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THE ROLE OF SELECTED ENVIRONMENTAL FACTORS ON THE REGENERATION OF (Ocotea usambarensis)IN MOUNT KENYA FOREST, KENYA

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ABSTRACT

Despites the propagation efforts, density of Ocotea usambarensis has continued to diminish in the southern slopes of Mount Kenya. The species which is native in the montane forest is seldom on farm and found as remnant species. The concerns on the role of environmental factors and how they influence regeneration of Ocotea usambarensis have been sidelined resulting to lack of adequate information that would be required for modeling how to reestablish Ocotea usambarensis. This study therefore examined the role of Rainfall, Humidity, Temperature, wind speed and soil characteristics on regeneration of Ocotea usambarensis. The study was conducted in the southern slopes of Mount Kenya forest. Data on environmental factors, regeneration status and species diversity were analyzed using regression, Pearson Correlation, Shannon- Wiener (H□) Index and Simpson (D) Index. The regeneration status was "J" shaped with mature trees more than regenerants. The relationship was strong (R2 = 78%) between humidity and rainfall (P < 0.05) while for temperature and wind speed were insignificant. The correlation between soil compositions varied significantly (P< 0.05). The soil pH positively correlated with soil nutrients while Cation exchanges capacity negatively correlated with potassium and silicon. It was observed that Diospyros abyssinica was growing in close association with O. usambarensis playing the role of nurse species. With the absence of seedlings in most of the sites and the limiting environmental factors, promotion of vegetative propagation and enrichment planting would enhance conservation and restoration of the species in Mt. Kenya forest. The high levels of soil nutrients and Cation exchange capacity in forest soils indicated the need to maintain them high on farm for optimal growth rate. Enhancing optimal environmental conditions for growth would enhance conservation and restoration of the Ocotea usambarensis.

Keywords: Ocotea Usambarensis , Regeneration, Biodiversity, Conservation and Mount Kenya

1. INTRODUCTION

Ocotea usambarensis regeneration and replacement patterns are determined by the natural processes which exist in a forest ecosystem and the environmental heterogeneighty. The seedlings growth in the understorey of tropical forests encounters a highly dynamic environment which varies both spatially and temporarily (Chazdon et al., 1996). Based on the growth requirements, tropical tree species are classified into pioneers and shade - tolerant (Whitmore, 1996). Seedlings of shade tolerant species can survive prolonged periods of shade in forest

ISSN: 2456-8643

understory and show a narrower range of photosynthetic responses when grown under different Environmental conditions than do pioneer species (Riddoch et al., 1991).

Ocotea usambarensis (Camphor) is a tree species with significant economic, environmental, social and cultural importance. The species is found in tropical forests which harbor between 50% and 90% of Earth's terrestrial plant species International Union for Conservation of Nature and United Nations Environmental Programme (IUCN & UNEP, 1992). *Ocotea usambarensis* was once dominant in the wet forests of the Eastern Aberdares and Mt. Kenya up to an altitude of 2,600 meters above sea level, but is now rare due to over-exploitation, low seed viability, browsing, game damage and poor regeneration (Gachathi, 2007). Germination of seeds is sporadic often taking 2-3 months and the trees mature in 60-75 years (Daniel et al., 2006). According to Bussmann (2001), large scale logging of Camphor trees predominantly destroys its regeneration leading to secondary forest types. The over exploitation, exploration and conversion of forest ecosystems to different land use systems normally result in the decimation of biodiversity and extinction of many valuable indigenous plant species and animals (Akotsi & Gachanja, 2004). The indigenous tree species of economic importance including *O. usambarensis* have low density in tropical forests which indicates their elimination due to the increasing demand for fuel wood, timber and medicinal use (Maina, 2013).

*Ocotea usambarensis*is is among the main targeted timber species for selective logging (Kleinschroth, et al., 2013). This is because of its valuable wood for timber (Gathaara, 1999). Its medicinal value and high quality timber has led to its overexploitation endangering this unique tree species. The extraction situation is compounded by the slow growth rate, low seeds viability, browsing by wild animals, game damage and difficult in seedlings propagation (Albrecht, 1993; Poorter et al., 1996). Other common species of large timber trees exploited in Mt. Kenya forest are; *Juniperus procera* (Cedar), *Olea europeae*(Wild Olive), *Hagenia abyssinica* (East African Rosewood), *Croton macrostachyus* (Croton), *Vitex keniensis* (Meru Oak) and *Ficus thonningii*(Strangler fig) (Mugumo (Beentje, 2008). Githae et al. (2015) reported that several native tree species of environmental and socio-economic value are threatened by human activities and therefore should be conserved. There is a wide range of biological diversity not only in terms of ecosystems but also in terms of plant species in Mount Kenya ecosystem. There are values attributed to Mount Kenya forest by all the various groups of people living around the forest. The forest provides an important location for religious and other rituals for the people. Some tree species growing in southern slopes of Mount Kenya like *Ficus thonningii* are considered sacred while others are used for both socio-economic and environmental services. Conservation of *Ocotea usambarensis* preserves its vitality.

Sustainable utilization of *Ocotea usambarensis* would be achieved if adequate information on the regeneration dynamics and the environmental influence was available. Tree planting has often focused on exotic species, however exotic species have failed to replace indigenous timber in places where high quality timber is needed for furniture and interior furnishings (Oballa and Musya, 2010). The communities adjacent to Mount Kenya forests use the forests for timber, fuel

Vol. 3, No. 04; 2018

ISSN: 2456-8643

wood, grazing areas and non-timber forest products like honey harvesting, medicinal extracts and domestic water. Remnant trees are retained in the farm lands of the local people to improve livelihoods (Kewesa et al., 2015). Degradation of *Ocotea usambarensis* native in Mount Kenya forest is mainly due to exploitation for timber and other uses coupled with lack of adequate information on the role of environmental factors on regeneration (Rutten, et al., 2015).

