

Assessing the Impact of NPK Application Rates at different Growth Stages on morphology and Biomass Yield of *Tephrosia vogelii* Hook. f. (Fabaceae)

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Research Article

Keywords: fertilizer, yield, agroforestry, pesticidal, legumes

Posted Date: January 13th, 2025

DOI: <https://doi.org/10.21203/rs.3.rs-5795666/v1>

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Additional Declarations: No competing interests reported.

Abstract

A two-year field study investigated the effects of varying rates of fertilizer NPK 20.10.10 and timing of application on the vegetative growth and biomass yield of *T. vogelii* (Fish bean) at the study area in 2019 and 2020 cropping seasons. Treatments consisted of three rates of N.P.K 20.10.10. (0, 100 and 200 kg/ha) and two fertilizer application periods (pre-anthesis and at pod commencement), giving a combination of $3 \times 2 \times 3 = 18$ treatments. Randomized Complete Block Design (RCBD) with three replications was used to disperse all treatments in the field. Results showed that *T. vogelii* plants that were fertilized pre-anthesis with 200 kg/ha N.P.K. 20.10.10 in both years had higher growth and yield performance, outstripping plants that received 0 and 100 kg/ha NPK. Interactively, 200 kg/ha of NPK fertilizer at early pre-anthesis gave the best performance of the plant during the study. The study demonstrates that *T. vogelii* is suitable propagated in the study area and inorganic fertilizer at 200 kg/ha NPK is optimum for basal fertilization.

1 Introduction

Tephrosia vogelii Hook. f. (Fabaceae) commonly called fish bean is a leguminous plant native to tropical Africa, having applications ranging from green manure and agroforestry practices, to pesticidal and medicinal uses (Hossain et al. 2021). It is used in tropical Africa for numerous ethno-medical and traditional practices. The leaf is ichthyotoxic and has been used in the management of insect pests. It has also been used by women as abortifacient and to induce menses. The leaf macerate is purgative and emetic, while the sap is used to treat diarrhoea. The leaf-sap and root scrapings are used as ear and tooth ache remedies, respectively. The plant extracts have also been used in the treatment of tuberculosis, typhoid fever and localized fungal infections. The biological activities are due mainly to rotenoids isolated from the plant (Dzenda et al. 2004).

It is a small leguminous tree which can be used as mulch in improving soil fertility, owing to its nitrogen fixing ability. In addition to green manure, it is also used as wind breakers and temporary shade crop in cocoa, coffee, tea, rubber, coconut and cinchona plantations (Jama et al. 2000). Because of its dense growth, it is suitable as a hedge plant and for firewood. Its extracts can be medicine for skin diseases and internal worms. *Tephrosia vogelii* is not grazed by livestock, hence maybe useful in solving the perennial clashes between herders and farmers in Nigeria and sub-Saharan Africa. Rotenone and deguelin are the most toxic rotenoids in fish bean. Rotenone is classified by the World Health Organization (WHO) as a moderately hazardous or Class II pesticide, which can be used for the control of pests in the field, in storage or domestic animals (Koigi 2011). Because of its high rotenone content, large size, rapid growth and adaptation to a wide range of growing conditions, *T. vogelii* was selected in the United States of America for study and development as a new, non-food crop species, prior to the emergence of synthetic pyrethroids (USDA 2015). A study in East Africa, found that farmers ranked *T. vogelii* as the most efficacious and preferred pesticidal plant species (Mkindi et al. 2017). In spite of its economic importance, especially in sustainable agriculture and pest management, the agronomy of *T. vogelii*, is scarcely reported in literature (Gibson et al. 2020). Crucial for optimizing leguminous plant productivity is fertility management, as nitrogen, phosphorus, and potassium are vital for growth, development, and yield (Alvarado et al. 2022). In efforts aimed at improving the agronomic management of *T. vogelii* for its inclusion in sustainable farming systems, this study therefore evaluated the effects of inorganic fertilizer on growth and biomass yield of *T. vogelii* in a rain forest agro-ecological area in Nigeria,.

