Impact of Agroforestry Leaf Mulches on the Growth and Yield Performance of Sorghum in a Semi-Arid Region

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Research Article

Keywords: Agroforestry, Mulching, Sorghum, Crop yield, Organic amendment, Sustainable agriculture, agronomic performance

Posted Date: September 17th, 2025

DOI: https://doi.org/10.21203/rs.3.rs-7411848/v1

Additional Declarations: No competing interests reported.

Abstract

Soil nutrients are essential chemical elements that support plant growth guaranteed by agroforestry systems with the production of leaf mulch to improve soil properties. Adopting agroforestry as a sustainable soil management practice has the potential to improve soil property and structure. Existing studies in the use of specific agroforestry tree leaves as mulch for its soil fertility improvement potential in sorghum cultivation are inadequate. This study assessed the effect of leaf mulch from selected agroforestry tree species on sorghum agronomic performance.

The study adopted a 3x3x4 factorial layout in a randomized complete block design. Three varieties of sorghum seeds (NGB05843, NGB05731, NGB06187) were planted on 39 raised beds (12 treatments with one control per block), evenly overlaid with fresh leaf-mulches of uniform age from four agroforestry tree (*Leucaena leucocephala, Artocarpus altilis, Sesbania grandiflora*, and *Moringa oleifera*) species at application rates of 1.50, 2.00 and 2.50 kilograms. Data collected were analyzed using descriptive and inferential statistics at 5% significance level.

Findings revealed that the control plot had the highest sorghum seed weight (68.50 g) against treatment plots (*A. altilis* (65.00 g), *M. oleifera* (57.30 g), *S. grandiflora* (52.00 g), *L. leucocephala* (42.67 g)). Sorghum variety, mulch type and application rate significantly influenced growth and yield.

The study concluded that, agroforestry mulches significantly improved sorghum growth and grain yield. *A. altilis* and *M. oleifera* mulches were more effective in promoting sorghum development. Farmers are encouraged to adopt the use of agroforestry tree species leaf as mulch to assist in soil nutrient improvement.

INTRODUCTION

Sorghum is a drought-tolerant cereal widely grown in semi-arid regions of Africa and Asia. Despite its resilience, sorghum yields in smallholder systems remain low, mainly due to poor soil fertility and inadequate management practices (Wortmann et al., 2009). Organic mulching has emerged as a sustainable technique for improving soil health and crop productivity. Agroforestry trees such as Moringa, Leucaena, and Sesbania offer locally available biomass that can be used as mulch. This study aims to evaluate the effects of leaf mulch from selected tree species on the growth and yield of sorghum in a semi-arid environment.

Agroforestry has risen to prominence as a land-use strategy to help address global climate change and provide other environmental, economic, and social benefits. However, systematic knowledge on the human environment impacts of agroforestry practices and interventions remains lacking. Agroforestry is promoted for its potential for carbon sequestration, soil erosion and control, improved nutrient and water cycling, as well as other socio-economic benefits and greater agricultural productivity (Akinnifesi et al., 2007). While researchers and policy makers have long studied and supported agroforestry practices in low and middle-income countries, particularly in tropical regions, recognition and promotion of agroforestry in the temperate climates typical of developed countries gained prominence in the early 21st century (Jose et al., 2012).

The production of Sorghum in sub-Saharan Africa has been comparatively low due to biotic and abiotic stresses (Teshome et al., 2018) such as drought, low soil fertility, and high soil acidity as the major abiotic stresses capable of causing significant yield losses in sorghum and biotic stresses (diseases and insect pests) (Amelework et al., 2016).

It is a known fact that cassava and maize are staple foods in South-Western Nigeria which might bare the occasion to wonder; what is the importance of sorghum to the south west, Nigeria? What is the growing interest in sorghum cultivation about? The cultivation of sorghum has traditionally been majorly in Northern Nigeria because of the favorable agro-climatic conditions. But, over the time, there has been an increasing interest in the production of sorghum in the South-West Nigeria due to such factors as Industrial demand, supply-chain efficiency, national production deficit, increase in population and regional migration. These are parts of the major driver for this shift in sorghum production.

The demand for Sorghum as a result of growing industrial need in South-West, Nigeria for breweries and beverages has grown significantly in the recent years. Sorghum grits are widely used as substitutes for barley in the production of alcoholic and non-alcoholic beverages by many beverage companies, such as Nigerian Breweries and Guinness Nigeria. These had increased the demand to source sorghum locally so as to reduce costs and comply with government policies on raw material sourcing (Blueprint, 2024). Sorghum is a key ingredient in food processing industries for the production of composite flour which is used in the production of food such as bread, biscuits and noodles. Increasing consumer demand for this food and produce in South-West, Nigeria has become one of the major drivers for an increased demand for sorghum (Daily Trust, 2024).

Sorghum is also used in livestock feed, aluminum ore refining, and construction materials. This has further increased its industrial relevance, increasing the demand for its production in the south west, Nigeria (FAO, 2023). It is a well-established fact that Nigeria is one of the world's largest production hubs for sorghum, but the current production levels do not meet domestic demand.

