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EFFECTS OF TEAK CANOPY COVER AND NPK FERTILIZER APPLICATION ON GROWTH OF GINGER IN AGROFORESTRY TRIAL, ILE-IFE, NIGERIA

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ABSTRACT
Non-timber forest products issues are of global interest due to their importance among rural and urban dwellers for income, healthcare and food security. This study investigates the effects of Tectona grandis canopy cover and NPK (Nitrogen, Phosphorus, Potassium) fertilizer (15:15:15) application on growth parameters of Ginger (Zingiber officinale Roscoe, Zingiberaceae) in Ile-Ife, south-western Nigeria. Twelve replicates of ginger plots (6m^2 each) were laid in a completely randomised block design within and outside Teak plantations. Six replicates were treated with NPK (15:15:15) in a split dose at two and 6 weeks old, while others serve as control. Growth indices such as foliage, tiller numbers, and plant height per plot were obtained for two cropping seasons. Data obtained were analysed using ANOVA and descriptive statistics. Tiller formation in ginger was significantly inhibited by Teak canopy with or without NPK fertilizer (0.000 and 0.033, $\rho \leq 0.05$). Ginger heights were not significantly different within Teak plantation with or without NPK (0.647); however, there were significant differences between heights of ginger grown within and outside Teak plantations, (0.000 and 0.011, $\rho \leq 0.05$). Foliage production in ginger was higher outside teak plantation, (0.000 and 0.007, $\rho \leq 0.05$), while NPK also enhanced foliage production in ginger significantly, (0.000, $\rho \leq 0.05$). The study concluded that incorporation of Ginger in plantations such as Teak and other fast growing indigenous species can enhance plantation benefits in terms of biomass yield. Further research in this area is recommended in agroforestry systems.

Keywords: Ginger, Teak canopy, tiller formation, leaf production, agroforestry.

INTRODUCTION
Non-timber forest products (NTFPs) provide food, medicine and materials for domestic use, while some of them also provide cash income when traded in local, national or international markets (Clark, 2001). It is now generally recognized that NTFPs play important role in the economy of forests based communities, since they are used for subsistence and sometimes for sale, providing cash income, (Adepoju and Salau, 2007). Hanvan and Wiersun (1999) argued that in Cameroon a high proportion of NTFPs is not extracted from natural forests, but from anthropogenic (human – modified) vegetation types such as secondary forests, young fallow vegetation and Cocoa plantations. Hence commercial production of highly valued NTFPs in forestry plantations (anthropogenic) offers wide opportunities for development in multiple-use forest management, as it would contribute to raising household income and would allow a certain degree of specialization in production. This system will encourage community participation in the management of forest plantations adjoining their communities. Efforts towards better and improved management of anthropogenic vegetation on multiple use bases for NTFPs production are, therefore, worthwhile.

Agroforestry system is being promoted as a more appropriate land use system than monocropping practices for smallholders worldwide. However, detailed studies on the sustainability of different land use systems are limited, (Hamood, 2009). Substantial research efforts on NTFPs have focussed on different agroforestry systems worldwide, their plant components, farmer's perception/adoption, tree and agricultural yield studies and economic analysis (Chinnamani, 1993, Amusa *et al.*, 2011). NTFPs are important factors in forest management but their production have been historically neglected by forest managers, (Amusa *et al*., 2012) hence; detailed studies on the NTFP production after canopy closure in plantation projects are limited, especially in Nigeria. Research into commercial production of NTFPs in natural and plantation forests for sustainable supply and livelihood in sub-saharan Africa has not received commensurate attention of researchers. Grahams (2004) noted, that the biological and ecological information required to develop strategies for sustainable harvesting is poorly developed for even the most commonly traded NTFPs in Africa. Production of NTFPs within forest crop plantations and natural forests is an area researchers need to focus for breakthrough in sustainable NTFPs production globally. If sufficient quantity of NTFPs could be produced alongside timber in a multiple land use system, the forest will deliver a return higher in value than the value of alternative land uses.