2 Materials and methods

Location of the study

The study was conducted under rain-fed conditions at Akpabuyo, Cross River State, Southeast Nigeria ($8^{\circ} 27' \text{ E}$; $4^{\circ} 28' \text{ N}$), in 2019 and 2020 planting seasons. Seeds of *T. vogelii* (Provenance Ife) were inoculated with *Bradyrhizobium japonicum* and used for nursery according to agro-forestry procedures outlined by Singh (1994).

Experimental design

The experiment was a 2×3 factorial laid out in RCBD having three replications. Fertilizer N.P.K. 20:10:10 was applied at 0, 100 and 200 kg/ha, at two stages of plant phenology (seedling stage and immature pod stage). Specifically, the following treatment combinations were evaluated: Zero fertilizer application at seedling stage; 100 kg/ha NPK 20:10:10 applied at seedling stage; 200

kg/ha NPK 20:10:10 applied at seedling stage, zero fertilizer application at immature pod or any other stage; 100 kg/ha NPK 20:10:10 applied at immature pod stage and 200 kg/ha NPK 20:10:10 applied at immature pod stage.

Data collection and analyses

Weather data for the area during the period of study was obtained from the Nigerian Meteorological Service (NIMET), Calabar, while the physico-chemical properties of soil at the study site were determined following the procedures of Pansu & Gautheyrou, (2003). Analysis of data was done using GenStat 10.3 DE edition (2011), and post-hoc test was done using Duncan's New Multiple Range Test (DNMRT) at 5% probability level.

3 Results

Soil properties of the study site

The soil tests (Table 1), showed acid loamy sand with low total nitrogen, available phosphorus and exchangeable bases. Moderate organic carbon as well as effective cation exchange capacity was recorded, while the base saturation was adjudged to be high (95.21 and 93.66) in both years.

Weather report at study site is presented in Table 2. In 2019, the study area received a well-distributed, bi-modal total rainfall of 3182.2mm, with peaks occurring in July (576.8mm) and August (660.4mm), while the mean minimum and maximum ambient temperature were 22.0 and 34.8°C, respectively. The relative humidity, daily number of sunshine hours, and mean wind speed were 69-91%, 1.8-6.4, and 24.05-37.33 seconds, respectively in Table 6. The following year, the area also received a slightly less, but equally well-distributed rainfall of 2530.1mm, the highest falling in October (421.6mm) and July (597.4mm). A maximum and minimum air temperature of 34.5°C and 22.2°C was experienced in the months of January and February respectively, while the relative humidity was between 72 and 91%. The daily number of sunshine hours ranged from 2.2 - 5.2, with a wind speed of 19.26 - 31.41m⁻². Averaged over both years, total amount of rainfall received in the months of April, May and June was 388.5, 462.9 and 669.9mm, respectively, while the corresponding maximum daily temperature was 32.2, 31.5 and 30.5°C. Similarly, relative humidity was 85.0, 84.0 and 89.0% for April, May and June, respectively with a daily sunshine of 4.5, 4.6 and 4.3 hours per day.

Height of fish bean in two cropping seasons

The effect of applying different rates of NPK 20:10:10 fertilizer at two phenology stages and their interactions on height of *T. vogelii* plants is presented in Table 3. At all periods of sampling in both years, plants to which fertilizer was applied grew significantly taller than others. Although those that received 200 kg/ha NPK were taller, the difference in plant height was statistically similar to those that received 100 kg/ha (Table 1). Similar to the effect of fertilizer rates, the stage of plant growth at which fertilization occurred also affected plant height significantly at 9 and 11 weeks only, with seedling stage fertilizer application resulting in significantly taller plants ($P<0.05$) compared to application at the immature pod stage. The interaction effect on plant height was significant at all sampling periods except 7 WAP. The tallest plants were produced in the plots to which 200 kg/ha NPK 20:10:10 fertilizer was applied at the seedling stage, while the shortest plants were obtained in the control plots. The other treatment combinations were at the borderline between the tallest and the shortest. This pattern was similar for both years.

