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# Impact *of Calliandra calothyrsus* Fallow on Soil Fertility and Crop Yield in the Forest-Savannah Transition Zone of Cameroon

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**Abstract**
An experiment was carried out in farmers' fields in Kiki village for four consecutive years in order to investigate the effect of *Calliandra calothyrsus* Meissner planted fallow on soil fertility and maize yield improvement, as compared to natural fallow. Cluster Analysis (CA) grouped the experimental farms in two different soil series named series 1 (n=6) and series 2 (n=3), differentiated mostly with the organic matter content and exchangeable cations. After 12 months of Calliandra growth, tree height was 2.07 m and diameter at breast height 1.7 cm; but, with a relatively low biomass production (0.92 $t.ha^{-1}$ leaf and 1.6 $t.ha^{-1}$ wood biomass). Calliandra treatments significantly ($p<0.05$) increased pH, exchangeable bases and ECEC in both soils (at the end of experiment), as compared to natural fallow. Maize grain yield also increased significantly ($p<0.05$) every year under Calliandra treatment in the two soil series, producing 45% (series 1) and 55% (series 2) extra yield in the third year as compared to the first year.

**Keys words**: Biomass production, Calliandra growth, maize yield, planted fallow, soil chemical properties

**Résumé : Impact de la Jachère à *Calliandra calothyrsus* sur la Fertilité du Sol et les Rendements de Culture dans la Zone de Transition Forêt-Savane du Cameroun.**

Une étude a été conduite pendant quatre années consécutives dans neuf champs paysans à Kiki dans le but d'évaluer l'effet de *Calliandra calothyrsus* planté dans un système de jachère améliorée sur la fertilité du sol et les rendements de maïs. Les neuf champs ont été regroupés en deux séries en fonction de la matière organique et des bases échangeables ; série 1 (n=6) et série 2 (n=3). Douze mois après la mise en place, Calliandra avait atteint une hauteur de 2.07 m et un diamètre à hauteur de poitrine de 1.7 cm ; avec une biomasse relativement faible (0.92 $t.ha^{-1}$ de feuilles et 1.6 $t.ha^{-1}$ de bois). Malgré cette faible production de biomasse, Calliandra a augmenté de façon significative ($p<0.05$) le pH, les bases échangeables et la capacité d'échange cationique effective dans les deux séries de sol (à la fin de l'étude) comparé à la jachère naturelle. Chaque année, les rendements de maïs augmentaient aussi de façon significative ($p<0.05$) dans les parcelles de Calliandra dans les deux séries de sol. En troisième année, ces rendements ont augmenté de 45% et de 55% dans les séries 1 et 2 respectivement par rapport à la première année.

**Mots clés** : Production de biomasse, croissance de Calliandra, rendement de maïs, jachère améliorée, propriétés chimiques du sol.

## Introduction

Low crop yield was identified as a major problem during the diagnostic and design survey in the Mbam Division (NCRE, 1994). According to farmers of this forest-savannah transition zone, this problem is largely attributed to low fertility status of soils. For their subsistence food crop production, these farmers have long relied on shifting cultivation systems in which land clearing is by slash-and-burn practice and a long fallow period is used to restore soil fertility. But, as it has happened in many other parts of the tropics under shifting agriculture, rapid growth in population and land use pressure have led to a reduction of fallow duration below the minimum threshold required for the system' sustainability (Conway ,1997).
In the search for the alternatives to this slash-and-burn agriculture, improved fallow technology has been identified as one of the promising strategies (Brady ,1996). Under controlled and high management conditions of research stations, the technology has shown to improve soil fertility and sustain crop yields (Kaho *et al., 2004*; Kanmegne *et al* 2003). However, very few field experiments on planted fallow have been carried out under farmer's field conditions in the forest-savannah transition zone of Cameroon.
This study was therefore conducted in farmers' fields in Kiki village with the objective to assess the potentials of *Calliandra calothyrsus* planted fallow to improve soil fertility and crop yield in this transitional ecosystem.

