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ASIAN JOURNAL OF
SCIENCE AND TECHNOLOGY

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 5, Issue 12, pp.777-781, December, 2014

RESEARCH ARTICLE

SOIL FERTILITY, WEED BIOMASS AND CASSAVA (*MANIHOT ESCULENTA* CRANTZ) PERFORMANCE UNDER DIFFERENT MULCH TYPES

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ARTICLE INFO

Article History:
Received 15th September, 2014
Received in revised form
09th October, 2014
Accepted 16th November, 2014
Published online 30th December, 2014

Key words:
Biomass,
Fassava,
Fertility,
Mulch,
Foil,
Weed.

ABSTRACT

Although**,** empirical evidence from many parts of the world indicates significant and positive effects of mulching on improving soil conditions, crop yield, as well as suppression of weeds, with resultant improved agricultural productivity. However, in Southwestern Nigeria, there is paucity of published scientific data and research information on the relative effectiveness of mulch types on improving soil conditions, cassava root yield and reducing weed biomass. Consequent upon this, a two – year field experiment was designed and executed at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, during 2010 and 2011 cropping seasons to assess effects of mulch types on soil fertility, weed biomass and cassava (*Manihot esculenta* Crantz) performance. The experiment was laid out in a randomized complete block design with three replicates. The different mulch types included: Rice straw mulch (RSM); polythene mulch (PM) and no mulch (NM), which served as the control. The results obtained indicated existence of significant (P = 0.05) differences between the two mulch types as regards their effects on soil fertility, weed biomass and cassava root yield performance. At the end of 2010 cropping season, mulching resulted in significant increases in soil organic carbon (SOC) from 0.56 g kg^{-1} for NM to 0.69 and 0.83 g kg^{-1} for PM and RSM, respectively. Similarly, at the end of 2011 cropping season, mulching resulted in significant increases in SOC from 0.40 g kg^{-1} for NM to 0.56 and 0.89 g kg^{-1} for PM and RSM, respectively. At the end of 2010 cropping season, mulching significantly increased total N from 0.30 g kg^{-1} for NM to 0.40 and 0.49 g kg^{-1} for the respective PM and RSM. At the end of 2011 cropping season, mulching significantly increased total N from 0.25 g kg^{-1} for NM to 0.32 and 0.56 g kg^{-1} for the respective PM and RSM. Mean values of cassava root yield data across the two years of experimentation indicated that, mulching resulted in significant increases in cassava root yield from 7.77 t ha^{-1} for NM to 10.49 and 11.94 t ha^{-1} for PM and RSM, respectively. In contrast, mulching significantly decreased weed population density from 90.8 weeds m^{-2} for NM to 60.5 and 76.8 weeds m^{-2} for the respective PM and RSM.

INTRODUCTION

Mulching is an important cultural practice, which has been found, for centuries, to be beneficial to plantation and arable crops (Datta, 2009; Can, 2012). Mulching, involving the use of mulch materials of plant origin, not only smother weeds, but suppresses weeds through the release of certain toxic chemicals, known as allelochemicals into the micro – environment (Onor, 2010; Black, 2011; Aina, 2012; Usor, 2012). Mulching results in significant improvement in soil organic matter status, following decomposition of the mulch materials, especially, if they are of plant origin (Black, 2011; Can, 2012). It follows therefore, that mulching, through organic matter addition to the soil, can be helpful in managing the fragile and highly weathered tropical soils (Mucu, 2011; Pestov, 2012).

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Mulching also helps to protect the soil from erosion, reduce soil surface temperature, increase water infiltration rate, maintain soil structure, especially, if combined with conservation tillage practices and provides a favourable environment for biological activities in the soil (Ayeni, 2008; Van, 2011; Gett, 2012). Another beneficial effects of mulching is conservation of soil moisture, a condition that accelerates microbial decomposition of the native soil organic matter, with resultant release of nutrients contained therein into the soil system (Ajah, 2012; Rao, 2012; Can, 2012). Besides, Alarape (2010) and Usar (2012) had reported that, soil moisture conservation, associated with mulching, ensures maximum fertilizer use efficiency of maize, and this, according to these authors, explain why there was more yield response to fertilizer treatments by early planted maize than late sown maize, and why the yield of late sown maize was lower than that of the early planted maize.

