Growth and nutrient uptake of mangosteen grown under shade levels[1,2]

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ABSTRACT

Mangosteen is a tropical fruit with great economic potential. The major impediment to the development of a mangosteen industry is the long prebearing stage that seedlings require to produce fruits. There is little information regarding optimum nursery practices to enhance growth and development of mangosteen seedlings. Two experiments were conducted to determine the effect of various shade and fertilizer treatments on growth of young mangosteen plants. Each experiment lasted 22 months from transplanting to harvest. Seedlings were grown under 0, 30, 50, 70 and 90% artificial shade and received 3, 6, and 9 g per pot of a 15-4.8-10.8% (N-P-K) commercial fertilizer mixture at three, eight and 15 months after planting. Plants grown under 50% shade and supplied with 9 g of fertilizer accumulated significantly more dry matter, had thicker stems, grew taller and developed a larger leaf area. Plants grown under full sunlight grew little or died.

Key words: mangosteen, shade, nutrition, dry matter

RESUMEN

Crecimiento y absorción de nutrientes en mangostín crecido bajo niveles de sombra

El mangostín es una fruta tropical con gran potencial económico. Sin embargo, su producción comercial es limitada debido al largo período juvenil que necesita antes de producir frutas por primera vez. Hay muy poca información sobre las mejores prácticas agronómicas para acelerar el crecimiento y desarrollo de plántulas de mangostín. Se establecieron dos experimentos de 22 meses de duración cada uno para determinar el efecto de varios niveles de sombra artificial y fertilización en el crecimiento de plántulas de mangostín. Las plántulas fueron crecidas bajo 0, 30, 50, 70 y 90% sombra y recibieron 3, 6 y 9 g por tiesto de un abono comercial con análisis 15-4.8-10.8% (N-P-K) a los tres, ocho y 15 meses después de la siembra. Las plántulas crecidas bajo 50% de sombra y fertilizadas con 9 g de abono acumularon una cantidad significativamente mayor de materia seca, desarrollaron tallos más gruesos y crecieron más altas que las plántulas con los otros tratamientos. Plantas crecidas a pleno sol apenas se desarrollaron o murieron.

Palabras clave: mangostín, siembra, nutrición, materia seca

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INTRODUCTION

Mangosteen (*Garcinia mangostana* L.) is a tropical fruit of attractive shape and color with excellent flavor. It has great economic potential and is often referred to as "Queen of Fruits" or "the finest fruit of the world." The species belongs to the Clusiaceae family and is believed to be a hybrid between *G. hombroniana* and *G. malaccensis* (Kanchanapoom and Kanchanapoom, 1998; Rao and Ramathao-Rao, 1998). The tree is strictly tropical in climate and soil requirements as it does not tolerate temperatures below 5°C, nor does it adapt to limestone or sandy soils.

There are no known commercial clones of mangosteen. The preferred method of propagation is by seed, which are recalcitrant (Doijode, 2001). Because the seeds are formed from nucellar tissues, they produce apomictic seedlings that when fully grown are identical to the parent tree (Tinggal, 1992). A major impediment to the development of a mangosteen industry is the long pre-bearing stage (8 to 15 years) that seedlings take to bear fruits (Wiebel et al., 1992). The authors have attempted with mixed results to enhance mangosteen growth by grafting it onto closely related species. Nursery practices to stimulate faster plant growth include enriching the atmosphere with CO_2, applying plant growth regulators, and inoculating roots with arbuscular mycorrhiza, all of which have shown mixed results (Masri and Azizah, 1998; Wiebel et al., 1992; Downton et al., 1990). This paper presents results of a study directed at enhancing growth of mangosteen seedlings through fertilization and shading.

MATERIALS AND METHODS

Two experiments were established, 16 December 1997 (year 1) and 23 July 2001 (year 2), at the Tropical Agriculture Research Station, Mayagüez, Puerto Rico. The 30-yr mean monthly maximum and minimum temperatures are 31.7 and 19.9°C. Mangosteen seedlings at the four-leaf stage with an average height of 8 cm were planted in Tall-One Treepots[5] (Hummert International, Earth City, MO) at the rate of one seedling per pot. Pots were 34.5 cm tall, 10 by 10 cm at the top and 8 by 8 cm at the pot base. Each pot was filled with a mix containing equal parts of a clay loam soil and Pro-Mix BX® having the following chemical characteristics: pH, 7.16; organic carbon, 4.63%; total N, 0.16%; P, 50 µg/

[5]Mention of trade names or commercial products in this manuscript is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the USDA-ARS or by the Agricultural Experiment Station of the University of Puerto Rico.