The Minister of Agriculture and Food Security recently noted that national sorghum production is insufficient to meet both food and industrial needs. This was noted to be as a result of low productivity, poor seed quality, and post-harvest losses (Daily Trust, 2024).

Increased industrial reliance on sorghum has created supply gaps, making localized production in the South-West, a strategic move to supplement existing sources (FAO, 2023).

The South-West, region hosts a significant number of food processing industries, breweries, and animal feed manufacturers. Establishing local sorghum farms will yield several benefits such as;

i. Reduction in transportation costs: Local production would remove transportation expenses and ensure a more stable supply as against sourcing from Northern Nigeria with its high logistics costs (Blueprint, 2024).
ii. Insecurity, Political instability, climate change, and infrastructural challenges in the North occasionally disrupt sorghum production and supply. Cultivating sorghum in the South-West, will ensure a secondary production hub, thereby causing supply stability (Daily Trust, 2024).
iii. Nearness to processing plants will enhance product freshness and efficiency in industrial processing (FAO, 2023).

While sorghum cultivation in South-West, Nigeria faces significant challenges related to awareness, pest control and market access, the Nigerian government has implemented various policies to promote sorghum cultivation, aiming to meet rising industrial demand and achieve national self-sufficiency in grain production. These initiatives focus on improving productivity, financing, and seed quality to support farmers across different regions, including the South-West.

Agricultural Transformation Agenda (ATA)- Launched in 2011, identified sorghum as one of five priority crops for development. Its aim was to;

i. Increase sorghum production from 9.3 million metric tons to 11.3 million metric tons by 2015, focusing on modernizing agriculture through public-private partnerships (Aderemi, 2023).
ii. Encourage private-sector investment in sorghum processing industries, particularly in flour mills and breweries.

Agricultural Transformation Action Plan (ATAP)- Introduced in 2011, emphasized agriculture as a key driver of economic growth and planned to recognize sorghum as a strategic crop, with a focus on:

i. Production of fortified foods for the Home-Grown School Feeding Program and the World Food Program.
ii. Expand the use of sorghum in the malt industry for beverage production (FAO, 2023).

Anchor Borrowers' Program (ABP)- launched by the Central Bank of Nigeria (CBN) and the Federal Ministry of Agriculture and Rural Development (FMARD), provides: Zero-interest loans and farm inputs to smallholder farmers cultivating priority crops, including sorghum and provide training and support for modern sorghum farming techniques. In 2021, the program supported approximately 1.2 million farmers nationwide, with plans to increase beneficiaries to 5 million by 2022 (USDA, 2022). Seed System Enhancement for Sorghum- the Nigerian government, in partnership with the Institute for Agricultural Research (IAR) and the International Maize and Wheat Improvement Center (CIMMYT), introduced improved sorghum varieties such as: SAMSORG 52 and SAMSORG 53 – high-yield, drought-tolerant varieties suitable for Nigeria's agro-ecological zones. The Farm and Community-Managed Seed System (FCMSS) approach has strengthened access to high-quality seeds, increasing yields and reducing dependency on imports (CIMMYT, 2023).

The government of Nigeria provides incentives, such as tax breaks and subsidies, to industries using locally grown sorghum for production and encouraged partnerships between research institutions, private companies, and farmer cooperative societies to boost production, processing and storage facilities in regions like the South-West (Aderemi, 2023). Efforts to boost the adoption of sorghum in South-West Nigeria include awareness campaigns highlighting its nutritional and economic benefits. Agricultural shows and exhibitions have also been used to promote improved sorghum varieties, and partnerships with industries such as flour millers and breweries have explored to increase demand (CGIAR, 2023).

The reviewed literatures showed that application of mulches has been addressed but, existing studies in the use of specific agroforestry tree leaves as mulch for its soil fertility improvement potential in sorghum cultivation are lacking. This study therefore, aims to fill in this missing gap in literature.

The word mulch has been derived from the German word "*molsch*" which means "easy to decay," and mulches have widely been used for vegetable production since ancient times (Lightfoot, 1994). Mulching is referred to as spreading various covering materials on the surface of soil to minimize moisture losses, reduce weed population and to enhance crop yield (Kader et al., 2019; Nalayini, 2007). Mulches could potentially minimize water runoff, improve infiltration capacity of soil, restrain weed population via shading, and act as obstacle in evapotranspiration (Rathore et al., 1998). Mulching also has some other positive environmental effects such as temperature regulation of soil and plant roots, minimize nutrient losses, cut down soil erosion and compactness, and improved physical conditions of soil (Ngouajio & McGiffen, 2004).

Mulches got attention in the late 1930, though in a negative sence when it was observed that these materials could alter the surrounding conditions of agricultural lands, forest areas, and horticultural lands. Some earlier studies showed a number of such damaging effects caused by mulches (Bedford & Pickering, 1919). In 1941, deep mulches were used for trees and shrub plantation (Pirone, 1941), because these deep-type mulches give protection to drought stress such as frost injury and freezing damage of crop plants in harsh environmental conditions. More water conservation was achieved when the same quantity of material was used as mulch compared with what was incorporated into the soil (Singh et al., 1991). The by-products of agricultural and forestry domains have been used as mulches in the mid-1900s (18th century) (Clifford & Massello, 1965). Other materials gained popularity and were used as mulch such as trimmings of trees and shrubs, wastes of animals, stubbles, and residues of crop plants. Landscape mulches were also seen in 1957 but there was no scientific research work carried out on them.

