RJF Research Journal of Forestry

OPEN ACCESS

Impact of Tree-Crop Distance on Pine (*Pinus patula*) Growth in Intercropping Under the Plantations Establishments Livelihood Scheme (PELIS)

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ABSTRACT

Background and Objective: In the Plantation Establishment and Livelihood Improvement Scheme (PELIS) there is no recommended spacing between the crops and trees (microsite distances). Therefore, the study determined the influence of microsite distances on the growth of *Pinus patula*. **Materials and Methods:** In PELIS, the treatments constituted of *P. patula* and crops (cabbages) at tree crop microsite distance (20, 50, 100 and 150 cm). Plots of 10×10 m were replicated 3 times at two sites. Data was analyzed using one-way ANOVA and significantly different means by Duncan's Multiple Range Test. Growth of *P. patula* in terms of root collar diameter (RCD) and height was measured for 6 months. **Results:** The best growth in DBH and height occurred at a tree crop microsite distance of 100 cm followed by 50 cm which was significantly higher than the control ($p<0.05$). Similarly, the best growth trends in terms of average height occurred at a tree crop microsite distance of 100 cm followed by 50 cm which was significantly higher than the control ($p<0.05$) at both sites. **Conclusion:** The present study demonstrates that in PELIS tree crop microsite distance is an important factor that affects the growth of trees and therefore it is recommended tree-cropping microsite distances of 100 and 50 cm for *Pinus patula* establishment.

KEYWORDS

Tree-crop microsite distance, growth performance, *Pinus patula*, Plantations Establishments Livelihood Scheme (PELIS), Kenya

INTRODUCTION

There is increasing demand for forest products to provide energy, food, fuel, medicine, fodder, as well as construction materials[1,2]. There is also the problem of increasing food production to meet the ever-increasing food demand for the burgeoning population[3]. Simultaneous requirements for trees and food especially among adjacent forest dwellers require strategies and/or approaches that transform food systems with trees and forests within the same parcel of land[4]. For several years, sustainable farming systems such as agri-silviculture in forest lands where trees are grown together with crops have been practiced in an endeavor to ensure sustainable forest management[5].

ISSN: 2151-8262 (Online)
ISSN: 1819-3439 (Print)
https://doi.org/10.3923/rjf.2024.10.16

Received: 17 Aug. 2024
Accepted: 24 Nov. 2024
Published: 25 Nov. 2024

The Plantation Establishment and Livelihood Improvement Scheme (PELIS) used in Kenya[6] allows the forest adjacent dwellers to use the forest to grow food crops while tending the young plantation trees. In Kenya where the practice is widespread, residents of the forest are allocated freshly cleared areas to plant food crops for up to 3 years while tree species become established[7]. In most areas of Kenya where plantation establishment is practiced, farmers grow a single crop mainly; Irish potatoes, beans, carrots, peas, vegetables, etc or intercrop of these subsistence crops during the cropping season, in addition to the growth of plantation tree species for 3-4 years[8,9]. This planting sequence continues until the plantation establishment can no longer support any subsistence crops thus ensuring maximum survival and growth of the trees and crops while farmers have access to productive forestland[10].

Several tree species have been grown successfully in PELIS including; *Eucalyptus saligna*, *C. lusitanica* and *P. patula*[11,12], where *P. patula* is the most important plantation tree species in Kenya[9]. In PELIS, trees and crops are grown in different spatial arrangements for enhanced growth and survival of the plantation tree species to respond to different aspects of the tree-crop arrangements[13-15]. The crop-tree interactive dynamics and variations in spacing can also influence the growth and survival of plantation tree species. In general differential tree-crop spatial arrangements will enable crops and trees to compete for growth factors such as light, water, nutrients, oxygen and carbon dioxide and the outcome of this competition is, a change in plant growth of the species in the mixture[16].

A comprehensive understanding of tree growth is therefore essential. However, there is still very scanty information on the growth of plantation tree species when intercropped with crops under varying tree-crop spacing arrangements in PELIS. Based on the foregoing, this research determined the influence of tree crop microsite distance on the successful establishment of *P. patula* plantation in a PELIS system.

MATERIALS AND METHODS

Study area: The study was carried out in Timboroa and Kipkurere Forests within Uasin Gishu County, Kenya for a period of 8 months from May, 2022 to January, 2023. The County lies between Longitudes 34°50' East to 35°37' East and Latitudes 0°03' South to 0°55' North. The County shares common borders with Trans Nzoia County to the North, Elgeyo Marakwet County to the East, Baringo County to the South East, Kericho County to the South, Nandi County to the South West and Kakamega County to the North West. It covers a total area of 3,345.2 km^2.

