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Eco-morphological diversity of neem (*Azadirachta indica* A. Juss) in northern Nigeria

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Abstract

Azadirachta indica is reported to be a species that appears in different forms both in the cultivated and wild habitats. The plant species tend to record varying forms in various agroclimatic zones, in its young state and also when fully matured and in the pattern of its growth, in the products it produces as well as its genetic make-up. The main objectives of this study therefore were to examine the morphological similarities and differences among the individuals of the selected plant population and determine the ethno-botanical relevance of the trees within and around the immediate localities. In terms of seed morphology, neem seeds Borno and Sokoto States were heavier (50.9 –69.1g/10 seed). However, differences in seed length among samples obtained from all locations were minimal ($p>0.05$). Significant differences in seedling emergence during Screen House study was recorded ($p<0.05$). Similar significant differences in emergence time among the seedlings collected within the various locations. Delay in seedling emergence was more prominent in the Borno and Yobe seedlings. There were statistical differences in the foliar characteristics of the seedlings obtained from the various locations. The highest total number of leaves (31-37 leaves) was obtained in the Nasarawa seedlings, compared to seedlings from Benue State (13–15 leaves per plant). The leaves of the seedlings obtained from Borno State were broadest ($p<0.001$).The study revealed that certain neem trees in specific locations had morphological similarities and differences with some others in distant locations, thus suggestive of highly effective dispersal mechanisms.

Keywords: neem, morphology, diversity, Azadirachta *indica*, similarity.

Introduction

Azadirachta indica (A.Juss, n=14), well known as Neem, belongs to the family Meliaceae. Neem is a versatile multipurpose tree of the tropics and has in fact been described as the tree for solving global problems or even as the "village dispensary"[1]. Neem is a hardy evergreen tree commonly found in South Asia and parts of Africa. Neem is dominant in Myanmar (Burma) and India; butthis can also be located in Bangladesh, Sri Lanka and African countries, as well. In India alone, an estimated 14 million trees exist. Neem is also indigenous to India, Myanmar and Java, and in fact, it is believed that these are the regions where Neem has originated[1,2]. However, the introductions are so old and widely spread at present that current knowledge of the wild distribution of Neem has become uncertain.

Hardy and quickly growing, the plant has a straight trunk, long, spreading branches, and bark that is somewhat thick, rough, and longitudinally fissured. A mature tree can reach a height of 7 to 15 meters [4]. The tree can survive for more than 200 years and begins producing the yellowish ellipsoidal drupes (fruits) in approximately 4 years. In 10 years, it reaches full productivity. Compound imparipinnate leaves with up to 15 leaflets grouped in alternate pairs with terminal leaflets make up the leaves. The leaflets are up to 6 cm long, lanceolate, and narrow. In the leaf axils, there are numerous, fragrant white panicles of flowers. Plantation stands are typically created via seed propagation in nurseries followed by direct planting in the field. When ripe, the one-seed Neem fruit is yellow and measures about one inch in length[4].

The Neem tree (*Azadirachta indica*) is a versatile tropical multipurpose tree with the Indian subcontinent as its origin[5]. It is referred to as the "village pharmacy" and is considered "a tree for global problem solving"[1]. As such, the Neem tree is named because each of its parts is beneficial, be it in one way or the other.The different Neem materials used including bark, seeds, timber leaves, and so on. Neem has various uses and can be used in craft, agriculture, construction, medicine, cosmetics, etc. Neem also uses phytomedicine, which is one of its key uses. Neem is gaining further popularity worldwide as a result of its many applications[6]. The main aim of this study was to find out the morphological dissimilarities and closeness among the various neem trees taken from the chosen plant population.

Materials and Methods

Plant Sample Collection: The research was carried out between February and July of 2019. The studied was designed in such a way that 27 individual Neem tree species spread within the 4 agro-ecological zones of Northern Nigeria (Figure-1). Formal identification of the samples done with assistance from Plant Taxonomy and Herbarium Unit of the Department of Plant Biology and Biotechnology, University of Benin, Benin City. It was ensured that tree species of interest were not sampled within a single location, but a wider coverage such that they represent designated ecological zones of interest. Seeds were collected from each tree as described by FAO [7].

