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Full Length Research Paper

The effects of intra-specific competition on survival in a *Casuarina Equisetifolia* spacing trial in Gede, Malindi, Kenya

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Competition for resources (light, water and nutrients) is one of the major causes of poor growth, suppression and delayed harvests in woodlots. In severe cases it may lead to death altogether. While many authors have reported on the possible mechanisms and effects of inter-specific competition (between different species), few studies in Kenya have looked at competition effects between similar species (intra-specific competition) and how this phenomenon affects tree survival. Intra-specific competition can be made worse by planting trees very close together; a very common practice among many farmers who grow *Casuarina* at the Coast. *Casuarina equisetifolia* is one of the most important agroforestry/farm-forestry tree species along the Kenyan Coast. In a spacing trial of *C. equisetifolia* established in 2003, trees grown at 1-by-1m spacing showed poor growth (data not shown), with more deaths (78 %) after a prolonged drought spell in 2005. Meanwhile, trees in the same area grown at 2.5-by-2.5m spacing had higher survival. It can be elucidated that the increased deaths resulted from increased intra-specific competition. Farmers are therefore, advised not to use very close spacing to avoid loss of growth and avoidable tree death from severe intra-specific competition, especially in dry sites and/or during prolonged droughts.

Key words: *Casuarina equisetifolia*, Intra-specific competition, spacing, drought, mortality

INTRODUCTION

Spacing trials have traditionally been carried out to come up with practical spacing for commercial tree crops to reduce intra-specific competition, optimize growth and get quick returns (Kirongo *et al*. 2012). Even with good rainfall and crop husbandry (weeding, climber cutting, fertilization), individual trees will still need sufficient growing space to ensure optimum growth (Auld *et al*. 1987, Evans 1982). Trees with ample growing space show much stronger growth and can better withstand pests and diseases and thus mature earlier and hence reducing investment risk (Evans 1982, Auld *et al*. 1987, Balneaves and Clinton 1992).

Spacing trials are designed to create growing environments that mimic resource capture (especially light) and/or available moisture and nutrients (Nambiar and Sands 1993). It is fair to assume therefore, that a research plot is a resource pool and the trees in a particular plot utilize this pool to their own individual benefit. Each tree theoretically has thus a resource pool available to it; to exploit at leisure.

It is also important to appreciate that a tree will have a "zone of influence" (Wagner and Radosevich 1991). This "zone of influence", where the tree has most command and "power" over the resources it exploits will define its dominance in terms of root coverage, crown spread and general health. Thus suppressed trees (due to competition or disease) will have low exploitative power even in their own "zone of influence". This is where neighbours can maximize resource gain by increasing their resource pool (Kirongo 1996, Balneaves 1982, Lowery *et al*. 1993), (Figure 1).

In plantations where trees are kept longer for timber production, managers need to thin before between-tree competition becomes significant so as to minimize growth losses arising from intra-specific (between-tree) competition (Evans 1982). In trees grown on-farm by

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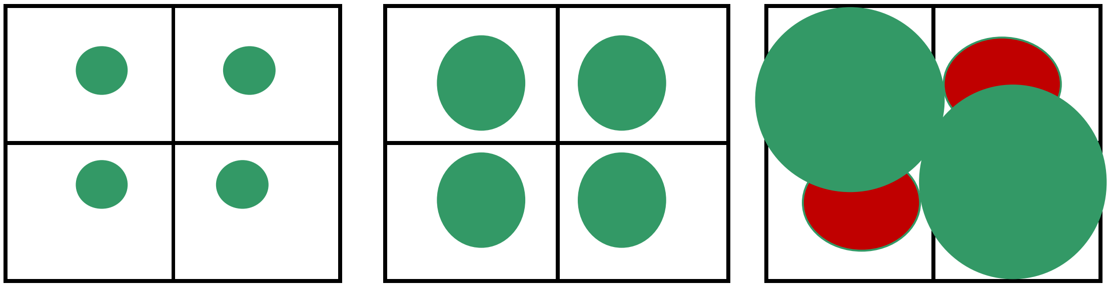

(a) Beginning - equal "zone of influence"

(b) Middle phase - increased "zone of influence"; but no suppression

(c) "Unequal zone of influence" and resource pool and onset of suppression of some individuals (Intra-specific competition)

Figure 1: Diagram showing hypothetical increase of individual tree's zone of influence with time until onset of suppression of some individuals (Source: Kirongo 2006).