The county experiences a high and reliable rainfall with an average annual rainfall ranging between 624-1560 mm, which occurs between March to September, with distinct peaks in May and August. The dry spell starts in November and ends in February. The average temperature ranges between 7-29°C[17]. Soils in the study area have low fertility due to leaching and loss of humus through continuous cultivation. The soil is heavy in texture and mainly orthic ferralsols and humic aerosols[18].

Mixed subsistence agriculture is the main economic activity in the study area. The average total farm size is 0.58 ha. The major economic activities practiced in the region include large-scale barley farming, dairy and horticulture farming. Maize is the main food crop. Other crops grown include; sunflower, wheat, pyrethrum, beans, cabbages and potatoes. The area is classified under low low-medium in the agro-ecological zone.

Data collection and measurements: At the PELIS sites of Timboroa and Kipkurere Forest where *P. patula* plantation and crops are usually grown, four treatment plots of 10×10 m were developed and executed in triplicate. The treatments were plantation tree-crop distances of 20, 50, 100 and 150 cm with complete weeding (Fig. 1). The control for the experiment was tree crop microsite distance of 20 cm. Random samples of 10 trees were sampled for growth measurement. Growth was measured monthly in terms of root collar diameter (RCD) and height of *P. patula* from the time of transplantation for 6 months.

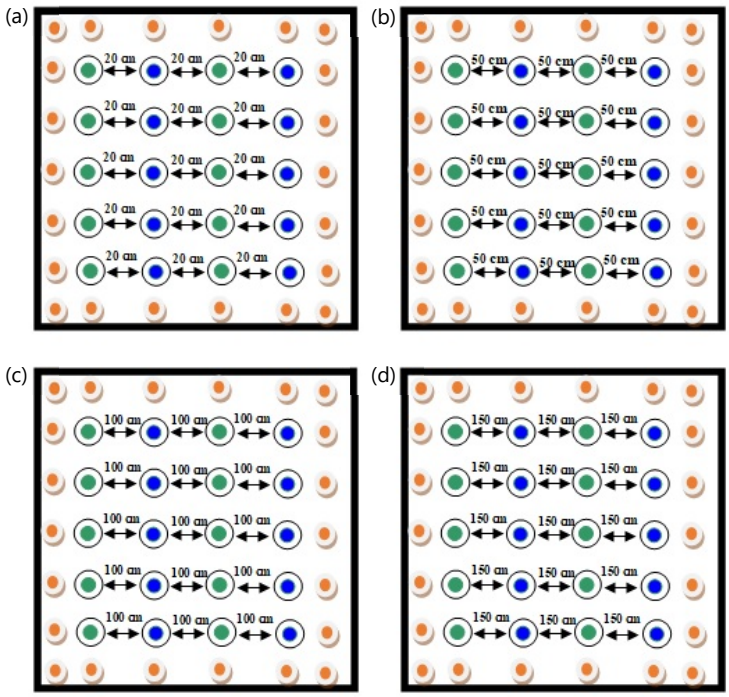

Fig. 1(a-d): Plot layout showing 10×10 sized plots with tree-crop distance at the center, (a) 20 cm with complete weeding, (b) 50 cm with complete weeding, (c) 100 cm with complete weeding and (d) 150 cm with complete weeding

The inner zone green for crops and blue for trees was assessed periodically while the outer seedlings (orange) formed the guard row. The experiment was done in Complete Randomised Design (CRD).

Data analysis: Growth of *P. patula* plantation tree species was measured in terms of RCD and height in PELIS system based on the microsite distance. Mean values of RCD and height between treatments were tested with one-way ANOVA. Significantly different means ($p<0.05$) were discriminated using the Duncan's Multiple Range Test. The relationship between growth trends in RCD and height against time was demonstrated by regression analysis of the form growth. A test for common slope was used to compare coefficients in regression equations:

$$\text{RCD, height} = \beta_0 + \text{Weight} \times \text{Time}$$

where, β_0 is a constant.

RESULTS

The final RCD and height of *Pinus patula* concerning microsite distances in Timboroa and Kipkurere during the 6-month experimental period are presented in Table 1. The best growth in RCD and height occurred at a tree crop microsite distance of 100 cm followed by 50 cm which was significantly higher than the control ($p<0.05$) at Timboroa and Kipkurere. The best growth in terms of height occurred at a tree crop microsite distance of 100 cm followed by 30 cm which was significantly higher than the control ($p<0.05$) at both sites.

Growth in tree RCD and tree height under different microsite distances over the 6 months was shown in Fig. 2(a-b) and Fig. 3(a-b). Significantly higher growth trends in RCD and tree height occurred at a tree crop microsite distance of 100 cm followed by 50 cm which was better than control ($p<0.05$) at Timboroa and Kipkurere. Tree crop microsite distance of 150 cm was the least, respectively.