## Materials and methods

### *The study site*

The study was conducted at Kiki, a village of the Bafia Sub-division, Centre Cameroon. Geographically, the site is situated $4^{o}38'$ N and $11^{o}33'$ E, in the forest-savannah transition zone. The average altitude is 500 m above sea level. The rainfall distribution shows a bimodal pattern with annual average between 1200 to 1500 mm.. The soils are highly weathered and grouped under Ultisols

### *The experiment implementation and management*

In March 1999, the trial was established on nine farms with *Calliandra calothyrsus* seedlings at 4 m x 0.25 m. The experiment was made of two treatments (T1= a *Calliandra* tree plot and T2= a control plot with natural fallow vegetation) and each farm representing a replication. The plot size was 12 m x 16 m.
Data were collected on trees at three months interval till 12 months after seedlings planting. After 12 months, the trees were all pruned at 5 cm above the ground level. Biomass was then separated into wood and leaf material. The biomass of the natural fallow plot was estimated in four 1 x 1 m quadrates where all the weeds and litter were collected, weighed in the field and a sub-sample taken for estimating the dry weight biomass. Afterwards, the two plots (T1 and T2) were cleared and the vegetation incorporated into the soil prior to maize seeding.

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Estimating the biomass dry weight mass, slashed wood, leaf biomass and natural fallow vegetation were weighted separately and sub-samples of 300 g were collected and oven-dried at 60$^{o}$c for 24 hours until constant weight.
For three consecutive years, maize (variety CMS 8704) was sown (at the first growing season starting mid-March) between the Calliandra alleys at 0.75 m inter and 0.5 m intra row spacing. At maturity, maize plant from 8 m x 8 m plot was harvested by hand and maize grain yield adjusted to 15% moisture content.

*Soil sampling and laboratory analyses*

Composite soil samples were taken in each farm (from five spots on the diagonals) within 0-15 and 15-30 cm depths to determine the base-line fertility status of the trial sites at the beginning of the experiment. At the end of the third-year of maize cropping, composite soil samples were similarly collected in each farm per treatment. All the soil samples were analysed in the IRAD soil and plants laboratory at Nkolbisson (Yaounde) for pH, organic C, total N, exchangeable cations (Ca, Mg, K, Na, Al, H) and available P. The methods used to determine these elements are described in Anderson and Ingram (1993).

*Statistical analysis*

Descriptive statistics, analysis of variance (ANOVA) and means separations (Turkey' HSD methods) were used to describe the data on tree growth, biomass production, soil characteristics and maize yields.
To evaluate the comparability of the nine farms from their base-line fertility status, 10 soil variables determined from the two soil depths at the beginning of the experiment were used to perform an agglomerative hierarchical cluster analysis (CA) based on Ward's grouping method and correlation matrix (Webster and Oliver, 1990).

## Results and discussion

*Comparability of the nine experimental farms*

Cluster analysis (CA) has been successfully applied in soil survey to create classes within which the members are generally alike and substantially different from the members of the other classes ( Webster and Oliver, 1990; Yemefack *et al.*, 2005). The aim is to statistically minimize within-group variability while maximizing among-group variability, in order to produce relatively homogeneous groups. We used a hierarchical numerical classification system to reveal the various levels of similarities and allow a variable number of groupings of the nine farms.
Fig. 1 shows the dendrogram resulting from the application of Ward's method on the correlation matrix of 10 soil parameters collected in two topsoil depths. The nine farms were aggregated in two main groups at the highest level: one group (soil series 1) with six farms and another group (soil series 2) with three farms. Further subdivisions occurred within the two groups at the lower dissimilarity levels; however these subdivisions show little differentiation and are hard to separate. This may suggest that management practices are the underlying factors of differentiation between these topsoil classes. However, the grouping of these farms also correlates with their spatial distribution in the study area as observed in the field; meaning that we are likely dealing with two different soil series.

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Based on this result, we further considered the two soil series separately for comparison in soil properties and crop yields.