Effect on number of branches per plant

Except at 7 WAP only, effect of N.P.K. was significant on branching. However, at subsequent periods of sampling, all fertilized plants produced significantly higher branching than unfertilized ones, with 200 kg/ha treated plants bearing significantly more branches than those receiving 100 kg/ha 20:10:10 at 9 and 11 WAP (Table 4). Seedling stage fertilization consistently performed better ($P<0.05$) than immature pod stage, and in general, significantly more branches were borne by those plants that were fertilized at the seedling growth stage. In the 2020 cropping season, there was no statistical difference between unfertilized plants and those that received 100 kg/ha 20:10:10 fertilizer at 7 WAP. However, at 11 WAP, all fertilized plants had significantly more branches than unfertilized plants (Table 4). Similar to the results of 2019, significantly more branching was recorded for plants fertilized at the seedling than at the pod growth stage.

Effect on number of leaves per plant

The effects of fertilizer rate and time of application, and their interactions on number of leaves of *Fish bean* at 7 – 11 WAP in 2019 and 2020 are presented in Table 5. The effect of fertilizer rates on the number of leaves of *Fish bean* was significant at all sampling periods except 7 WAP. The number of leaves increased significantly ($P \leq 0.05$) as fertilizer rates increased from 0 to 200 kg/ha. When 200 kg/ha N.P.K. 20:10:10 fertilizer was received, it resulted in significantly ($P \leq 0.05$) higher number of leaves than the control and plants that received 100 kg/ha N.P.K. The control consistently produced the lower number of leaves than when fertilizer was received. The effect of time of fertilizer application was significant on number of leaves produced per plant at all sampling periods, except at 7 WAP. Fish bean that received NPK 20:10:10 fertilizer during seedling stage produced more leaves at 9 to 11 WAP, ($P \leq 0.05$) than those that received fertilizer at pod stage. The effect of the interaction of fertilizer and time of application on number of leaves was significant at all sampling periods except 7 WAP. The significantly higher ($P \leq 0.05$) number of leaves was recorded in fish bean that received 200 kg/ha NPK fertilizer at seedling stage while the lowest number of branches was recorded on fish bean plants in the control plots regardless of time of fertilizer application. Other treatment combinations were intermediate between the highest and the lowest (Table 5).

Total whole plant biomass

The effects of fertilizer rate and time of application, and their interaction on total plant biomass of Fish bean at 10 and 13 WAP are presented in Table 6. The effect of fertilizer rates on total plant biomass of Fish bean was significant at 10 and 13 WAP in both years. Plants that received 200 kg/ha NPK fertilizer produced more biomass ($P \leq 0.05$), than the control and 100 kg/ha NPK fertilized plants at 10 and 13 WAP respectively. Whole plant biomass increased significantly ($P \leq 0.05$) as fertilizer rates increased from 0 – 200 kg/ha. The time of fertilizer application significantly influenced total plant biomass. Plants that received NPK 20:10:10 fertilizer at seedling stage were superior ($P \leq 0.05$) in whole plant biomass yields relative to those that received fertilizer treatment at pod stage. The effect of the interaction of fertilizer and time of application on whole plant biomass of Fish bean was significant at 10 and 13 WAP. Significantly higher ($P \leq 0.05$) total plant biomass values were obtained when plants received 200 kg/ha NPK 20:10:10 fertilizer at seedling stage while the lowest whole plant biomass was obtained from Fish bean plants in the control plots. The other treatment combinations were at the intermediate between the highest and the lowest levels indicated.