farmers on short rotation for pole production, farmers want to maximize returns within a short time without the need to thin as there is normally no attractive market for thinned material under such short regimes, especially in the Kenyan Coast (Kirongo 2003). Under these circumstances, it is imperative that growing conditions are well manipulated to favour the desired crop trees so that they can be sold off quickly at reasonable prices. Researchers therefore, need to come up with spacing regimes that favour the growing of short rotation crops without exposing the trees to any significant competition (both intra- and inter-specific) (e.g. Kirongo *et al*. 2012)

Previous reports on *Casuarina* spacing at Gede indicated that farmers preferred 1.5-by-1.5 m and 2.0-by-2.0 m spacing (Wairungu *et al*. 2002). However, the study approach was based on farmers' views rather than from findings of spacing trials, for example. Thus due to the "weak" scientific basis there was concern that decisions based on these recommendations would still remain mainly subjective. Moreover, field observations showed that majority of farmers still used 1m-by-1m (Kirongo 2003). In view of this, an on-station spacing trial of *C. equisetifolia* was set up at Gede in 2003 with improvements on some of the flaws observed in earlier, similar studies. The objective of this study was to underscore the effects of spacing on survival and thereby come up with scientifically supported spacing recommendations for farmers growing *Casuarina* on short rotation for building poles.

While many authors have reported on the detrimental effects of close spacing on tree growth, the main concern at the Coast was tree death which was accentuated by unfavourabe weather, in particular droughts (See Plate 1). Farmers can always get some value from trees even if they are small but it is when the trees completely die altogether that they suffer most losses. Intra-specific competition which can be made worse by planting trees very close together; a very common practice among many farmers who grow *Casuarina* at the Coast, can lead to significant tree death given the increased drought incidences.

MATERIAL AND METHODS

Study Site and Data Collection:

The study was set up at Gede Regional Research Centre in June 2003 during the long rains. Gede is located at the Coast of Kenya in Malindi District. The Research Centre is along the Malindi-Mombasa main tarmac road about 20 km from Malindi and 2 Km from the Watamu junction. The temperatures average 32^0C and rainfall is bimodal with most rains falling in May-July and short rains in October-November and averaging 1.100 mm per annum. The main dry season is usually from December to March and sometimes extends into April. The soils are mostly light sandy soils devoid of organic matter. Machua and Lelon (2004) reported soils in many parts of the region, especially light sands to lack enough nitrogen and organic matter which are important for crop growth.

Experimental Design and Layout

The trial was set up in a randomized complete block design (RCBD). Two contrasting treatments were used namely 1-by-1 m and 2.5-by-2.5 m tree spacing. Due to lack of enough land only two replicates and two contrasting treatments could be used. This is normally

Plate 1: Close spacing of *Casuarina* (left) at Kwa Chery farm Malindi and good spacing for poles (right) at Mukutano farm Malindi. (Photo: Balozi B. Kirongo)

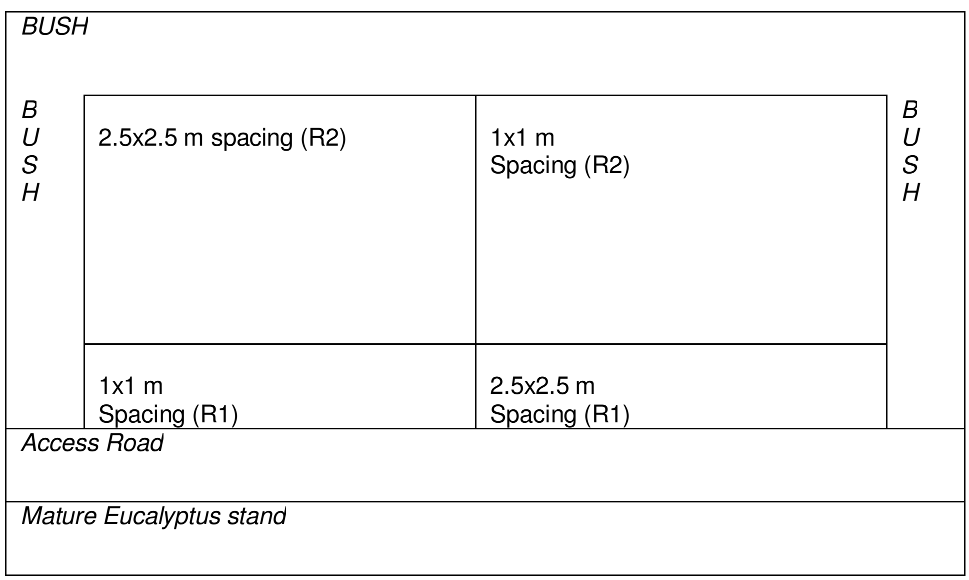

Figure 2: Field layout of Experiment

common in trials set up on farm lands as most farmers would like to use their land for growing food crops. The two treatments were chosen so as to represent the lower and upper spacing most commonly used in the region. The wider spacing (2.5-by-2.5 m) is the one normally used by government officers (KEFRI and Kenya Forest Service) while the smaller spacing is the closest spacing farmers use with variants in between. The siting of the experiment was next to a mature *Eucalyptus* stand (Figure 2) as this was the only land available.