**(insert Fig. 1)**

*Tree growth and biomass production*

Despite the grouping of the experimental farms in two groups by cluster analysis, Calliandra growth characteristics did not show any significant difference between the nine experimental farms. Consequently, all the farms were here analysed in a single set. Fig. 2 shows the results of C*alliandra* growth characteristics at each of the three-month intervals. After 12 months, tree height and stem diameter were 2.07 m and 1.8 cm respectively**.** The species produced in average 0.92 $t.ha^{-1}$ leaf biomass and 1.63 $t.ha^{-1}$ wood biomass. However, under optimum conditions, (rainfall of 2000 to 4000 mm/year, fertile soils), *Calliandra* is reported to grow to a height of 4 m with a diameter of 3.3 cm and produce 5.2 and 19.2 $t.ha^{-1}$ of leaf and wood biomass respectively in one year (Chamberlain, 2001). This is far greater than the current results. Plant height and stem diameter increments are considered good indicator for sites conditions. Their low values in this case are likely to support the farmers' view about the poor climatic and soil conditions of the area. Rainfall ranging between 1200-1500 mm/year is also a limiting factor. The two factors may probably justify the slower growth of the species at this site. In similar environment, Kanmegne et al. (2003) reported that total height and stem diameter of Calliandra were 2.81 m and 2.09 cm respectively at age 12 months, corroborating the results of this study.

**(insert Fig. 2)**

*Effect of treatments on soil chemical characteristics*

Table 1 presents the results of ANOVA by treatments applied to the two soil series in the two soil depths. Exchangeable cations and pH showed to be the most sensitive soil variables to these treatments; with significant probabilities ($p<0.05$) in both soil series at the two soil depths. Organic carbon and available P were only marginally sensitive to these treatments. Although we are here dealing with a different cropping system, these results are more or less similar to that of Yemefack et al (2005) who showed that pH, Ca, available P and organic carbon (in decrease order) were the most sensitive soil chemical properties to slash-and-burn agriculture in humid forest zone of Cameroon. However, without the practice of burning Ca was less sensitive under our treatments, while total exchangeable bases (TEB), effective cation exchange capacity (ECEC) and pH appeared to be the most dynamics soil properties.

In soil series 1, TEB and ECEC were significantly ($p<0.05$) higher under Calliandra plots than the control at the beginning of the experiment at 0-15 cm depth. In soil series 2 that was previously rich in organic matter and exchangeable cations, the TEB an ECEC decreased significantly ($p<0.01$ and $p<0.05$ respectively) after three years of cropping at both depths under both Calliandra and control plots compared to the initial values. Similar decrease in TEB and ECEC in soil under agroforestry system have been reported by Kaho et al (2004) in Centre Cameroon.

Exchangeable Mg was significantly ($p<0.001$) very low in both treatments (T1 and T2) at the end of the experiment in the two soil series. Similarly, was exchangeable K in soil series 2 at both depths. With this decrease in Mg and K under both Callinadra and natural

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fallow plots after cultivation, we agreed with Iwafor and Kumar (1995) that, under intensive cropping, Mg deficiency may become a limiting factor to crop production. The most striking here was the significant ($p<0.05$) increase of total acidy (TA) correlatively with the increase in pH under Calliandra treatment. We would have expected a TA decrease with the increase of pH. At the moment, we have no explanation to this.

**(insert Table 1)**

*Effect of treatments on maize grain yield*

Fig. 3 shows the results of maize yields during the three years cropping on each treatment. The general trend shows that soil series 2 produced higher yield than soil series 1 in all the treatments. The average production between the three cropping years clearly shows the discrepancy between soil series 1 and 2: 1914 vs. 1288 $kg.ha^{-1}$ for Calliandra treatments and 1558 vs. 907 $kg.ha^{-1}$ for Natural fallow treatment respectively. Natural fallow treatment did not show any positive change in maize yield during the three years of cropping in both soil series. On the contrary, Calliandra treatment showed a consistent increase of maize yield during the three years cropping on both soil series. Here again soil series 2 showed much significant ($p<0.05$) yearly increase in maize yield than soil series 1; with a relative yield increase of 55% and 45% respectively between the first and the third cropping.