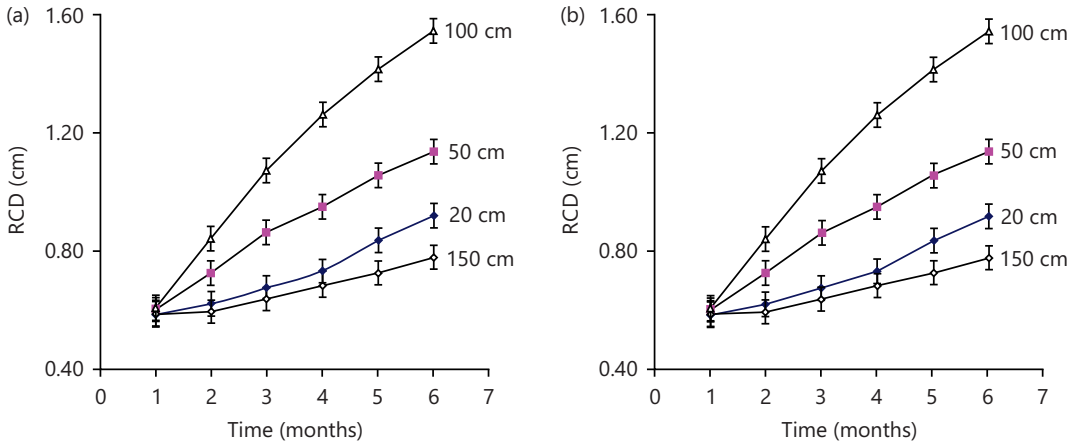

Fig. 2(a-b): Tree growth in RCD (cm) of *Pinus patula* during the study, (a) Site 1: Timboroa and (b) Site 2: Kipkurere

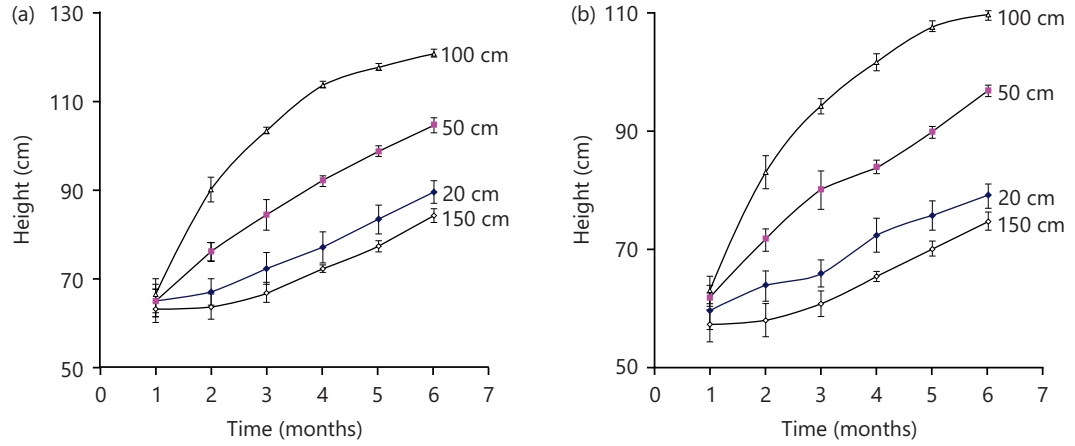

Fig. 3(a-b): Tree growth in height (cm) of *Pinus patula* during the study, (a) Site 1: Timboroa and (b) Site 2: Kipkurere

Table 1: Final RCD and height (Mean±SEM) of *Pinus patula* concerning microsite distances at the two study sites

	RCD		Height	
Microsite	Timboroa	Kipkurere	Timboroa	Kipkurere
20 cm	0.92±0.13^{b}	0.72±0.13^{b}	89.59±6.56^{b}	79.08±2.07^{b}
50 cm	1.14±0.12^{c}	1.02±0.12^{c}	104.46±7.69^{c}	96.74±0.99^{c}
100 cm	1.54±0.11^{d}	1.40±0.12^{d}	120.74±6.92^{d}	109.60±10.93^{d}
150 cm	0.78±0.12^{a}	0.63±0.11^{a}	84.23±4.61^{a}	74.73±8.21^{a}
ANOVA				
F	12.673	15.232	48.4523	51.457
p-value	0.0034	0.0023	<0.0001	<0.0001

Means with the same letters as superscripts down the column are not significantly different (p>0.05) based on DMRT and SEM: Standard error of the mean

Regression analysis of the growth rates of *Pinus patula* growth trends in height is provided in Table 2. Growth trends in terms of height occurred at a tree crop microsite distance of 100 cm followed by 50 cm which was better than control (p<0.05) at Timboroa and Kipkurere.