Sample storage: The plant materials collected from each tree were on seeds from mature fruits. The seeds were then given labels based on the geographic locations of trees as provided on Table-1 and kept in the Herbarium for future use. Accession codes were given to seeds collected from specific trees as per specified location (Table-1), for which further study would be conducted in the nursery.

Sowing of Seeds: The seeds were presoaked for 24 hours in chilled water and the endocarp removed so as to increase its germination capacity. planting of seeds into pots made up of fine river sand was done in drills 15 cm apart. Seeds were sown at 2.5 cm deep in nursery bags and partially covered with earth to protect against birds and insects. The bags were sparingly watered to prevent caking.

Screen House Study: Soils used for screen house experiment were those collected from the various locations from which plants were identified.

These soils were mixed together to obtain a composite sample. The soils were then distributed into nursery bags at 10kg sun-dried soil per bag. Seeds of test plant obtained from the various locations were then sown at a 3 seeds per nursery bag and then thinned down to one after seedling establishment.

Statistical analysis: Results were presented in Mean of 3 replicates. Complete randomized experimental design was chosen for the study having assumed homogeneity of the entire experimental plot when soils were pooled before use. A single factor analysis of variances (ANOVA) was used. Statistical analyses were performed using the SPSS® version 23 as well as the PAST® version 2.17c were used according to Hammer O., Harper D.A.T. & Ryan P.D.[8] where necessary.

Results and discussion

There were differences in the seed characteristics of the different locations. The seeds from Borno and Sokoto States were heavier (50.9 – 69.1g/10 seed). However, differences in seed length among samples obtained from all locations were minimal (Table-2). As for the seed length, there was no significant difference collected from different locations. However, Sokoto State had the longest seed length (2.4mm) while the least seed length was found among Kano samples (1.1mm). There was significant difference in the seed weight of the neem seeds. Seeds from Sokoto had the heaviest seeds (69.1) while those from Kano had the lightest (21.0).

There were significant differences in emergence time among the seedlings collected in the various locations (Table-3). Delay in seedling emergence was more prominent in the Borno and Yobe seedlings while seeds collected from Nasarawa recorded least days to seedlings emergence (8.2). Seedlings collected from the North Central region - Abuja, Benue and Nasarawa, were typically shorter than those of locations in the North Eastern parts of Nigeria. It was found in Borno samples for instance where it had 16.0 cm plant height compared to Benue samples (8.6 cm). There was however no significant difference in the stem girth across all samples collected in different regions of the country considered. All stem girth ranged from 1.0-1.7 cm.

Foliar parameters among population five days after transplanting in the nursery are been presented in Table 4.19. There were significant statistical differences in the foliar characteristics of the seedlings obtained from the various locations. The highest total number of leaves (31-37 leaves) was obtained in the Nasarawa seedlings, compared to seedlings from Benue State (13–15 leaves per plant). Similar observations were notice in leaf length where Borno samples had the longest (43.0) while Nasarawa had the shortest leaf length (12.9). The leaves of the seedlings obtained from Borno State were broadest ($p<0.05$), while those from Nasarawa were the narrowest ($p<0.05$).

Discussion: Seedlings collected from the North Central region - Abuja, Benue and Nasarawa, were typically shorter than those of other locations. Amount of rainfall is opined as a contributory factor for this reason because as one moves from the central parts of the country to the Eastern parts, the amount of rainfall increases sharply. This finding however disagrees with work done by Hammer O., Harper D.A.T. and Ryan P.D.[9] who working on neem reported that lower rainfall areas showed slower growth than places of higher rains. Fruit and seed characteristics, e.g., weight, length, width, diameter, yield etc. are found to be highly variable both within and between provenances of neem[9,10]. It is reported that due to the more favorable weather conditions like amount of rainfall, type of soil, relative humidity and atmospheric temperatures found in those areas which is more suitable for the proper growth of neem. Neem tree requires little water and plenty of sunlight[1,11,12] opined that, seedling characters are positively correlated with provenance mean annual rainfall.

Two adaptive features in plants that are influenced by both genetic and environmental variables are seed germination and dormancy. The possibility for a seed lot to germinate under specific circumstances is known as seed germination[13].