Mulches could be of organic, inorganic and synthetic origin. The organic mulches consist of animal and plant residues. The most commonly used organic mulches include straws, husks, grasses and cover crops (live mulches), saw dust, compost, and manures (Rathore et al., 1998),

A *mulch* is a layer of material applied to the surface of soil for the sole purpose of soil moisture conservation, fertility improvement, weed management, erosion control etc. There are three basic kinds of mulch: organic, inorganic and synthetic: **Organic mulches** include formerly living material such as chopped leaves, straw, grass clippings, compost, wood chips, shredded bark, sawdust, pine needles and even paper. In addition to weed suppression, organic mulch improves the soil as they decompose. **Inorganic mulches** include non-living materials such as stones, pebbles, slabs etc., while synthetic mulch includes black plastic and geotextiles (landscape fabrics). Inorganic and synthetic mulches do not break down to enrich the soil (Dan, 2022).

Mulches have been widely used in agricultural lands, orchards, forests, and landscapes in many parts of the world (Smith et al., 2012). Generally, mulches reduce competition from weeds, maintain soil temperature, and reduce evaporation from soil (Jose et al., 2012). Mulches protect the soil from wind, water, and traffic-induced erosion. Mulches also improve soil properties by improving moisture retention capacity, releasing different nutrients, and enhancing biological activities (Garrity, 2004). Therefore, with the improved soil properties, plants grow better (Jose 2009; Jose & Bardhan, 2012). The capability of mulching in the control of nutrient level

absorption, temperature and water level of the soil makes it multifunctional (Petrikovszki et al., 2016). But for mulch to yield effective results in agricultural practices, some basic requirements must be met, such as the source, allelopatic effect, decay efficiency, etc. Mulch, most importantly, should help conserve soil moisture and improve nutrient obtainability as well regulate soil temperature (Manzello et al., 2014), even though various types of organic mulch have different effects on weed control, plant growth, and soil properties (Jodaugiene et al., 2006), unfortunately, little or nothing has been done in assessing the problems faced by agroforestry adopters which could be a strong determinant of food security and soil sustainability in Nigeria. This study therefore, was carried out to determine the effects of different organic mulches on weed presence in reference to sorghum agronomic performance and soil characteristics.

MATERIALS AND METHODS

The study was carried out at the Teaching and Research Farm of Babcock University. Babcock University is situated in Ilishan-Remo (latitude 6°53'44" N and longitude 3°43'18" E) 80m elevation in Ikenne Local Government Area of Ogun State. The Local Government was carved out of the defunct Remo Local Government in September 1991, it is bounded in the West by Obafemi-Owode Local Government, in the South by Sagamu Local Government, in the East by Odogbolu Local Government and in the North by Remo-North Local Government. The inhabitants are mainly of remo origin, trading and farming are their predominant occupation, with a population of 202,980 according to National Population Commission report of 2006. (Adeleye & Okezie, 2012)

Experimental Material

Seed Collection

Three cultivars of sorghum Seeds (NGB05843, NGB05731 and NGB06187) were collected from the National Centre for Genetic Resources and Biotechnology (NACGRAB), Ibadan, Oyo State, Nigeria. The accessions represent part of the institutional working germplasm collections which were grown locally by farmers in Nigeria.

Mulch Collection

Fresh leaves of four agroforestry (*L. leucocephala*, *A. altilis, S. grandiflora, M. oleifera)* trees species were collected. *L. leucocephala*, *A. altilis* and *M. oleifera* were collected from Forest Research Institute of Nigeria (FRIN), Ibadan Nigeria, while *S. grandiflora* was collected from the National Horticulture Research Institute (NIHORT). All leaves were from trees of relatively uniform age, because they were collected from plantations. A total of 18 kg of each species of mulch was used for the experiment.

Methods

Field Preparation, Experimental Design and Cultural Practices

The experimental field of 40.5 m^2 was manually prepared at the onset of rainy season in May. The layout of the experimental plot was set up using pegs, lines and measuring tapes. The field was divided in three (3) blocks consisting of thirteen (13) raised beds per block, measuring 0.18 m^2 with inter bed distance of 0.6 m and inter block distance of 0.9 m between blocks respectively.

The study consisted of a 3 x 3 x 4 factorial experiment laid out following a randomized complete block design and replicated three times (Table 3.1). The factors in the experiment were varieties of Sorghum namely NGB05843, NGB05731 and NGB06187. The levels of mulch applied were 1.50 kg, 2.00 kg, 2.50 kg, and the agroforestry tree species were *L, leucocephala*, *A. altilis, S. grandiflora, M. oleifera* serving as treatments. The control plots were without treatment.