Plots were 0.1225 ha (quarter acre) in size. The bigger plots had 196 trees while the smaller plots had 961 trees. The plots were big so as to enhance the visual impact and ensure that farmers could “appreciate” the treatment effects readily. Plots were weeded thrice during the first 2 years and thereafter when need arose. Weeding was done by casuals using hand held hoes, as is the normal practice by woodlot farmers. The trial was not irrigated but was grown under rain-fed conditions.

Growth data (height and diameter at ground level) were assessed at 6 months, 1 year, 2 years and 3 years of age. Survival was computed for each plot during each

Table 1: Table of plant Survivals (percent number of individuals surviving) for year 2 and 3

	Close spacing (1-by-1 m)			Wide spacing (2.5-by-2.5 m)		
Replications	R1	R2	Mean	R1	R2	Mean
Year 2 (2005)	54%	75%	65%	59%	83%	71%
Year 3 (2006)	19%	26%	23%	49%	62%	57%

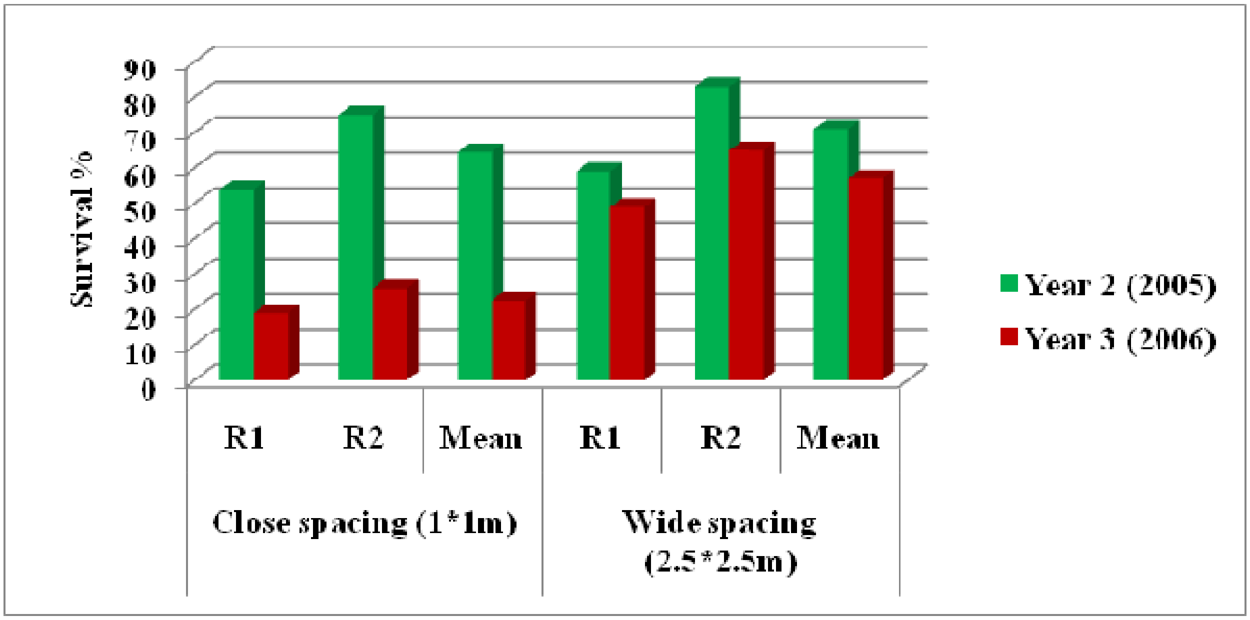

Figure 3: Survival percentages for *C.~~asuarina~~ equisetifolia* in a spacing trial at Gede (R1 = replicate 1 and R2 = replicate 2).

assessment date by counting the number of surviving trees in a plot at each measurement time. During the second year of growth (May 2005 to April 2006) there was a severe drought which affected the growth of most trees in the whole region. The third year data was collected in July 2006 and analyzed for reporting. Data was analysed using descriptive statistics and results presented in graphs and tables. Analysis of variance (Anova) was also carried out for Arcsine transformed survival data. This paper reports only on the effects of intra-specific competition on survival.