In contrast, dormancy is a condition in which viable seeds do not sprout despite being given conditions typically favorable for germination, such as sufficient moisture, suitable temperature regimes, and light. According to Sahmidst L[14,] and Abudureheman B. et al.[15] seed germination and breaking out of seed dormancy depend on temperature and moisture. A plant's life cycle always revolves around dormancy and germination, which serve as crucial survival mechanisms in natural populations[16]. Delay in seedling emergence was more prominent in the Borno and Yobe seedlings. This may be due to increased seed dormancy associated with seeds collected from the North Eastern part of Nigeria compared to the ones from the North Central which agrees with[12] who suggested that neem engages adaptation mechanism to response to water stress when the seedling is at its early growth stage. Neem tree requires little water and plenty of sunlight[1]. Foliar parameters among population at 5 days after transplanting in the nursery have been presented on Table-4. There were statistical differences in the foliar characteristics of the seedlings obtained from the various locations.

The highest total number of leaves (31-37 leaves) was obtained in the Nasarawa seedlings, compared to seedlings from Benue State (13–15 leaves per plant). The leaves of the seedlings obtained from Borno State were broadest ($p<0.001$). Kundu, S.K. & P.M.A. Tigerstedt[12] working on principal component and cluster analysis of the variation in the seedling growth traits of ten (10) neem provenances from Myanmar, Bangladesh, India, Pakistan, and the Sudan under growth chamber conditions revealed three distinct populations, with provenances from the high rainfall regions being separated from those from the low rainfall areas. The ratio of shoots to roots and the quantity of leaves correlated with mean annual rainfall, and gives a clue that neem tends to bring about mechanism for adaptation in response to water shortage at the early growth of the seedlings. This agrees with the current finding as Benue has more amount of annual rainfall compared to Nasarawa state. The amount of sunlight is more in the North Eastern and North Western parts of Nigeria than the North Central parts with more rate of photosynthesis which could be the reason for the broader leave sizes in the region.

Table-1: Sample codes for collection of plant samples during the study.

Code	Plant physical location	State	Agro-ecological zone
YBE-BK-1	Malari Car Park, Yobe, Damaturu	Yobe	Sahel savanna
YBE-BK-2	Cattle Market, Potiskum	Yobe	Sahel savanna
YBE-BK-3	Fed. Univ., Gashua.	Yobe	Sahel savanna
ADA-BK-1	FCE, Yola	Adamawa	Southern Guinea savanna
ADA-BK-2	Palace of Mubi Emirs	Adamawa	Southern Guinea savanna
ADA-BK-3	COE, Ganye	Adamawa	Southern Guinea savanna
BNO-BK-1	Church of the Brethren, Wulari, Maiduguri	Borno	Sahel savanna
BNO-BK-2	AU, Biu	Borno	Sahel savanna
BNO-BK-3	Unimaid	Borno	Sahel savanna
KNO-BK-1	Gidan Buhari Road, T/Wada Kano	Kano	Sudan savanna
KNO-BK-2	BayeroUniversity, Kano state	Kano	Sudan savanna
KNO-BK-3	Dala Orthopedic Hospital, Kano	Kano	Sudan savanna
SKO-BK-1	UDFU, Sokoto	Sokoto	Sudan savanna
SKO-BK-2	Sani Dingyadi Sec. Sch. Farfaru, Sokoto	Sokoto	Sudan savanna
SKO-BK-3	Main Market, Sokoto	Sokoto	Sudan savanna
KDN-BK-1	ABU, Zaria	Kaduna	Northern Guinea savanna
KDN-BK-2	Car park, Sabo, Kaduna	Kaduna	Northern Guinea savanna
KDN-BK-3	Stanbic IBTC	Kaduna	Northern Guinea savanna
NSA-BK-1	OMBI-1, Lafia	Nasarawa	Southern Guinea savanna
NSA-BK-2	Hope academy secondary school, Akwanga	Nasarawa	Southern Guinea savanna
NSA-BK-3	Awe Car Park	Nasarawa	Southern Guinea savanna
ABJ-BK-1	Lungi Barracks, Maitama Abuja.	Abuja	Derived savanna
ABJ-BK-2	Mambilla Barracks, Asokoro Abuja	Abuja	Derived savanna
ABJ-BK-3	State House Medical Centre, Asokoro Abuja	Abuja	Derived savanna
BNE-BK-1	Uni Agric, Makurdi	Benue	Derived savanna

BNE-BK-2	Benue State University, Makurdi	Benue	Derived savanna
BNE-BK-3	Peace House, Gboko	Benue	Derived savanna

Table-2: Seed characteristics among population.