4 Discussion

The analysis of variance indicated that all assessed parameters varied significantly except number of branches and number of leaves at 7WAP for both years. This indicated that the application of fertilizer on oat had a substantial effect on the studied parameters. The superior performance of Fish bean that received NPK 20:10:10 fertilizer relative to those without fertilizer application suggests that the compound fertilizer had provided nutrients to the plant, enhancing the general wellness of the plant, resulting in a higher vegetative growth and superior biomass yield. The macro elements N, P and K are essential for the growth, development and seed yield of tree legumes (Bashir et al. 2020; Okweche et al. 2024). Nitrogen is needed for protein production, leaf growth, and support of metabolic processes such as photosynthesis (Ali and Wulan, 2018). Phosphorus on the other hand, plays a role in stimulating root growth and the formation of a efficient rooting system in young plants, as a constituent material for nuclei (nucleic acids), fats, and proteins (Djumaeva et al. 2010). Potassium plays a role in the formation of proteins and carbohydrates, increasing plant resistance to pests and diseases, and improving the quality of crop yields (Glover et al. 2012). Soil is the media for plant nutrients, hence adding nitrogen containing fertilizers to the soil can increase immediate nutrient availability for plants (Subhan et al. 2009, Okweche et al. 2024). Low biomass yield from poorly fertilized plots obviously resulted from low fertility. According to Fungameza (1991) and Drechsel et al. (1996), the amount of biomass produced by *T. vogelii* is influenced by the fertility status of the soil. Enhanced vegetative performance. Fish bean from fertilizer at seedling stage relative to flowering stage is evidence that the time of applying fertilizer had significant impact on the growth and yield, regardless of fertilizer rates applied. This supports the hypothesis that early nutrient uptake plays a significant role in the early establishment of plants (Bhat et al. 2022). The poor performance of Fish bean in the plots treated with fertilizer after flowering suggests that late application of fertilizer was not beneficial to plant growth and biomass yield. The superiority of Fish bean plants treated with 200 kg/ha NPK 20:10:10 fertilizer rate at seedling stage relative to those treated with 100kg/ha NPK 20:10:10 at flowering indicates that timing of fertilizer application is very important in Fish bean production. This is particularly important in agroforestry systems, where early-stage growth contributes to faster canopy cover and better soil protection. Alvarado et al. (2022) emphasized the importance of early fertilization for optimizing growth and yield in leguminous crops. Early nutrient availability allows plants to allocate more resources to growth, leading to improved overall biomass production. Even when the fertilizer rate is increased, improper timing will

make it far less beneficial for plants. Similarly, Ndor and Faringoro (2020), while working on the effect of time of application of NPK fertilizer on the performance of cowpea observed that plots that received NPK fertilizer earlier at 2 WAP were superior in both vegetative and yield performance relative to when NPK fertilizer was applied prior to flowering. The better vegetative and yield performance of Fish bean in the plots treated with 100 kg/ha NPK fertilizer at seedling stage relative to application at flowering, shows that the application of NPK fertilizer at the right time and dose had positive influence on growth and biomass yield of Fish bean. This corroborates the report of Amujoyegbe and Alofe (2003), that the application of NPK fertilizer at appropriate time and right quantities will increase the availability of soil nitrogen. Generally, application of NPK fertilizer increased yield and yield components of beans, this is in agreement with other results obtained by Arf et al. (2011) and Nascente et al. (2012) from other crops. This availability of nitrogen will in turn aid processes such as protein formation. Having the ability to produce adequate protein which is used in the process of cell division and differentiation will result in, rapid growth of tissue and organs.

Conclusion

Application of higher NPK 20:10:10 at the rate of 200kg /ha fertilizer at seedling stage gave higher growth and Biomass yield of fish bean than lower fertilizer rate of 100kg/ha at flowering stage. The rate of 200kg/ha of NPK 20.10.10 is recommended at the seedling stage to boost performance of *T. vogelii*.

Declarations

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contribution

Emmanuel Bassey EffaEBA, BOB: Conceptualization, experimental work, and interpretation of the analyzed data, SIO, WBB: Data analysis, writing and reviewing the manuscript.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Tables

Table 1: Physico-chemical properties of soil in the study site

	2019	2020
Physical properties		
Sand (%)	75.70	79.30
Silt (%)	15.20	10.00
Clay (%)	9.10	10.70
Texture	Loamy sand	Loamy sand
Chemical Properties		
pH (H ₂ O)	5.47	5.55
Total Nitrogen (%)	0.07	0.11
Available phosphorus (mg/kg)	47.57	64.25
Organic Carbon (%)	1.87	1.81
Exchangeable potassium (cmol/kg)	0.08	0.08
Exchangeable Calcium (cmol/kg)	6.86	7.40
Exchangeable Magnesium (cmol/kg)	1.95	1.93
Exchangeable Sodium (cmol/kg)	0.07	0.06
Exchange acidity (H ⁺)	0.45	0.64
Effective Cation Exchange Capacity (ECEC)	9.41	10.11
Base saturation (%)	95.21	93.66

