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THE ROLE OF *Psidiumguajava* L.,SEED BANK AS A STRATEGY FOR ITS SUCCESSFUL INVASION OF KAKAMEGA RAINFOREST, WESTERN KENYA

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ABSTRACT

Kakamega rainforest is the only lowland remnant of the great Guineo-Congolean rainforest in Kenya. This natural resource in the Western Kenya is being progressively colonized by various alien invasive plant species with the *Psidiumguajava*L., being the most important. It has interfered with the ecological integrity of the entire forest threatening its biodiversity. Studies have previously shown that *P. guajava* invasiveness could be attributed to its aggressive regeneration, profuse seeding and allelopathy. In this study we investigatedthe role of *P. guajava* soil seed bank as a strategy in its successful invasion of the forest. Soil samples were collected in 18 different quadrats from three invasion zones; 6 in the highly invaded zones, 6 in the lightly invaded and 6 in the no invasion zones, each quadrat measuring 10cm× 10cm.From each quadrat, 500cm^3 of soil samples were collected at different soil depths; 0-5cm, 5-10cm and 10-15cm. The soil samples were then placed in germination pots in a greenhouse and the seeds allowed to germinate over a duration of 90 days at a temperature range of 20-25^{o}c. Our results indicated that most of the seeds (59%), which regenerated were found in the highly invaded zones, as compared to the lightly invaded (33%) and zones of no invasion (8%). It also indicated that there wassignificant difference in regeneration of seeds in the highly invaded (F (2, 15) =18.97 p=0.0001) and lightly invaded (F (2, 15) =21.48 p=0.001) zones. Most of the seeds regenerated in the 0-5cm depthas compared to the deeper depths. No significant difference was observed in the no invasion zones (F (2, 15) =3.39 p=0.61). The successful invasion of *P. guajava* is therefore attributed to among other factors its rich soil seed bank and its ability to store seeds in greater depths of the soil.

Keywords: Seed bank, Invasiveness, *Psidiumguajava*, Kakamega Rainforest.

INTRODUCTION

Tropical rainforest are the world's most diverse ecosystem providing habitat for more than half of the world's known terrestrial plants and animal species (Althof, 2005). Kakamega rainforest, harbours immense and unique biodiversity (Mbuvi *et al*., 2009;Vuyiya *et al*., 2014), and provides several ecological services (Kiefer & Bussman, 2008). The forest can only sustain its uniqueness and provision of services when it has a stable biodiversity. However, land degradation, deforestation, impacts of climate change and spread of invasive species have threatened the biodiversity in Kakamega rainforest (Vuyiya *et al*., 2014).*Psidium guajava L*., is a member of Myrtaceae family originally from Southern Mexico to Northern South America (Chapla & Campos, 2010).It has distinctive traits which

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makes it easily identified such as a thin, soft and copper-colored bark that flakes off, showing a greenish coating beneath(Chollom *et al*., 2012). It has been registered as an aggressive invasive species (GISD, 2010). According to the findings of Chapla & Campos, (2010), *P. guajava*changes habitats, alter ecosystem functions and services and crowd out and replace native species. In Kakamega rainforest, it has been recorded to be the most successful invasive species (KIFCON, 1994). Its capacity to successfully invade various ecosystems has been attributed its ability to produce numerous seeds which remain viable for long, dispersal agents such as avian and mammalian vectors (Chollom *et al*., 2012) and allelopathy (Chapla & Campos, 2010).An incident of an invasive species storing its seeds in soilfor its recruitment and establishment has been reported in *Poaannua* L., (Ziemian, 2014).Soil seed bank can be defined as all viable seeds contained in soil profile, including those in the soil surface(Csontos, 2007; Saatkamp *et al*., 2014). It serves as a reservoir of viable seeds for plants in the soil (Gioria *et al*., 2012). It also represents a form of dispersal in space and time, allowing the colonization of new localities(Luzuriaga *et al.*, 2005). With respect to a study done by Gioria *et al*., (2012), a seed bank provide invasive species with a competitive advantage over native species dueto seed persistence. Seeds of most successful invasive species in soil seed bank can remain viable for a long duration of time until suitable conditions for germination are met.