Nwonwu (1987) observed that in the past, taungya systems have been employed to reduce plantation establishment cost, however, this system is limited as the forest plantation canopy closes. The food crops were normally cultivated for three years, after which the shade from the trees impeded further cultivation of the crops (Agyeman *et al*, 2003). Studies on the agronomy, biology and compatibility of NTFP's are required for their optimum production, (Duchense *et al*, 2000, Duchesne *et al*., 2001 and Guariguata *et al*., 2009). Most of the NTFPs are not domesticated, nor established in plantation as their counterpart timber species, they are, therefore, endangered due to dwindling natural forests globally. There is the need to generate data on the incorporation of NTFPs with tree species in agroforestry systems. Rao *et al.,* (2004), proposed integrating shade - tolerant medicinal and aromatic plants (MAPs) as lower strata species in tree crop plantations.

Medicinal and aromatic plants are among the most valuable NTFPs in most regions worldwide due to their increasing awareness and subsequent role in economic enhancement both at local and national levels. Their high value can provide an additional incentive for sustainable management of forest resources. Apart from healthcare, medicinal plants are mainly the alternate income-generating source of underprivileged communities adjoining forest estates (Myers, 1991, Lacuna, 2002). Gunnar (1982) emphasized the need for improved propagation techniques, genetic improvement, silvicultural management, marketing and economics of medicinal plants and other important NTFPs. Rhizome of Ginger (*Zingiber officinale* Roscoe, Zingiberaceae – Plate 1) is an important medicinal plant utilized as spice and medicine globally. It is traded internationally and contributes significantly to India and China national economies (Tyler *et al.* 1981). Sabur *et al* (1993) observed that Ginger gave high yields when intercropped and is an ideal shade crop under *Paulownnia elongata* plantations in China. This work assessed the growth performance of Ginger in Teak plantation as NTFP undergrowth in a multiple forest use management.

Plate 1: Ginger rhizomes (item of commerce).

METHODS

Study site: The Teak plantation is located in the Teaching and Research Farm, Obafemi Awolowo University, Ile – Ife, Nigeria. It is located on latitude 7^0 28^1N and longitude 4^0 33^1E. Mean annual rainfall is 1200mm. The plantation was established in 1980 for pole production in a 6m by 3m spacing. It is even-aged with close-canopy. There are however pockets of openings allowing enough light to support the undergrowth. The ground flora is dominated by shrubs and herbs such as *Alchornea laxiflora, Urena lobata, Dalbergia welwenschii, Chromolaena odorata*, seedlings of *Antiaris toxicaria* and *Newbouldia laevis* amongst others. The trees were aligned in east-west direction to maximize the use of sunlight by the trees.

Sampling Procedure and Sample Size

A total of twelve (12) 6m x 6m – sample plots were randomly located within the plantation; a replicate of the layout was also located in an open field about 10m away to prevent the shading effect of the plantation. The plots were randomly selected within and outside the forest plantation. Six of the plots were treated with NPK fertilizer while the other six plots had zero fertilizer application.

Experimental design

Completely Randomized Block Design (CRBD) was employed in the study. Tree count was carried out in the selected plantation plots with average of 14.8 trees per plot. Any plot with large variance in diameter at breast height (dbh) of (± 3 cm) to the mean tree was discarded and replaced. A sub-plot size of $648m^2$ each was tilled manually in the plantation and in the open field outside the plantation as control.

Ginger seedlings were raised from rhizomes in temporary nursery close to the experimental plots. After Three (3) weeks of growth in the nursery, vigorous seedlings were selected for planting on the field. Seedling height, number of leaves and number of tillers were recorded at maturity (32 weeks) before harvesting.

RESULTS

Effect of Teak canopy and NPK fertilizer on tiller formation in ginger

Ginger stands were grown for eight months in the experimental site, in both NPK and zero fertilizer plots. Average ginger tillers produced were less in plots under canopy than those grown outside the plantation (Fig. 1).

