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Response of okra (*Abelmoschus esculentus* (L.) Moench) and soil properties to different mulch materials in different cropping seasons

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ABSTRACT

The type of materials used as mulch and season of application may determine its impact on soil physical and chemical properties and crop yield. Hence, field experiments were carried out during 2015 (dry) and 2016 (wet) cropping seasons to determine the effect of various mulch materials on soil properties, leaf nutrient composition, yield and growth of okra (*Abelmoschus esculentus* (L.) Moench). The experiment consisted of four mulch materials (a) *Pueraria phaseoloides,* (b) *Mucuna pruriens*, (c) *Pennisetum purpureum*), (d) *Panicum maximum* and a control (no mulch application). The five treatments were arranged in a randomized complete block design with four replications. Application of mulch reduced bulk density, soil temperature and increased porosity, soil moisture content, pH, OM, soil and leaf N, P, K, Ca, Mg, pod yield and growth of okra compared with the control. Legume mulch materials (LMM) (*Pueraria and Mucuna)* produced higher values of OM, N, P, K, Ca and Mg compared with grass mulch materials (GMM) (*Pennisetum and Panicum)* in both seasons. GMM significantly ($p \leq 0.05$) reduced bulk density and soil temperature and increased porosity and moisture content compared with the LMM in 2015. The correlation coefficient showed that the yield of okra in 2015 was dependent on soil physical properties while the yield in 2016 was dependent on soil chemical properties. GMM in 2015 produced 49% and 158% higher pod yield compared with LMM and the control, respectively. LMM increased the pod yield of okra in 2016 by 56% and 122% compared with GMM and the control, respectively. Therefore the use of grass materials as mulch in the dry season and the use of legume mulches during the wet season maximized yields.

1. Introduction

Okra (*Abelmoschus esculentus* (L.) Moench) is a vegetable crop and a member of the family Malvaceae. Okra probably originated from East Africa and today is widely distributed in the tropics, subtropics and warmer parts of the temperate region (Echo, 2003). Okra plays an important role in human diet by supplying carbohydrates, proteins, fats, minerals and vitamins that are usually deficient in the stable food (main food source such as rice) (Abd El-Kader et al., 2010). The essential and non- essential amino acids that okra contains are comparable to that of soybean (Farinde et al., 2007). In Nigeria, okra is mainly used in making soup and is eaten along with pudding food (food made from flour and does not involve chewing but instant swallow and is traditionally eaten with fingers).

Despite the numerous benefits and nutritional value of okra, its optimum yields (2–3 t ha^{-1}) and quality have not been attained in the tropical countries partly because of a continued declined in soil fertility. One of the ways to increase yield of okra in order to meet its global demand is the application of mulch materials at different cropping seasons. In Nigeria, there are two distinct seasons for okra, the peak and the lean seasons. During the peak season (wet season), okra is produced in large quantities, much more than what the populace can consume. During the lean season, okra fruits are produced in low quantities, and does not meet demand (Bamire and Oke, 2004). The lean season of okra production falls within the second cropping season and the dry season, hence soil water conservation and soil temperature moderation is important. Okra plants require warm temperatures and is unable to tolerate low and high temperature for long time. The optimum soil temperatures are in the range of 21–30 °C, with minimum soil temperatures of 18 °C and maximum of 35 °C (Abd El-Kader et al., 2010). Okra is a high water use despite having notable drought tolerant (Ghannad et al., 2014). The plant forms a deeply penetrating tap root with dense shallow feeder roots reaching out in all directions in the upper 0.45 m of soil. For high yield, adequate water supply and relatively moist soils are required during the total growing period (Abd El-Kader et al., 2010). These authors reported that application of 1798.2 m^3/acre of water

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Table 1
Meteorological data of the study area.

	Aug. 2015	Sep. 2015	Oct. 2015	Nov. 2015	Dec. 2015
Rainfall (mm)	62.4	293.8	119.6	81.8	0
Relative humidity (%)	91.7	92.2	89.7	73.2	39.2
Mean temperature (°C)	22.7	22.8	25.7	26.6	27.9

	Jan. 2016	Feb. 2016	Mar. 2016	Apr. 2016	May 2016	Jun. 2016	Jul. 2016
Rainfall (mm)	0	5.1	99.8	148.7	186.4	183.4	245.2
Relative humidity (%)	35.7	45.6	76.5	81.4	88.1	82.4	93.5
Mean temperature (°C)	27.6	27.1	25.1	24.4	24.2	23.1	24.6

Source: Meteorological unit, Landmark University, Omu-Aran, Kwara State, Nigeria.

Table 2
Soil physical and chemical analysis of the experimental site before experimentation.

