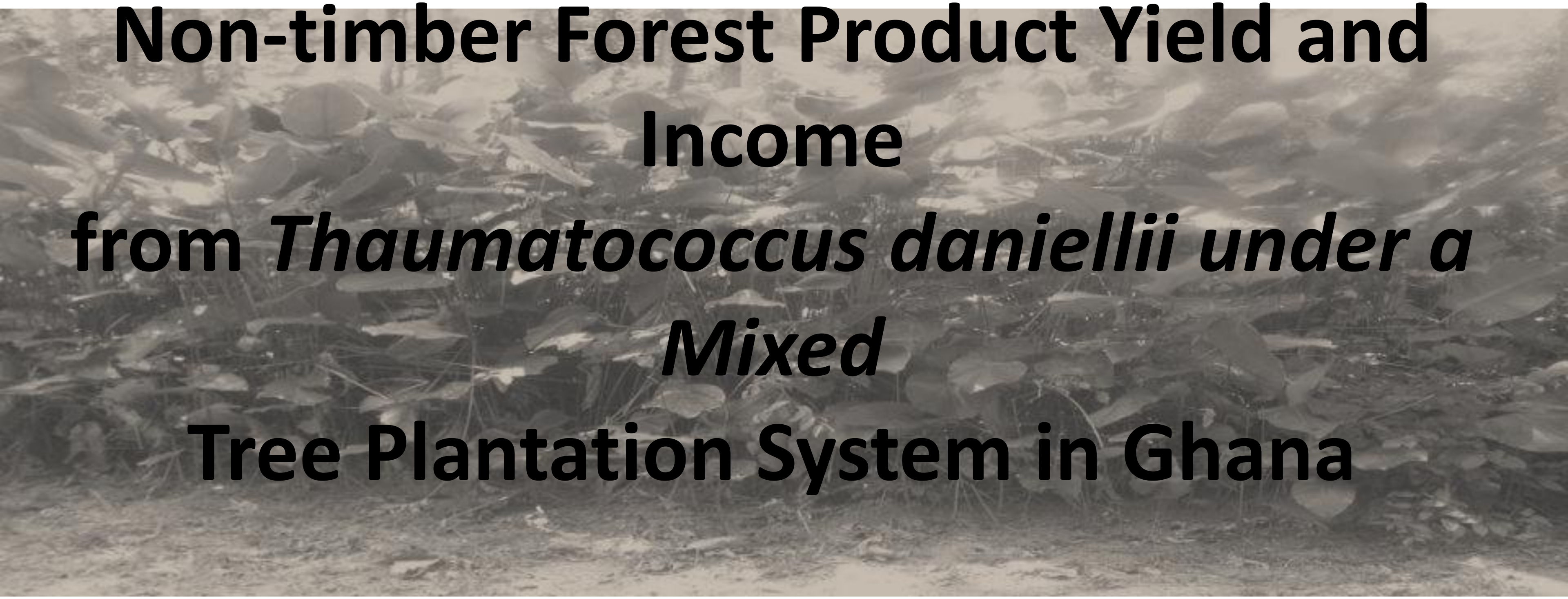
Non-timber Forest Product Yield and Income from *Thaumatococcus daniellii under a Mixed* Tree Plantation System in Ghana



Samuel Boadi[1], Francis Ulzen-Appiah
Department of Social Forestry, Faculty of Forest Resources Technology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana;

M. Baah-Acheamfour, Ghulam M. Jamro
Dept. of Renewable Resources, University of Alberta, 4-37 Earth Sciences Building, Edmonton, Alberta, T6G 2E3

Introduction

- Nontimber forest product (NTFP) exploitation has been recognized as potential alternative to forest management practices, such as clear-cut logging [Sunderland et al., 2004].

- With a strong market and long-term value accruing from the harvest of NTFPs, their economic benefits could override the short-term gains of converting forests to other land-uses such as timber and agriculture [Yeboah et al., 2003].

Introduction cont'd.

- *Thaumatococcus daniellii (Benn.) Benth., a* perennial wild understorey herb, is one of the promising NTFPs, whose economic potentials have not been fully exploited in most African countries, including Ghana.

- *Thaumatococcus daniellii* is harvested from the wild for its fruits, from which a protein based sweetener called thaumatin is extracted from the arils [Abbiw, 1990].

Introduction cont'd.

- Local people use thaumatin as sweeteners by licking the seeds to sweeten porridge or fermented palm wine [Ekpe and Ottou, 2006].

- Thaumatin is a recognized food additive and has potential in drug, confectionaries, and beverage manufacturing [Sunderland et al., 2004; Swift et al., 2002].

- Ekpe and Ottou [2006] reported that *T. daniellii* fruits were sold at \$0.50kg^{-1} in the local markets.

Plate 2 *Thaumatococcus daniellii fruits*

Introduction cont'd.