Although, empirical evidence from many parts of the world indicates significant and positive effects of mulching on improving soil conditions, crop yield, as well as suppression of weeds, with resultant improved agricultural productivity. However, in Southwestern Nigeria, there is dearth of published scientific data and research information on the relative effectiveness of mulch types on improving soil conditions, cassava root yield and reducing weed biomass. To this end, a two – year field experiment was designed to assess the effects of mulch types on fertility status of an Alfisol, cassava root yield and weed biomass.

MATERIALS AND METHODS

Study site: An experiment was carried out at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, during 2010 and 2011 cropping seasons. The soil in the study site belongs to the broad group Alfisol (SSS, 2002). The soil was highly leached, with low to medium organic matter, deep red – clay profile, with top sandy loam texture. The study site had been under continuous cultivation of a variety of arable crops, among which were cassava, maize, melon, cocoyam, sweet potato, prior to the commencement of this study.

Table 1. The chemical properties of the soil prior to 2010 cropping season

Soil properties	Values
pH	4.8
Organic carbon (g kg^{-1})	0.97
Total nitrogen (g kg^{-1})	0.68
Available phosphorus (mg kg^{-1})	0.52
Exchangeable bases (cmol kg^{-1})	
Potassium	0.57
Calcium	0.46
Magnesium	0.51
Sodium	0.38
Exchangeable Acidity	0.23
Effective Cation Exchangeable Capacity (ECEC)	2.15

Collection and analysis of soil samples: Prior to planting, ten core soil samples, randomly collected from 0 – 15 cm soil depth, were bulked inside a plastic bucket to form a composite sample, which was analyzed for chemical properties. At the end of each year cropping, another set of soil samples was collected in each treatment plot and analyzed. The soil samples were air – dried, ground, and passed through a 2 mm sieve. The processed soil samples were analyzed in accordance with the soil and plant analytical procedures, outlined by the International Institute of Tropical Agriculture (IITA) (1989).

Experimental design and treatments: The experiment was laid out in a randomized complete block design with three replicates. The different mulch types included: Rice straw mulch (RSM); polythene mulch (PM) and no mulch (NM), which served as the control. Each plot size was 3 m x 3 m.

Planting, weeding, collection and analysis of data: Planting of cassava was done on March 1 and March 3 in 2010 and 2011, respectively. Stem – cuttings (20 cm long each) of early maturing cassava variety, Tropical Manihot Series (TMS) 30572, obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, were planted at 1 m x 1 m (10,000 cassava plants ha^{-1}).Weeding was carried out manually at 3, 6, 9, 12 and 15 weeks after planting (WAP), using a hoe. Before each weeding operation, data on weed population density and dry weight were collected, by counting and harvesting all the weeds within a 50 cm x 50 cm quadrat, randomly placed in four locations within each treatment plot. The harvested weeds were weighed fresh and later oven – dried, until a constant weight was obtained. At harvest (12 months after planting, MAP), data were collected on cassava root yield and yield components. All the data were subjected to analysis of variance, and treatment means were compared, using the Duncan Multiple Range Test (DMRT) at 5% level of probability.

RESULTS

The chemical properties of the soil prior to 2010 cropping season.

Changes in nutrient status of an Alfisol at the end of 2010 and 2011 cropping seasons.