Soil seed bank also allow invasive species to overcome density-dependent effects and allee effects, thereby enabling them to effectively establish themselves particularly during the introduction stage(Kramer *et al.*, 2009).Despite the availability of well-developed theoretical role of soil seed bank in plants invasion, quantifiable evidence of seed banks promoting plant invasiveness and invasibility are rare (Gioria *et al*., 2012). In Kakamega rainforest, cases of *P. guajava*seeds germinating from the soil, even after their thickets are destroyed by fire have been reported (Kawawa, 2016).Therefore this study aimed at determining the availability and regeneration of *P. guajava* seeds under various depths of the forest soil as a possible strategy it uses to successfully invade the forest. This information will be significant for understanding the regeneration ability of *P. guajava* so as to inform the mitigation of its invasion and threat on forest biodiversity.

MATERIALS AND METHODS

This study was done in Kakamegarainforest in Western part of Kenya. The forest lies about 50 km North of Lake Victoria between 0° 9‶ N, 0° 25‶N and 34° 49‶ E, 34° 57‶ E at an altitude between 1500 to 1700m(Kiplagat*et al.*, 2008).Temperature range from 18^{o}C to 29^{o}C with minima of 11^{o}C to 12^{o}C (Kiefer & Bussman, 2008). The annual rainfall show high variation with an average of 2007 mm over the recent 19-year period (Mammides *et al.*, 2008).Soil samples were collected from three zones of the forest. These zones included areas heavily invaded by *P. guajava*, lightly invaded and areas where there were no invasion by *P. guajava*as was previously done by (Obiri *et al.*, 1998).A total of 18 quadrats, i.e. 6 in each zone, measuring10 × 10cm were established. Soil auger was used to collect 500cm^3 of soil (Tang *et al.*, 2006) at three different depths of 0-5cm, 5-10cm and 10-15cm from each quadrat. The samples were then kept separately in plastic bags and transported to a greenhouse at Kenya Agricultural and Livestock Research Organization (KALRO), Kakamega for analysis. In soil preparation, the soil samples were spread out on plastic sheets and allowed to air-dry in the laboratory. When thoroughly dry, the soil samples were sieved through 1-cm-mesh sieve to remove the coarsest plant fragments and stones. The sieved soil samples werethen placed on plastic germination pots of 10 x 20cm with 5cm depth plastic pot (Ashton *et al*., 1998).Fifty four plastic germination pots of soil samples of each depth were arranged in a greenhouse. The pots were first half filled with sterilized sand. Each pot had small holes at the bottom to prevent the soil from becoming water-saturated. Seeds in the soil sample from each of the forest floor depths were then allowed to germinate under full sun and moist conditions, with a temperature range of 20-25^{0}C in the greenhouse (Godefroid *et al*., 2006). All the pots were maintained at field capacity by watering. Monitoring was undertaken weekly, and seedlings that were readily identifiable, recorded and discarded, for a duration of 90 days (Luzuriaga *et al*., 2005). Voucher specimens were collected from the field of study and used for confirmation purposes (Ashton *et al*., 1998). However, seedlings of other species which regenerated were not recorded in this study. To calculate the seed densities per metre square, the seed count in a sample were divided by the area of the sample(Ziemian, 2014). All the data was subjected to normality test before analysis. Since all the data were normal, a parametric test was used. SPSS, (Version 22) was used for analysis. ANOVA was used to compare means and Tukey Post hoc test values were used to separate the significant different means at $p \leq 0.05$.

RESULTS

A total of 266 seedlings of *P. guajava* regenerated from the soil seed bank. The highly invaded zones of the forest had the richest seed bank for *P. guajava*. In it, 1400 seeds/m^2 in 0-5cm depth, 850 seeds/m^2 in 5-10cm depth and 367 seeds/m^2 in 10-15cm depth were observed. This represented 59% of all the seedlings that regenerated. In the lightly invaded zones, 800 seeds/m^2 in 0-5cm depth, 433 seeds/m^2 in 5-10cm depth and 250 seeds/m^2 in 10-15cm depth were observed, representing 33% of the seedlings. In the forest zones where there were no invasion, 200 seeds/m^2 in the 0-5cm depth, 100 seeds/m^2 in 5-10cm depth and 33 seeds/m^2 in 10-15cm depth were also observed, making up for 8% of the seedlings which regenerated (Figure 1&2).