Population	Wt. of 10 seeds (g)		Seed length (mm)	
	Mean (µ)	Δµ	Mean (µ)	Δµ
YB-BK-1	36.0	-3.10	1.5	-0.11
YB-BK-2	39.3	0.20	1.6	-0.01
YB-BK-3	33.9	-5.20	1.4	-0.21
AD-BK-1	38.0	-1.10	1.6	-0.01
AD-BK-2	41.2	2.10	1.7	0.09
AD-BK-3	35.5	-3.60	1.5	-0.11
BN-BK-1	59.0	19.90	1.7	0.09
BN-BK-2	59.2	20.10	1.7	0.09
BN-BK-3	50.9	11.80	1.5	-0.11
NS-BK-1	29.0	-10.10	1.6	-0.01
NS-BK-2	25.0	-14.10	1.4	-0.21
NS-BK-3	22.3	-16.80	1.2	-0.41
AJ-BK-1	30.0	-9.10	1.8	0.19
AJ-BK-2	25.9	-13.20	1.6	-0.01
AJ-BK-3	26.0	-13.10	1.6	-0.01
BeN-BK-1	46.0	6.90	1.7	0.09
BeN-BK-2	39.7	0.60	1.5	-0.11
BeN-BK-3	39.7	0.60	1.5	-0.11
KD-BK-1	41.0	1.90	1.6	-0.01
KD-BK-2	35.3	-3.80	1.4	-0.21
KD-BK-3	30.5	-8.60	1.2	-0.41
SK-BK-1	68.0	28.90	2.4	0.79
SK-BK-2	68.7	29.60	2	0.79
SK-BK-3	69.1	30.00	2.4	0.79
KN-BK-1	25.3	-13.80	1.5	-0.11
KN-BK-2	21.8	-17.30	1.3	-0.31
KN-BK-3	21.0	-18.10	1.1	-0.51
F-statistic	59.709		15.491	

P-value	<0.001	<0.001

Δμ Deviation from general mean.

Table-3: Emergence time for seedling among population 21 days after transplanting in the nursery.

Population	*Emergence time (d)		Plant length (cm)		Stem girth (mm)	
	Mean (μ)	Δμ	Mean (μ)	Δμ	Mean (μ)	Δμ
YB-BK-1	26	9	12.0	0.13	1.5	0.16
YB-BK-2	28	11	13.1	1.23	1.6	0.26
YB-BK-3	25	8	11.3	-0.57	1.4	0.06
AD-BK-1	12	-5	13.0	1.13	1.6	0.26
AD-BK-2	13	-4	14.1	2.23	1.7	0.36
AD-BK-3	11	-6	12.1	0.23	1.5	0.16
BN-BK-1	28	11	16.0	4.13	1.7	0.36
BN-BK-2	28	11	16.0	4.13	1.7	0.36
BN-BK-3	24	7	13.8	1.93	1.5	0.16
NS-BK-1	13	-4	11.0	-0.87	1.4	0.06
NS-BK-2	11	-6	9.5	-2.37	1.2	-0.14
NS-BK-3	10	-7	8.2	-3.67	1.0	-0.34
AJ-BK-1	16	-1	12.0	0.13	1.4	0.06
AJ-BK-2	14	-3	10.3	-1.57	1.2	-0.14
AJ-BK-3	12	-5	8.9	-2.97	1.0	-0.34
BeN-BK-1	16	-1	10.0	-1.87	1.2	-0.14
BeN-BK-2	14	-3	8.6	-3.27	1.0	-0.34
BeN-BK-3	12	-5	8.6	-3.27	1.0	-0.34
KD-BK-1	17	0	14.0	2.13	1.4	0.06
KD-BK-2	15	-2	12.1	0.23	1.2	-0.14
KD-BK-3	13	-4	10.4	-1.47	1.0	-0.34
SK-BK-1	19	2	14.0	2.13	1.5	0.16
SK-BK-2	16	-1	12.1	0.23	1.5	0.16
SK-BK-3	14	-3	10.4	-1.47	1.5	0.16
KN-BK-1	20	3	15.0	3.13	1.5	0.16
KN-BK-2	17	0	12.9	1.03	1.1	-0.24
KN-BK-3	15	-2	11.1	-0.77	1.0	-0.34
F-statistic	23.076		5.363		5.102	