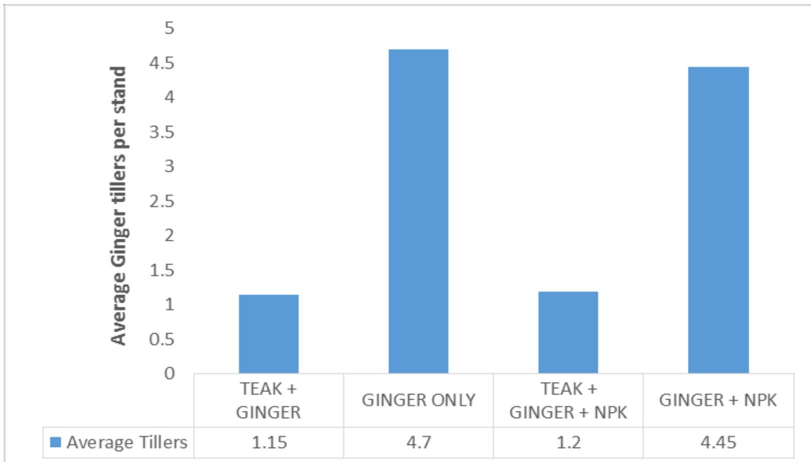

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Fig 1: Effect of Teak canopy and NPK fertilizer on tiller formation in ginger.

ANOVA of ginger tiller formation

Means of ginger tillers in year one showed significant differences; however, plots located within the forest estate have no significant differences in the means of ginger tillers/stand (0.942, $\rho \leq 0.05$). This result showed that application of inorganic fertilizer does not influence ginger tiller formation under teak plantation. There were significant differences between plots under forest canopy and plots outside forest cover, (Table 1). The effect of fertilizer was however significant in the plots outside forest estate (0.030, $p \leq 0.05$) with NPK treated plots having higher number of tillers. In year two, similar trend was observed, fertilizer effects was not significant between plots under forest canopy (0.420, $p \leq 0.05$) in ginger tiller formation.

Table 1: ANOVA of teak plantation canopy effects on ginger tillers formation

Plots	Year 1 Mean Difference	Sig	Year 2 Mean Difference	Sig
A&B	-4.8497	0.000*	-2.3991	0.000*
A&C	0.0144	0.942	0.1176	0.420
A&D	-4.4423	0.000*	-2.7186	0.000*
B&C	4.8641	0.000*	2.5167	0.000*
B&D	0.4074	0.030*	-0.3195	0.033*
C&D	-4.4567	0.000*	-2.8362	0.000*

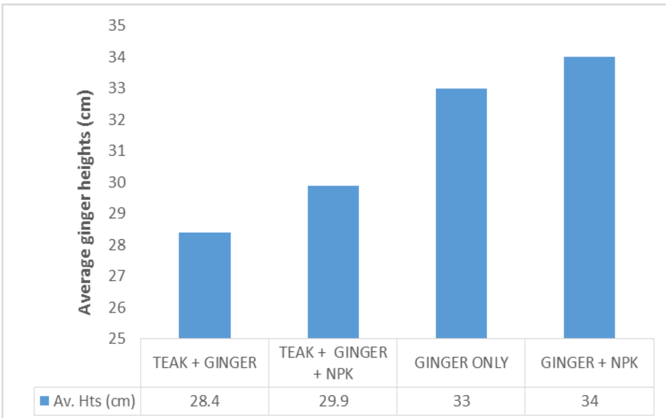
Key: A = Teak + Ginger + NPK, B = Ginger + NPK, C = Teak + Ginger, D = Ginger only, $\rho \leq 0.05$**.** Source: Field experiment, 2007 and 2008

Effect of teak canopy and fertilizer on ginger heights

Average heights of ginger were higher in plots treated with NPK (29.9cm) under canopy than plots without NPK (28.4cm). Also outside the canopy plots with NPK (34cm) had higher heights than plots without NPK (33cm) as shown in Figure 2.