The significant increase in maize grain yield with continuous cropping under the Calliandra treatment indicates that the effect of Calliandra-leaf mulch was not only immediate, but also accumulative over the seasons. Improved fallow treatment was then efficient as resulting from accumulative residual effects from the previous years. This suggests that the synchronisation process of nutrients release from pruning and plant uptake should play an important role for more efficient use of pruning in this technology. Indeed, the absence of significant effect of treatment on nitrogen and the resulting increase in crop yield imply the influence of a synchronisation process by which nitrogen release from plant biomass mineralization was immediately use for crop growth. That is what justifies the observed effect of Calliandra-leaf on maize grain yield on these soils with very low N content. It is also well known that nitrogen deficient soils are more likely to response well to tree fallow ( Kang, 1997). This is supported by the study in forest zone of Cameroon where Kanmegne et al. (2003) found significantly higher maize grain yield from planted fallow plots as compared to natural fallow plots.

*Farmer evaluation of the technology*

The informal discussions with farmers after three years of Calliandra fallows indicated a strong interest showed by farmers in the technology. The number of Calliandra fallow increased from 9 to 25 in 2001 and 42 in 2002. The majority of farmers valued the improvement of soil fertility and increased yield in the tree plots as major benefits. Weed suppression, production of stakes, fuel wood, and the possibility of keeping bees as added advantages were also rated by the farmers. Thus, with time farmers realized that the technology also provides secondary benefits which were not apparent in the first plan when the system is tested. However, farmers complained of inappropriate equipments (tools), excess labour and too much time required to respect the 30 cm height compared to traditional system where slashing is done at ground level. Kanmegne and Degrande (2002) observed a similar trend in farmers adoption and adaptation of planted fallow in the humid forest zone of Cameroon.

## Conclusion

Despite the low productivity of *Calliandra calothyrsus* under the environmental conditions of our experimental site, the study has shown that planted fallow with *Calliandra calothyrsus* resulted in a build up of soil fertility and a significant increase in maize grain yield as from the first year of continue cropping and onwards. However, the short duration of the experiment could not allow quantify thresholds on the extent and rates of this effect.

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**Table 1:** Comparing soil properties changes between treatments at the end of the experiment within the two soil series

| | OC | TN | Av. P | pH water | K | Mg | Ca | TEB | TA | ECEC |
|---|---|---|---|---|---|---|---|---|---|---|
| | (%) | (%) | (ppm) | | ----------------Cmol.kg$^{-1}$---------------------- | | | | | |
| | | | | **0-15 cm** | | | | | | |
| *Soil Series 1 (n=6)* | | | | | | | | | | |
| Begin Experiment | 0.71 | 0.039 | 2.89 | 5.42 a | 0.13 | 0.69 a | 0.96 | 1.79 ab | 0.05 | 1.85 ab |
| Planted Calliandra | 0.80 | 0.043 | 2.38 | 6.37 b | 0.16 | 0.22 b | 1.48 | 1.97 a | 0.12 | 2.09 a |
| Natural fallow | 0.66 | 0.035 | 1.95 | 6.01 b | 0.12 | 0.16 b | 0.83 | 1.20 b | 0.15 | 1.35 b |
| SE | 0.05 | 0.003 | 0.38 | 0.15 | 0.02 | 0.07 | 0.19 | 0.22 | 0.03 | 0.21 |
| Probability p | 0.130 | 0.270 | 0.243 | 0.001 | 0.379 | 0.000 | 0.069 | 0.046 | 0.122 | 0.049 |
| *Soil Series 2 (n=3)* | | | | | | | | | | |
| Begin Experiment | 0.90 a | 0.075 | 4.35 | 5.42 a | 0.24 a | 1.31 a | 1.69 | 3.32 a | 0.02 a | 3.34 a |
| Planted Calliandra | 1.10 b | 0.092 | 4.22 | 6.07 b | 0.21 ab | 0.25 b | 1.33 | 1.96 b | 0.17 b | 1.81 b |
| Natural fallow | 0.91 a | 0.077 | 2.61 | 5.83 a | 0.16 b | 0.23 b | 1.18 | 1.64 b | 0.16 b | 1.78 b |
| SE | 0.03 | 0.018 | 0.70 | 0.11 | 0.02 | 0.14 | 0.14 | 0.28 | 0.04 | 0.28 |
| Probability p | 0.004 | 0.778 | 0.226 | 0.017 | 0.047 | 0.002 | 0.051 | 0.009 | 0.049 | 0.013 |
| | | | | **15-30 cm** | | | | | | |
| *Soil Series 1 (n=6)* | | | | | | | | | | |
| Begin Experiment | 0.71 | 0.038 | 2.33 a | 5.40 a | 0.14 | 0.64 | 0.89 | 1.70 | 0.05 a | 1.75 |
| Planted Calliandra | 0.75 | 0.042 | 1.58 ab | 6.02 b | 0.11 | 0.41 | 1.13 | 1.74 | 0.14 b | 1.89 |
| Natural fallow | 0.69 | 0.038 | 1.26 b | 5.88 b | 0.09 | 0.14 | 0.79 | 1.13 | 0.18 b | 1.31 |
| SE | 0.05 | 0.004 | 0.23 | 0.09 | 0.02 | 0.15 | 0.15 | 0.24 | 0.02 | 0.23 |
| Probability p | 0.076 | 0.797 | 0.013 | 0.000 | 0.253 | 0.104 | 0.282 | 0.161 | 0.004 | 0.220 |
| *Soil Series 2 (n=3)* | | | | | | | | | | |
| Begin Experiment | 0.81 | 0.052 | 4.017 | 5.47 | 0.29 a | 0.91 a | 1.85 a | 3.10 a | 0.02 a | 3.27 a |
| Planted Calliandra | 0.96 | 0.080 | 2.74 | 5.77 | 0.16 b | 0.20 b | 1.06 b | 1.48 b | 0.25 b | 1.71 b |
| Natural fallow | 0.84 | 0.075 | 2.10 | 5.94 | 0.12 b | 0.19 b | 0.87 b | 1.23 b | 0.17 b | 1.38 b |
| SE | 0.06 | 0.017 | 0.69 | 0.13 | 0.02 | 0.18 | 0.09 | 0.24 | 0.04 | 0.25 |
| Probability p | 0.212 | 0.499 | 0.216 | 0.105 | 0.003 | 0.043 | 0.001 | 0.003 | 0.013 | 0.006 |

