraded acidic soils, which create the need for sustainable agricultural practices (Akobundu, 1993; Obiokoro, 2005). As noted by Akobundu (1993), a combination of several factors such as deforestation, poor agricultural technologies, excessive grazing, and increasing human population have greatly contributed to depletion of soil resource. Understanding the farming ecosystem (biotic and abiotic) and identifying low cost technologies that will enhance natural resource conservation are, therefore, needed for crop productivity. One of the options for creating a sustainable farming environment for crop production is the use of plant materials as organic mulch material. Application of dead mulch in planted fields has been used to influence soil micro-environments such as moisture and temperature, prevents soil crust formation, leaching of mineral fertilizer (Adetayo and Fawusi, 1988;Anikwe *et al.*., 2007; Glab and Kulig, 2008) and increase crop yields (Sinkeviciene *et al.*, 2009; Uwah and Imo, 2011). Increased soil moisture also ensures that macropores are filled with sufficient water and oxygen which enhance diffusion of oxygen and soluble substrates (Linn and Doran, 1984; Zhou *et al.*. 2014). Integrated farming systems which combine dead weeds as organic mulch along with mineral fertilizer can also contribute to soil fertility restoration (Tian *et al.*., 1994).

Nutrient release from decomposing organic mulches (slow and fast decomposing types) have been shown to have significant positive effects on the soil. Available macronutrients such as potassium and phosphorus have been shown to increase with grass and straw mulch (Cadavid *et* *al*.., 1998; Sonsteby *et al*.., 2004), while mulching with legumes such as mucuna, tropical kudzu, phospho and centro promotes soil organic matter and reduces the need for chemical nitrogen application (Akobundu, 1993). Improvement in soil physical and chemical properties and good maize grain yield were reported from mulching with plant residue (Bhatt *et al*.., 2004 and Khurshid *et al*.., 2006). Yield and yield components of yam were observed to be increased by mulching compared to those on unmulched plots (Eruola *et al*.., 2012). A combination of mineral nitrogen and *Leucaena* pruning as mulch resulted in significant maize grain yield (Tian *et al*.., 1994).

This field investigation was therefore undertaken to determine the comparative effects of organic mulches and mineral nitrogen application on soil moisture, soil temperature and yield and yield components of maize.

**MATERIALS AND METHODS**

The experiment was conducted in the Teaching and Research Farm unit of Department of Agricultural Science Education Unit, Delta State University, Abraka, Nigeria during the 2011 and 2012 cropping seasons. Abraka town lies on latitude $5^0$ 46'N and longitude $6^0$ 5'E in the Niger Delta area of South-South zone, Nigeria. The area has a bimodal rainfall consisting of the early rains (mid-March-July) and late rains (September-November) with an average temperature of $26.7^0$C and yearly rainfall of 232cm.

The experiment was a randomized complete block design consisting of eight treatments, namely, four levels of nitrogen (urea) applications at the rates of 0 (control), 40, 80 and 120kgN/ha and four levels of weed-based mulch supplemented with 40kgN/ha. The weeds used as mulching materials were guinea grass (*Panicum maximum*), tropical kudzu (*Pueraria phaseoloides*), goose grass (*Eleusine indica*) and stylo (*Stylosanthesgracilis*). Maize plants were planted at 90cn between rows and 30cm within rows. Air dried weeds were applied at the rate of 4.5t/ha in form of mulch to maize (cv. TZSR-Y) plants after two days of planting. Application of urea was at the first and six WAP. In order to determine the nutrient content of added mulch materials to supplemented nitrogen, the nitrogen, phosphorus and potassium content of the weeds were analyzed using methods described by IITA (1982). During the period of crop growth, soil temperature measurements were made at two-weeks interval at a depth of 10cm. In each experimental plot, five soil core samples were taken at the top 10cm layer to determine the soil moisture retention. The water retention was determined using the gravimetric method.

The duration effect and prime effect of soil temperature and soil moisture were determined using methods described by Tian *et al*.. (1994). The duration effect was estimated from the time period within which the soil temperature/ soil moisture reduction is greater than the mean $LSD_{0.05}$ over the experimental period, while the prime effect is the average of the soil moisture/ soil temperature reduction relative to the control within the first month after application of dried weed mulch.

At harvest, data on components of yield (number of cobs per plant, number of grains per cob, cob length, cob girth, 100 grain weight) and grain yield were determined.

Data collected were subjected to analysis of variance (ANOVA), and significantly different means were separated using LSD at 5% level of probability.