g; K, 227 µg/g; Ca, 2,790 µg/g; and Mg, 779 µg/g. Shade treatments were provided by covering 93- × 93- × 114-cm cages with black DeWitt® knitted shade cloth providing 0%, 30%, 50%, 70% and 90% shade. These shade treatments admitted 1,950; 1,330; 830; 350; and 240 µmol photons m^2/s, respectively, at noon on a clear day. Cages were spaced 80 cm apart and arranged in a randomized complete block design with five replications in experiment 1 and three in experiment 2. Each replication contained five shade treatments (main plots) that were split to accommodate three fertilizer levels (subplots). There were three rows per main plot, each with four experimental plants per fertilizer treatment.

Fertilizer treatments consisted of applying either 3, 6, or 9 g/pot of 15-4.8-10.8% (N-P-K) Osmocote Plus® fertilizer (Scotts-Sierra, Co., Marysville, OH) at three, eight, and 15 months after establishing the experiments. Each experiment lasted 22 months.

Stem diameter at 6 cm from soil, plant height, leaf length and width for each plant were determined in each experiment approximately every three months. A regression equation similar to that used by Goenaga et al. (1991) was developed prior to the initiation of this study to non-destructively estimate leaf area of mangosteen plants during the experimental period. For this purpose, measurements of leaf length and width were recorded for 175 leaves picked at different stages of development. Immediately after measurement recording, leaf area was measured with a LI-3100 area meter (LI-COR, Inc., Lincoln, NE). The best-fit curve [$Y = 0.19142 + 0.71697(x)$, $r^2 = 0.98$, $p \leq 0.05$] was determined by using the GLM procedure of the SAS System (SAS Inst., 1987). The independent variable (x) was defined as the product of leaf length × width.

At the end of each experimental period, plants in the subplots were removed from pots, washed and divided into leaves, stems and roots. Samples were oven-dried to constant weight at 70°C for dry matter determination. The dry samples were ground to pass a 1.0-mesh screen and analyzed for N, P, K. Nitrogen was determined by the micro-Kjeldhal procedure (IBSNAT, 1987); P by the molybdovanado-phosphoric acid method (IBSNAT, 1987); and K by atomic absorption spectrometry (Perkin-Elmer, 1994). Analyses of variance and best-fit curves were determined by using the GLM procedure of the SAS System (SAS Institute, 1987). Only coefficients at $p \leq 0.05$ were retained in these models.

RESULTS AND DISCUSSION

Dry Matter Production and Partitioning

Shade and fertilizer treatments as well as the shade x year interaction showed highly significant ($P \leq 0.01$) effects on leaf, stem, root and total dry weight (analysis of variance not shown); therefore, these data were analyzed separately by year. Overall, higher dry weights were attained when plants were grown under 50% shade in both years regardless of fertilizer level (Figure 1). Averaged over fertilizer levels, regression-predicted values for total dry weight of plants grown under 50% shade were 96, 72, 71 and 84% higher than when grown at 0, 30, 70 and 90% shade, respectively, in year 1; and 99, 25, -5 and 12% higher in year 2 (Figure 1). Regardless of fertilizer treatment and year, plants grown under full sunlight (i.e., 0% shade) produced insignificant amounts of dry matter as compared to plants grown under various levels of shade. Mangosteen has been identified as a shade-tolerant tree (Nakasone and Paull, 1998; Wiebel et al., 1992), all of which explains the little adaptation this crop has for high photon fluxes (PPF) encountered under full sunlight conditions. Prolonged periods of high PPF have resulted in photoinhibition of *Xanthosoma* spp., another shade-tolerant crop (Valenzuela et al., 1991).

For all shade levels and fertilizer treatments, plants allocated the greatest percentage of their total dry matter to leaves (Figure 2). Averaged over fertilizer treatments, leaves of plants grown at 30, 50, 70, and 90% shade accounted for about 58% of the total plant dry matter in year 1. A similar response was obtained for year 2 (Figure 2). Following leaves, plants allocated more dry matter to stems and then to roots, regardless of shade level or fertilizer treatment. However, in contrast to that of leaves, the partitioning ratio declined significantly for stems and roots with increases in shade levels.

Nutrient Content

Year and the year × fertilizer interaction had no significant effect on total plant N, P, K content, leaf area, plant height or stem diameter; therefore, these data were averaged over years. Regardless of shade level, higher total N, P, K content was found in plants supplied with 9 g of fertilizer (Figure 3). All nutrients, particularly N, were taken up in greater amounts by plants grown under 50% shade. Plants grown at this shade level absorbed 37, 30, and 32% more N, P, K, respectively, when supplied with 9 g of fertilizer than with 6 g (Figure 3).

