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Population structure and regeneration status of *Prunus africana* (Hook.f.) Kalkm. after selective and clear felling in Kibale National Park, Uganda

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*Prunus africana* is a globally threatened indigenous medicinal tree species, and food for many primates. Its population has declined in Sub-Saharan Africa due to unsustainable harvest and poor protection. In this study, we determined the population density, population structure and regeneration status of *P. africana* in the former clear felled, selectively logged and primary forests of Kibale National Park, and assessed the effects of dense cover of *Acanthus pubescens* on its regeneration. Trees were measured from 180 randomly established plots. The densities of *P. africana* seedlings and saplings differed significantly among the three forests while that of poles and mature trees did not. The density of seedlings was significantly higher in the selectively logged than in primary forests. The density of saplings was higher in clear felled than in selectively logged forests. Tree density was not negatively affected by *A. pubescens* cover. Clear felled areas had a more stable population structure with better regeneration, while selectively logged and primary forests had unstable population structures with poor recruitment potential. Our results show that *P. africana* regenerates more in intensively disturbed forest areas than less disturbed or primary forests, highlighting the importance of regenerating forests in the conservation of *P. africana*.

Key words: *Acanthus pubescens*, density, disturbance, population dynamics, regeneration, restoration, size class distributions, succession, tropical forest.

INTRODUCTION

African cherry (*Prunus africana* (Hook.f.) Kalkm.) is a globally vulnerable tropical tree species (IUCN, 2013), included as Appendix II by CITES in 1995 (Cunningham et al., 1997), and by FAO panel of Experts on Forest Genetic Resources as a species with maximum action priority in Africa (Navarro-Cerrillo et al., 2008). The population of mature sized trees has declined in many Sub-Saharan African forests due to subsistence and large

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Abbreviations: CITES, Convention on International Trade on Endangered Species; FAO, Food and Agriculture Organization; IUCN, International Union for the Conservation of Nature; RAC, regenerating age classes; SCD, size class distribution.
of A. pubescens on the regeneration of P. africana. We predicted that the recruitment rate of P. africana would be higher in the former clear felled and selectively logged areas than in the primary forest areas (Fashing, 2004). We expected to find higher densities (individual/ha) within the former clear felled and selectively logged than in the primary forest areas. We also anticipated that the densities of P. africana would negatively correlate with the cover of A. pubescens (Chapman and Chapman, 2004).

MATERIALS AND METHODS

Study area

This study was conducted in the Kanyawara compartments of Kibale National Park (KNP), located 20 km south-east of Fort Portal, western Uganda (0°13′-0°41′ N and 30°19′-30°32′ E). The park covers approximately 795 km². Rainfall is highly variable, but generally bimodal with peaks between March–May and September–November (Struhsaker, 1997). Mean annual rainfall at Kanyawara averages 1547 mm year⁻¹ and annual means for daily minimum and maximum temperatures are 14.9 and 20.2°C (1990–2001), respectively (Chapman et al., 2005).

The study sites were located in four regenerating aged forests of the former clear felled coniferous plantation, hereafter referred to as ‘clear felled areas’, RAC9, RAC11, RAC14, RAC19, name indicating the approximate years since clear felled (Table 1, Nyafwono et al., 2014; Malinga et al., in press); three natural forest compartments selectively logged at varied intensities between 1967 and 1969 (K13, K14 and K15); and two primary forest compartments (K30 and K31). Compartment K13 was heavily logged (50% basal area reduction) during 1968–69 and treated with aboricide, Finopal (2:1 mixture of 2,4-D and 2, 4, 5-T). K15 was heavily logged from 1968 to 1969 (40% basal area reduction), whereas K14 was lightly selectively harvested in 1969 with basal area reduction of 25-27%. The primary forest compartment K30 had only two to three trees per hectare felled by pit sawyers in 1970 with minimal impact, while K31 was not harvested (Struhsaker, 1997). Logging activities resulted into large canopy gaps and forest tracts at various levels of disturbances and degradation (Kasenene, 2007b).