P-value	<0.001	0.002	0.002

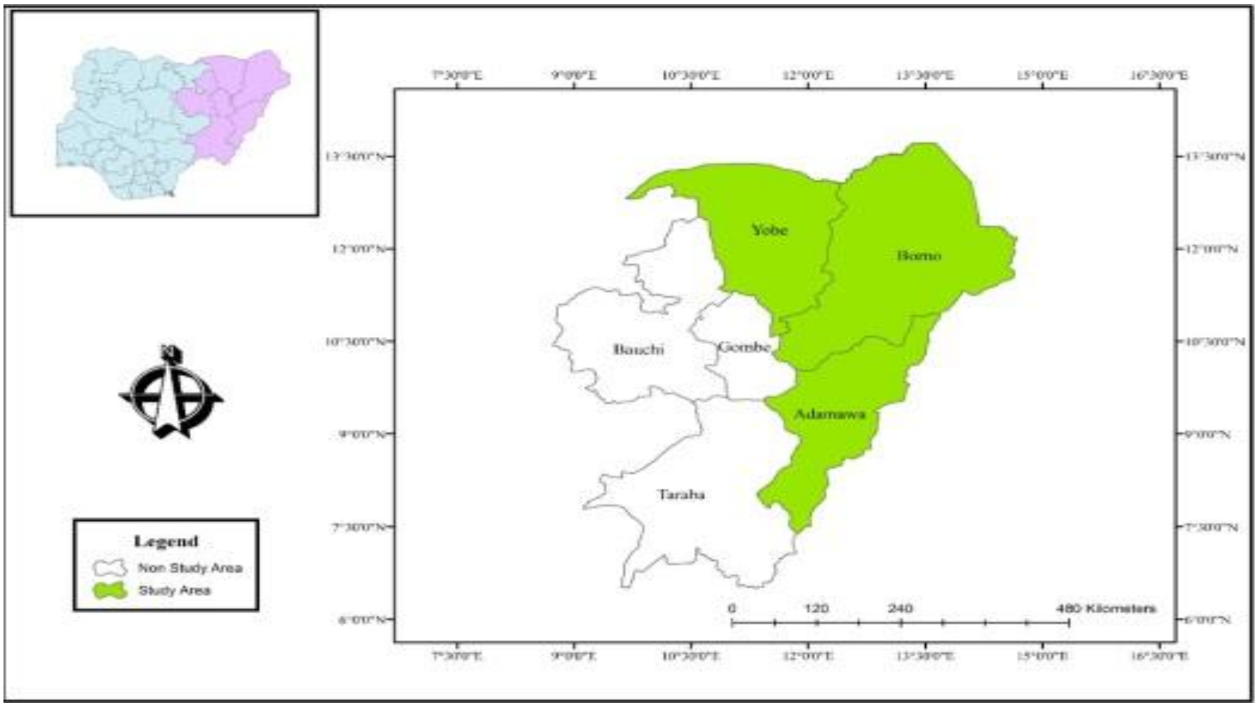
*Rounded off to the nearest whole number; Δμ deviation from the mean.

Table-4: Foliar parameters among population 35 days after transplanting in the nursery.