Keys: OC=organic carbon; TN= total nitrogen; Av. P =available phosphorus; TEB= total exchangeable bases; TA=total acidity; ECEC= effective cation exchange capacity; SE = Standard error of the mean;
Means in the same column followed by different letters are significantly different at the level shown by the probability p.

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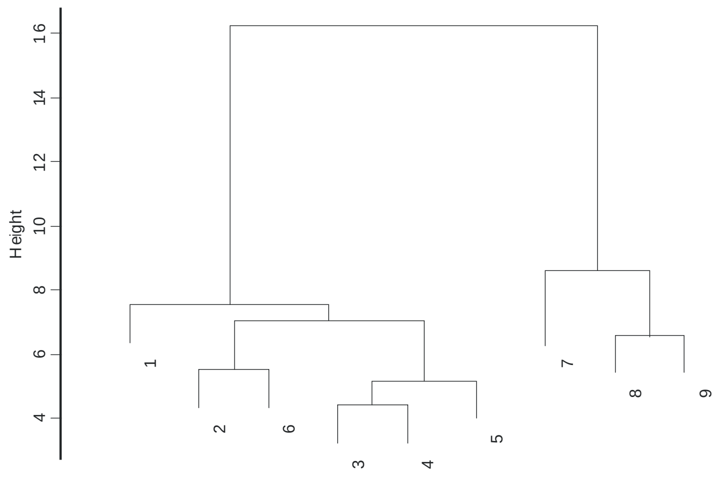


**Figure 1**: Dendrogram of the nine experimental farms grouped based on 12 soil parameters measures at two topsoil depths.

