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Allelopathic effects of leachates of African peach (*Nauclea diderrichii*) and white afara (*Terminalia superba*) on germination and growth of maize

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Abstract. *Onefeli AO, Oluranti OI, Uthman KT, Aderibigbe AA, Mustapha MB. 2024. Allelopathic effects of leachates of African peach (*Nauclea diderrichii*) and white afara (*Terminalia superba*) on germination and growth of maize. Cell Biol Dev 7: 22-27.* This study was done to identify the allelopathic interference and nature of *Nauclea diderrichii* (De Wild.) Merr. and *Terminalia superba* Engl. & Diels on seed germination, the Seedling Vigour Index (SVI), and the growth of the seed of maize (*Zea mays* L.), to determine the best selection of tree species for agroforestry. The study was done at the University of Ibadan, Ibadan, Nigeria, both in the laboratory and on an agroforestry site. The freshly dried leaves of *N. diderrichii* and *T. superba* were collected and ground into powder to make leachate. The 3%, 6%, and 12% treatment leachate were made by soaking the powder for 24 hours, and the maize seeds were watered with the leachate. Statistical analysis was done with the data collected from the growth parameters for the two species using ANOVA, T-test, and Correlation. The *N. diderrichii* showed a slightly more effect on the maize than *T. superba*; the inhibitory effect of *N. diderrichii* was high with the increase in concentration of 3% (1.52), 6% (0.35), and 12% (0.81)) treatments, comparing mean values with the control. The two species have an inhibitory effect on most of the growth parameters. It was evident that *N. diderrichii* has more inhibitory effect on maize at high concentrations than *T. superba*. Seedling shoot dry weight had the strongest correlation with the SVI among the growth parameters. The result shows that *T. superba* is more suitable for agroforestry systems than *N. diderrichii*.

Keywords: Agroforestry, allelopathy, growth parameters, inhibitory effect, *Nauclea diderrichii*, *Terminalia superba*

INTRODUCTION

Agroforestry is one of the aspects of forestry that accommodates various specialized knowledge for the development of sustainable rural production. Agroforestry is a recognized land use method, where trees provide environmental services and products. It is widely known that agroforestry activities have environmental benefits. However, the decrease in agricultural crop yield in agroforestry practices has recently been traced to the allelopathic effect of the trees on the crops (Kunzelmann 2021). Kumar and Guru (2014) agree that agroforestry has many benefits for crops, as well as promoting a good livelihood for rural communities. However, these benefits have been threatened due to some negative factors through chemicals released by the trees used for agroforestry practices.

Nauclea diderrichii (De Wild.) Merr. is an indigenous tree species that is used in agroforestry practices to promote land use and improve the yield of farmers in Nigeria. This species is known as an evergreen species, and belongs to the family Rubiaceae. It is mostly found in the Tropical Rainforest zone (Abdulrahman and Adamu 2019). The leaf of *N. diderrichii* is rich in phytochemicals such as tannins, hexane, ethyl acetate, methanol, alkaloids, glycosides, phenolic compounds, phytosterols, saponins etc. that justify the tree as a traditional medicinal tree (Mustofa et al. 2000; Neuwinger 2000; Obute and Ekiye 2008; Addo-Danso et al. 2012). *Terminalia superba* Engl. & Diels belongs to the families of Combretaceae. It is also an indigenous tree species that is used in agroforestry practices to promote land use and improve the farmers yield (Onefeli and Stanys, 2019; Onefeli et al. 2019). Much research has not been done on the effect of *T. superba* allelochemicals on crops like other species. However, indigenous tree species have been found to contain some phytochemicals that can either stimulate or inhibit the growth of crops (Onefeli et al. 2021). This allelopathic chemical could be further investigated to know the differential effects of *T. superba* on various crops and probably if the allelopathic nature of the tree species can be used in weed management to enhance the productivity of the agroforestry systems further.