Fig. 2: Effect of teak canopy and NPK fertilizer on height of ginger

ANOVA of teak plantation effects on ginger heights/stand



Ginger heights had significant differences in all the plots except plots A&C (0.647) which were both located within the Teak plantation, (Table 2). However, in year two significant differences were observed in ginger height/stand in plots A&C (0.001) contrast to year one result. Also, no significant difference was observed in ginger height/stand between plots B&D (0.158) located outside the forest estate. Plots within and outside forest blocks demonstrate significant differences in their average heights, Ginger in forest plantation had higher heights than ginger outside forest plantation.

Table 2: ANOVA of teak plantation effects on ginger heights/stand

Plots	Year 1 Mean Difference	Sig	Year 2 Mean difference	Sig
A&B	-7.4789	0.000*	-1.8614	0.039*
A&C	-0.4986	0.647	2.8224	0.001*
A&D	-3.1534	0.004*	-3.1249	0.000*
B&C	6.9803	0.000*	4.6839	0.000*
B&D	4.3254	0.000*	-1.2635	0.158
C&D	-2.6549	0.011*	-5.9474	0.000*

Key: A = Teak + Ginger + NPK, B = Ginger + NPK, C = Teak + Ginger, D = Ginger only, $\rho \leq 0.05$**.** Source: Field experiment, 2007 and 2008

Effect of canopy and NPK fertilizer on leaf production in ginger

NPK fertilizer treated plots under teak canopy showed higher numbers of leaves than plots without NPK fertilizer, same trend was repeated in plots outside teak canopy, (Fig. 3).

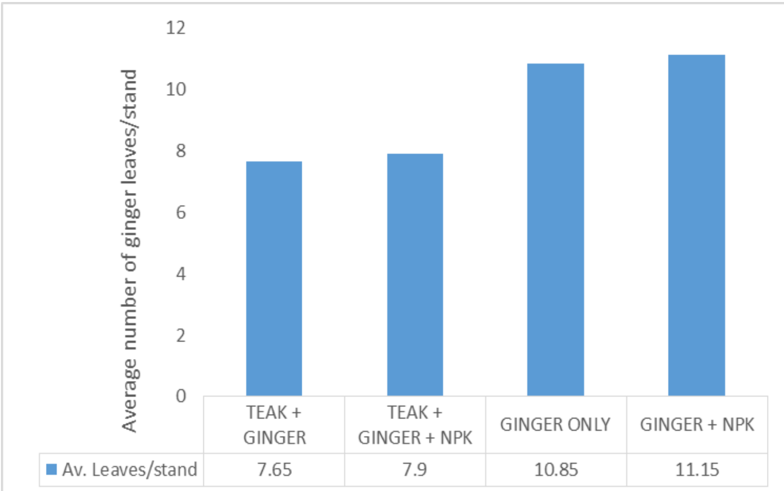


Fig. 3: Effect of teak canopy and NPK fertilizer on leaf formation in ginger

ANOVA of average numbers of ginger leaves

There were significant differences recorded in all the plots for average number of leaves/ginger stand (Table 3). The effect of fertilizer as well as forest cover was significant on leaf formation in ginger. Ginger stands within the fertilizer plots produced more leaves than ginger planted without fertilizer, while those grown outside forest estate produced higher number of leaves than ginger located under forest cover.