Marura and Lemmens (2008) reported that although *Ocotea usambarensis* provides valuable timber and has been over exploited, very little research has been done on its growth rates, phenological and regeneration responses to environmental cues. Kleinsclhroth, et. al (2013) reported that natural regeneration of *Ocotea usambarensis* in Mount Kenya forest is inadequate for the recovery of the valuable timber species and additional conservation measures should be considered. The farmers have not succeeded in planting the *Ocotea usambarensis* seedlings on their farm due to lack of information on the species environmental factors requirements and management. The specific environmental condition requirements for the regeneration need to be ascertained. This study was designed to establish the role of environmental factors on regeneration of *Ocotea usambarensis* and inform the requirements for its conservation and management.

Area of the Study

The study was carried out in the southern slopes of Mount Kenya forest within Tharaka Nithi County as depicted in Figure 1.

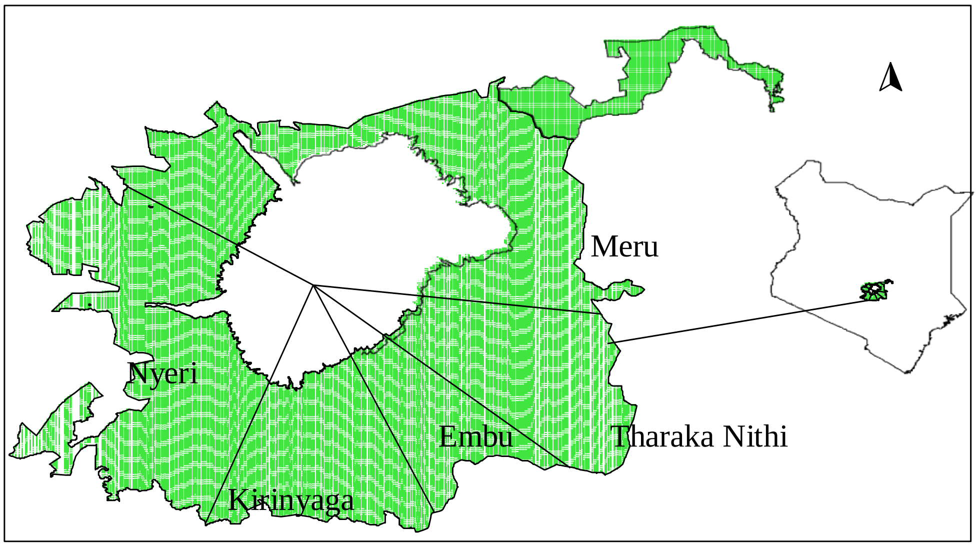


Figure 1: Map of the Study Area

Source: KFS, (2010)

The study was carried out in the southern slopes of Mt. Kenya forest. Mt Kenya Forest is located to the east of the Great Rift Valley, along Latitude 0' 10'S and longitude 37' 20'E. It bestrides the equator in the central highland zones of Kenya. The mountain is situated in two Forest Conservancies and five forest management zones namely Nyeri and Kirinyaga in Central Highlands Conservancy and Meru Central, Meru South and Embu in Eastern Conservancy. The climate of Mt. Kenya region is largely determined by altitude. There are great differences in altitude within short distances, which determine a great variation in climate over relatively small distances. Average temperatures decrease by 0.6 C for each 100m increase in altitude. An afro-alpine type of climate, typical of the tropical East African high mountains, characterizes the higher ranges of Mt. Kenya. The altitudes with the highest rainfall are between 2,700 and 3,100m, while above 4,500m most precipitation falls as snow or hail. Frosts are also common above 2500 m a.s.l. The study was on the altitude range of 1400-2400m a.s.l both for on-farm and forest establishment (figure 1).

Research Design

The study adopted an ecological research survey design and correlation design. The ecological survey desigh was applied on the regeneration assessment which involved description of the ecological state of affairs as they exist. The description of *Ocotea usambarensis* regeneration status was done following the design. The classification of seedlings, saplings and mature trees was aided by the design. Correlation design was applied on soil parameters determination whereby the parameters correlation coefficients were determined.

Selection of the Study Site

The southern site was chosen for the study because *Ocotea usambarensis* is native to the area and supposedly does very well on this side of Mount Kenya forest. Kiang'ondu, Kiamuriuki and Chogoria forest sites were preferred for they are rarely encroached. Ocotea forest type is the largest within the dry montane forest of Mount Kenya forest comprising of 27,000 hectares which is 25% of montane forest type (Beentje, 2008). Three main quadrats measuring 100 m x 100 m within the natural forest with mature *Ocotea usambarensis* species were purposely sampled on the southern slopes of Mount Kenya Forest for the study. The quadrats were identified and marked in Kiang'ondu, Kiamuriuki and Chogoria forest sites which were atleast 5 Km apart. In each of the main quadrat, subquadrats of 20 m x 20 M were marked for tree species biodiversity establishment. The tape measure was used to delineate the quadrats and the subquadrats. The Global positioning system (GPS) was used to georeference the location and marking of the qudtrats. Point centered quarter (PCQ) method was applied in determining species biodiversity.

Data Collection

Environmental factors data that included climatic aspects of rainfall, temperature, relative humidity and wind speed were monitored through the aid of TAHMO automatic weather station which was mounted at the Chuka University Compound while regeneration status were observed and recorded through DBH classes. The New LocClim software was used to monitor the environmental parameters in the forest by use of coordinates. The software is design in such a way that the data was averaged for the nearest 10 weather stations within a radius of 10KM on monthly basis. The software focused on temperature, precipitation, Humidity and wind speed. Other environmental parameters monitored through the software include Potential evapotranspiration and the sunshine. Data on soils was collected from the soil samples that were collected from the quadrants.