Applying 9 g of fertilizer had the greatest effect on plants grown under 50% shade. In these plants, total dry weight increased by 19 and 60% when compared to plants that received 3 and 6 g of fertilizer, respectively, in year 1; and by 17 and 55% in year 2 (Figure 1). Plants grown at shade levels above or below 50% did not benefit from the application of 9 g of fertilizer (Figure 1). Plants supplied with 9 g of fertilizer and grown under 50% shade also had the greatest leaf area, plant height and stem diameter (Figure 4). These plants developed a

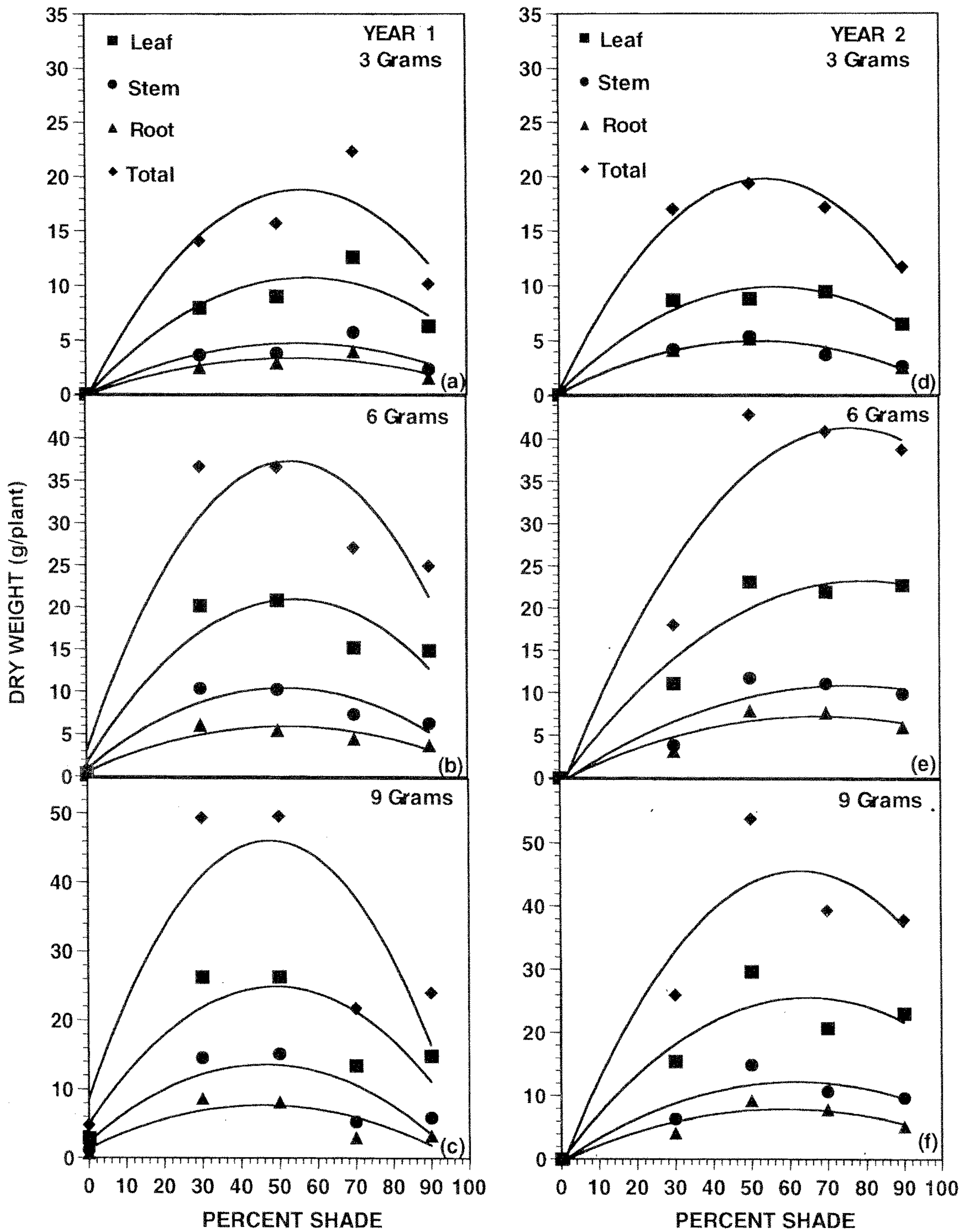

FIGURE 1. Total, leaf, stem and root dry weight of mangosteen plants as influenced by levels of shade and fertilizer.

leaf area that was 60 and 31% greater than that of plants supplied with 3 and 6 g of fertilizer, respectively. Similarly, these plants were 18 and 40% taller and had a stem diameter that was 14 and 27% thicker than that of plants grown under the same shade treatment but supplied with 3 and 9 g of fertilizer, respectively (Figure 4).