- The growing interest and increased demand for natural sweeteners and flavour enhancers, combined with existing international approval of thaumatin means the plant faces serious threat from massive harvest in secondary forests [Yeboah et al., 2003; Wojciech et al., 2005; Chieh, 2008].

- Fruit collection is reported to have provided employment to many people in Ghana [Ekpe and Ottou, 2006, Swift et al., 2002].

Introduction cont'd.

- Between 1990 and 2012, the total production of arils from *T. daniellii* in Cote d' Ivoire ranged from 10,250 kg to 25,600 kg. Given \$16 kg^{-1} as average price for frozen aril, this production earned between \$160,000 and \$400,000 annually in exports to the UK [Bonnéhin, 1997].

- Hence, there is an apparently untapped potential to improve rural livelihoods in West and Central Africa through cultivation of *T. daniellii* [Wojciech et al., 2005].

Problem statement

- The exploitation of *T. daniellii* exclusively from the wild has been reported to be neither sustainable nor meet industrial demand [Yeboah et al., 2003].

- Destruction of secondary forests due to poor harvesting techniques has led to yield reduction across its range and forces collectors to travel further into reserved forests to find adequate supplies of foliage and fruits.

Problem statement cont'd

- Massive fruits collection from primary forests may result in loss of food and habitat for the insects and rodents such as grass cutters (*Thryonorays swinderianus)* and rats of the forest floor [Ekpe and Ottou, 2006].

- Very limited attempts have been made to cultivate *T. daniellii*

Justification

- Despite both the foliage and fruits having great economic benefits, it is currently unknown to what extent defoliation will influence fruit production.

- This necessitates a study that could help to estimate the quantity of foliage that could be harvested at a time without adverse effects on fruiting.

- To date, the relationship between defoliation and fruiting with respect to *T. daniellii* stands is not well understood.

Objectives

- The objectives of this study were:

i. To determine the impacts of variable foliage harvesting on fruit yield (number and weight), flowering and specific leaf area of cultivated *T. daniellii* under mixed stands of seven agroforestry tree species in Ghana

ii. To determine the potential income that could be obtained by local farmers from leaf and fruit collection.

Hypotheses

We hypothesized that:

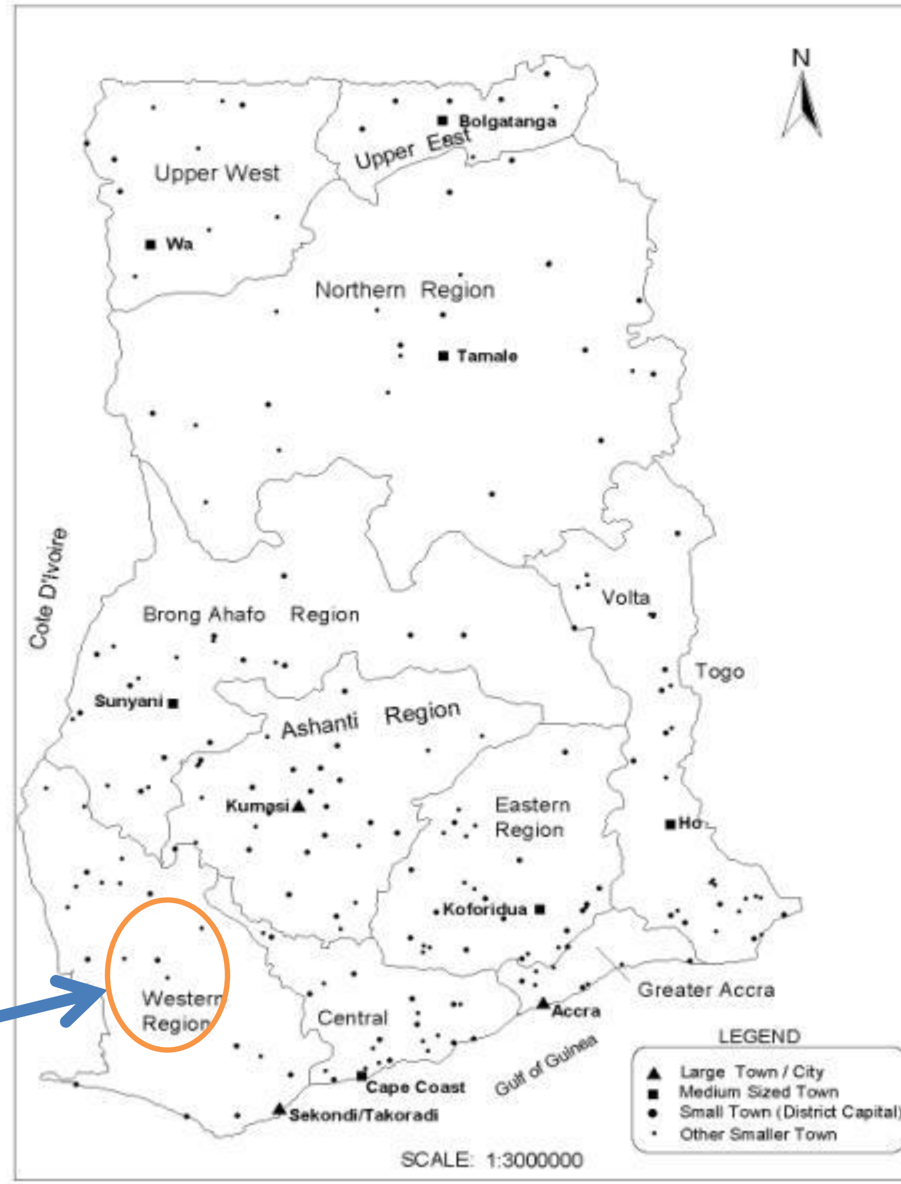
i. Controlled foliage harvests of *T. daniellii* will not reduce fruit yield (i.e., fruit number and fruit wet weight), flowering and stimulate compensatory growth with respect to specific leaf area