Purposeful sampling was applied during the marking of the plots to ensure the target mature tree species were present. Systematic sampling was done to determine the species diversity through the point centered quarter method.

Environmental Factors

Rainfall, temperature, relative humidity, radiation and wind speed were monitored for 12 months using Automatic Weather Station (AWS) and New_LocClim software. The automatic weather station is designed in such a way that the recording was done hourly. Observations at noon were averaged for monthly record for each of the environmental factor. The soil pH, cation exchange capacity (CEC), electrical conductivity (EC), soil organic matter (SOM) and soil macro and micro elements were characterized using procedures according to Yash (1998) at Soil Cares Laboratory.

Soil samples were collected at a depth of 20 - 60c m from the forest plots and from the on-farm plots using soil auger. A composite sample was prepared for on farm plot and for the forest plot for characterization. Automatic weather station from Trans-African Hydro Meteorological Observatory (TAHMO) weather station was installed for monitoring the climatic parameters. Table 4 shows the configuration of the sensors while Table 5 indicates the parameters measured and the degree of accuracy.

Table 1: TAHMO Micro Environment Monitor (MEM)

Sensor	Operating temperature range
Anemometer	-40 to 50 C
Rain gauge	0 to 60 C
Pyrometer	-40 to 60 C

Barometer	-40 to 85 C

Table 2: The Setting of the Climatic Parameters Monitored by the TAHMO
Automatic Weather Station

Parameter	Range	Resolution	Accuracy
Wind speed	0 to 60 m/s	0.01 m/s	3 %
Wind direction	0 to 359 degrees	1 degrees	3 degrees
Temperature	-40 to 80 C	0.1 C	0.5 C
Relative humidity	0 to 100% RH	0.1% RH	3%
Vapor pressure	0 to 47 kPa	0.01 kPa	0.3 kPa
Precipitation	0 to 230 mm/hr	0.014 mm	5%
Solar radiation	0 to 1,750 W/m2	1 W/m2	5%
Barometric pressure	49 to 109 kPa	0.015 kPa	0.4 kPa

The weather station was installed within a secure compound at Chuka University where there was permanent security and a perimeter fence. The station was accessed through the main gate. The installation adhered to the following specifications outlined in the installation mannual: Dimensions of 3m x 3m square and 1.5m high, chain-linked and barbed wire fencing with steel posts and a metal lockable gate with a padlock. The Siting was ideal to produce reliable and quality quality data. The station was installed in an open area away from buildings, trees, or any other object that may obstruct the sensors. The station was mounted at a height of 2 meters above ground level using a steel pipe that was 2.5 meters long, with 2 meters above ground and one and half meter buried in concrete.

Assessment of Regeneration status of Ocotea usambarensis

Three plots of 100m x 100 m containing mature tree species of *Ocotea usambarensis* were marked within the southern region of Mount Kenya forest using GPS for regeneration assessment and population structure. The plots were 5 - 10 km apart. Point centered quarter

ISSN: 2456-8643

(PCQ) method was applied within the plot for trees regeneration assessment and biodiversity determination (figure 5). The initial sampling points were purposely selected next to a mature *Ocotea usambarensis* tree. Following a perpendicular line to either compass direction, other sampling points were determined at 20 m interval. The diameter at breast height (DBH) was measured for the nearest tree species on either direction of the point. The *Ocotea usambarensis* plantsidentifiedin the plots were grouped as; >30cm for mature trees, 10-30 cm for saplings and < 10 cm for seedlings. The status of regeneration was recorded as good if seedlings and saplings >mature trees, fair if seedlings >saplings and poor if mature trees >seedlings. The mature plants were marked for phenophases assessment.

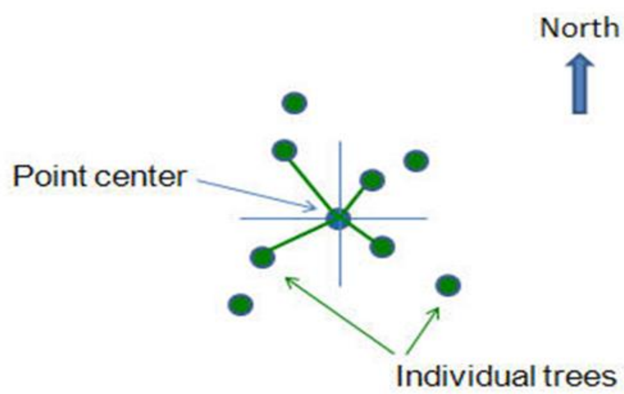


Figure 2: Species Identification by Use of Point Cantered Quarter Method

DATA ANALYSIS

Regression and correlation analysis were done to determine the relationship between the environmental factors and soil parameters respectively. Shannon-Weiner diversity index (Magurran1988) and Simpson Diversity index were used to determine species importance and diversity. The Shannon-Weiner index was calculated using the following equation:

$$D = \sum (n_i / N)^2 \quad \text{(ii)}$$

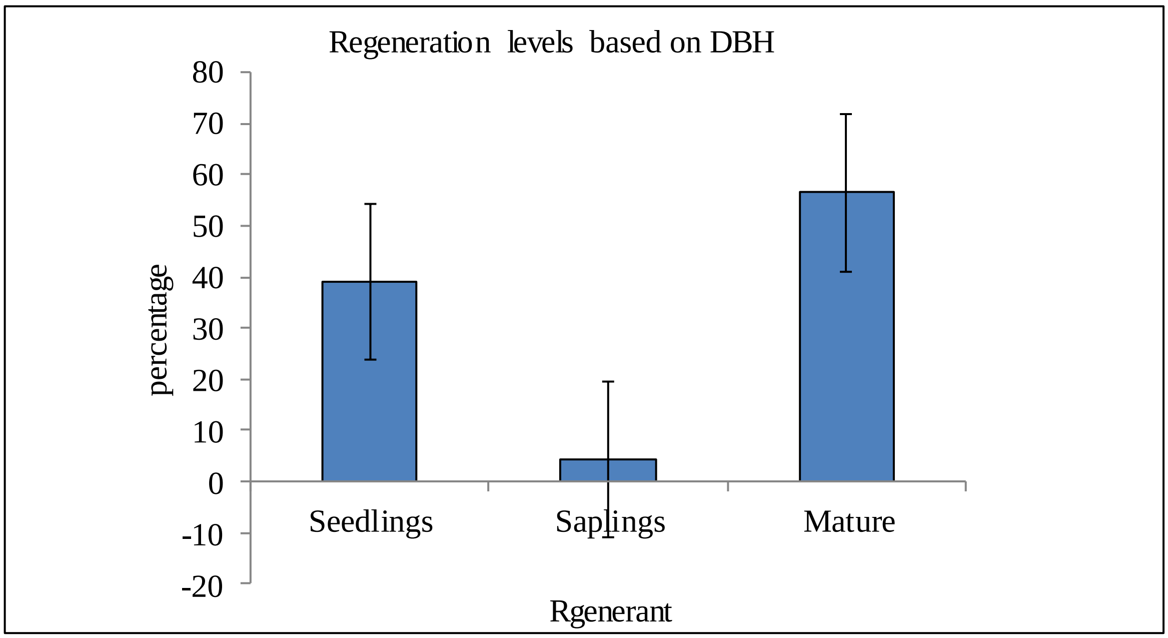
$$H' = -\sum [n_i/N] \log_e [n_i/N] \quad \text{(i)}$$

RESULTS

The Relationship Between The Environmental Factors and the Regeneration of **Ocotea usambarensis**

Regeneration is the replacement of the same plant involves both the physiological and developmental mechanisms inherent in plant biology as well as external ecological factors, including interactions with other biota, climate and disturbances. *Ocotea usambarensis* is known to experience low pollination that limits production of seeds and establishment of seedlings (Newmark, 2002). It therefore regenerates often from suckers and coppices. Moreover, it has very short seed viability which precludes the formation of a seed bank. This is because seeds dry out before germination (Bussmann, 1999; Baskin & Baskin, 2005).

4.3.1 Determination of Regeneration status of *Ocotea Usambarensis*



Seedlings; DBH = < 10 CM, Saplings, DBH = 10-30 CM and DBH = >30 CM for mature trees

Figure 3: Regeneration status of *Ocotea regeneration* based on DBH classes

Overall, 56% of the Ocotea plants were mature trees with a DBH of more than 30cm. seedlings comprised of 39% while saplings were only 4% (Figure 1). The plants were grouped on diameter classes as; < 10 cm for seedlings, 10-30 cm for saplings and >30cm for mature trees. The significantly ($P<0.05$) low development of saplings was coupled with influence of environmental factors and the disturbance.

Table 3: Distribution of Ocotea usambarensis within the Study Area

Species	Mature%	Saplings %	Seedlings %
Location			
Kiang'ondu	30.77	0.00	13.33
Kiamuriuki	23.08	0.00	0.00
Chogoria	46.15	100	86.67
Overall	56.52	4.35	39.13

Mature – DBH = >30cm, Sapling – DBH = 10cm - 30cm and Seedling – DBH = <10cm

Overall, mature trees of *Ocotea usambarensis* were more than the regerants in the study area (56.52%). Forty six percent of the mature species were found in Chogoria forest while 30% was found in Kiang'ondu forest and 23% in Kiamuriuki forest. Eighty six percent of the seedlings were found in Chogoria forest. There were no seedlings and saplings in Kiamuriki as shown in Table 1. Fair regeneration was observed in Chogoria whereas regeneration in Kiang'ondu and Kiamuriuki forest areas was poor. The seedlings were mainly of root suckers and not seed germination.

Tree Species in Association with *Ocotea usambarensis*

The tree species growing in association with *Ocotea usambarensis* were categorized using the Shannon - Wiener index computation and Simpson diversity index (Table 2, 3 & 4). The diversity was firly distributed within the study area with diversity indices of 6.93, 7.55 and 3.68 for Kiang'ondu, Kiamuriuki and Chogoria respectively. The Shannon Wiener computation indices were 2.04, 2.12 and 1.56 for Kiang'ondu, Kiamuriuki and Chogoria respectively. *Diospyros abyssinica, Commiphora eminii* and *Fagaropsis angolensis* were found to be in close association with *Ocotea usambarensis* with a Pilnpi > 0.3 in each case. *Ocotea usambarensis* therefore compete with other species in the association for space and environmental factors that include climatic as well as soil nutrients.

Table 24: Diversity Indices for Kiang'ondu

Species	Abundance	Pi	pi^2	LnPi	Pi Ln Pi
Ocotea usambarensis	6	0.2	0.04	-1.6094	-0.3219
Diospyros abyssinica	6	0.2	0.04	-1.6094	-0.3219

Vol. 3, No. 04; 2018

ISSN: 2456-8643

Rauvolfia caffra	2	0.07	0.0049	-2.6593	-0.1862
Ficus thinnongii	1	0.03	0.0009	-3.5066	-0.1052
Commiphora eminii	5	0.17	0.0289	-1.7719	-0.3012
Vitex kenniensis	3	0.1	0.01	-2.3026	-0.23026
Celtis africana	1	0.03	0.0009	-3.5066	-0.1052
Fagaropsis angolensis	1	0.03	0.0009	-3.5066	-0.1052
Croton macrostachyus	1	0.03	0.0009	-3.5066	-0.1052
Dombeya toriida	0	0.00	0.0000	0.0000	0.0000
Anthocleista grandiflora	4	0.13	0.0169	-2.0402	-0.2652