There was a total of 39 raised beds (13 per block including 1 control) of which each agroforestry species leaf was used to mulch each raised bed in three (3) replicates in the weight of 1.50 kg, 2.00 kg and 2.50 kg, evenly spread in not less than 2cm thick (measured with a meter rule), for each of the 3 varieties of the sorghum crop planted (Table 1). The agroforestry tree species leaves were applied to the prepared raised beds and allowed about three weeks before planting to allow onset of decomposition so as to prevent nitrogen depletion and soil acidity, allowing proper air and water flow (Addai & Alimiyawo, 2015; Thompson & Myers, 2021).

Mulch Volume Determination

In the establishment of the volume of fresh mulch application, 5 cm depth was applied as recommended by the USDA Natural Resources Conservation Services (2017).

Therefore, Mulch volume was calculated as follows

Volume = L x B x W (where L and B are the length and breadth of the raised bed and W is the recommended width of mulch).

Therefore,

V = 0.30 m x 0.60 m x 0.05 m

= 0.009 m^3

The density of applied fresh leaf mulch

= D X V. where D is the given density and V is the volume derived.

The standard volume for fresh mulch application is 200 kg/m^3

∴ 200 X 0.009 = 1.8 kg

Table 1
Experimental Factors in the Experimental Design

Sorghum cultivars	Mulching leaves	1.50 kg	2.00 kg	2.50 kg
NGB05843, NGB05731 and NGB06187	*L. leucocephala* (LL)	LL 1.5	LL 2.0	LL 2.5
	A. altilis (AA)	AA 1.5	AA 2.0	AA 2.5
	S. grandiflora (GS)	GS 1.5	GS 2.0	GS 2.5
	M. oleifera (MO)	MO 1.5	MO 2.0	MO 2.5
	Control (CON)			

Statistical Analysis

The collected data were subjected to descriptive and inferential statistics where percentage and standard deviation were evaluated as well as analysis of variance (ANOVA) to measure the level of significance between the means of mulch type applied, the rate of application and the interaction between them. Then, the means were separated with Duncan's Multiple Range Test at 5% and 1% probability to test the specific significant differences between means (compare treatment effects). Statistical Analysis System version 9 (SAS) tool was employed for the analysis.

RESULTS AND DISCUSSION

Effect of Mulch Treatment and Application Rate on Sorghum Growth and Yield Performance

The results in Table 2 shows the different treatment groups across various growth and yield parameters of the three sorghum varieties across six key parameters, using both means and standard deviations to draw insights. Days to germination revealed the mean values of all varieties to be 4.00 ± 0.33 days across all treatments. The mean leaf count for the 12 weeks treatment period ranged from 2.13 ± 0.6 to 12.57 ± 0.80 leaves and 2.67–12.67 mm for the control plots. Mean leaf length value, ranged from 64.89 ± 1.72 to 929.60 ± 19.03 mm across all treatments for the 12 weeks treatment period. Whereas, the control plots had the range of 65.33–875.33 mm for the 12 weeks period. Furthermore, the general mean stem girth had 0.38± 0.04 mm to 23.20 ± 2.47 mm range for the treatment period.

The average week to fruiting is 12.23 ± 0.57 weeks while the actual fruiting period ranged from 11.67–13.50 weeks for specific plant treatment plot. Then, maturity was attained at the average age of 17.31 ± 0.56 weeks. Whereas, the actual maturity and harvesting was done at 16.33–18.00 week according to individual plant readiness. Of the three sorghum varieties planted, variety 1 attained maturity fastest (12.21 weeks) than variety two (13.64), and three 3 (17.93 weeks) which recorded the slowest to attain maturity. Variety three showed the most consistency in growth and maturity characteristics while others are highly variable. The dataset is presented in the appendix.

The interaction effect of application rate and mulch type on growth and yield performance revealed that, among all treatments, M. oleifera at 2.50 kg mulch rate was conspicuous, recorded the highest stem girth (31.13 mm) and the highest panicle weight (196.00 g). This could point to the superior nutrient content of *M. oleifera* mulch, which is known for its rich mineral profile (Khalid et al., 2015). Enhanced stem girth under this treatment may reflect better vascular development and water transport, which aligns with the findings of Olasantan (2007) and Agele et al. (2011) on the impact of organic mulch on crops vegetative growth.

On the other hand, *A. altilis* at 2.50 kg application rate also produced high seed weight (67.00 g) and number of grains (1830.50), which in comparison, was better than the control. Revealing that *A. altilis* mulch may contribute to improved grain filling, possibly through gradual nutrient release and sustained soil moisture. Adediran et al. (2004) similarly observed enhanced grain characteristics when organic mulch was integrated into cropping systems. In contrast, L. leucocephala at 2.5 kg application rate resulted in lower seed weight (37.00 g) and grain count (1185) compared to the 1.50 kg application rate and other treatments. This may suggest a threshold beyond which decomposition of L. leucocephala mulch may lead to allelopathic effects or nitrogen immobilization, as suggested by Kumar et al. (2019).

Even though, the control plots generally showed good yield performance but were not consistently superior across traits, reinforcing the value of mulching not only for weed suppression but also for sustainable sorghum productivity. Above all, these interactions highlighted the importance of selecting the appropriate mulch type and matching it with optimal application rate, of which, *M. oleifera* at 2.50 kg and A. altilis at 2.00–2.50 kg appear to be the most promising combinations for enhancing both vegetative and reproductive traits.