## RESULTS

### Nutrient Content of Organic mulch

Analysis of the nutrient contents of the added weed mulch (Table 1) indicates that the amount in of nitrogen in kg $ha^{-1}$ used along with urea and the various mulch materials was as follows: guinea grass 81.6, tropical kudzu 169.3, goose grass 78.1 and stylo 158.7. The order of phosphorus content in the mulch materials were tropical kudzu 35.8, stylo 24.7, guinea grass 19.9 and goose grass 11.5 kg $ha^{-1}$., while potassium had a similar sequence to that of phosphorus, with tropical kudzu recording the highest K content (72.9 kg $ha^{-1}$), while goose grass had the least (23.4 kg $ha^{-1}$).

**Table 1: Quantity of nutrients added (in kg $ha^{-1}$) with 4.5t $ha^{-1}$ of mulching materials and urea at different rates**

| | N | | P | | | K |
|---|---|---|---|---|---|---|
| | In* | Or* | In* | Or* | In* | Or* |
| Control | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | 40 | 0 | 0 | 0 | 0 | 0 |
| 80 | 80 | 0 | 0 | 0 | 0 | 0 |
| 120 | 120 | 0 | 0 | 0 | 0 | 0 |
| 4.5t/ha guinea grass + 40N | 40 | 41.6 | 0 | 19.9 | 0 | 31.7 |
| 4.5t/ha tropical kudzu + 40N | 40 | 129.3 | 0 | 35.8 | 0 | 72.9 |
| 4.5t/ha goose grass + 40N | 40 | 38.1 | 0 | 11.5 | 0 | 23.4 |
| 4.5t/ha Stylo + 40N | 40 | 118.7 | 0 | 24.7 | 0 | 58.4 |

* In-Inorganic source

*Or-Organic source

### Soil Microclimate

The mean soil moisture, soil temperature and their prime effects are shown in Table 2, while Figure 1 shows the duration effect of soil temperature and soil moisture.

***Soil temperature***: The mulched plots generally had lower soil temperature during the growth of maize (Table 2). The mean soil temperature of the legumes, tropical kudzu and stylo were not significantly different from the control, but the grasses, guinea grass and goose grass were observed to be significantly reduced. Mulching effects with grasses were more than the legumes, hence the grasses maintained lower soil temperature through the maize growth period. Soil temperature ranged from $26.8^0C$ (guinea grass) to $28.9^0C$ (control). Guinea grass had the highest prime effect (-2.4) and longer duration effect (Figure 1) of 85 days, while tropical kudzu had the lowest prime effect (-1.4) and shorter duration effect (33 days).

***Soil moisture*****:** The mean soil moisture content was increased by mulching during the maize growth period. Application of guinea grass indicated the highest soil moisture content of 23.8%. This was followed by goose grass, with the least observed in tropical kudzu. As observed in soil temperature, guinea grass had the highest prime effect (4.8), which was more than that from tropical kudzu, and almost the combined effect of tropical kudzu and stylo (Table 2). The duration effect (Figure 1) of 72 days observed with guinea grass was 2.3times higher than tropical kudzu, and also higher than the combined effect of tropical kudzu and stylo.

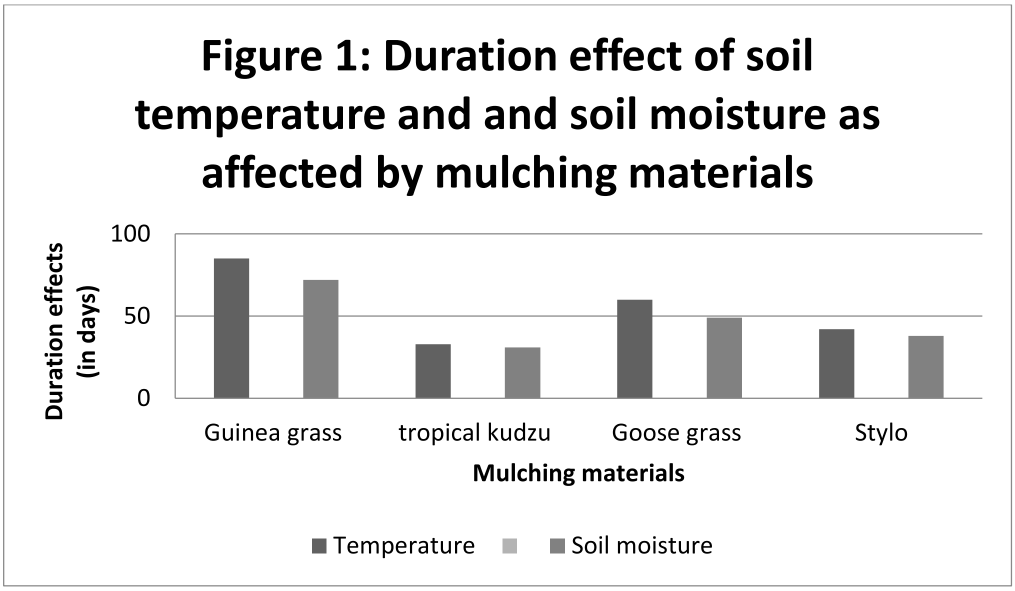


**Table 2: Mean soil temperature and moisture content of mulching materials and their prime effects during the cropping period**