DISCUSSION

During this study, the best growth of *P. patula* occurred at a tree crop microsite distance of 100 cm followed by 50 cm which was better than growth in the control. Better growth at 100 cm off the crop distance may be due to the distribution of nutrients for the trees and crops in the shared space[13,19]. Trees

Table 2: Regression analysis of tree height-time growth rate and during the study period

Location	Treatment (microsite) (cm)	Equation	F	p-value	R^2 value
Site 1	20	Ht = 5.0332*T+58.142	193.9675	0.0002	0.9796
	50	Ht = 7.8006*T+59.468	310.4727	<0.0001	0.9831
	100	Ht = 10.380*T+65.642	31.62832	0.0049	0.8877
	150	Ht = 4.3169*T+56.1942	71.9884	0.0012	0.9351
Site 2	20	Ht = 3.9815*T+55.5212	302.886	<0.0001	0.9869
	50	Ht = 6.6454*T+57.4053	221.3801	0.0001	0.9822
	100	Ht = 9.2582*T+61.1436	47.63961	0.0023	0.9225
	150	Ht = 3.639*T+51.6808	90.27524	0.0006	0.9575

and crops grown under these differential conditions of intercropping may affect soil conditions through nitrogen fixation which affects crop growth and yield[20]. However, trees also compete with crops for environmental resources and their negative effects may outweigh the potential benefits[21]. In general, differential tree-crop spatial arrangements will enable crops and trees to compete for growth factors such as light, water, nutrients, oxygen and carbon dioxide and the outcome of this competition is, a change in plant growth as demonstrated in the current study.

Several studies have found differences in plantation tree species growth under different tree-crop arrangements. One of the results, confirms that continuous maize cropping at a tree-crop distance of 1 m had no significant competitive effect on the growth of Salm wood during the first year after plantation establishment[22]. In combination with three successive maize crops, a very early positive response of Eucalyptus tree species to increasing tree-crop distance was found[23]. In São Paulo, Brazil, tree height and diameter at breast height of *Eucalyptus alba* also increased with increasing distance (50, 100 and 150 cm) between the trees and a maize crop[24]. In the case of Salm wood, basal diameter was the only variable that gave such an early significant response[24]. However, after one year of continuous intercropping the regression slopes were steeper for Salm wood than for *Eucalyptus*, because increasing tree-crop distance finally had more importance for Salm wood. In association with cassava, *Eucalyptus* appeared to compete for light with the crops through rapid, continuous height growth, especially when the tree-crop distance was reduced from 1 m to 60 cm[25]. On the other hand, different fruit trees were able to improve growth under increasing tree-crop spacing between 200-750 cm even when watering was reduced[16].

With increasing awareness of its importance, silvicultural practices have been incorporated into more recent tree growth dynamics[26]. However, it is often difficult to examine species' silvicultural practices and measure the quality of microsite patches. There is also a lack of clear understanding of the role of crop-tree interaction on the growth of plantation tree species establishment under different environmental conditions (relative humidity, vapor pressure deficit and resources (gradients in light) which can all be modified in fields with varying degrees of crop-tree spatial arrangements.

CONCLUSION

Growth in terms of RCD and height were optimized at tree crop microsite distances of 100 and 50 cm at the two sites but was least at a tree crop microsite distance of 150 cm. The present study demonstrates that in PELIS, a microsite is a significant factor that affects the growth of trees and therefore we recommend tree-cropping microsite distances of 100 and 50 cm to optimize *Pinus patula* growth establishment. Therefore, there is a need for future studies that optimize food production without compromising tree growth in PELIS.

SIGNIFICANCE STATEMENT

The practice of leasing out forestlands to the local community members to plant crops in the space between trees is a common practice in several regions that encourage forest management. However, the correct tree-crop microsite distance that would yield the best growth for trees is relatively unknown. This

study aimed to determine the Influence of tree crop microsite distance on the growth of Pine (*Pinus patula*) intercropped with conventional crops in plantation establishments. The study was conducted in a humid forest in Kenya for 7 months. The study established that tree-crop microsite distance influences the growth of trees. The information is useful for the management of commercial forest plantations to enhance the wood industry.

ACKNOWLEDGMENTS

The authors acknowledge the financial support granted by the National Research Fund (NRF), Kenya funds (No: NRF/RCD/ST&I 6th CALL Mas/145). The authors also the management of Timboroa and Kipkurere tree nurseries where the study was conducted. The authors acknowledge the Kenya Forest Service and Kenya Forestry Research Institute (KEFRI) for administrative and technical support during data collection. We also thank the University of Eldoret for providing expertise and equipment during data collection and analysis.

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