Table 3: ANOVA of effect of teak canopy and NPK on leaf production in ginger

Treatment	Year 1 Mean difference	Sig	Year 2 Mean difference	Sig
A&B	-6.0621	0.000*	-0.8167	0.007*
A&C	-1.2288	0.000*	1.3280	0.000*
A&D	-4.7618	0.000*	-1.4114	0.000*
B&C	4.8333	0.000*	2.1447	0.000*
B&D	1.3003	0.000*	-0.5947	0.049*
C&D	-3.5331	0.000*	-2.7394	0.000*

Key: A = Teak + Ginger + NPK, B = Ginger + NPK, C = Teak + Ginger, D = Ginger only, $\rho \leq 0.05$. **Source**: Field experiment, 2007 and 2008

DISCUSSION

Effect of Teak canopy and NPK fertilizer on tiller formation in Ginger

Teak plantation inhibits tiller production in ginger as shown in Fig.1, the average number of tillers per stand produced under teak canopy without inorganic fertilizer was 1.15 while the average ginger tillers per stand produced outside the teak canopy without NPK was 4.7. Similar trend was observed in ginger stands grown with NPK fertilizer. Ginger outside teak plantation produced higher numbers of tillers per stand than ginger grown with NPK under teak plantation. Average ginger tillers produced under teak canopy with NPK revealed an average of 1.2 tillers per stand, while an average of 4.45 tillers per stand was produced in ginger grown outside the canopy cover with NPK (Fig. 1). High level of shade provided by teak canopy, root structure and the allelopathic effect may be responsible for the poor tillerring in ginger grown in the plantation vis-a-vis those outside, (Healey and Gara, 2003). Canopy in teak hinders ginger plant from adequate light intensity in the forest floor, while ginger requires good light intensity of about 25% for optimum photosynthesis, (Valenzuela, 2011). Also, the interaction between the root of teak and ginger predisposes ginger to soil nutrient competition. Sasikumar *et al*, (2008) and Lujiu *et al*, (2010), found that ginger is an exhausting crop and requires large amounts of nutrients, especially potassium (K) and nitrogen, availability of these nutrients in teak plantation soil will influence tiller formation in ginger.

Analysis of variance (Table 1) shows significant differences in tiller formation between ginger grown under forest cover and outside forest cover with or without application of NPK fertilizer, (0.000, 0.000, $\rho \leq 0.05$). Thus, the poor tiller production by ginger grown in the teak plantation may be associated with the allelopathic nature of *Tectona grandis,* inadequate light intensity in the forest floor and competition for essential nutrients in the plantation.

Tillerring of ginger was not enhanced by NPK fertilizer significantly (0.942, 0.420, Table 1) on two doses application in the plantation of *Tectona grandis.* Average tiller production in ginger under canopy with NPK was 1.2 tillers per stand, (Fig 1). Ginger grown in plots without inorganic fertilizer in teak plantation yielded a lower number of tillers (1.15 tillers per stand). These results are in contrary to results in China and India, where NPK fertilizer was observed to enhance foliage production in ginger, (Sadanandan *et al*, 2000, Li *et al*, 2004). Generally, potassium based fertilizers are known to influence biochemical and physiological processes vital to plant growth, yield and quality, (Marschner, 1995; Cakmak, 2005, Lester *et al*, 2010). Teak has been reported to possess allelopathic character by secretion of certain hormones that suppress the development of other plants around it, (Macias *et al* 2004**,** Siddiqui *et al,* 2009, Macias *et al* 2010*)*. Ginger stands under teak may have been affected by the allelopathic substances introduced into the forest soil by teak litter decomposition. Also the high litter accumulation in the forest soil inhibits ginger growth, (Healey and Gara, 2003). Foliage production is reduced as a result of scanty tillers and subsequently lowers photosynthetic activity. In financial terms, it may not be viable to incorporate ginger into mature teak plantation as a form of multiple land use.