Tables 2 and 3 show chemical properties of an Alfisol as affected by mulch types at the end of 2010 and 2011 cropping seasons. At the end of 2010 cropping season, mulching resulted in significant increases in soil pH from 4.0 for NM to 5.3 and 6.0 for PM and RSM, respectively. Similarly, at the end of 2011 cropping season, mulching resulted in significant increases in soil pH from 3.2 for NM to 4.5 and 6.5 for PM and RSM, respectively. At the end of 2010 cropping season, mulching resulted in significant increases in soil organic carbon (SOC) from 0.56 g kg^{-1} for NM to 0.69 and 0.83 g kg^{-1} for PM and RSM, respectively. Similarly, at the end of 2011 cropping season, mulching resulted in significant increases in SOC from 0.40 g kg^{-1} for NM to 0.56 and 0.89 g kg^{-1} for PM and RSM, respectively. At the end of 2010 cropping season, mulching significantly increased total N from 0.30 g kg^{-1} for NM to 0.40 and 0.49 g kg^{-1} for the respective PM and RSM. At the end of 2011 cropping season, mulching significantly increased total N from 0.25 g kg^{-1} for NM to 0.32 and 0.56 g kg^{-1} for the respective PM and RSM. At the end of 2010 cropping season, mulching resulted in significant increases in available P from 0.20 mg kg^{-1} for NM to 0.30 and 0.37 mg kg^{-1} for PM and RSM, respectively. At the end of 2011 cropping season, mulching resulted in significant increases in available P from 0.16 mg kg^{-1} for NM to 0.24 and 0.43 mg kg^{-1} for PM and RSM, respectively.

Table 2. Chemical properties of an Alfisol as affected by different mulch types after 2010 cropping season

Treatments (Mulch types)	pH	Org. C (g kg^{-1})	Total N (g kg^{-1})	Av. P (mg kg^{-1})	Exchangeable bases (cmol kg^{-1}) K	Ca	Mg	Na
NM	4.0c	0.56c	0.30c	0.20c	0.20c	0.24c	0.21c	0.18c
PM	5.3b	0.69b	0.40b	0.30b	0.33b	0.32b	0.33b	0.26b
RSM	6.0a	0.83a	0.49a	0.37a	0.42a	0.41a	0.41a	0.33a

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). NM = No mulch; PM = polythene mulch; RSM = rice straw mulch.

Table 3. Chemical properties of an Alfisol as affected by different mulch types after 2011 cropping season

Treatments (Mulch types)	pH	Org. C (g kg^{-1})	Total N (g kg^{-1})	Av. P (mg kg^{-1})	Exchangeable bases (cmol kg^{-1}) K	Ca	Mg	Na
NM	3.2c	0.40c	0.25c	0.16c	0.14c	0.20c	0.16c	0.14c
PM	4.5b	0.56b	0.32b	0.24b	0.27b	0.26b	0.25b	0.20b
RSM	6.5a	0.89a	0.56a	0.43a	0.48a	0.45a	0.46a	0.38a

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). NM = No mulch; PM = polythene mulch; RSM = rice straw mulch

Table 4. Weed population density (weeds m^{-2}) as affected by mulch types

Treatments	1 MAP		2 MAP		3 MAP		4 MAP		
(Mulch types)	2010	2011	2010	2011	2010	2011	2010	2011	Mean
NM	118a	108a	99a	96a	82a	80a	72a	71a	90.8a
PM	90b	87b	73c	70c	50c	51c	33c	30c	60.5c
RSM	93b	91b	85b	81b	71b	72b	61b	58b	76.8b

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). NM = No mulch; PM = polythene mulch; RSM = rice straw mulch; MAP = months after planting.

Table 5. Weed dry weight (g m^{-2}) as affected by mulch types

Treatments	1 MAP		2 MAP		3 MAP		4 MAP		
(Mulch types)	2010	2011	2010	2011	2010	2011	2010	2011	Mean
NM	45.1a	44.7a	38.1a	37.8a	32.1a	31.6a	26.1a	25.8a	35.2a
PM	20.1b	19.4b	14.7c	14.2c	11.0c	10.2c	7.0c	6.8c	12.9c
RSM	22.3b	22.0b	16.0b	17.1b	12.8b	12.3b	10.1b	9.4b	14.0b

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). NM = No mulch; PM = polythene mulch; RSM = rice straw mulch; MAP = months after planting.