| | Soil Temperature($^0$C) | | Soil Moisture (%) | |
|---|---|---|---|---|
| | Mean | Prime effect | Mean | Prime effect |
| Control | 28.9$^a$ | | 20.2$^b$ | |
| 4.5t/ha guinea grass | 26.8$^c$ | -2.4 | 23.8$^a$ | 4.8 |
| 4.5t/ha tropical kudzu | 28.0$^b$ | -1.4 | 20.5$^b$ | 2.0 |
| 4.5t/ha goose grass | 27.2$^{bc}$ | -1.9 | 22.6$^a$ | 3.7 |
| 4.5t/ha Stylo | 27.8$^a$ | -1.6 | 21.1$^b$ | 2.9 |
| LSD (5%) | 0.9 | | 1.7 | |

Means with the same letters within the column are not significantly different (P <0.05)

In this study, mulching with organic materials was observed to reduce soil temperature and increased the soil moisture content. The thick organic mulch layers must have provided sufficient protection against solar radiation, which would have contributed to reduced soil temperature, decline in evaporation of moisture from the soil, thus enhancing the retention of soil moisture. This agrees with the findings of other researchers (Wicks *et al*.., 1994; Eruola *et al*.., 2012; Aminu-Taiwo *et al*.., 2014). The grass based mulches (guinea grass and goose grass) had a more pronounced indirect effect on the soil relative to the legume based mulches (tropical kudzu and stylo). This is confirmed from the longest duration effect and highest prime effect of both surface soil temperature and moisture in guinea grass mulched plots. Related studies (Lal, 1978; Tian etal., 1994) also showed higher indirect effects of *Acioa* mulch and other materials on maize.

**Components of yield and maize grain yield**

***Components of yield***: The components of yield of maize as affected by nitrogen and mulching materials are shown in Table 3. The effect of nitrogen and mulch supplemented with nitrogen was significant for all components of yield of the maize crop. Application of nitrogen had significant effect on number of cobs per plant. The number of cobs were within the range of 1.23 (control) and 1.53 (120N). Though plants with applied tropical kudzu had higher number of cobs per plant, significant increase was not observed between the mulching materials (Table

3). Significant increase in weight per cob was observed with applied nitrogen at 120N (116.4g), while the control recorded the least weight per cob (86.3g). Among the nitrogen treatments, 40N indicated the least cob weight (94.3g)), while guinea grass showed the least (96.2g) among the mulch materials.

The cob length showed significant differences with applied nitrogen and weed-based mulch (Table 3). Applied nitrogen at 120N, tropical kudzu and stylo supplanted with 40N showed highest cob length of 13.8cm, 13.0cm and 13.2cm respectively. The control treatment had the shortest cobs (10.6cm). Though application of nitrogen and mulch materials showed no significant effect on cob girth, the least cob girth was observed with the control and goose grass with values of 4.6cm and 5.1cm respectively, while 120N recorded the highest cob girth of 6.2cm.

The effect of nitrogen application and mulching materials on the number of grains per cob of maize was significant (Table 3). Increasing nitrogen increased the number of grains per cob with a maximum of 406.8 grains at 120N. Lower number of grains was observed with grass mulch with values of 320.7 and 330.6 in guinea grass and goose grass respectively, while the legumes, tropical kudzu and stylo recorded higher number of grains per cob with values of 372.6 and 363.3 respectively. The effect of applying dried weeds as mulch was significant on 100 grain weight of maize. The highest effect was observed in the plot mulched with tropical kudzu with value of 28.4g followed by stylo (28.1g) and least in goose grass (26.4g). The maize plants that received 120N recorded the highest 100 grain weight of 30.2g among all treatments in the study.