Allelopathy is known as the interference process in which chemical substances released from living or dead plants, can either have a positive or negative effect on the germination or growth of plants associated with it (Lalmuanpuii 2012). Allelopathy is said to have an involvement in many natural and manipulated ecosystems, which can have an impact on the transformation or evolution of various plant communities, plant failure or exotic plant invasion (Ridenour and Callaway 2001; Inderjit and Nilsen 2003). The chemicals that cause allelopathic interference are present in many plants and in various organs or parts of the plant, which include the bark, fruits, leaves and exudate (Sazada et al. 2009). Allelopathic chemicals are known as unwanted byproducts, products of metabolic reactions in plants or secondary plant products (Turk and Tawaha 2003; Yokotani et al. 2003; Iqbal et al. 2006). Victor et al. (2006) reported that the chemicals can be transferred, transported, or diffused through the soil and can be metabolized, transformed, formed into compounds, or attached to organic matter, which may have effect on the seeds. The span or time of field autotoxicity differs with the geographic location and with the environment. The rain leachate extract is a more ecological method to check for the allelopathic potentials of tree species because it represents the natural field conditions better than the other methods (Lorenzo et al. 2011; Song et al. 2018). The symptoms of allelopathy interactions should be specific, because these interactions are essential to knowing how to eliminate the causes of interference in chromatographic studies (Oyun 2006).

Garrity (2012) reported that in the future, land use may face pressing challenges across countries; however, these challenges can be managed well with the proper knowledge of agroforestry systems. One of the main setbacks that can be associated with allelopathic research is the single usage (application) of leachate in most of the culture studies or segmented treatments, this culture excludes the biotic and abiotic factors that have the potential to interfere with the allelopathic reactions in the field (Ens et al. 2009). There are several environmental factors (such as soil, light, temperature, and precipitation), the availability of water resources, understory vegetation, and nutrients that are essential to determining or estimating the allelopathy interference as this relies on them (Catherine et al. 2006; Ahmed et al. 2008; Catherine et al. 2008; Ahmed et al. 2017). It is important that we check or estimate the compatibility of allelopathic trees and crops before choosing the crops for an agroforestry system (Parvin et al. 2011).

Therefore, this study was carried out to evaluate and estimate the interferences of leachate from *N. diderrichii* and *T. superba* on seed germination, growth, and seedling vigor index of *Zea mays* L. with a view of determining the compatibility of African peach (*N. diderrichii* and white afara (*T. superba*) on maize, as well as the morphological traits for allelopathic interference assessment of tree species on the maize seedlings.

MATERIALS AND METHODS

Study area

The study was conducted at the David Okali Laboratory of the Department of Forest Production and Products (Figure 2), and the agroforestry site of the University of Ibadan, Ibadan, Nigeria (Figure 1). The University of Ibadan is located between the latitude of $7^0 28$`N and longitude of $3^0 52$`E at an altitude of 277m. The land is characterized by dry and wet seasons and tropical forests. From April to October is the wet season in the country, and the other season (dry) runs from November to March, likewise, the temperature ranges from 22^0C to 31^0C (Onefeli and Agwu 2015).