Table 2a: Effect of Mulch Treatment and Application Rate on Sorghum Growth and Yield Performance

Mulch	Rate (kg)	DG	L. C wk2	L. C. wk4	L. C. wk6	L. C. wk8	L. C. wk12	L.L.wk2 (mm)	L.L.wk4 (mm)	L.L.wk6 (mm)	L.L.wk8 (mm)	L.L.wk12 (mm)	S.G.wk2 (mm)	S.G.wk6 (mm)	S.G.wk12 (mm)
A. altilis	1.50	3.67^{a}	3.00	4.67	7.67	11.00	13.67^{a}	66.00	157.33	454.00	774.00	924.67	0.40	12.37	22.80
	2.00	4.00^{a}	3.00	5.00	8.33	10.33	12.67^{a}	65.00	157.33	447.33	762.00	953.33	0.33	12.47	22.27
	2.50	4.33^{a}	2.33	4.00	7.67	10.33	13.00^{a}	67.33	157.00	448.00	773.33	937.00	0.37	13.00	22.40
L. leucocephala	1.50	3.67^{a}	1.67	3.67	8.00	10.67	13.67^{a}	67.50	156.50	463.00	770.00	927.50	0.30	12.93	23.95
	2.00	3.67^{a}	1.00	3.67	7.00	9.33	12.00^{a}	65.00	153.00	460.00	758.00	938.00	0.45	13.80	23.70
	2.50	4.00^{a}	2.00	4.33	7.33	9.33	12.00^{a}	66.50	162.00	464.00	780.00	950.00	0.37	13.13	21.63
M. oleifera	1.50	4.00^{a}	2.33	4.67	8.00	10.67	12.33^{a}	64.33	154.00	449.33	763.33	923.33	0.37	12.47	22.00
	2.00	4.33^{a}	1.33	3.33	7.33	9.33	11.67^{a}	62.50	148.00	444.00	736.00	938.00	0.40	13.90	23.20
	2.50	4.00^{a}	2.00	5.00	7.33	9.00	12.00^{a}	63.33	155.67	452.67	753.33	936.67	0.40	12.53	31.13
S. grandiflora	1.50	4.33^{a}	2.33	5.00	8.00	10.67	14.00^{a}	65.33	152.00	450.67	750.00	921.67	0.37	12.60	22.13
	2.00	4.33^{a}	1.67	4.33	8.00	10.00	11.67^{a}	62.67	151.33	428.00	747.33	925.00	0.35	13.75	22.65
	2.50	3.33^{a}	2.33	4.33	7.33	9.00	12.00^{a}	62.67	155.00	448.00	762.67	934.33	0.43	12.80	22.40
Control		4.33^{a}	2.67	5.00	8.67	10.67	12.67^{a}	65.33	152.00	457.33	742.67	875.33	0.37	12.87	21.77
Mean		4.00	2.13	4.39	7.74	10.30	12.57	64.89	154.70	451.30	759.00	929.60	0.38	13.97	23.20
S.D.		0.33	0.60	0.58	0.48	0.73	0.80	1.72	3.55	9.39	13.20	19.03	0.04	0.53	2.47

Values followed by different letters in the same column are significantly different from each other at p < 0.05.

Note: DG- days to germination, L.C- leaf count, L.L- leaf length, S.G- stem girth

Table 2b: Effect of Mulch Treatment and Application Rate on Sorghum Growth and Yield Performance

Mulch	Rate (kg)	Wk. to Fruit	Wk. to Harvest	No of Tiller/plant	No of Panicles	Panicle weight (g)	No of grains (unit)	seed weight (g)
A. altilis	1.5	12.00^{b}	17.00^{bc}	3.00^{ab}	1.67^{abc}	99.33^{ab}	1705.00^{abc}	61.50^{abc}
	2	11.67^{b}	17.00^{bc}	3.67^{ab}	2.00^{abc}	115.00^{ab}	1987.50^{a}	66.50^{ab}
	2.5	11.67^{b}	17.00^{bc}	3.67^{ab}	2.00^{abc}	143.00^{ab}	1830.50^{abc}	67.00^{ab}
L. leucocephala	1.5	13.50^{a}	18.00^{ab}	3.00^{ab}	1.00^{c}	83.50^{ab}	1423.00^{abc}	47.00^{abc}
	2	13.00^{ab}	18.50^{a}	4.00^{a}	1.00^{c}	129.00^{ab}	1322.00^{bc}	44.00^{bc}
	2.5	12.67^{ab}	17.67^{abc}	3.50^{ab}	3.00^{a}	159.50^{ab}	1185.00^{c}	37.00^{c}
M. oleifera	1.5	11.67^{b}	16.33^{c}	3.50^{ab}	1.50^{bc}	118.50^{ab}	1920.00^{ab}	70.00^{a}
	2	12.50^{ab}	17.50^{abc}	2.50^{ab}	2.50^{ab}	169.50^{ab}	1609.50^{abc}	52.00^{abc}
	2.5	12.00^{a}	17.00^{bc}	3.00^{ab}	2.00^{abc}	196.00^{a}	1537.00^{abc}	50.00^{abc}
S. grandiflora	1.5	11.67^{b}	17.00^{bc}	2.67^{ab}	1.33^{bc}	92.33^{ab}	1367.00^{abc}	46.00^{abc}
	2	12.33^{ab}	17.33^{abc}	2.33^{b}	1.67^{abc}	59.33^{b}	1765.00^{abc}	58.00^{abc}
	2.5	12.00^{b}	17.00^{bc}	3.33^{ab}	2.33^{abc}	159.67^{ab}	1589.00^{abc}	52.00^{abc}
		12.33^{ab}	17.67^{abc}	3.33^{ab}	2.00^{abc}	142.33^{ab}	1804.00^{abc}	68.50^{ab}
Mean		12.23	17.31	3.19	1.85	128.23	1618.81	55.35
SD		0.57	0.56	0.5	0.58	38.54	244.99	10.67