H' = ΣPi Ln Pi = 2.04

D = $1/\Sigma pi^2$ = 6.93

Table 35: Diversity Indices for Kiamuriuki

Species	Abundance	pi	pi^2	lnpi	pi ln pi
Ocotea usambarensis	3	0.1364	0.0186	-1.6094	-0.2195
Diospyros abyssinica	4	0.1818	0.0331	-1.6094	-0.2926
Rauvolfia caffra	1	0.0455	0.0021	-2.6593	-0.1209
Ficus thinnongii	0	0.0000	0.0000	0.0000	0.0000
Commiphora eminii	4	0.1818	0.0331	-1.7719	-0.3222
Vitex kenniensis	3	0.1364	0.0186	-2.3026	-0.3140

ISSN: 2456-8643

Celtis africana	0	0.0000	0.0000	0.0000	0.0000
Fagaropsis angolensis	2	0.0909	0.0083	-3.5066	-0.3188
Croton macrostachyus	1	0.0455	0.0021	-3.5066	-0.1594
Dombeya toriida	2	0.0909	0.0083	-2.0402	-0.1855
Anthocleista grandiflora	2	0.0909	0.0083	-2.0402	-0.1855

H' = Pi Ln Pi = 2.12

D = $1/\Sigma pi^2$ = 7.55

Table 46: Diversity Indices for Chogoria

Species	Abundance	pi	pi^2	lnpi	pi ln pi
Ocotea usambarensis	13	0.4483	0.2009	-0.8023	-0.3597
Diospyros abyssinica	6	0.2069	0.0428	-1.5755	-0.3260
Rauvolfia caffra	1	0.0345	0.0012	-3.3668	-0.1161
Ficus thinnongii	0	0.0000	0.0000	0.0000	0.0000
Commiphora eminii	2	0.0690	0.0048	-2.6736	-0.1844
Vitex kenniensis	1	0.0345	0.0012	-3.3668	-0.1161
Celtis africana	2	0.0690	0.0048	-2.6736	-0.1844
Fagaropsis angolensis	0	0.0000	0.0000	0.0000	0.0000
Croton macrostachyus	0	0.0000	0.0000	0.0000	0.0000
Dombeya toriida	4	0.1379	0.0190	-1.9812	-0.2733

Vol. 3, No. 04; 2018

ISSN: 2456-8643

Anthocleista grandiflora	0	0.0000	0.0000	0.0000	0.0000

H' = Pi Ln Pi = 1.56

$D = 1/\Sigma pi^2$ = 3.68

Effects of Temperature on Regeneration of *Ocotea usambarensis*

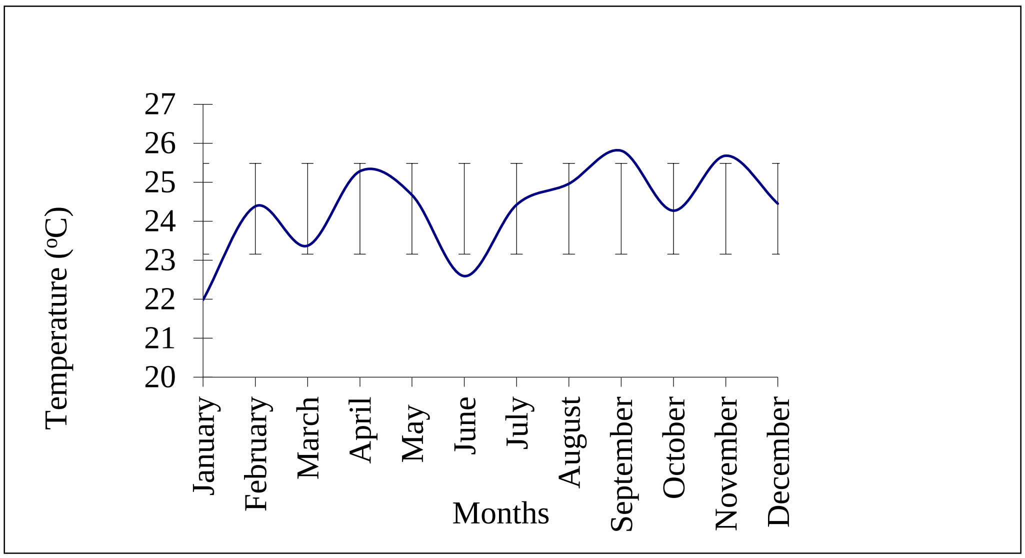


Figure 4: Influence of Temperature on Regeneration of Ocotea usambarensis

The mean annual temperature was 24.32 ^{0}C with a standard deviation of 1.16 as indicated in figure 3 . Temperatures were comparatively low in the month of June during which leaf fall occurred.