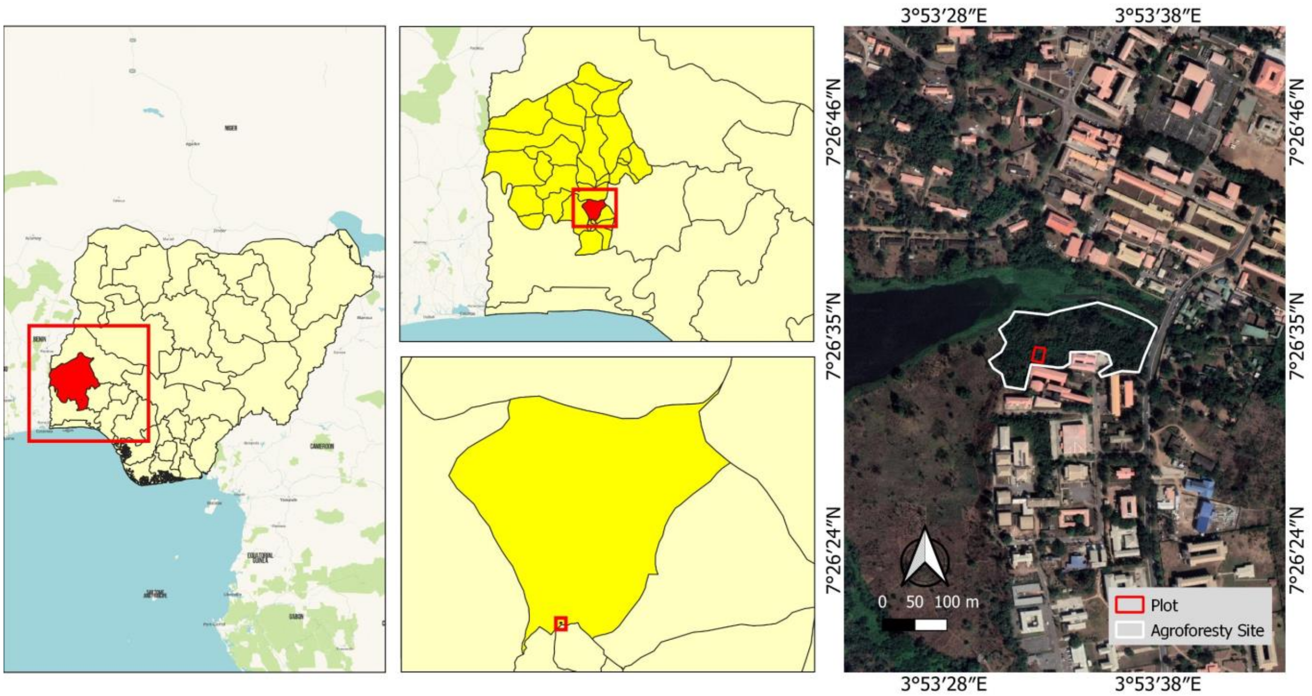

Figure 1. Map of the agroforestry plot, University of Ibadan, Nigeria

Experiment procedure

The sterilized grains of *Z. mays* were collected from the Department of Forest Production and Products at the University of Ibadan, Oyo State. The collected sterilized grains were to be used for planting on the agroforestry plot and also for an allelopathic experiment to determine the impact of the trees species leachates on growth variables and the germination of maize. There was a total of 18 replicates for the experiment, with 6 maize grains planted in each polythene pot using a loamy topsoil as the planting media.

A plot of 5 m by 10 m was allotted for the practical activity of the agroforestry planting. Four ridges were made on the plot with a depth of 0.3m, a width of 0.6m, and an enspacement of 0.6 m. While the dimension of each ridge was also 0.6 m by 10 m. The freshly dried leaf samples of *N. diderrichii* and *T. superba* were collected from the leaf litters in front of the Department of Forest Production and Products and the freshly dried leaves that were picked were all sun-dried, ground into powder by mechanical grinder. The 12% leachate of *N. diderrichii* and *T. superba* was obtained by mixing 30 g of the ground fine powder into 960 mL of distilled water. The soaked ground powder of the prepared leaves was shaken thoroughly and then kept for 24 hours. Also, the 6% leachate of *N. diderrichii* and *T. superba* was obtained by mixing 30 g of the ground fine powder into 480 mL of distilled water, and 30 g into 240 mL, then shaking the mixture well and leaving it for 24 hours.