ii. The management of *T. daniellii* stands for both leaf and fruit collection will be more profitable in terms of gross income to local farmers as compared to sole fruit

Materials and Methods

Study Area and Site Description

The present study was conducted in Oda-Kotoamso (05° 52´ N; 02° 29´ W), a town located in the Western Region of Ghana (Figure 1).



Study Area and Site Description cont'd

- The area lies in the hot humid tropical rain forest zone with an annual rainfall between 1400 and 2000 mm.

- Experimental plots were laid in 6-year old established stands of *T. daniellii* under a uniformly spaced mixed stand of agroforestry trees.

Study Area and Site Description cont'd

- The tree stand, averagely aged 10 years, consisted of species including *Entandrophragma angolense, Ceiba petandra (L.), Milicia excelsa (Welw.), Terminalia superba (Engl.), Khaya ivorensis (Chev.), Khaya senegalensis* (Desr.), and *Antrocaryon micraster (Chev.).*

- *The average* crown diameter, diameter at breast height, and height of the trees ranged from2.0mto 17.0m, 0.12mto 0.45m, and 17.0m to 57.0 m, respectively.

Experimental Design

- The experimental set up was *a* randomized complete block design. There were four blocks and three foliage harvest treatments plus a control.

- There were total of 16 treatment plots each with a dimension 3m × 4m ($12m^2$) and were spaced 5m apart.

- To ensure homogeneity, treatment plots were situated within a perimeter defined by four different tree species.

Experimental Design

- *T. daniellii plants on each* plot were then thinned to uniform leave population of 142 (12 leaves/m^2) after which the treatments were imposed.

- Treatments involved harvesting leaves and maintaining a specified leaf population per plot out of 142 at 16 weeks interval.

- Harvest treatments imposed on the remaining 142 leaves were *T1 = no harvesting (control), T2 = 25% (36* leaves), *T3 = 50%(71 leaves), and T4 = 75% (106 leaves).*

Data Collection

- Data were collected on fresh weight of harvested foliage, fruit number, and fruit fresh weight over 64 weeks at 16 weeks interval.

- Number of flowers per treatment was monitored over 12 weeks at 3 weeks interval.

- For specific leaf area (SLA) determination, 10 uniformly sized leaves were harvested from each treatment plot at week 64.

Data Collection cont'd

- Average leaf area and dry matter per treatment were then calculated.

- Specific leaf area was determined according to [Gunn et al., 1999] as follows:

$$SLA = \frac{\text{Average leaf area } (cm^2)}{\text{Average leaf biomass } (g)} \qquad \textbf{[eqn. 1]}$$

Data Collection cont'd

- The total income from fruit sale (TFI) over 64 weeks was calculated as follows

TFI = Price per kg of fresh fruits × Total harvested fruits per treatment/ha [eqn. 2]

- Total leaf income (TLI) = Average price per kg leaf bundle × Total harvested leaves per treatment/ha [eqn. 3]

- Percent reduction in fruit (PRF) yield

$$PRF = 100\% - \frac{[\text{Total fruit yield for harvest treatment} \times 100]}{\text{Total fruit yield for control}} \quad [\text{eqn. } 4]$$

Statistical Analyses.

- *Analyses of Variance (ANOVA) by* SAS PROC MIXED procedure [SAS Institute, 2012] and Tukey's studentized ranged (HSD) test (P < 0.05) were used to compare the effect of different harvesting intensities on measured growth parameters.

- The assumption of normality and homogeneity of variance was assessed with the Kolmogorov-Smirnov test using the PROC UNIVARIATE procedure in SAS (data not shown).

- All data conformed to normal distribution. A Parametric Welch's ANOVA test was used to deal with nonhomogeneous variances in situation where data transformations do not help achieve variance homogeneity.

Results and Discussion

Effect of Foliage Harvest on *T. Daniellii* Growth.

- Foliage harvest significantly (P = 0.036) affected number of fruits.

- Fruit number decreased with increased foliage harvest intensity (Figure 2).

- Control stands produced the greatest number of fruits (11458/ha), but it was not different from that produced from the 25% foliage harvest (8958/ha).