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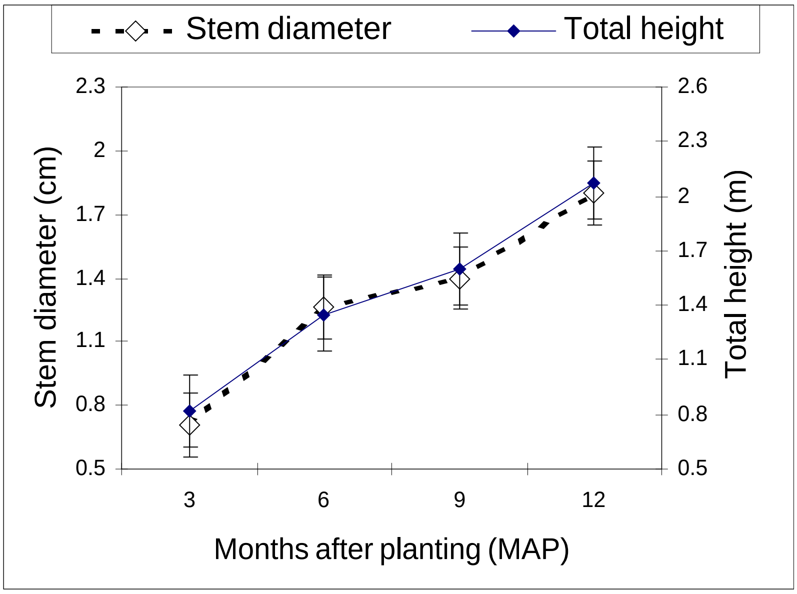


**Figure 2**: Mean stem diameter (in cm), mean height (in m) of *Calliandra calothyrsus* at Kiki, Cameroon.

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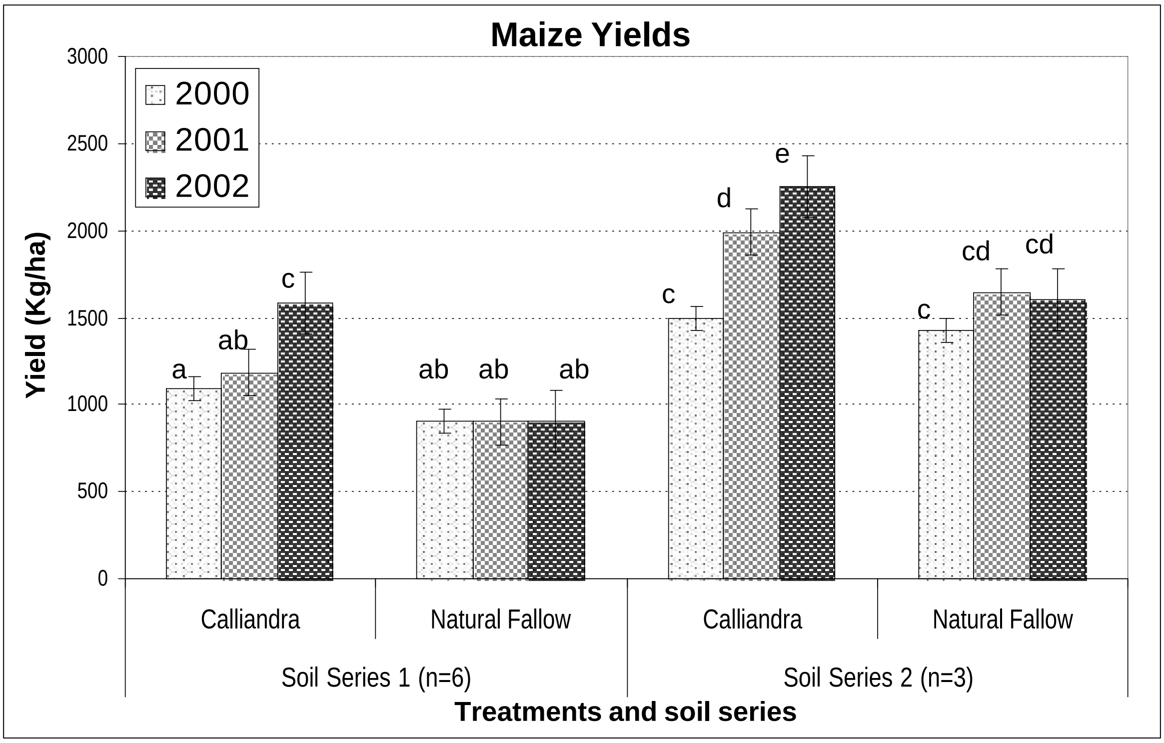


**Figure 3**: Maize grain yields by treatments and soil series for the three consecutive years. Vertical line-bars show the standard error of the mean. Yields with the same letter are not significantly different at $p<0.05$.

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