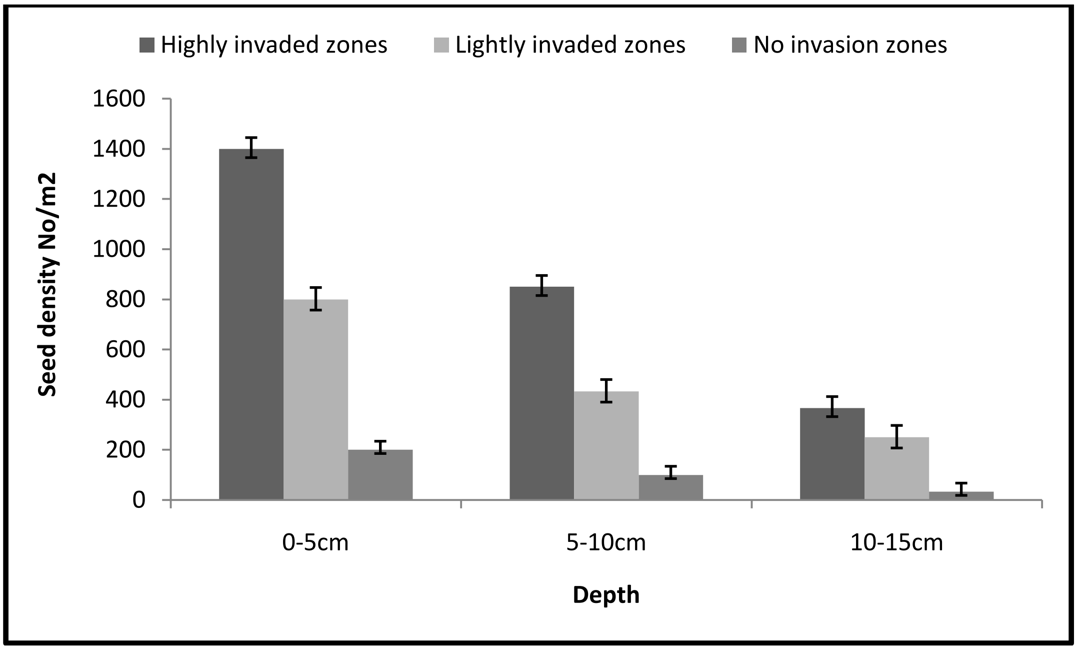

Figure 1: Regeneration of *P. guajava* seed density in Kakamega rainforest

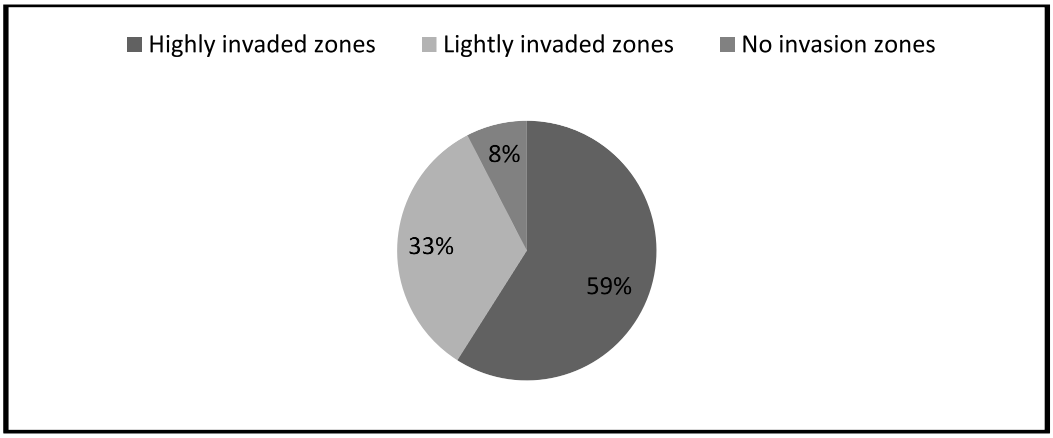

Figure 2: *P. guajava* seed regeneration based on its invasion of Kakamega rainforest