Population	*Total no of leaves/plant		Leaf length (cm)		Leaflet area(cm^2)	
	Mean (μ)	Δμ	Mean (μ)	Δμ	Mean (μ)	Δμ
YB-BK-1	18	-2	28.0	-0.59	60.5	3.42
YB-BK-2	20	0	30.6	2.01	66.1	9.02
YB-BK-3	17	-3	26.4	-2.19	57.0	-0.08
AD-BK-1	17	-3	30.0	1.41	62.1	5.02
AD-BK-2	18	-2	32.5	3.91	67.3	10.22
AD-BK-3	16	-4	28.0	-0.59	58.0	0.92
BN-BK-1	25	5	43.0	14.41	77.4	20.32
BN-BK-2	25	5	43.1	14.51	77.6	20.52
BN-BK-3	22	2	37.1	8.51	66.7	9.62
NS-BK-1	36	16	16.7	-11.89	50.3	-6.78
NS-BK-2	31	11	14.4	-14.19	43.4	-13.68
NS-BK-3	37	17	12.9	-15.69	38.8	-18.28
AJ-BK-1	17	-3	26.6	-1.99	54.6	-2.48
AJ-BK-2	15	-5	22.9	-5.69	47.1	-9.98
AJ-BK-3	15	-5	23.1	-5.49	47.4	-9.68
BeN-BK-1	15	-5	21.1	-7.49	47.1	-9.98
BeN-BK-2	13	-7	18.2	-10.39	40.6	-16.48
BeN-BK-3	13	-7	18.2	-10.39	40.6	-16.48
KD-BK-1	19	-1	28.5	-0.09	55.4	-1.68
KD-BK-2	16	-4	24.6	-3.99	47.8	-9.28
KD-BK-3	14	-6	21.2	-7.39	41.2	-15.88
SK-BK-1	25	5	40.2	11.61	71.2	14.12
SK-BK-2	25	5	40.6	12.01	71.9	14.82
SK-BK-3	25	5	40.8	12.21	72.3	15.22
KN-BK-1	21	1	38.4	9.81	68.6	11.52
KN-BK-2	18	-2	33.1	4.51	59.1	2.02
KN-BK-3	17	-3	31.8	3.21	51.0	-6.08
F-statistic	20.502		38.021		12.95	

P-value	<0.001	<0.001	<0.001

*Rounded off to the nearest whole number; Δμ deviation from the mean.



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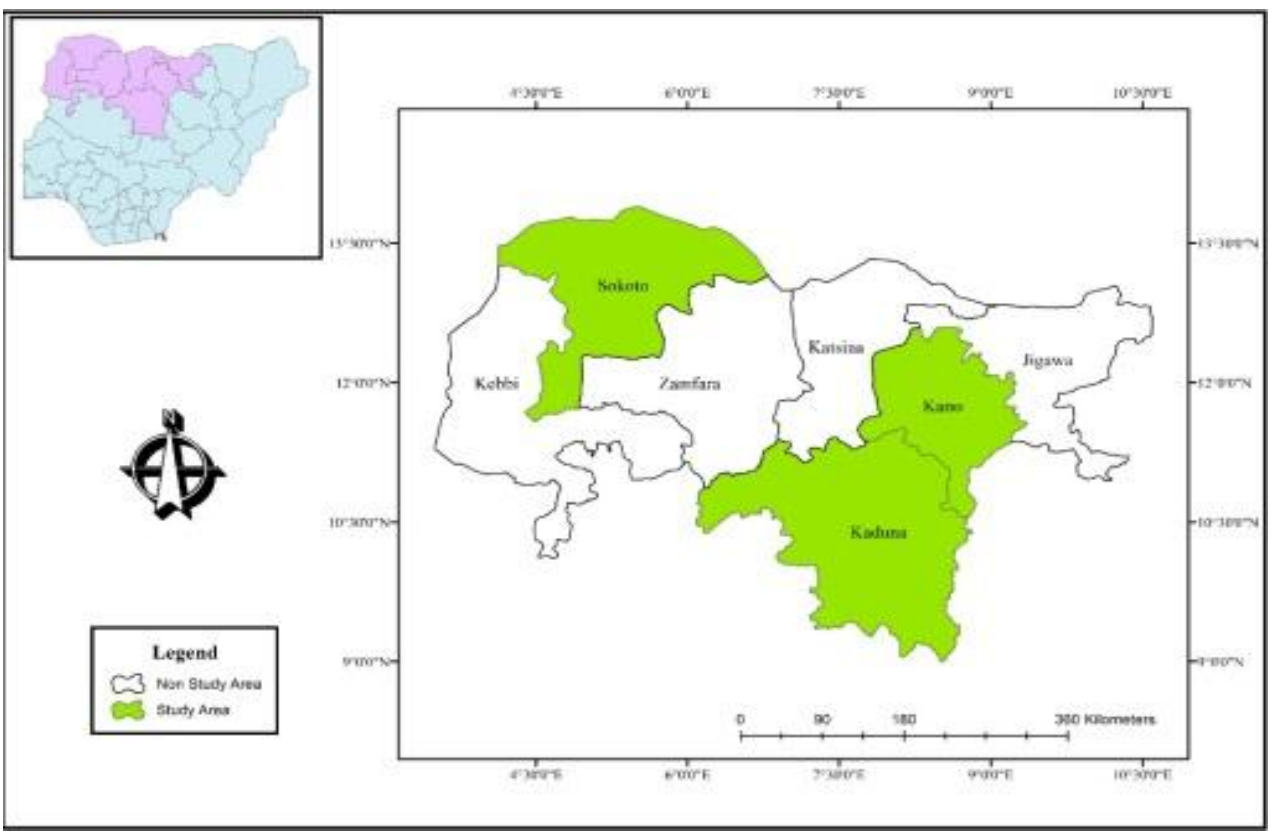