Effects of rainfall on regeneration of *Ocotea usambarensis*

Vol. 3, No. 04; 2018

ISSN: 2456-8643

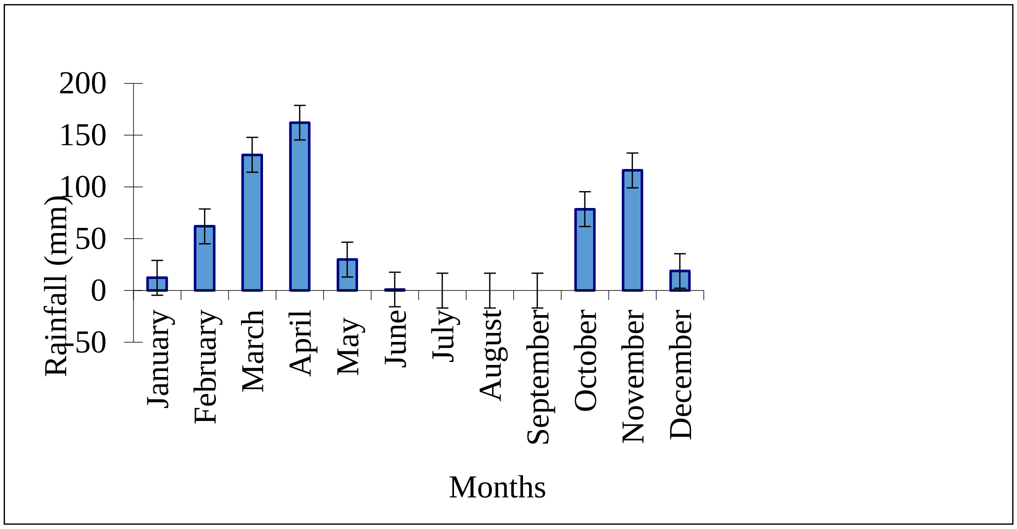


Figure 4: Influence of Rainfall on Regeneration of Ocotea usambarensis

The rainfall depicted a bimodal type with distinct seasonality. The mean annual rainfall was 51.09mm and a standard deviation of 58.32. There was minimal rainfall in the month of June and none rainfall in the months of July, August and September.

Effects of Humidity on regeneration of *Ocotea usambarensis*

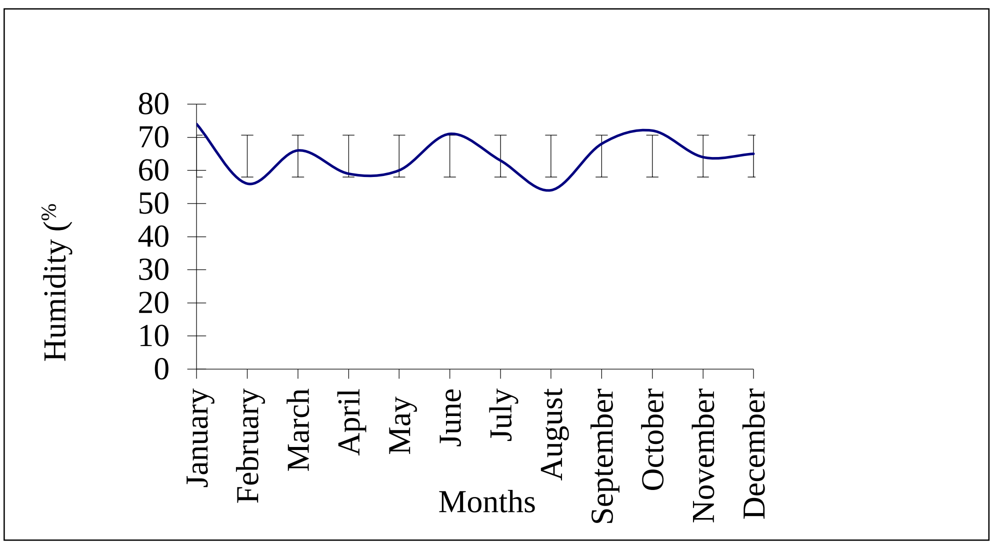


Figure 5: Influence of Humidity on Regeneration of *Ocotea usambarensis*

Figure 5 shows the results of monthly humidity that were fairly uniform. The mean annual humidity was 64.33 with a standard deviation of 6.32. Flowering and leaf flush occurred during the periods of high humidity while leaf fall peaked in August during which the period was of low humidity. The relative humidity controls the opening and closing of the stomata which regulates loss of water from the plant through transpiration as well as photosynthesis. Moist air has a higher relative humidity with relatively large amounts of water vapor per unit volume of air. Existence of seedlings and saplings indicate the significant role of relative humidity in regeneration.

Effects of wind speed on regeneration of *Ocotea usambarensis*

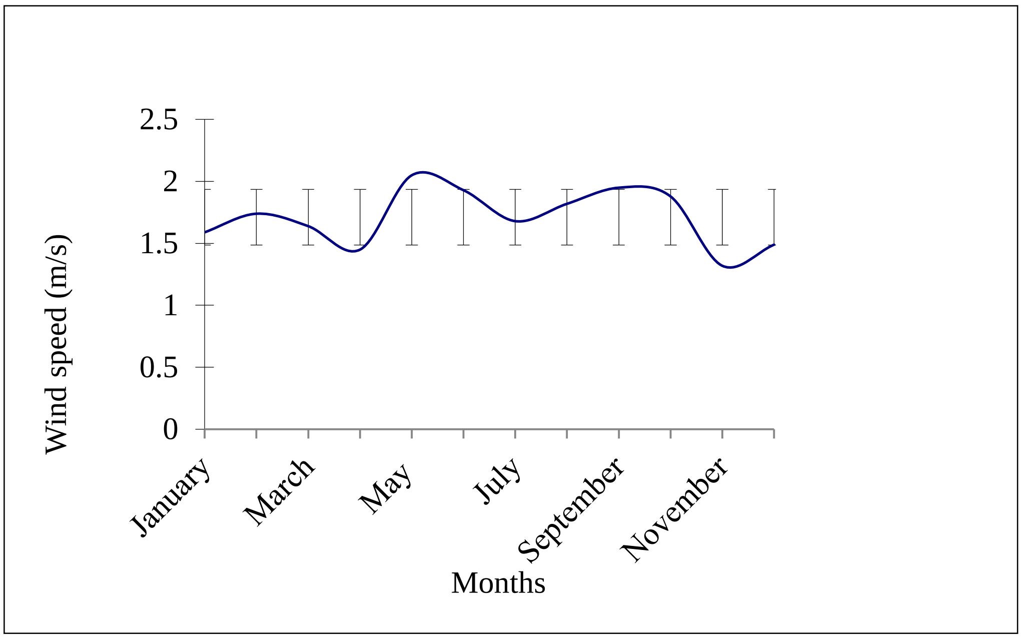


Figure 6: Influence of wind speed on Regeneration of Ocotea usambarensis

Wind speed during the study period was fairly uniform. The mean wind speed was 1.7 with a standard deviation of 0.22. High wind speed in May favors seed spread since it coincided with the seed shedding. Relatively high speed in December and January enhances pollination.