Table 2: Weather data at Calabar area in 2019 and 2020

Month	Max temp		Min temp		Rel. humidity		Solar hrs.		Wind speed		Rainfall total		Rainy days	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Jan	34.8	34.5	22.0	22.5	69	74	6.4	5.2	34.06	22.81	38.2	0.3	2	1
Feb	34.1	34.0	22.8	22.2	78	72	6.1	5.0	27.08	26.44	76.8	4.0	3	1
March	33.5	33.0	22.5	23.0	83	78	5.2	4.8	32.59	31.38	182.6	141.3	7	8
April	32.3	32.0	23.0	24.4	85	86	4.6	4.4	28.51	28.21	191.8	196.7	13	16
May	31.6	31.5	23.5	25.0	84	84	4.8	4.3	24.05	24.12	220.6	242.3	15	16
June	30.8	30.2	23.8	24.8	89	87	4.8	3.8	26.67	25.00	378.6	291.3	22	24
July	30.2	28.1	24.0	24.5	91	90	1.8	2.1	24.81	22.97	576.8	363.0	25	26
Aug	29.0	28.5	24.5	24.0	92	82	1.8	4.5	25.59	26.67	660.4	112.6	28	13
Sept	29.8	28.1	24.2	24.6	90	91	2.3	2.2	32.05	21.33	462.8	597.4	24	30
Oct	30.5	28.5	23.8	24.2	88	89	3.0	2.8	36.22	19.26	210.4	421.6	18	24
Nov	32.0	30.0	23.0	23.8	85	82	4.1	3.8	34.74	22.93	176.8	158.2	18	1.4
Dec	33.0	32.5	22.5	23.0	78	75	5.2	4.9	37.33	31.41	6.4	1.4	1	1

Source: Nigeria Meteorological Service (NIMET), Calabar

Table 3: Height of fish bean in two cropping seasons after NPK fertilization at two growth stages

Treatment	2019			2020		
	7WAP	9WAP	11WAP	7WAP	9WAP	11WAP
Fertilizer rate (kg/ha)						
200	40.43 ^{ab}	49.20 ^{ab}	63.80 ^b	38.20 ^a	49.80 ^{ab}	64.62 ^b
100	43.65 ^a	53.70 ^a	71.20 ^a	38.10 ^a	55.50 ^a	73.37 ^a
0	38.77 ^b	45.50 ^b	54.90 ^c	37.50 ^a	46.90 ^b	53.62 ^c
TOA						
Seedling	40.42 ^a	54.20 ^a	70.30 ^a	37.40 ^a	55.40 ^a	71.17 ^a
Pod	41.48 ^a	44.70 ^b	56.30 ^b	38.50 ^a	46.10 ^b	56.57 ^b
Interaction						
100kg x seedling	38.7 ^a	55.50 ^{ab}	71.30 ^a	37.90 ^a	53.00 ^b	72.13 ^b
100kg x pod	42.13 ^a	42.80 ^c	56.30 ^b	38.50 ^a	46.60 ^b	57.10 ^c
200kg x seedling	43.77 ^a	59.40 ^a	82.10 ^a	38.10 ^a	64.10 ^a	89.33 ^a
200kg x pod	43.53 ^a	48.00 ^{bc}	60.20 ^b	38.10 ^a	47.00 ^b	57.40 ^c
0kg x seedling	38.77 ^a	47.70 ^{bc}	57.30 ^b	36.20 ^a	49.20 ^b	53.03 ^c
0kg x pod	38.77 ^a	43.30 ^c	52.40 ^b	38.90 ^a	44.60 ^b	55.20 ^c

In a column, means followed by the same letter are not significantly different by DNMRT at 5 % probability level. TOA = stage of application.

Table 4 Branching of fish bean in two cropping seasons affected by NPK fertilization at two growth stages