Parameter	Value
Sand (%)	75
Silt (%)	14
Clay (%)	11
Textural class	Sandy loam
Bulk density ($Mg\,m^{-3}$)	1.49
Total porosity (%)	43.5
pH (water)	5.58
Organic matter (%)	2.85
Total N (%)	0.16
Available P ($mg\,kg^{-1}$)	10.6
Exchangeable K ($cmol\,kg^{-1}$)	0.14
Exchangeable Ca ($cmol\,kg^{-1}$)	1.8
Exchangeable Mg ($cmol\,kg^{-1}$)	0.36

to okra plant through drip irrigation was found to be sufficient for the plant. An efficient use of limited water resources during the dry/lean season is important. There is, therefore, a need to study the effect of soil management practices on soil water, temperature, soil density, nutrient supply and okra yield. These practices include mulching.

Mulching is reported to ameliorate soil moisture deficient and extremely high soil temperature regimes, mitigate low temperatures and improves soil fertility and yield of crops (Agele et al., 2000; Olasantan, 1988; Adekiya et al., 2015) and eliminate compaction of ridges and mounds (Aina, 1979). Mulching has also been shown to improve water infiltration, reduce evaporation and run-off, control weeds and improve soil structure (Olasantan, 1988). Mulching is practicable in derived-savannah zone of Nigeria due to high rainfall of the wet season and resulting heavy vegetation growth. It has been reported (Hochmuth et al., 2015) that tomatoes, peppers, egg plants, strawberries and melons are produced under mulches in southern Florida. In India, okra production increased significantly under straw mulch following saw dust mulch over control. The application of straw mulch increased tomato and okra yield over the control (Batra et al., 1985; Gupta and Gupta, 1987). However, research information is scarce on response of okra to mulch materials in Nigeria.

Elephant grass (*Pennisetum purpureum*) and Guinea grass (*Panicum maximum*) are of the family Poaceae and are common grasses in every ecological zone in Nigeria. The effectiveness of using elephant grass (*Pennisetum purpureum*) as mulching material was evaluated in the laboratory using a rainfall simulation set at rainfall intensities typical of the tropics (Adekalu et al., 2006). The results of the study showed that mulching the soil with elephant grass residue may benefit cropping (second cropping) by increasing stored soil water for use during dry weather and help to reduce erosion on sloping land. In Peru (Wade and Sanchez, 1983), mulching with guinea grass decreased top soil temperature by 5 °C prior to the establishment of a crop canopy, conserved soil moisture in the top 5 cm during dry weather, prevented surface crusting and decreased weed emergence. Ewulo et al. (2011) also reported that when elephant grass and guinea grass were applied to yam (*Dioscorea rotundata*), the mulch materials increased vine length, number of branches and leaves, tuber weight, leaf N, P, K, Ca and Mg significantly ($p \leq 0.05$) compared with the control. Tropical kudzu (*Pueraria phaseoloides*) has been found to protect the soil from erosion and loss of plant nutrients through leaching and runoff (Tian et al., 2001). Velvetbean *(Mucuna pruriens)* has been found to modify the structure, composition, diversity and interaction of soil biota that can promote soil structure and nutrient availability (Ortiz-Ceballos and Fragoso, 2004).

The type of materials used as mulch and the time (cropping season) they are applied may determine its impact on soil physical and chemical properties and crop yield. This is due to the biochemical qualities of the plant materials. Soil fertility enhancement due to mulching can be attributed to the promotion of microbial activity and consequent enhancement of decomposition of organic material (Agele et al., 2010). Mulches can bring a lot of N and P to the soil and therefore reduce the need for other nutrient inputs. However, there is scanty information on the use of different mulch materials at different cropping seasons on soil properties, growth and yield of okra. There is a need to ascertain the extent to which different weed species could be used as mulch at different cropping seasons for soil improvement and okra performance. Therefore, the objective of the current study was to compare the effect of elephant grass (*Pennisetum purpureum*), guinea grass (*Panicum maximum*), tropical kudzu (*Pueraria phaseoloides*) and Velvetbean *(Mucuna pruriens)* applied as mulch at different cropping seasons on soil properties, leaf nutrient concentrations, growth and okra yield. It was hypothesized that soil properties (at different cropping seasons) and okra yield will react differently to different mulch materials. Experiments were conducted to evaluate these working hypothesis; which seasons or mulch treatments will have greater effect?

2. Materials and methods

2.1. Site description and treatments

Field experiments were carried out at the Teaching and Research Farm, Landmark University, Omu-Aran, Kwara State, Nigeria during 2015 (dry) and 2016 (wet) cropping seasons. Landmark University lies between lat 8^0 9′N and long 5^0 61′E and is located in the derived savanna ecological zone of Nigeria. The rainfall pattern was bimodal with peaks in June and October (Table 1). The total annual rainfall in the area was about 1227 mm in 2015 with mean air temperature of 26.2 °C and mean relative humidity of 75.9%. In 2016, the total annual rainfall in the area was about 1240 mm with mean air temperature of 27.3 °C and mean relative humidity of 78.5%. The soil at the site of the experiment is an Alfisol classified as Oxic Haplustalf or Luvisol (Adekiya et al., 2015). The experimental area was cropped with maize for two years, left fallow for two years, then mechanically cleared by ploughing and harrowing.