Study species

P. africana (Hook. f.), also known as African cherry, belongs to the subfamily Prunoideae in the Rosaceae family and genus Prunus. It is an evergreen canopy tree species that can grow between 25 to 30 m in height (Hall et al., 2000). It is distributed primarily in montane and middle-elevation forests of Sub-Saharan Africa (Hall et al., 2000, Stewart, 2009). The leaves are simple, alternately arranged, and elliptic to oblong or slightly ovate. The flowers are small, creamy white, androgy nous, wind pollinated and are distributed in axillary racemes of 3.5-8 cm long (Lovett et al., 2006). The fruit is a red or red-brown ellipsoid drupe, 0.7 cm long and 1.1 cm in diameter (Hall et al., 2000; Lovett et al., 2006), and is dispersed by birds and monkeys (Fashing, 2004).

Study design and tree measurement

The Kanyawara forest area in KNP was classified and mapped a priori into nine differently aged successional forests by inspection of Landsat images (Malinga et al., in press). In each of the nine aged

density distributions and regeneration status of P. africana in the different forest areas; and 3) determine the effects of dense cover of A. pubescens on the regeneration of P. africana. We predicted that the recruitment rate of P. africana would be higher in the former clear felled and selectively logged areas than in the primary forest areas (Fashing, 2004). We expected to find higher densities (individual/ha) within the former clear felled and selectively logged than in the primary forest areas. We also anticipated that the densities of P. africana would negatively correlate with the cover of A. pubescens (Chapman and Chapman, 2004).

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successional forest, the location of 20 sampling plots was randomly established using a relative grid system, based on the actual sizes of RACs (RAC9-RAC19), and others (K13, K14, K15, K30 and K31) approximately on the same sized areas as RACs. At each GPS location, study plots were established with sides oriented to north (40 m) and east (20 m) direction. If the plot extended into foot trails or inaccessible points such as steep slopes, it was re-oriented perpendicular from that direction.

In each plot, we counted the number of individuals and measured for either stem diameter (saplings, poles and mature trees) or diameter above the root collar for seedlings (Kent and Coker, 1992). The species was identified by a trained botanist at the Makerere University Biological Field Station (MUBFS) Mr. Richard Sabiti, and voucher specimens have been deposited at MUBFS. The diameter of saplings, poles and mature trees were measured at the 1.3 m height, that is, diameter at breast height (DBH). Tree diameters of mature trees (diameter class > 20 cm), poles (diameter class 10–20 cm), saplings (diameter class 5–10 cm) and seedlings (diameter class 0–5 cm) were measured in nested plots of 40 × 20, 20 × 20, 20 × 10 and 10 × 10 m, respectively. At each plot, we visually estimated the percentage cover of Acanthus pubescens as follows: 0, <1% = 1, <10% = 10, <20% = 20, <30% = 30, etc. Because of low tree observations, in each aged successional forest, plots were regrouped into three forest areas based on previous history of disturbance, namely; clear felled (RAC9, RAC11, RAC14 and RAC19, logged between 9 to 19 years ago (80 plots)); selectively logged (K13, K14 and K15, logged 42-43 years ago (60 plots)); and primary forest (K30 and K31 (40 plots)), respectively.

To examine the population structure (distribution of individuals in the different size classes) and regeneration patterns of *P. africana* in each of the three forests, tree counts were converted into densities (individuals ha⁻¹) of *P. africana* in each size class (seedlings, saplings, poles and mature trees). A non-parametric Kruskal-Wallis test was used to compare *P. africana* densities in each size class among forests, since the data were not normally distributed. Whenever differences were significant, Mann-Whitney *U* test as a pair wise comparison was used. All analyses were conducted with IBM SPSS Statistics, Version 19.