Treatment	2019			2020		
	7WAP	9WAP	11WAP	7WAP	9WAP	11WAP
Fertilizer rate (kg/ha)						
100	1.60 ^a	4.07 ^b	5.62 ^b	1.80 ^b	4.40 ^a	7.05 ^b
200	2.08 ^a	4.85 ^a	6.92 ^a	2.45 ^a	5.32 ^a	8.75 ^a
0	2.33 ^a	3.25 ^c	4.20 ^c	1.63 ^b	3.03 ^b	4.85 ^c
TOA						
Seedling	2.09 ^a	4.91 ^a	6.91 ^a	1.92 ^a	5.23 ^a	8.29 ^a
Pod	1.92 ^a	3.20 ^b	4.24 ^b	2.00 ^a	3.27 ^b	5.48 ^b
Interaction						
100kg x seedling	1.40 ^a	4.77 ^b	7.23 ^b	1.23 ^b	5.47 ^b	8.33 ^b
100kg x pod	1.80 ^a	3.37 ^c	4.00 ^c	2.03 ^{ab}	3.33 ^c	5.77 ^c
200kg x seedling	1.90 ^a	6.43 ^a	9.07 ^a	2.63 ^a	7.27 ^a	11.57 ^a
200kg x pod	2.27 ^a	3.27 ^c	4.77 ^c	2.27 ^{ab}	3.37 ^c	5.93 ^c
0kg x seedling	2.97 ^a	3.53 ^c	4.43 ^c	1.90 ^{ab}	2.97 ^c	4.97 ^c
0kg x pod	1.70 ^a	2.97 ^c	3.97 ^c	1.70 ^{ab}	3.10 ^c	4.73 ^c

In a column, means followed by the same letter are not significantly different by DNMRT at 5 % probability level. TOA = stage of application.

Table 5: Number of leaves of fish bean in two cropping seasons affected by NPK fertilization at two growth stages

Treatment	2019			2020		
	7WAP	9WAP	11WAP	7WAP	9WAP	11WAP
Fertilizer rate (kg/ha)						
100	6.18 ^a	8.53 ^b	10.17 ^b	1.80 ^b	4.40 ^a	7.05 ^b
200	6.75 ^a	9.47 ^a	11.30 ^a	2.45 ^a	5.32 ^a	8.75 ^a
0	6.12 ^a	7.77 ^c	8.38 ^c	1.63 ^b	3.03 ^b	4.85 ^c
TOA						
Seedling	6.32 ^a	9.31 ^a	10.99 ^a	1.92 ^a	5.23 ^a	8.29 ^a
Pod	6.38 ^a	7.87 ^b	8.91 ^b	2.00 ^a	3.27 ^b	5.48 ^b
Interaction						
100kg x seedling	5.77 ^a	9.30 ^b	11.57 ^a	1.23 ^b	5.47 ^b	8.33 ^b
100kg x pod	6.60 ^a	7.77 ^b	8.77 ^b	2.03 ^{ab}	3.33 ^c	5.77 ^c
200kg x seedling	6.97 ^a	10.93 ^a	13.17 ^a	2.63 ^a	7.27 ^a	11.57 ^a
200kg x pod	6.53 ^a	8.00 ^b	9.43 ^b	2.27 ^{ab}	3.37 ^c	5.93 ^c
0kg x seedling	6.23 ^a	7.70 ^b	8.23 ^b	1.90 ^{ab}	2.97 ^c	4.97 ^c
0kg x pod	6.00 ^a	7.83 ^b	8.53 ^b	1.70 ^{ab}	3.10 ^c	4.73 ^c

In a column, means followed by the same letter are not significantly different by DNMRT at 5 % probability level. TOA = stage of application.

Table 6: Effect of NPK fertilizer rate and growth stage at application on biomass in two cropping seasons

Treatment	Biomass (t/ha)			
	10WAP	13WAP	10WAP	13WAP
Fertilizer				
100	14.98 ^b	78.40 ^b	17.85 ^b	78.30 ^b
200	20.06 ^a	106.10 ^a	23.77 ^a	96.30 ^a
0	10.23 ^c	57.00 ^c	11.97 ^c	59.40 ^c
TOA				
Seedling	18.50 ^a	99.70 ^a	22.03 ^a	91.30 ^a
Pod	11.67 ^b	61.30 ^b	13.70 ^b	64.70 ^b
Interaction				
100kg x seedling	19.47 ^b	99.40 ^b	22.99 ^b	93.50 ^b
100kg x pod	10.48 ^c	57.50 ^c	12.72 ^c	63.10 ^c
200kg x seedling	25.74 ^a	142.60 ^a	31.46 ^a	119.00 ^a
200kg x pod	14.38 ^{bc}	69.50 ^c	16.07 ^c	73.60 ^c
0kg x seedling	10.30 ^c	57.10 ^c	11.64 ^c	61.40 ^c
0kg x pod	10.16 ^c	57.00 ^c	12.31 ^c	57.40 ^c

In a column, means followed by the same letter are not significantly different by DNMRT at 5 % probability level. TOA = time of application.