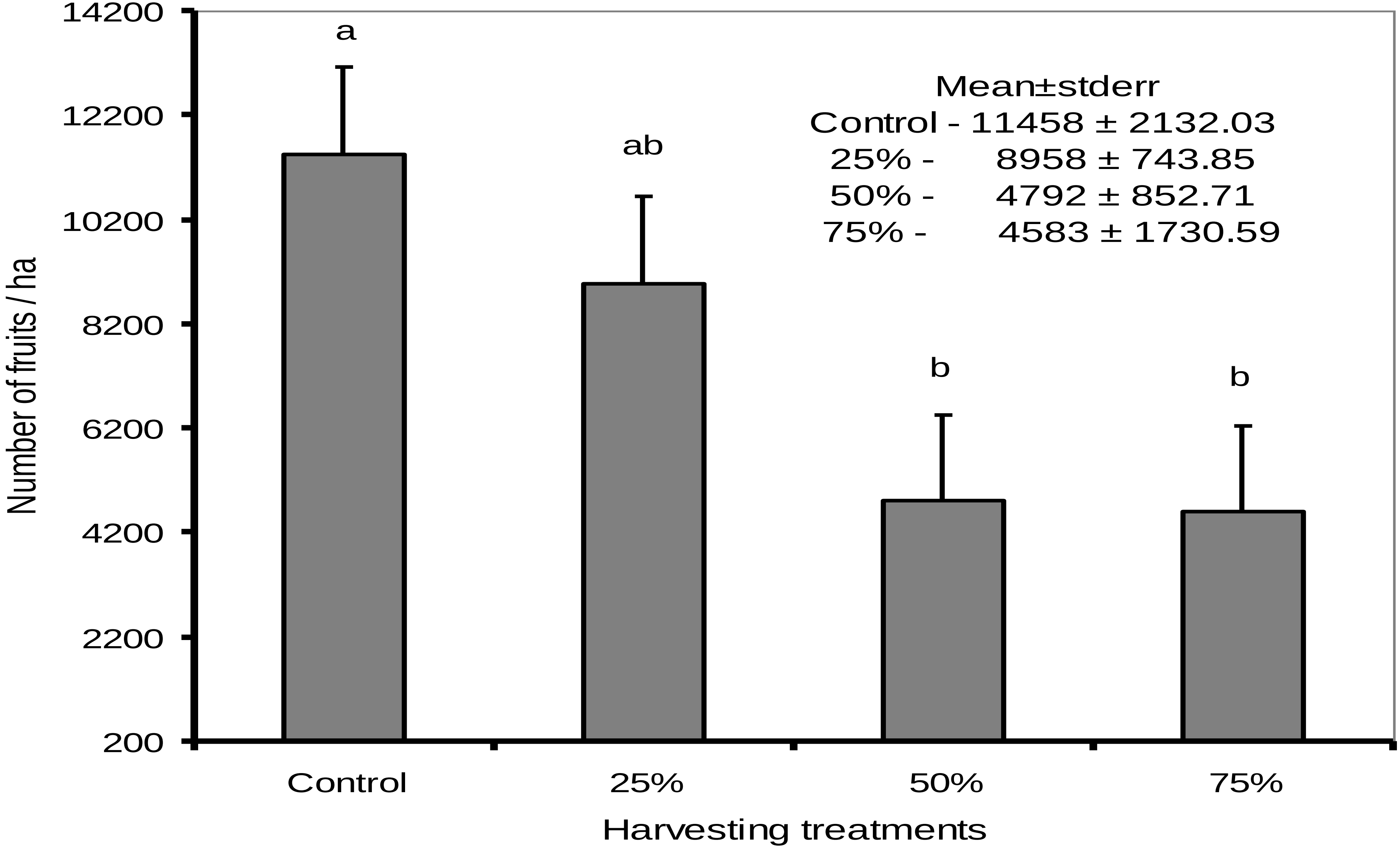


Figure 2: Effect of foliage harvest intensity on total fruit number of *T. daniellii* in the humid tropical rainforest zone of Ghana.

- However, the number of fruits produced from the control stands was significantly greater than what was produced from stands with 50% (4792/ha) and 75% (4583/ha) foliage removals.

- The pattern of fruit production showed that fruit number declined with time for all treatments except for the control which recorded a sharp increase at week 64 (Figure 3).