Effects of soils on regeneration

There was adequacy of most of the plants nutrients required by plants both for macronutrients and the micro nutrients levels. Only potassium soil and silicon were in low quantities in the soil. The nutrient levels for Organic carbon, total nitrogen, total phosphorus, total sulfur, calcium, magnesium and zinc in the soils were in high quantities in comparison with the thresh hold ranges (Table 5).

Table 7: Influence of Soils on Regeneration of Ocotea usambarensis

Parameter	Unit	Analysis Results	Range low	Range High	low	Adequate	High
PH(KCL)	pH Value	5.9	4.9	6.4		*	
Organic Carbon	g/Kg	186.5	17	50			*
Total Nitrogen	g/Kg	12.8	1	2			*
Total Phosphorus	g/Kg	0.9	0.2	0.6			*
Total Sulfur	g/Kg	2.4	0.3	0.5			*
Potassium (exch)	mnol+/kg	8.5	1.5	3			*
Calcium (exch)	mnol+/kg	121.9	15	25			*
Magnesium (exch)	mnol+/kg	30.1	4.5	10			*
Zinc (M3)	mg/kg	5.8	2.5	4			*
Copper (M3)	mg/kg	N/A					
C E C	mnol+/kg	343.5	75	200			*
Total Aluminum	g/Kg	80.1	70	112		*	
Total Potassium	g/Kg	3.3	11	23	*		
Total Silicon	g/Kg	196.2	240	340	*		
Total Iron	g/Kg	59.4	31	81		*	

Vol. 3, No. 04; 2018

ISSN: 2456-8643

The Pearson correlation coefficient matrix for elements in the soil samples was determined to aid in establishing the influence of physico-chemical properties on regeneration of *Ocotea usambarensis.* The results obtained are presented in Table 6.

Table 6: Pearson Correlation Coefficient Matrix for the Soil Elements

	Organic carbon	Total nitrogen	Total phosphorus	Total sulfur	Total aluminum	Total potassium	Total silicon	Total iron	Cation exchange capacity
PH	0.339	0.259	0.712	0.259	0.876	0.4	0.528	0.921	0.623
Organic carbon		0.992	0.789	0.996	-0.15	-0.308	-0.502	0.062	0.897
Total nitrogen			0.78	0.999	-0.238	-0.421	-0.6	0.009	0.888
Total phosphorus				0.764	0.314	-0.299	-0.221	0.612	0.979
Total sulfur					-0.236	-0.386	-0.581	-0.006	0.877
Total aluminum						0.639	0.843	0.911	0.176
Total potassium							0.902	0.272	-0.317
Total silicon								0.554	-0.325
Total iron									0.46

Vol. 3, No. 04; 2018

ISSN: 2456-8643

The correlation between soil elements was significant (P< 0.05). The correlation was positive for most of the elements and the negative correlations were weak with values close to -1. The soil pH positively correlated with all the soil elements while Cation exchanges capacity negatively correlated with potassium and silicon. These findings are consistence with the findings of Tabarelli, Aguiar, Ribeiro, Metzger and Peres, (2010). who when working on propagation of Ocotea using root sucker cuttings reported that root cuttings exhibited variability in leaf phenology and regeneration in different growth regimes.

DISCUSSION

Influence of environmental factors on regeneration of *Ocotea usambarensis*

The study established that the population structure of *Ocotea usambarensis* is characterized by high proportion of mature individual with DBH> 30 cm and few regenerants with DBH<10cm depicting "J" shape structure thus unstable. Overall, 56% of the *Ocotea Usambarensis* plants were mature trees with a DBH of more than 30cm. seedlings comprised of 39% while saplings were only 4% (Figure 1). The plants were grouped on diameter classes as; < 10 cm for seedlings, 10-30 cm for saplings and >30cm for mature trees. The significantly (P<0.05) low development of saplings was coupled with influence of environmental factors and the disturbance. The species association was fairly distributed within the study site with diversity indices of 6.93, 7.55 and 3.68 for Kiang'ondu, Kiamuriuki and Chogoria respectively. The Shannon Wiener computation indices were 2.04, 2.12 and 1.56 for Kiang'ondu, Kiamuriuki and Chogoria respectively. The regenerants were observed from the root system thus agreeing with Louppe, et.al, (2008) in their report that under natural conditions, *Ocotea usambarensis* regenerates mainly by suckers because undamaged seeds are uncommon. After natural mortality of an old tree, the gap is first filled by fast growing pioneer species, in the shade of which the *Ocotea usambarensis* suckers can establish, and after death of the pioneer species, they can develop into new trees, Bussman (2001). It was observed that in Mount Kenya forest, *Diospyros abyssinica*, *Commiphora eminii* and *Fagaropsis angolensis* were found to be in close association with *Ocotea usambarensis* with a Pilnpi > 0.3 in each case. *Ocotea usambarensis* therefore compete with other species in the association for space and environmental factors that include climatic as well as soil nutrients. The species also play the role of nurse species. *Ocotea usambarensis* is considered to be a climax species although it also exhibits characteristics of pioneer species. *Ocotea usambarensis* regenerates from suckers, coppices and rarely from seed. At some stages of its growth it behaves as a light demander than a shade tolerant, Also, at any stage when camphor is felled, root suckers are produced which, although able to persist under shade, grow rapidly in half or full light (Mugasha, 1996).