Values followed by different letters in the same column are significantly different from each other at p < 0.05

Effect of Four Agroforestry Tree Species Leaf Mulch on Growth and Yield Performance of Sorghum

Table 3 shows that mulch type significantly influenced key agronomic traits including days to 50% flowering and harvest, panicle weight, and number of grains, while mulch application rate had a significant effect only on number of panicles ($p < 0.05$). The interaction between mulch and application rate however, did not significantly affect any of the observed measured parameters ($p > 0.05$), indicating that the effect of mulch was mostly independent of application rate.

Among growth parameter traits, leaf count at maturity was significantly influenced by block effects ($p < 0.05$), likely due to environmental heterogeneity, while leaf length and stem girth were not significantly influenced by any treatment factors. Days to flowering and harvest were significantly reduced by mulch application ($p < 0.05$), suggesting that organic mulches may have enhanced soil microclimate and moisture retention, accelerating crop development as reported by Teasdale and Mohler (2000) and Adediran et al. (2004).

Mulched plots generally outperformed the control plot under yield parameters, with increased panicle weight, number of grains, and seed weight. This aligns with findings by Olasantan (2007) and Agele et al. (2011), who opined that mulching improves soil fertility and structure, which in turn enhances nutrient availability and crop yield components.

Ironically, while mulch type significantly influenced grain yield ($p < 0.05$), the rate of mulch application had no significant effect on seed weight or panicle weight, suggesting that mulch quality (chemical composition, decomposition rate) may play a more significant role than quantity of the mulch applied. This observation confirmed previous studies which emphasized the importance of mulch type over mere biomass quantity (Kumar et al., 2019; Narayanasamy, 2018).

Table 3
a: Effect of Four Agroforestry Tree Species Leaf Mulch on Growth and Yield Performance of Sorghum

Source of variation	df	DG	L. C wk2	L. C. wk4	L. C.wk6	L. C. wk8	L. C. wk12	L.L.wk2 (mm)	L.L.wk4 (mm)	L.L.wk6 (mm)	L.L.wk8 (mm)	L.L.wk12 (mm)	S.G.wk2 (mm)	S.((m
Block	2	0.16	2.07	2.47*	11.47**	36.69**	37.36**	311.44**	248.77**	1081.80**	1965.60**	10056.65*	0.10**	87.
Mulch	4	0.37	2.41	1.47	2.08*	1.94	1.41	17.53	61.64**	555.42*	1285.69**	6423.55	0.00	0.5
Rate	2	0.09	0.87	0.47	0.60	4.62*	5.49	9.69	60.01*	254.87	741.60*	698.22	0.00	1.9
Mulch x Rate	8	0.37	0.39	0.88	0.38	0.51	0.79	2.20	15.52	79.09	133.49	157.26	0.01*	0.5
Error	28	0.32	1.02	0.73	0.71	1.14	2.33	9.67	13.06	189.18	216.93	2449.11	0.00	0.5

*Values followed by * in the same column are significantly different from each other at p* < 0.05

*Values followed by ** in the same column are significantly different from each other at p* < 0.01
Note: DG- days to germination, L.C- leaf count, L.L- leaf length, S.G- stem girth

Table 3
b: Effect of Four Agroforestry Tree Species Leaf Mulch on Growth and Yield Performance of Sorghum

Source of variation	df	Wk to Fruit	Wk to Harvest	No of Tiller/plant	No of Panicles	Panicle weight (g)	No of grains (unit)	seed weight (g)
Block	2	40.74**	74.76**	16.11**	5.02**	91437.16**	1621312.82**	2815.35**
Mulch	4	2.20**	2.12**	0.87	0.19	4446.00	411571.25*	960.20**
Rate	2	0.21	0.69	0.29	2.22*	11057.61	44146.95	56.85
Mulch x Rate	8	0.32	0.24	0.61	0.86	1824.57	75568.14	130.48
Error	28	0.55	0.55	0.67	0.56	4132.30	110926.14	164.49

*Values followed by * in the same column are significantly different from each other at p* < 0.05

*Values followed by ** in the same column are significantly different from each other at p* < 0.01
Note: DG- days to germination, L.C- leaf count, L.L- leaf length, S.G- stem girth

Effect of Individual Agroforestry Tree Species Leaf Mulch on Growth and Yield Performance of Sorghum

The mean effect of mulch type on growth and yield parameters in Table 4 revealed that the use of different mulch types significantly influenced certain growth and yield parameters, even though not all differences were statistically significant. Among the mulched treatments, A. altilis, L. leucocephala, and M. oleifera showed favorable trends compared to the control.