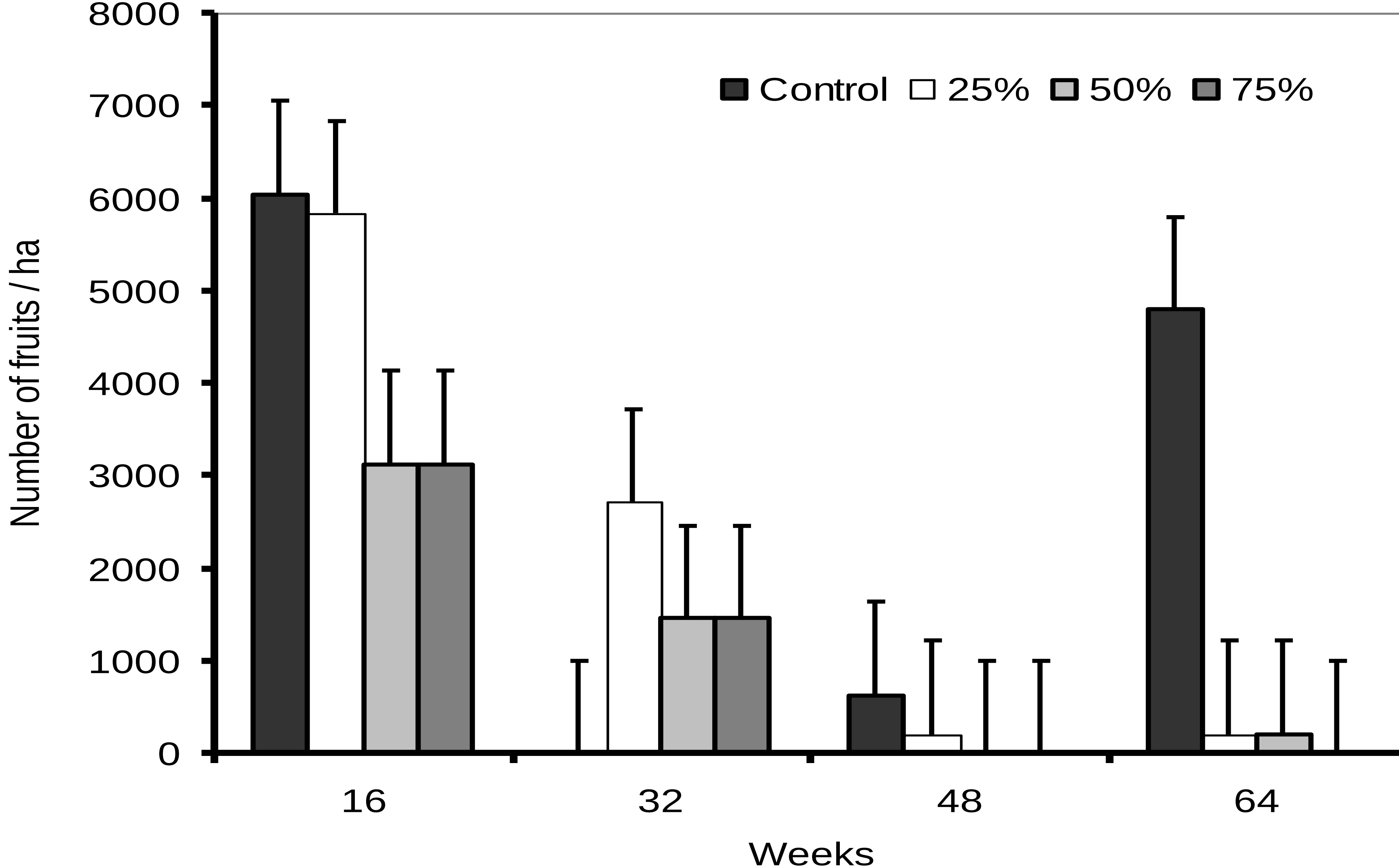


Figure 3: Total fruit number of *T. daniellii* in response to different foliage harvest intensities over 64 weeks.

- No significant difference (P = 0.163) was recorded among the different harvesting intensities in terms of overall weight of fruits produced (Figure 4).

- This result could imply that although control stands produced more fruits, the sizes of fruits could have been smaller than other harvested stands.