Effects of Teak canopy and NPK fertilizer on ginger height

Ginger height was inhibited by teak canopy of matured teak plantation in the experimental layout; average ginger heights were higher in plots outside teak canopy (33.0cm per stand) than in plots under teak canopy (28.4cm per stand) without inorganic fertilizer (Fig. 2). Limited light intensity available under the plantation amongst other factors may have retarded ginger heights; forest undergrowth in closed canopies competes for light intensity available for photosynthesis, nutrients availability and allelopathy from teak plant, hence slow growth rate (Thomas *et al.*, 1999). However, NPK fertilizer slightly enhanced the height of ginger as shown in Figure 2, ginger treated with NPK under teak gained higher average heights (29.9cm per stand) than those without NPK (28.4cm per stand). Similar results were obtained in plots outside teak canopy, ginger treated with NPK have higher heights (34.0cm per stand) than those without NPK (33.0cm per stand). NPK fertilizer has been reported to enhance vegetative growth in plants, (Brian, 2009).

Analysis of variance (ANOVA) showed no significant differences in average ginger height under teak plantation (A&C - 0.647, $\rho \leq 0.05$, Table 2), this indicates that NPK fertilizer does not enhance height in ginger significantly in teak plantation. The ANOVA confirmed that closed teak canopy significantly inhibits height in ginger (A&B - 0.039, $\rho \leq 0.05$, Table 2) irrespective of NPK fertilizer application. ANOVA also confirmed that application of NPK fertilizer does not lead to appreciable increase in average height of ginger in teak plantation, (0.647, $\rho \leq 0.05$, Table 2). No significant difference observed in the height between plots where NPK was applied and vice – versa in the plantation. However, plots within and outside forest plantations showed significant differences in ginger heights with higher heights in ginger planted outside the plantation, (0.000, 0.039, 0.000, 0.011, $\rho \leq 0.05$).

Effect of Teak canopy and NPK fertilizer on foliar production in ginger

The impacts of teak canopy on ginger led to reduction in average number of leaves produced per stand of ginger. Foliar production in ginger was higher in all the experimental plots outside the teak plantation than those grown within teak plantation. In Figure 3, average leaves/stand of ginger especially was higher (11.15 and 10.85 per stand) outside the canopy than (7.9 and 7.65 per stand) respectively in the NPK treated and zero inorganic fertilizer plots. NPK enhanced foliage production in ginger outside forest canopy with average of 11.15 leaves per stand in NPK plot compared to 10.85 leaves per stand in plots without NPK,. Similarly, leaf production was higher in plots treated with NPK (7.9 per stand) under forest canopy than plots without NPK application (7.65 per stand). In the plots under teak canopy, NPK fertilizer enhanced foliar production in ginger, Sadanandan *et al.,* (2001) noted that potassium (K), one of the principal elements of NPK is necessary in young growing tissues for cell elongation and possibly for cell division.

Significant differences in the Analysis of variance (ANOVA) also showed that teak canopy inhibits leaf formation in ginger compared to open field, (0.000 and 0.007, $\rho \leq 0.05$, Table 3). Inorganic fertilizer also showed significant difference in ginger foliage production, (0.000, $\rho \leq 0.05$). Ginger grown outside forest estate produced higher number of leaves than ginger located under forest cover, while ginger stands within the fertilizer plots possess higher number of leaves than ginger planted without fertilizer application. Similar result was obtained in Kenya where closed canopy of *Paulownia fortunei* was reported to inhibit leaf production in maize, (Muthuri *et al.,* 2005), NPK fertilizer improve folial yield in ginger planted in open field, (Lujiu Li *et al*., 2010). It also enhances vegetative production in plants generally due to the positive influence of phosphorus element in leaf stomata opening that increases photosynthetic rate in plants.

CONCLUSION

The study revealed that optimum ginger growth was hindered by teak canopy, hence its' used as non - timber component of a multiple forest management in teak plantations require further research in the area of required solar insolation and the optimum age of teak that will tolerate ginger as undergrowth. Combination of indigenous tree species and ginger is also recommended for trials in agroforestry schemes. Ginger rhizome production could generate employment opportunities for local communities adjoining forest plantations and its proceeds can be used in the plantation maintenance thereby reducing plantation cost. Also, private tree growers in plantation forestry can explore the economic potentials of compatible forest undergrowth prior to canopy closure.

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