The leachate was sieved out of the water using a mesh sieve after 24 hours, and 100 mL of the leachate water was used to water the 6 planted maize grains in the treatment polythene pots, while the distilled water was used for the control experiment for 7 days starting from day 1 of planting. The polythene pots of the treatments were arranged in a Completely Randomized Design (CRD) on the agroforestry plot. The day of first germination of the seed was after four days of planting, and the final germination of the seeds was obtained before the eleventh day of planting, according to procedure by Oyun (2006). The interference of the leachates on seed germination, shoot growth, and root growth was determined and evaluated by harvesting three plants randomly from the treatment polythene pots after 21 days of planting. The data relating to germination, yield and growth were analyzed. The mean germination time of the seeds was calculated using:

$$\sum = \frac{\text{nxd}}{N}$$

Where, n: no of seeds that germinated in day 1, d: number of days, N: Total number of seeds that germinated at the end of the experiment.

After 21 days, the seedlings growth/yield was evaluated by harvesting randomly, three plants from the treatments were collected and various growth variables were assessed Number of leaves was determined by visual counting. The dry root weight, dry shoot weight fresh root weight, and fresh shoot weight were measured using an electronic weighing balance while the fresh shoot length and fresh root length weight were measured by a ruler. The dry plants were dried in an oven for more than 48 hours to get a constant dry weight to be recorded. The SVI was evaluated as Seedling Vigor Index = dry weight per seedling/MGT X 100, and the data collected were subjected to Analysis of variance (ANOVA) and T-Test analysis using Microsoft Excel and SPSS. The Correlation co-efficient of the growth parameters were also evaluated, to know the relationship between SVI and the other growth parameters for all the treatments.

RESULTS AND DISCUSSION

Table 1 shows the interaction of the phytochemicals through the mean values of the treatment variables from the ANOVA table of *N. diderrichii* leachate on *Z. mays*. The table deduced that the leachate treatment significantly ($p<0.05$) influenced – Mean Germination Percentage (MGP) and Root Fresh Weight (RFW) of the maize, unlike the other variables that are not significantly ($p>0.05$) affected by the leachate concentrations. From the table, variables DFSG, RFW, NL, RL, RDW and SVI have their 3% treatment mean values greater than the control mean values, while the DFSG and NL variables have their 6% treatment mean values greater than the control mean values, and the variables RL, RFW, SDW, RDW, and SVI have their 12% mean values greater than the control mean values. MGT, MGP, SL, and SFW are the only variables with control means greater than the mean of the treatments.

Table 2 shows the mean values of the treatment variables from the ANOVA table of *T. superba* leachate on *Z. mays*. The table deduces that all the maize growth parameters present in the table are not significantly ($p<0.05$) influenced by the variation in *T. superba*'s leachate concentration except for the Root Fresh Weight (RFW), unlike the ANOVA table for species 1: *N. diderrichii*. From the table, variables SL, RL, RDW, RFW, SDW and SVI have their 3% treatment mean values greater than the control mean values, while the DFSG, NL, SL, RL, SFW, SDW and SVI variables have their 6% treatment mean values greater than the control mean values, and the variables DFSG, NL, RL, RDW, SFW, RFW, SDW, SL, and SVI have their 12% mean values greater than the control mean values. MGT and MGP are the only variables with control means greater than the mean of the treatments.

The p values of values in Table 3 below are not significant, showing no relationship between the two species, *N. diderrichii* and *T. superba* in tems of their leachate effect on the germination and growth of *Zea mays*. However, in terms MGT, DFSG, SL, RL, SFW, RFW, SDW, and RDW, *T. superba* had higher average values of 5.19, 3.87, 57.74, 23.87, 14.43, 3.03, 1.91 and 0.83 respectively as compared to the *N. diderrichii* with 4.91, 3.84, 57.10, 21.78, 11.88, 2.62, 1.64 and 0.70 average respectively. Mean Germination Time, DFSG: Day of First Seed Germination, MGP: Mean Germination Percentage, NL: Number of Leaves, SL: Shoot Length, RL: Root Length, SFW: Shoot Fresh Weight, RFW: Root Fresh Weight, SDW: Shoot Dry Weight, RDW: Root Dry

Weight, SVI: Seedling Vigour Index.