Although days to germination did not significantly vary across treatments, mulched plots exhibited slightly earlier emergence (3.78–4.11 days) compared to the control (4.33 days), the phenomenon which was explained by Teasdale and Mohler (2000) and Olasantan (2007) that mulches may enhance soil moisture and thermal regimes favorable for germination.

At maturity, leaf length was significantly lower in the control (87.53 cm), while mulched plots showed higher values of 93.83 cm in *A. altilis*, indicating better vegetative growth under mulched conditions. M. oleifera mulched plot notably recorded the highest stem girth (4.21 cm), which may relate to its richer nutrient composition and favorable decomposition rate as clearly reported by Kumar et al. (2019), thereby enhancing structural growth.

Considering the reproductive development parameters, L. leucocephala resulted in the longest time to flowering and harvest (13.06 and 18.06 days, respectively). This may reflect delayed senescence and prolonged vegetative growth; it however did not correspond to superior yield, as *L. leucocephala* recorded the lowest seed weight (42.67 g) and number of grains (1310) when it compares with other treatments.

In contrast, A. altilis and M. oleifera mulched plots consistently outperformed others in panicle weight, seed weight, and number of grains per plant, indicating their superior agronomic potential. M. oleifera in particular, produced the highest panicle weight (161.33 g) and grain counts (1688.83), while the control plot, despite having fewer tillers, recorded the highest seed weight (68.5 g) which could possibly be due to reduced intra-plant competition.

The variability in yield attributes among mulch types could as reported in literature, be attributed to differences in nutrient release patterns, mulch decomposition rates, and allelopathic properties (Agele et al., 2011; Narayanasamy, 2018). The mulch treatments likely enhanced soil structure and moisture conservation, translating into improved crop performance across most metrics.

Table 4
a: Effect of Individual Agroforestry Tree Species Leaf Mulch on Growth and Yield Performance of Sorghum

Mulch	DG	L. C wk2	L. C. wk4	L. C.wk6	L. C. wk8	L. C. wk12	L.L.wk2 (mm)	L.L.wk4 (mm)	L.L.wk6 (mm)	L.L.wk8 (mm)	L.L.wk12 (mm)	S.G.wk2 (mm)	S.G.wk6 (mm)	S.G (m
A. altilis	4.00a	2.78^{a}	4.56	7.89	10.56	13.11^{a}	66.11	157.22	449.78	769.78	938.33^{a}	0.37	12.61	22.
L. leucocephala	3.78a	1.56^{b}	3.89	7.44	9.78	12.56^{a}	66.33	157.17	462.33	769.33	938.50^{a}	0.37	13.29	23.
M. oleifera	4.11a	$1.89a^{b}$	4.33	7.56	9.67	12.00^{a}	63.39	152.56	448.67	750.89	932.67^{a}	0.39	12.97	42.
S. grandiflora	4.00a	$2.11a^{b}$	4.56	7.78	9.89	12.56^{a}	63.56	152.78	442.22	753.33	927.00^{a}	0.38	13.05	22.
Control	4.33a	2.67^{a}	5.00	8.67	10.67	12.67^{a}	65.33	152.00	457.33	742.67	875.33^{b}	0.37	12.87	21.

Values followed by different letters in the same column are significantly different from each other at p < 0.05
Note: DG- days to germination, L.C- leaf count, L.L- leaf length, S.G- stem girth

Table 4
b: Effect of Individual Agroforestry Tree Species Leaf Mulch on Growth and Yield Performance of Sorghum

Mulch	Wk to Fruit	Wk to Harvest	No of Tiller/plant	No of Panicles	Panicle weight (g)	No of grains (unit)	seed weight (g)
A. altilis	11.78	17.00	3.44	1.89	119.11	1841.00	65.00
L. leucocephala	13.06	18.06	3.50	1.67	124.00	1310.00	42.67
M. oleifera	12.06	16.94	3.00	2.00	161.33	1688.83	57.33
S. grandiflora	12.00	17.11	2.78	1.78	103.78	1573.67	52.00
Control	12.33	17.67	3.33	2.00	142.33	1804.00	68.50

Values followed by different letters in the same column are significantly different from each other at p < 0.05
Note: DG- days to germination, L.C- leaf count, L.L- leaf length, S.G- stem girth

Effect of Application Rate of Four Agroforestry Tree Species Leaf Mulch on Growth and Yield Performance of Sorghum

Table 5 shows the mean value of the rate of application on growth and yield performance of sorghum. Although there were no statistically significant differences in most measured parameters across mulch application rates, trends observed suggest that increasing mulch rate may offer slight agronomic advantages, especially regarding yield components. For example, plants treated with the 2.5 kg mulch application rate exhibited the highest panicle weight (160.10 g) and number of panicles (2.27), suggesting a potential positive relationship between mulch quantity and reproductive output. This aligns with findings by Agele et al. (2011), who noted that higher mulch quantities improved moisture retention and nutrient availability, particularly in tropical soils.