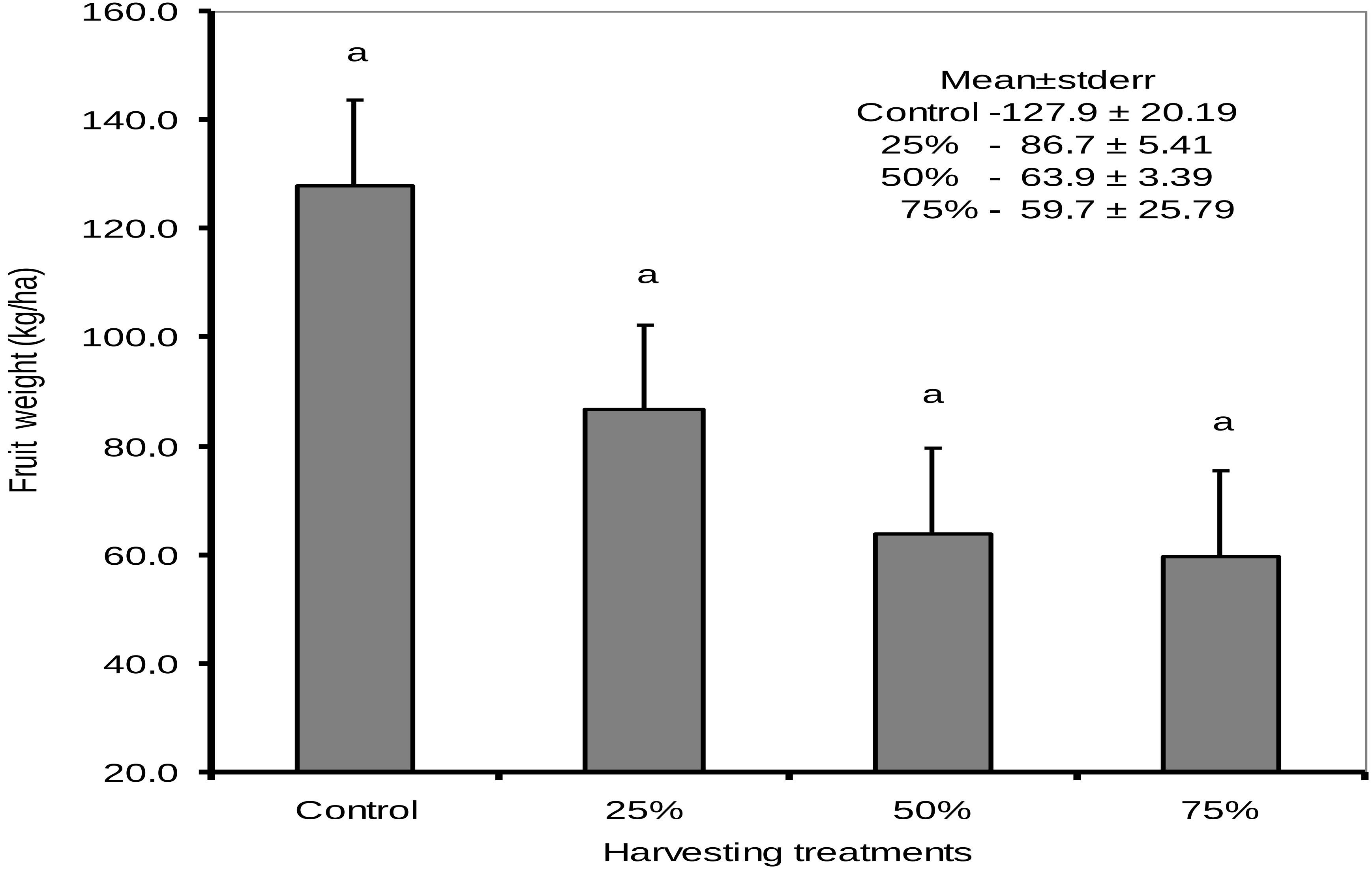


Figure 4: Effect of foliage harvest intensity on fruit weight of *T. daniellii.* Means (±SE)with similar letters do not differ significantly at 5% probability level.

- Harvesting of leaves may have a negligible effect on exploited plant population if

(i) individual plants survived the process;

(ii) a sufficient number of healthy leaves are left on each plant for photosynthesis;

(iii) the reproductive structures and apical buds are not damaged; and

(iv) sufficient time is allowed between successive harvests for the plant to produce new leaves [Ndangalasi et al.,2007].

- Collecting too many leaves from an individual plant can reduce the number of new ones and the number of flowers and fruits produced [Anderson, 1998].

- Although individual plants survived, biomass harvest may have reduced leaf population to the extent that only few matured leaves remained for photosynthesis.

- For *T. daniellii*, possible differences in fruit sizes could be due to increased demand to support dense populations.

- Hence, control stands, in addition to fruiting, could have also channelled more resources to support physiological activities of increased populations.

- Number of flowers significantly ($P < 0.001$) decreased with increased harvesting rate (Figure 5).

- Mean number of flowers recorded at week 64 was greatest for control (18 flowers) and lowest for 75% (no flower).