RESULTS AND DISCUSSION

The survival figures for the 2 spacing types used (i.e. 1-by-1 and 2.5-by-2.5 m) are shown in Table 1. During the assessment at the end of year 2 (2005), all survivals were above 50% (Table 1). In year 3 (2006) all treatments in the 1-by-1 m spacing suffered severe mortality with the best plot recording only 26% down from 75% the previous year (Table 1). In the wider spacing however, mortality was less and while one of the plot in replication 1 dropped to a survival below 50% (R1 = 49% see table 1) in 2006, this is partly thought to have been due to its close proximity to a mature *Eucalyptus* stand (see Figure 2: Layout). We believe that the loss of most trees in replication 1 belonging to the wider spacing may have been due to allellopathic effects resulting from the proximity of the replicate to a mature *Eucalyptus* stand. Similar observations, where *Casuarina* growth and survival were affected by its closeness to a mature *Eucalyptus* stand have been experienced at Gede (Kirongo 1993).

Figure 3 shows that even during 2005, the survival of trees in the closer spacing were already low compared to their counterparts in the wider spacing in both replicate 1 (R1) and replicate 2 (R2). While the drought of 2006 took its toll on all trees irrespective of spacing (reduction of survival in all treatments), trees in the closer spacing (1-by-1 m) were worst hit (Figure 3, Table 1). This is made clear by the reduction of survival of replication 2 (close spacing) from 75% to 26%. Replication 2 was further from the *Eucalyptus* stand (see Figure 2: Layout).

Analysis of variance of Arcsine transformed survival values showed that growing trees at wide spacing gave significantly better survivals (P=0.05) than the narrow spacing (table 2).

Similar results to those reported in this study have been observed elsewhere with reports of trees suffering growth

Table 2: Anova table for Arc transformed data

Source of Variation	SS	df	MS	F	P-value
Between Groups	1332.3	1	1332.3	17.5	0.05
Within Groups	152.5	2	76.3		
Total	1484.8	3			

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reduction due to competition for limited resources (Shainsky *et al*. 1992, Kirongo 1996, Kirongo 2000, Kirongo *et al*. 2002,). Trees growing together hardly discriminate against each other, thus competition for resources will occur between trees of all forms and species. The competition is most intense where trees have similar resource needs as is the case in even-aged, monocultures. Reducing spacing between trees will therefore exacerbate the negative effects. Sands and Nambiar (1984) and Nambiar and Sands (1993) reported serious growth losses resulting from intense competition for water and nutrients arising from competition effects. In Kenya, the negative effects of competition for resources have been reported to occur even in the fertile Highland sites where Kirongo *et al*. (2002) reported severe growth reduction of Cypress growing under competition. Meanwhile, in a spacing study of eucalypts in a Nelder design, Kiringo *et al*. (2012) reported poor growth of trees in the inner circles (0.4x1m spacing) of the Nelder and better growth for trees in the outer circles (2.4x1m spacing) of the Nelder. This further supports the fact that closely spaced trees grow poorly compared to those with ample spacing.By growing trees too closely therefore, farmers unknowingly predispose the trees to severe competition amongst each other and weeds (grasses grow very fast following showers in Gede). Under drought conditions, water becomes very limiting and this may in turn affect nutrient availability (in solution) to the root zone as well. Given the poor nature of the Gede sandy soils which lack organic matter and nitrogen (Machua and Lelon 2004) underground resources for growth are expected to be very limiting. While it is an established fact that *Casuarina* harbor *Frankia* which fix nitrogen and thus expected to improve the fertility statuts of the site, this effect would still be diluted by competition. By planting trees too close the negative effects are magnified, especially if there is severe prolonged drought as was the case in 2005 in the area. Similar results have been reported for dry sites where even minimal competition can cause significant losses in tree growth (Mason and Kirongo 1999) or lead to death altogether under severe cases.

CONCLUSION

The findings from this study have shown that farmers growing *equisetifolia* on short rotation for pole production in the region need to use wider spacing than 1-by-1 m. While the fact that only 2 spacing types were studied limits choice of spacing (a comprehensive trial has been designed addressing this aspect), the results have made it clear that using spacing of 1.0-by-1.0 m, as most farmers still do, is not advisable. The study also showed succinctly that farmers using small spacing risked not only poor growth (data not shown) and poor incomes (inferred) but also lost most their crop during dry seasons. Farmers are therefore, advised to desist from using 1.0-by-1.0 m spacing for growing *Casuarina* on their farms, especially in drought prone areas.

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