Table 6. Cassava root yield and yield components as affected by mulch types at harvest

Treatments	Cassava root yield (t ha^{-1})			Cassava root length (cm)			Cassava root diameter (cm)		
(Mulch types)	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
NM	7.86c	7.68c	7.77	16.38c	16.22c	16.30	10.12c	10.00c	10.06
PM	10.51b	10.38b	10.49	19.23b	19.10b	19.17	18.12b	18.00b	18.06
RSM	11.89a	11.99a	11.94	21.40a	21.49a	21.45	20.71a	20.88a	20.79

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). NM = No mulch; PM = polythene mulch; RSM = rice straw mulch.

At the end of 2010 cropping season, mulching resulted in significant increases in exchangeable K from 0.20 cmol kg^{-1} for NM to 0.33 and 0.42 cmol kg^{-1} for PM and RSM, respectively. At the end of 2011 cropping season, mulching resulted in significant increases in exchangeable K from 0.14 cmol kg^{-1} for NM to 0.27 and 0.43 cmol kg^{-1} for PM and RSM, respectively. At the end of 2010 cropping season, mulching resulted in significant increases in exchangeable Ca from 0.24 cmol kg^{-1} for NM to 0.32 and 0.41 cmol kg^{-1} for PM and RSM, respectively. At the end of 2011 cropping season, mulching resulted in significant increases in exchangeable Ca from 0.20 cmol kg^{-1} for NM to 0.26 and 0.45 cmol kg^{-1} for PM and RSM, respectively. At the end of 2010 cropping season, mulching resulted in significant increases in exchangeable Mg from 0.21 cmol kg^{-1} for NM to 0.33 and 0.41 cmol kg^{-1} for PM and RSM, respectively.

Weed population density. Table 4 shows weed population density as affected by mulch types during 2010 and 2011 cropping seasons. Mulching significantly reduced weed population density from 90.8 weeds m^{-2} for NM to 60.5 and 76.8 weeds m^{-2} for the respective PM and RSM.

Weed dry weight. Weed dry weight as affected by mulch types during 2010 and 2011 cropping seasons are presented in Table 5. Mulching significantly reduced weed dry weight from 35.2 g m^{-2} for NM to 12.9 and 14.0 g m^{-2} for the respective PM and RSM.

Cassava root yield and yield components. Table 6 shows the effects of mulch types on root yield and yield parameters of cassava at harvest. Mulching significantly increased cassava root yield from 7.77 t ha^{-1} for NM to 10.49 and 11.94 t ha^{-1} for the respective PM and RSM. Similarly, mulching significantly increased cassava root length from 16.30 cm for NM to 19.17 and 21.45 cm for PM and RSM, respectively. Mulching significantly increased cassava root diameter from 10.06 cm for NM to 18.06 and 20.79 cm for PM and RSM, respectively.

DISCUSSION

Relative to the control treatment, the significant increases in pH of soil in the plots of rice straw mulch and polythene mulch, after cropping, corroborate the findings of Alarape (2010); Onyi (2012) and Pestov (2012), who noted significantly higher pH values of soil in rice straw and polythene mulch plots, compared to their unmulched counterpart. These observations can be ascribed to the significantly higher values of the exchangeable basic cations on the exchange sites of soil in the plots of rice straw mulch and polythene mulch than that of the soil in the unmulched plots. The lower values of exchangeable bases for the unmulched treatment, can be attributed to leaching of the exchangeable bases. This is because, in the plots of rice straw mulch and polythene mulch, there was complete ground coverage, with resultant drastic reduction in incident of leaching of these exchangeable bases, unlike what obtained in the unmulched plots. Rice straw mulch gave significantly higher values of exchangeable bases (i.e. higher pH values) than its polythene mulch counterpart, suggesting greater liming effects of rice straw on soil than the polythene mulch. This implies that, rice straw mulch, in view of its ability to raise the base status of the (i.e. reducing acidity), could serve as a good alternative liming material, if and when inorganic commercial limes are not available. The significantly higher values of soil organic carbon (SOC), total N, available P and exchangeable bases for rice straw mulch than its polythene mulch counterpart, corroborate the findings of Datta (2009) and Ajah (2012), who noted that, application of rice straw mulch resulted in significantly higher values of SOC, total N, available P and exchangeable bases than its polythene counterpart.