From Table 4, it can be deduced that all the growth parameters significantly correlated with the Seedling Vigour Index (SVI). The shoot dry weight appeared to have the highest value closer to 1 (0.57), followed by the root dry weight (0.47), and then the Shoot Fresh Weight (0.27).

Table 1. Mean values of the variables from the ANOVA table, showing the effect of *Nauclea diderrichii* treatments on *Zea mays*

ND Treatment Conc.	MGT	DFSG	MGP (%)	NL	SL (cm)	RL (cm)	SFW (g)	RFW (g)	SDW (g)	RDW (g)	SVI
Control	5.07	3.76	95.75[a]	6.25	60.46	21.93	13.39	2.29[b]	1.59	0.55	52.08
3%	4.95	3.88	89.61[ab]	6.96	46.31	25.38	7.35	4.77[a]	1.28	1.52	52.93
6%	4.81	3.8	88.93[ab]	6.42	54.31	17.89	9.47	1.27[b]	1.34	0.35	42.69
12%	4.56	4.1	82.6[b]	6.04	58.62	22.28	13.39	3.16[ab]	2.33	0.81	71.88
P value	0.460[ns]	0.460[ns]	0.007*	0.489[ns]	0.104[ns]	0.469[ns]	0.316[ns]	0.042*	0.073[ns]	0.121[ns]	0.530[ns]

Note: ns: not significant at 5% probability level, *: significant at 5% probability level.

Table 2. Mean values of the variables from the ANOVA table, showing the effect of *Terminalia superba* treatments on *Zea mays*

TS Treatment Conc.	MGT	DFSG	MGP (%)	NL	SL (cm)	RL (cm)	SFW (g)	RFW (g)	SDW (g)	RDW (g)	SVI
Control	5.3	3.85	93.73	6.27	55.21	22.52	13.7	2.55[b]	1.66	0.73	38.68
3%	4.93	3.9	86.43	6.02	58.78	25.01	12.6	2.59[b]	2.58	1.02	62.72
6%	5.08	3.89	83.33	6.44	61.42	22.71	15.03	1.82[b]	1.98	0.38	40.3
12%	5.3	3.88	91.41	6.64	60.81	28.29	18.51	6.54[a]	1.81	1.45	39.27
P value	0.760[ns]	0.998[ns]	0.213[ns]	0.830[ns]	0.799[ns]	0.601[ns]	0.801	0.026*	0.269[ns]	0.273[ns]	0.257[ns]

Note: ns: not significant at 5% probability level, *: significant at 5% probability level.

Table 3. The T-Test table of the mean values with the P value of the parameters showing the relationship between the two tree species

	Species	Mean	P value	Std. Deviation	Std. Error Mean
MGT	ND	4.91	0.17[ns]	1.15	0.15
	TS	5.19		1.00	0.14
DFSG	ND	3.84	0.84[ns]	0.59	0.08
	TS	3.87		0.75	0.10
MGP	ND	91.23	0.70[ns]	11.46	1.51
	TS	90.30		14.23	1.94
NL	ND	6.34	0.90[ns]	1.33	0.18
	TS	6.31		1.44	0.20
SL	ND	57.10	0.84[ns]	14.94	1.961
	TS	57.74		19.07	2.60
RL	ND	21.78	0.29[ns]	9.98	1.31
	TS	23.87		10.95	1.49
SFW	ND	11.88	0.24[ns]	9.36	1.23
	TS	14.43		13.29	1.81
RFW	ND	2.62	0.51[ns]	2.78	0.36
	TS	3.03		3.68	0.50
SDW	ND	1.64	0.22[ns]	1.03	0.13
	TS	1.91		1.25	0.17
RDW	ND	0.70	0.54[ns]	1.13	0.15
	TS	0.83		1.18	0.16
SVI	ND	54.33	0.16[ns]	46.53	6.11
	TS	43.49		33.41	4.55

Note:ns: not significant, ND: Species 1- *Nauclea diderrichii*, TS: Species 2 - *Terminalia superba*, MGT: Mean Germination Time, DFSG: Day of First Seed Germination, MGP: Mean Germination Percentage, NL: Number of Leaves, SL: Shoot Length, RL: Root Length, SFW: Shoot Fresh Weight, RFW: Root Fresh Weight, SDW: Shoot Dry Weight, RDW: Root Dry Weight, SVI: Seedling Vigour Index.