Stem girth also appeared to increase with mulch rate, with the 2.5 kg rate recording a much larger value (33.87 mm) compared to 1.5 kg and 2.0 kg rates (22.53 mm and 22.72 mm, respectively). Although this was not statistically significant, it may show cumulative improvements in soil structure and nutrient availability at higher levels of mulch (Narayanasamy, 2018; Kumar et al., 2019).

Ironically, the 1.5 kg mulch application rate recorded the highest seed weight (58.60 g), slightly higher than the 2.0 kg (57.80 g) and 2.5 kg (54.90 g) treatments, which could be due to lower intra-plant competition or more efficient partitioning of assimilates under lower mulch density, a phenomenon previously observed by Adediran et al. (2004).

Generally, while the effects of mulch application rate were not strongly pronounced, the 2.5kg rate generally enhanced yield traits, supporting the idea that optimized mulch quantity improves soil physical conditions and nutrient release dynamics (Olasantan, 2007).

Table 5

a: **Effect of Application Rate of Four Agroforestry Tree Species Leaf Mulch on Growth and Yield Performance of Sorghum**

Rate	DG	L. C wk2	L. C. wk4	L.C.wk6	L. C. wk8	L. C. wk12	L.L.wk2 (mm)	L.L.wk4 (mm)	L.L.wk6 (mm)	L.L.wk8 (mm)	L.L.wk12 (mm)	S.G.wk2 (mm)	S.G.wk6 (mm)	S.G.wk12 (mm)
1.5kg	4.00[a]	2.40[a]	4.60	8.07	10.73	13.27	65.70	154.37	454.87	760.00	914.50	0.36	12.65	22.53
2.0kg	4.13[a]	1.93[a]	4.27	7.87	9.93	12.13	64.10	152.33	447.33	749.20	925.93	0.38	13.36	22.72
2.5kg	4.00[a]	2.27[a]	4.53	7.67	9.67	12.33	65.03	156.33	454.00	762.40	926.67	0.39	12.87	33.87

Values followed by different letters in the same column are significantly different from each other at p < 0.05

Note: DG- days to germination, L.C- leaf count, L.L- leaf length, S.G- stem girth

Table 5

b: **Effect of Application Rate of Four Agroforestry Tree Species Leaf Mulch on Growth and Yield Performance of Sorghum**

Wk to Fruit	Wk to Harvest	No of Tiller/plant	No of Panicles	Panicle weight (g)	No of grains (unit)	seed weight (g)
12.23	17.20	3.10	1.50	107.20	1643.80	58.60
12.37	17.60	3.17	1.83	123.03	1697.60	57.80
12.13	17.27	3.37	2.27	160.10	1589.10	54.90

Values followed by different letters in the same column are significantly different from each other at p < 0.05

Note: DG- days to germination, L.C- leaf count, L.L- leaf length, S.G- stem girt

CONCLUSION

The low soil fertility and shortage of water as a result of climate change is generally making food production becoming extremely difficult. The rising demand for Sorghum as a result of growing industrial need in South-West Nigeria for food, breweries and beverage has grown significantly in the recent years. There is therefore the need to look into repairing the damaged soil structure and depleted soil nutrient by the adoption of organic mulch and use of beneficial crops that are tolerant to low soil nutrient until full restoration.

This research addressed part of these challenges through soil management (mulching), by determining the effects of leaf mulch from selected agroforestry species on sorghum yield. This study evaluated the effects of different mulch types and application rates on growth and yield performance of sorghum.

The results from this study on the growth and yield performance of sorghum showed that the mulch type significantly influenced key agronomic traits including days to 50% flowering and harvest, panicle weight, and number of grains, while mulch application rate had a significant effect only on number of panicles ($p < 0.05$). The interaction between mulch and rate of application, however, did not significantly affect any of the observed measured parameters ($p > 0.05$), indicating that the effect of mulch was mostly independent of application rate. Mulched plots generally outperformed the control plot under yield parameters, with increased panicle weight, number of grains, and seed weight. Also, although mulch type significantly influenced grain yield ($p < 0.05$), the rate of mulch application had no significant effect on seed weight or panicle weight. The mean effect of mulch type on growth and yield parameters revealed that the use of different mulch types significantly influenced certain growth and yield parameters, even though not all differences were statistically significant. The 1.5 kg rate recorded the highest seed weight (58.60 g), slightly higher than the 2.00 0kg (57.80 g) and 2.50 kg (54.90 g) treatments. M. oleifera at 2.50 kg mulch rate was conspicuous, recording the highest stem girth (81.13 mm) and the highest panicle weight (196.00 g). *A. altilis* at 2.50 kg application rate also produced high seed weight (67.00 g) and number of grains (1830.50), which in comparison, is better than the control.

The findings from this study highlights the importance of mulching from agroforestry tree species leaves in planting as it was highly effective in increasing panicle weight, number of grains, seed weight and completely suppressing weed growth.

Declarations

Author Contribution

The author (ADELEYE Z. Olufemi) confirms being the sole contributor of this work and has approved it for publication.

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