Figures

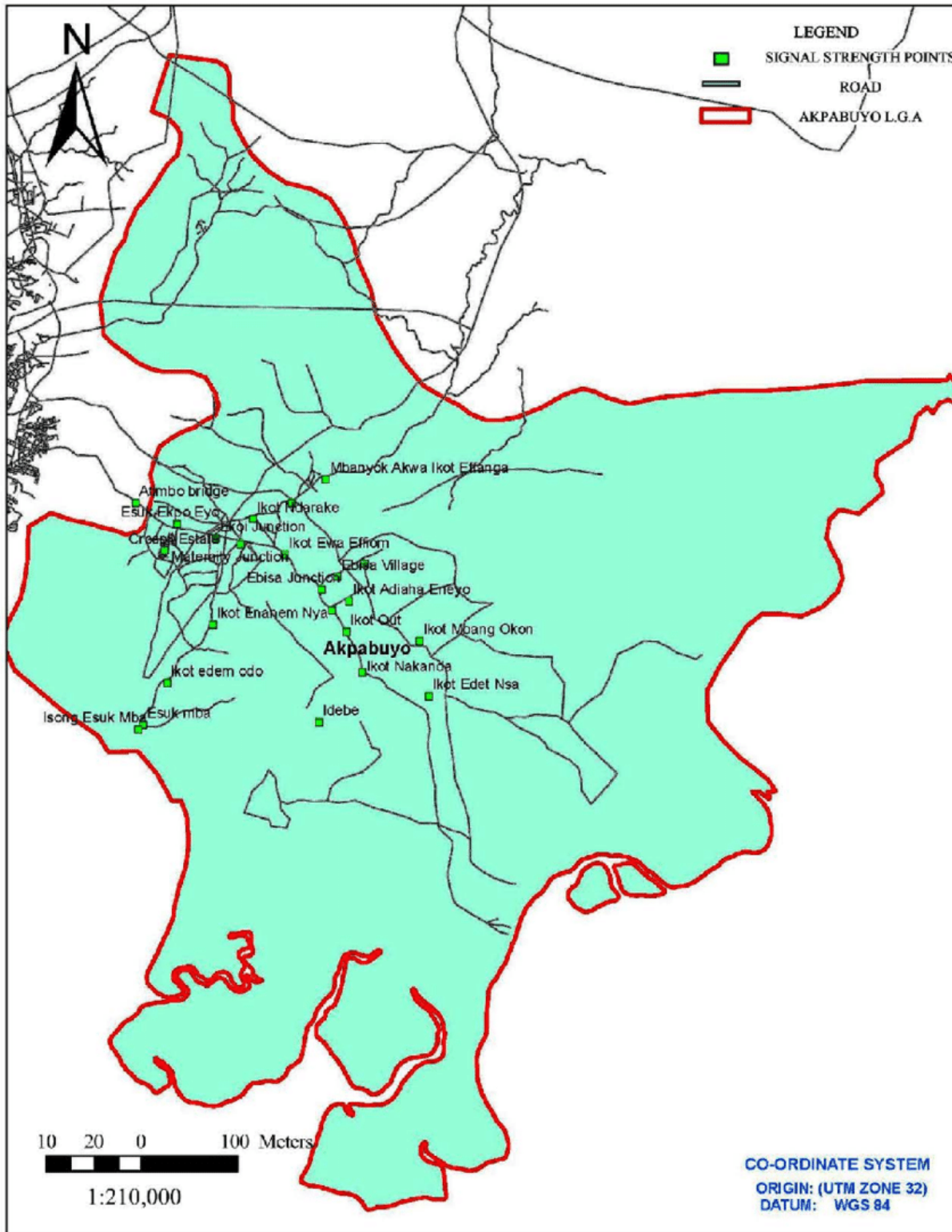


Figure 1

Map of Akpabuyo where the research was done