These observations can be attributed to release of nutrients by the rice straw mulch, on decomposition, unlike its polythene mulch counterpart. The observed higher nutrient status, associated with rice straw mulch, in this study, further testifies to high potential of plant residues in improving soil fertility, and enhancing soil resilience, as well as agronomic productivity (Ista, 2009; Dale, 2012). The lowest available P value of soil in the unmulched plots can be attributed to the lowest pH value of soil in unmulched plots. This is because, the availability of P in the soil, depends on the pH of the soil medium, with available P decreasing with decreasing pH (Zorok, 2012). The decreasing available P phenomenon, associated with increasing acidity or decreasing pH, is due to the conversion of P into unavailable forms under acid soil conditions, as a result of fixation by micro – nutrients, such as Fe and Al, which abound in acid soils (Zorok, 2012; Zynth, 2012).

The higher values of SOC, total N, available P and exchangeable bases, recorded in the plots of rice straw mulch, at the end of the second year (2011) cropping season, can be adduced to the residual effects of the first year (2010) rice straw mulch application, coupled with additional rice straw mulch application in the second year, which on decomposition, would have resulted in increased release of soil nutrients. In contrast, at the end of second year (2011) cropping season, values of SOC, total N, available P and exchangeable bases, for the control and polythene mulch treatments were lower than what obtained at the end of first year (2010) cropping season. The lower values of these nutrients at the end of the second year than the first year, can be attributed to uptake of these nutrients by cassava during the two years of cropping, especially with no nutrient addition to the soil by the polythene mulch, unlike its rice straw mulch counterpart. The significantly higher cassava root yield and yield components for rice straw and polythene mulch, confirm the observations of Usor (2012); Usar (2012) and Gett (2012), who, in their studies on cassava root yield performance under rice straw and polythene mulch, reported significantly higher cassava root yield for rice straw mulch and polythene mulch, compared to unmulched treatment.

The higher cassava root yield and yield components for rice straw mulch and polythene mulch can be attributed to attendant beneficial effects of mulching, such as release of nutrients, on decomposition (especially organic mulch, such as rice straw), weed suppression, moisture conservation, and improved water infiltration, all of which may have resulted in provision of favourable soil environment for optimum performance of cassava in the plots of rice straw mulch and polythene mulch. The significantly higher cassava root yield for rice straw mulch than that of its polythene mulch counterpart, can be ascribed to the ability of the former to furnish the soil with nutrients, on decomposition, unlike the latter, which cannot release nutrients into the soil. Unlike what obtained under the control and polythene mulch treatments, cassava root yield and yield components under rice straw mulch during the second year harvest, were higher than what obtained at the first year harvest. This can be adduced to higher fertility level of soil in the plots of rice straw mulch in the second year due to the residual effects of application of rice straw mulch in the first year.

The least values of weed biomass, associated with polythene mulch treatment, agree with the findings of Call (2011); Dale (2012) and Onyi (2012), who reported significantly lower weed biomass in the plots of polythene mulch than its rice straw counterpart in a cassava field. This can be attributed to high temperature that prevailed under polythene mulch. This is because, the black polythene mulch absorbs most incident solar radiation which is held by the upper layer of the soil, thus, causing it to heat up (Call, 2011; Onyi, 2012). The heat, so produced in the upper layer of the soil may have impaired germination of weed seeds in the soil system. Besides, the polythene mulch prevented weed emergence, and all this resulted in lower incident of weed infestation in the plots of polythene mulch. Based on the findings of the present study, rice straw mulch has agronomic value of reducing weed infestation on the farm, as well as enhancing nutrient availability in the soil, on decomposition. So, in view of this duality of purpose of rice straw mulch, its use as an organic source of plant nutrients will be of great economic benefit to the resource – poor farmers, who cannot afford to procure inorganic fertilizers due to their high cost and occasional scarcity in Nigeria.

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