**Table 3: Yield components of maize as affected by mulching materials and nitrogen fertilizer**

| Treatments | No. of cobs ($plant^{-1}$) | Weight $cob^{-1}$ (g) | Cob length (cm) | Cob girth (cm) | No. of grains ($cob^{-1}$) | 100 grain weight (g) |
|---|---|---|---|---|---|---|
| Control | $1.23^{a}$ | $86.3^{e}$ | $10.6^{c}$ | 4.6 | $300.1^{d}$ | $24.3^{d}$ |
| 40 | $1.30^{a}$ | $94.1^{d}$ | $11.8^{bc}$ | 5.1 | $314.6^{d}$ | $25.8^{cd}$ |
| 80 | $1.47^{a}$ | $108.1^{b}$ | $12.6^{ab}$ | 5.8 | $381.9^{b}$ | $27.9^{bc}$ |
| 120 | $1.53^{a}$ | $116.4^{a}$ | $13.8^{a}$ | 6.2 | $406.8^{a}$ | $30.2^{a}$ |
| 4.5t/ha guinea grass + 40N | $1.31^{a}$ | $96.2^{cd}$ | $12.3^{abc}$ | 5.6 | $320.7^{cd}$ | $26.9^{bc}$ |
| 4.5t/ha tropical kudzu + 40N | $1.43^{a}$ | $108.7^{b}$ | $13.0^{ab}$ | 5.7 | $372.6^{b}$ | $28.4^{ab}$ |
| 4.5t/ha goose grass + 40N | $1.36^{a}$ | $100.9^{c}$ | $12.1^{abc}$ | 5.1 | $330.5^{c}$ | $26.4^{bcd}$ |
| 4.5t/ha Stylo + 40N | $1.40^{a}$ | $106.2^{b}$ | $13.2^{ab}$ | 5.6 | $363.3^{b}$ | $28.1^{ab}$ |
| LSD (5%) | ns | 4.8 | 1.9 | ns | 18.7 | 2.3 |

Means with the same letters within the column are not significantly different ($P < 0.05$)

***Maize grain yield:*** Maize yield was significantly affected by nitrogen and mulching (Figure 2). Increased nitrogen application resulted in higher maize grain yield, with 120N recording the highest yield of 1292.6 kg/ha. The effect of organic mulching on grain yield was more pronounce with use of leguminous weeds as mulch, hence tropical kudzu and stylo gave higher grain yield of 968.5 kg/ha and 946.3 kg/ha respectively compared to the grasses which recorded 872.8 kg/ha (guinea grass) and 890.6kg/ha (goose grass)

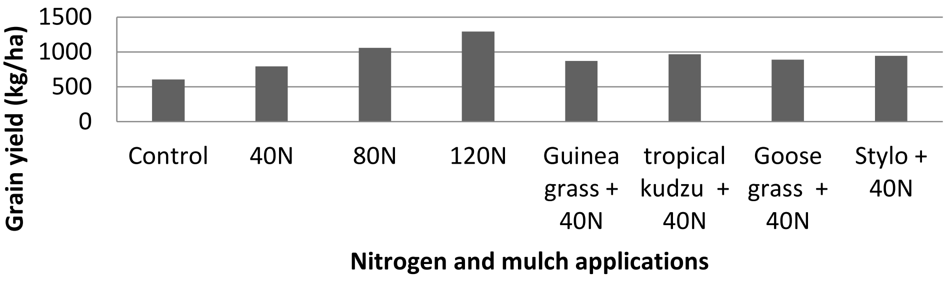


**Figure 2: Grain yield of maize as affected by nitrogen application and mulching materials [LSD(5%)= 108.6]**

Increased soil moisture under the mulching materials would have also increased the root density of the maize crops, through promoting lateral growth and abundance of roots and this might have enhanced higher nutrient absorption from the soil surface for increased performance of maize. Khurshid *et al.*. (2006) and Uwah and Imo (2011) also observed increased maize yield with high soil moisture retention from mulched field.

Components of yield and yield were higher with legume based mulches than with grass based mulch. Guinea grass and goose grass added lower quantity of nutrients (N, P and K), hence the direct soil nutrient contribution to maize yield was low due to their slow nutrient release. In contrast, the legume mulches, tropical kudzu and stylo contributed higher soil macronutrients (N, P and K). The legume mulches, with low C/N ratio and low polyphenol and lignin contents readily degrades at a faster rate, allowing for easier release of organic bound nutrients for crop use (Palm and Sanchez, 1991; Tian *et al*.., 1994).

## Conclusion

Based on the dual classification of organic mulching materials into “high quality” (with low C/N ratio and lignin content) and ‘low quality” (with high C/N and lignin content), it could be stated that utilization of “low quality “guinea grass and goose grass as mulch resulted in significant indirect effects on soil microclimate (soil moisture and soil temperature), while application of “high quality” tropical kudzu and stylo mulch produced significant direct effects on maize yield.

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