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### RESULTS AND DISCUSSION

Population densities of *P. africana* in the different forest areas

We recorded significant differences in the densities of *P. africana* seedlings and saplings across the three forest areas (Table 1). The densities of poles and mature trees did not differ significantly across the three forest areas (Table 1). According to the pairwise tests, seedling densities differed, and were significantly higher in the selectively logged than in the primary forests (*P* = 0.019), but no significant difference was found for sapling density between selectively logged and primary forests (*P* = 1.00, Figure 1). The high density of *P. africana* seedlings and saplings recorded in the selectively logged or clear felled areas in comparison with the primary forests support several previous studies indicating that *P. africana* can regenerate well in the more disturbed or forest gaps than in less disturbed forests (Kiama and Kiyrapi, 2001; Ndam, 1996; Fashing, 2004). This suggests that the tree is a light demanding secondary forest species.
Population structure and recruitment in different forests

Our results indicated that *P. africana* population structure in clear felled areas had a significant negative SCD slope (Slope = -2.176, $r^2 = 0.77$, $P < 0.001$, Figure 2) and an inverse J-shaped size class distribution, with a considerably smooth decline in the number of individuals from smaller to larger size classes (Figure 2). Such a trend is an indication of a healthy and stable population that are naturally replacing themselves through good recruitment (Condit et al., 1998; Mwima and McNeilage, 2003; Muoghalu, 2006; Tabuti, 2007). In contrast, the population structures of *P. africana* in the selectively logged and primary forests had positive slopes (Figure 2) which is indicative of an unstable population with a poor recruitment potential, that is, there are more individuals in the larger than in the smaller size classes. Such recruitment bottlenecks can weaken the population structure which might lead to local extinction of species (Obiri, et al., 2002; Tabuti and Magula, 2007; Gwali et al., 2009). The higher rates of recruitment of *P. africana* in clear felled areas might partly be due to higher rates of seed dispersal or seed banks in clear felled as compared to the selectively logged or primary forests (Farwig et al., 2006; Tesfaye et al., 2010). Previous studies have shown that *P. africana* trees in disturbed areas are visited more by dispersal agents, e.g., birds and monkeys than those in the primary forest (Chapman and Chapman, 2004; Farwig et al., 2006). The poor regeneration recorded in the primary or selectively logged forests could be attributed to insufficient light penetrating the forest floor (Fashing, 2004; Jimu et al., 2012).

Influence of *A. pubescens* cover on the regeneration of *P. africana*

At plot level, the cover of *A. pubescens* differed significantly between the clear felled, selectively logged and primary forests (Kruskal-Wallis test, $\chi^2 = 12.75$, df = 2, $P = 0.002$). Despite significant variations between forests, the cover of *A. pubescens* was positively associated with density of *P. africana* (Spearman correlations; rho = 0.21, $P = 0.004$) suggesting that, the increase in *A. pubescens* cover might not affect regeneration of *P. africana* as we expected. In KNP, dense *A. pubescens* cover occurs in logged sites and canopy gaps. This herb cover limits forest regeneration by slowing down tree seedling establishment, growth and survival by altering the light and nutrients availability to tree seedlings (Lawes and Chapman, 2006; Duclos et al., 2013). The high tolerance of *P. africana* to *A. pubescens* cover might be a result of its ability to grow relatively fast or establish in shade (Kiama and Kiyrrapi, 2001; Meunier et al., 2010). Our result suggest that *P. africana* might be an ideal species for forest restoration activities in logged areas dominated by extensive *A. pubescens* cover like in KNP.
Figure 2. Size class distribution plots of *P. africana* in the clear felled, selectively logged and primary forest areas of KNP. The y-axis represents the individuals (ha⁻¹) while the x-axis is tree diameter size class in 5 cm intervals from 0.1 to 60 cm.
Conclusion

In this study, we showed that clear felled and selectively logged areas support proportionally higher densities of *P. africana* seedlings and saplings than primary forests suggesting that it is a light demanding species. Additionally, our results show that *A. pubescens* cover does not negatively affect the regeneration of *P. africana* in KNP. Clear felled areas had a stable population structure, with good recruitment potential, whereas in the selectively logged and primary forests was unstable and had poor regeneration. This indicates that *P. africana* requires relatively heavy disturbances in order for it to regenerate, high-lighting the importance of the studied regenerating forests in the conservation of the tree species.

Conflict of Interests

The authors declare that there is no conflict of interest.

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REFERENCES