Table 4. The correction coefficient (r) showing the association between the SVI and the growth parameters

Seedlings growth parameters	Correction Coefficient (r)	p-value
Shoot length (cm)	0.205	0.300*
Root length (cm)	0.196	0.390*
Shoot fresh weight (g)	0.268	0.004*
Root fresh weight (g)	0.249	0.008*
Shoot dry weight (g)	0.571	0.000*
Root dry weight (g)	0.468	0.000*

Note: *: significant at 5% probability level

Discussion

From Tables 1 and 2, the allelopathic effects of *N. diderrichii* and *T. superba* leachates on the growth of maize, and the germination were shown according to the mean values of the growth parameters. The data showed that the two tree species leachates inhibited the growth of maize at different concentration.

At (P<0.05), the total days taken for the first germination of seed were delayed due to the reaction of the leachates of *N. diderrichii* and *T. superba* significantly higher with 12% concentration in *N. diderrichii* and 3% concentration in *T. superba*. Also, the germination percentage of the seeds decreased with increased concentration for *N. diderrichii* while there wasa significant decrease in germination percentage with increase in concentration except for 12% for *T. superba* compare to the control.

Also, there was a slight significant difference in the leachate effect of *N. diderrichii* only on the seedling root dry weight among the growth, and there was no significant difference among all the growth parameters . Therefore, it can beinferred that *N. diderrichii* has a more negative effect on the germination and growth of maize than *T. superba*.

The result of this study is in line with those reported by Abdulrahman and Adamu (2019), which estimated that *N. diderrichii* has a high potential negative effects on the germination of agricultural crops due to the presence of many phytochemicals in the plant that make it useful for medicinal purposes. From these findings, it was concluded that the inhibitory effect of *N. diderrichii* on the growth parameters on the growth parameters is more significant at a concentration of 12% than the germination as compared with *T. superba*. That was more pronounced in germination than the growth parameters.

The negative interference (inhibitory) of the leachates on *Z. mays* may be due to the interference in the physiological process of maize that leads to growth by the effect of the leachate. However, this was not directly evaluated, the inhibited effect of the leachates on the germination may be due to some reactions that might have occurred that affected the water absorption of the seed before the seed germination was initiated. Likewise, the seedling growth might have been affected by the leachates through the hindrance in the absorption of water and nutrients from the soil, which is essential for the growth of the plant, depending on the concentration of the leachates.

The two tree species, *N. diderrichii* and *T. superba* 3 are not significantly different according to the findings obtained from the current study. The species has a negative effect on germination and the growth of *Z. mays*. The seedling growth parameters showed positive correlation, with the Seedling Vigour Index (SVI). And the shoot dry weight happened to have exhibited the highest trait for allelopathic interference evaluation of maize.

In conclusion, the study provided essential information about the interference of these species allelopathic nature, which is highly important in understanding their potentials and an insight into the best species suitable for agroforestry practices. According to this study, *N. diderrichii* and *T. superba* have an inhibiting effect on the germination and growth of *Z. mays* at different concentrations.

Nevertheless, we have found out that the allelopathic nature of *N. diderrichii* is more effective in inhibiting maize than *T. superba* (*T. superba* stimulates growth more than the other species). This suggests that *T. superba* can be proposed for agroforestry using maize as the agricultural crop. This study revealed that more research should be done on the allelopathic nature or effect of *T. superba* on other agricultural crops aside from maize to determine its potential to inhibit the growth of other plants and to have a better understanding of how to use the tree species in agroforestry systems.

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