The results from one way ANOVA revealed that there were statistical differences in seed regeneration in the highly invaded zones (F (2, 15) =18.97 p=0.0001) and in the lightly invaded zones (F (2, 15) =21.48 p=0.001). However, in the zones of no invasion, no significance was observed (F (2, 15) =3.39 p=0.61). A Tukey post hoc test revealed that most of the seeds which regenerated both in the highly and lightly invaded zones were found at the upper layer of 0-5cm depth. The regeneration of seeds in this depth (0-5cm) in both zones was different from those in the subsequent lower zones. However, the regeneration of seeds in the no invasion zone had no significant difference from one anotheralong the vertical distribution (Table 1).

Table 1: Vertical distribution of *P. guajava*seeds along different zones of invasion in Kakamega rainforest

		Zones of invasion		
Kakamega	Depth	Highly invaded	Lightly invaded	No invasion
rainforest	0-5cm	$14\pm3.1_a$	$8.0\pm1.5_a$	$2.0\pm1.4_a$
	5-10cm	$8.5\pm2.8_b$	$4.3\pm1.5_{ab}$	$1.0\pm0.6_a$
	10-15cm	$3.7\pm2.8_c$	$2.5\pm1.4_b$	$0.3\pm0.5_a$

Mean values are presented as mean ± standard deviation per treatment. The different lowercases in each column expressed the extremely significant differences in different depths, p< 0.05.

DISCUSSION

A rich soil seed bank is essential for the success of any plant species(Godefroid *et al*., 2006). Based on this study, it is evident that *P. guajava* has a rich soil seed bank in Kakamega rainforest. Its ability to store seeds even in the deeper layer of the soil profile (10-15cm) could explain why it has successfully continued to regenerate, recruit and invade the forest even when subjected to harsh conditions such as fire. This is in agreement with the findings of Tesfaye *et al.*, (2004) who documented that a rich soil seed bank is a potential source of regrowth and recruitment to plant species in the event of disturbance. Thompson, (1979), in his classification of seeds banks based on longevity found that plants that are capable of storing their seeds in the deeper layers of the soil will successfully regenerate themselves. This is because the impact of disturbance might not reach the lower depths of the soil profile. The highly invaded zones had more regeneration of *P. guajava*seeds than the lightly and the no invasion zones. The explanation on this is that, highly invaded zones had the highest density of *P. guajava* plant. This means that there were more seeds produced and deposited in

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the soil in these zones, as compared to lightly invaded and no invasion zones. Previous study by Ziemian, (2014), recorded that more seedlings regenerate in areas where a particular species has a higher density. The presence of *P. guajava*seedlings regenerating in zones where it had not invaded could be explained by the fact that fruits containing seeds of *P. guajava*are eaten and the seeds continuously dispersed by wild animals such as baboons, birds, monkeys (Kawawa, 2016). These seeds have tough seed coats that enables them withstand the digestive enzymes along the digestive tract until they are release from the system (Buddenhagen *et al*., 2006).Sincethese wild animals keep migrating from one section of the forest to another, they release their faecal wastes containing the *P. guajava* viable seeds in the forest, and sometimes in the areas not invaded by *P. guajava*forming part of the soil seed bank. There were more seeds of *P. guajava*regenerating from the upper layer (0-5cm), than the middle (5-10cm) and the deepest layer (10-15cm). Patterns of decrease in species distribution and regeneration with increase in depth have been reported in other studies (Kellman, 1978; Young *et al*., 1987). This vertical reduction in seed regeneration is because seed density of soil seed banks of mature tropical rainforests decrease with increasing depth and the upper layer (0-5cm) accounts for more than 33% of the soil seed bank, giving the upper layer a greater difference in significance in comparison to the lower 5-10cm and 10-15cm depths (Csontos, 2007).

CONCLUSION

P. guajava has a rich soil seed bank. Its successful invasion in Kakamegarainforest is therefore attributed to among other facts, its rich seed bank and its ability to store seeds in deeper layers of the soil that enable it regenerate even when subjected to harsh treatments such as fire.

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