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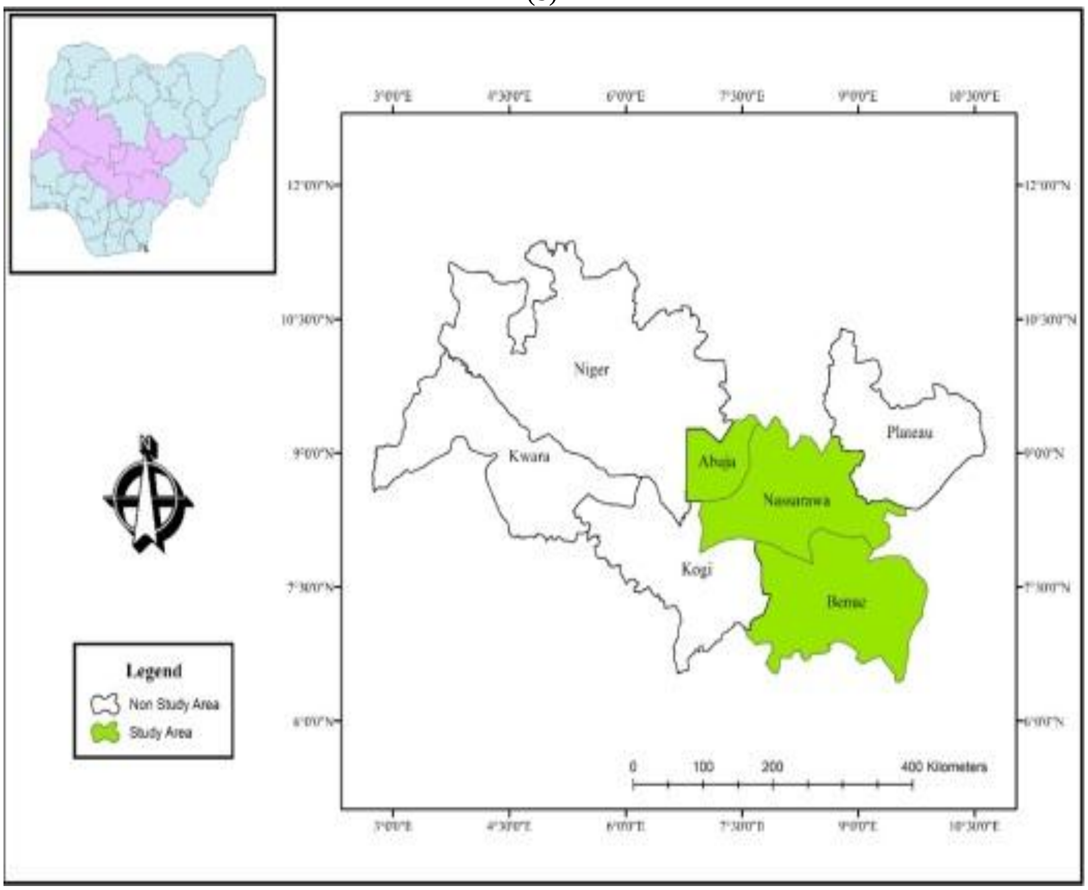

(c)

Figure-1: Map showing study area at the (a) North Eastern, (b) North West and the (c) North Central region of the country. Ethnobotanical information about the plant within the area sited[17].

Conclusion

The study thus showed morphological dissimilarities among the trees investigated. Given the economic importance of this tree, the dissimilarities reported is an important attribute for ecosystem management and germplasm conservation. Despite the morphological variability observed among neem trees in Northern Nigeria, it did not however affect their economic relevance or significance from one region to the other. It is therefore recommended that more parts of Nigeria where neem is found should be studied for more conservation possibilities.

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