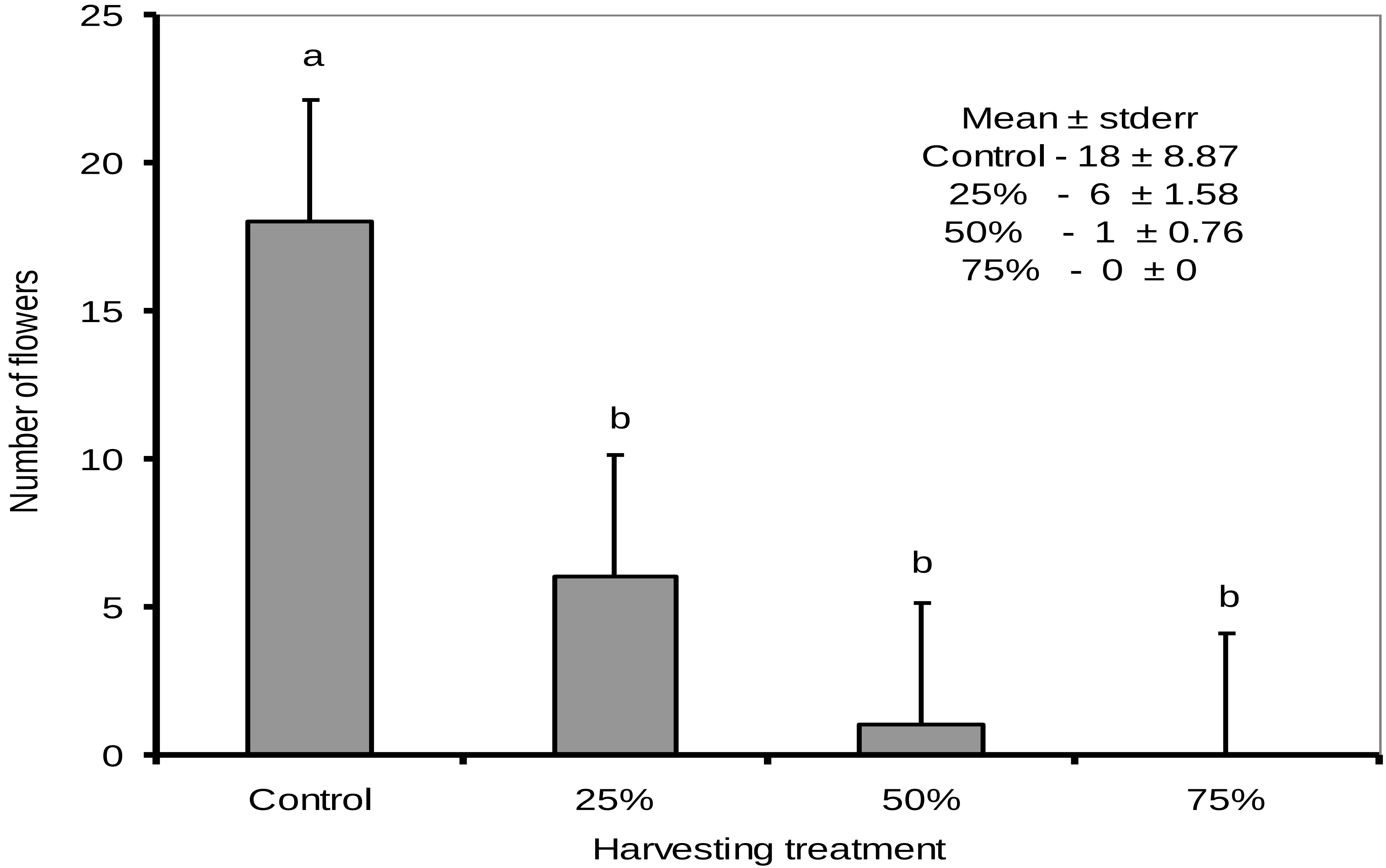


Figure 5: Effect of foliage harvest intensity on number of flowers of *T. daniellii.* Means (±SE) with similar letters do not differ significantly at 5% probability level.

- No significant (P = 0.498) differences were observed among harvest treatments with respect to SLA after 64 weeks.

- Specific leaf area ranged from 143.87 cm^2g^{-1} to 148.93 cm^2g^{-1} (Figure 6).