The mean annual temperature during the study period was 24.32 ^{0}C with a standard deviation of 1.16. Temperature influences all plant growth processes such as photosynthesis, respiration, transpiration, breaking of seed dormancy, seed germination, protein synthesis, and translocation. The low number of *Ocotea usambarensis* seedlings and saplings in comparison with mature trees indicates high seedling mortality rate due to temperature fluctuations and other environmental factors. At high temperatures the translocation of photosynthate is faster so that plants tend to mature earlier. Normally, plants survive within a temperature range of 0 to 50 C (Poincelot 1980). The favorable or optimal day and night temperature range for plant growth and maximum yields varies among plant species. Plant enzymatic activity and the rate of most physiological reactions generally increase with rise in temperature (Mader 1993). When temperatures are excessively high temperatures (>40^{o}c), denaturation of enzymes and other proteins occur. Excessively low temperatures can cause limiting effects on plant growth and development. Water absorption is inhibited when the soil temperature is low because water is more viscous at low temperatures and less mobile, and the protoplasm is less permeable. At temperatures below the freezing point of water, there is change in the form of water from liquid to solid. The expansion of water as it solidifies in living cells causes the rupture of the cell walls (Devlin, 1975).

The rainfall depicted a bimodal type with distinct seasonality. The mean annual rainfall was 51.09mm and a standard deviation of 58.32. It was unevenly distributed since there was minimal rainfall in the month of June and none in the months of July, August and September. Rainfall and Water is the most common form of precipitation and other forms of precipitation are freezing rain, stem through, dew, snowfall and hail (Eagleman 1985; Miller 2001). The amount and regularity of rainfall vary with location and climate types and affect the dominance of the types of vegetation and its regeneration as well as plant growth and its yield. Water inform of rain drops is the main source of water that percolates into the soils and thus constituting soil water available for plants. Inadequate soil water, results in wilting points when the plant looses water to the soil especially the seedlings which have poorly developed taproot thus low numbers of *Ocotea usambarensis* saplings and seedlings.

The mean annual humidity was 64.33 with a standard deviation of 6.32. The relative humidity controls the opening and closing of the stomata which regulates loss of water from the plant through transpiration as well as photosynthesis. Moist air has a higher relative humidity with relatively large amounts of water vapor per unit volume of air. Existence of seedlings and saplings indicate the significant role of relative humidity in regeneration.

Wind speed during the study period was fairly uniform. The mean wind speed was 1.7 with a standard deviation of 0.22. High wind speed favors photosynthesis and seed spread. Also the leaf fall that forms the forest floor which enhances moisture conservation needed for germination and seedling establishment. Moderate winds favor gas exchanges, but strong winds can cause excessive water loss through transpiration as well as lodging or toppling of plants. When transpiration rate exceeds that of water absorption, partial or complete closure of the stomata may ensue which restricts the diffusion of carbon dioxide into the leaves. As a result, there will be a decrease in the rate of photosynthesis, growth and yield (Edmond et al. 1978). The climatic factors cause limiting effects on various growth processes. However, the various climatic factors always operate together and interact with each other under natural conditions.

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The Pearson correlation coefficient matrix for nutrients in the soil samples was determined to aid in establishing the influence of physico-chemical properties on regeneration of *Ocotea usambarensis.* The correlation between soil elements was significant (P< 0.05). The correlation was positive for most of the parameters and the negative correlations were weak with values close to -1. The soil pH positively correlated with all the soil elements while Cation exchanges capacity negatively correlated with potassium and silicon. These findings are consistence with the findings of Tabarelli et al., (2010). who when working on propagation of *Ocotea usambarensis* using root sucker cuttings reported that root cuttings exhibited variability in leaf phenology and regeneration in different growth regimes. The soil fertility requirements for optimal *Ocotea usambarensis* seedlings establishment ware determined as; pH 6.4, Organic carbon 50g/kg, total nitrogen 2g/kg, total phosphorus 0.6g/kg, total sulfur 0.5g/kg, exchangeable potassium 3mnol+/kg, exchangeable calcium 25mnol+/kg, exchangeable magnesium 10mnol+/kg, zinc 4mg/kg, aluminum 112g/kg, total silicon 340g/kg, total iron 81g/kg and Cation exchange capacity of 200mnol+/kg.

CONCLUSION

Declining regeneration and death of some species which used to be dominant in tropical forests remains to be a matter of concern to ecologists (Richard et al., 2014). Of particular interest in this study was the *Ocotea usambarensis* which used to be the dominant canopy tree species of humid East African montane forests (Renvall and Niemelä, 1993). Many studies including (Jump, Carr, Ahrends, & Marchant, 2014); Lovett and Poćs, 1993; Maliondo et al., 1998; Hemp, 2006) have reported that the population structure of *Ocotea usambarensis* is dominated by mature trees, thus very unstable and in heavily logged areas, individuals with DBH< 50 cm are completely absent (Hamilton, 1989; Kleinschroth et al., 2013). Factors attributed to the decline of *Ocotea usambarensis* could be multiple, but stem mainly from habitat deterioration (Richard et al, 2014). Although several studies (Willan, 1965; Bussmann, 2001; Bitahiro et al., 2006) suggest that local condition requirements for advance growth of the young regenerants of *Ocotea usambarensis* remain largely unknown. The climate change aspects that alters the climatic factors and soil factors plays critical role in regeneration and establishment of the *Ocotea usambarensis* species. The seasonality of phenophases is altered by the climatic changes thus interfering with process such as pollination especially the insects.

RECOMMENDATION

Protection from cutting and herbivory damage of *Ocotea usambarensis* remaining in the forest and carrying on *in-situ* conservation for the species

Initiation and promotion of enrichment plantation program of the *Ocotea usambarensis* seedlings.

Vol. 3, No. 04; 2018

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