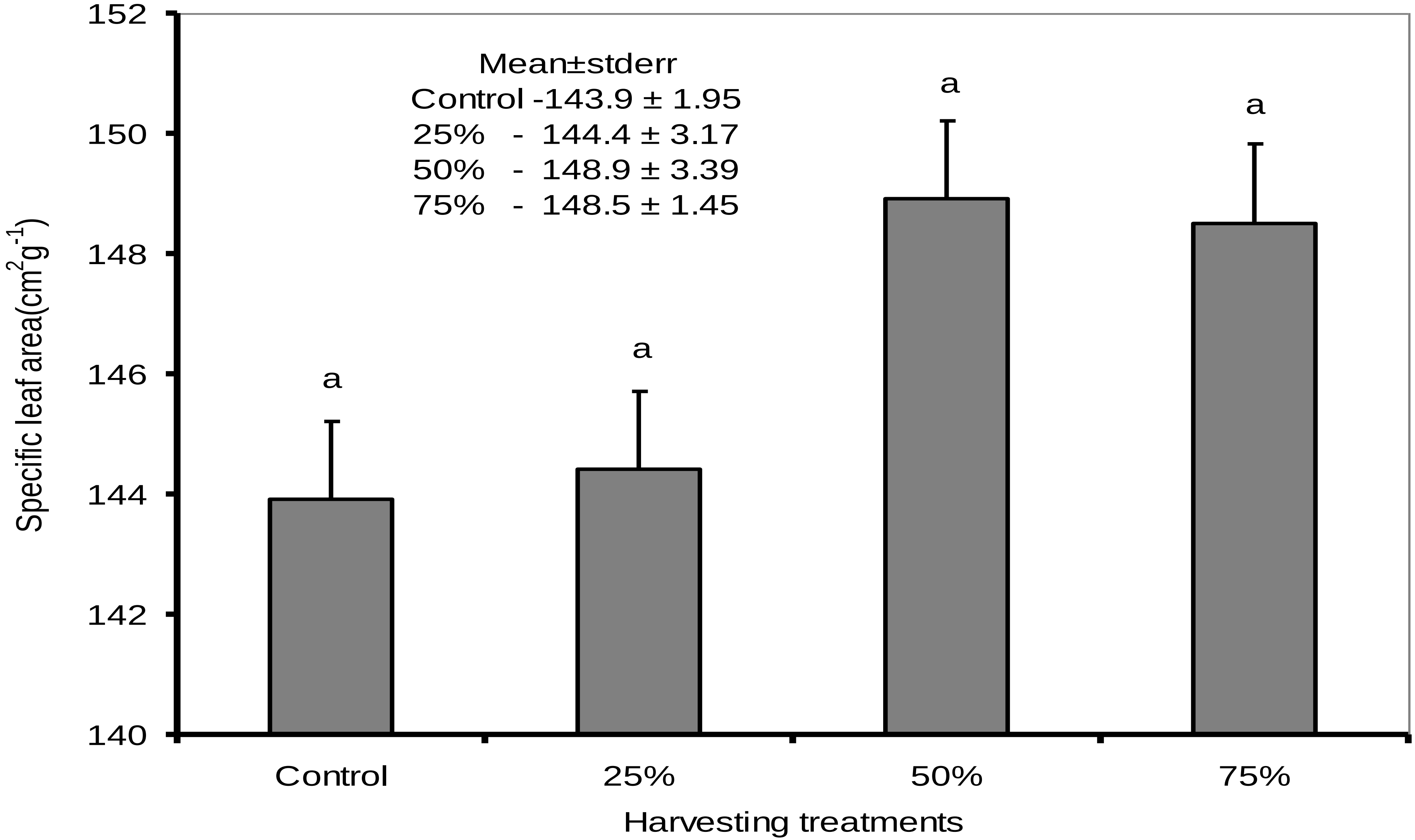


Figure 6: Specific leaf area response to *T. daniellii foliage harvest* intensity. Means (±SE) with similar letters do not differ significantly at 5% probability level.

Potential Incomes from Leaf and Fruit Harvest

- Generated income from fruit harvest increased with reduced foliage harvest intensity.

- Compared to the control which gave the highest fruit yield of 511.60 kg/ha and income of $107.44, there were 32.3%, 50.0%, and 53.3% reductions in fruit yields, respectively, for 25%, 50.0%, and 75% foliage harvest treatments.

Table 1. An estimated income from fruit and leave harvest of *T. daniellii* stands over 64 weeks

Foliage harvest intensity (%)	Total fruit weight (kg / ha)	Fruit income at $ 0.21 / kg	Total harvested leaf (kg / ha)	Leaf income at US $ 0.55 /kg	*Total income $ / ha
Control	511.60	107.44	0	0	107.44
25%	346.62	72.79	19,982.53	10,941.44	11,014.23
50%	255.64	53.68	31,298.75	17,137.64	17,191.32
75%	238.86	50.16	22,390.77	12,260.08	12,310.24

* Total income = Fruit income + Leaf income

Potential Incomes from Leaf and Fruit Harvest cont'd

- This could suggest that harvesting activities negatively impact on the fruiting of *Thaumatococcus daniellii* and cause a decline in incomes obtained from fruits as the degree of harvesting increases.

- Thus decreased incomes of \$72.79, \$53.68, and \$50.16 were obtained for 25%, 50.0%, and 75% foliage harvest treatments, respectively (Table 1).

Potential Incomes from Leaf and Fruit Harvest cont'd

- The highest leaf income of US $ 17,137.64 was obtained for 50% foliage harvest. This suggests that 50% leaf harvest of stands could be sufficient to sustain enough leaf production over an extended period of time.

- Leaf income from 75% harvest stands, US $ 12,260.08, was higher than US $ 10,941.44 from 25% harvest stands.

Conclusions

- The number of fruit per stand significantly decreased with increased foliage harvest. Therefore, we failed to accept the hypothesis that foliage harvest does not affect fruit number.

- Total fruit weight was not influenced by foliage harvest. Hence, we failed to reject the hypothesis that foliage harvest does not affect fruit weight.

Conclusions

- No significant differences in specific leaf area were obtained at week 64 for all treatments. This could indicate a high compensatory growth of *T. daniellii* in response to foliage harvest. Therefore, we failed to accept the hypothesis that foliage harvest does not stimulate compensatory growth.

Conclusions

- The study showed that management of *T. daniellii* for both leaf and fruit harvest could be more beneficial to local farmers as compared to fruit harvest only.
- Income from the sale of fruits and leaves was greatest for the 50% harvest, intermediate for 25 and 75% harvest, and lowest for the no harvest treatment.

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