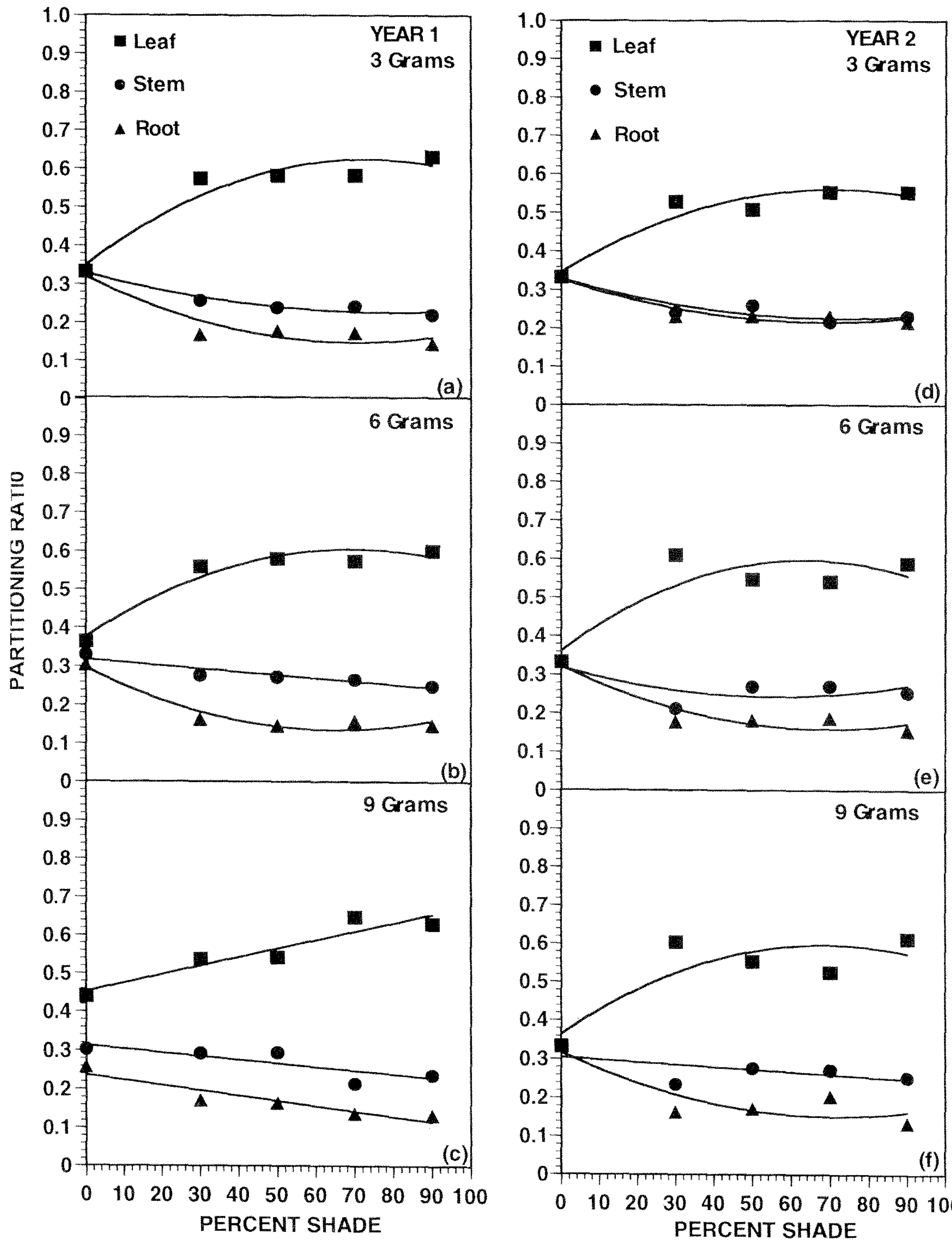

FIGURE 2. Relationship between dry matter partitioning among different parts of mangosteen plants and percentage shade.

Figure 5 shows the effect of days after transplanting (DAT) on leaf area development, plant height and stem diameter. Only results obtained at the highest fertilization treatment (i.e., 9 g) and shade levels 0, 50, and 90% are presented. Response values for plants grown at 30

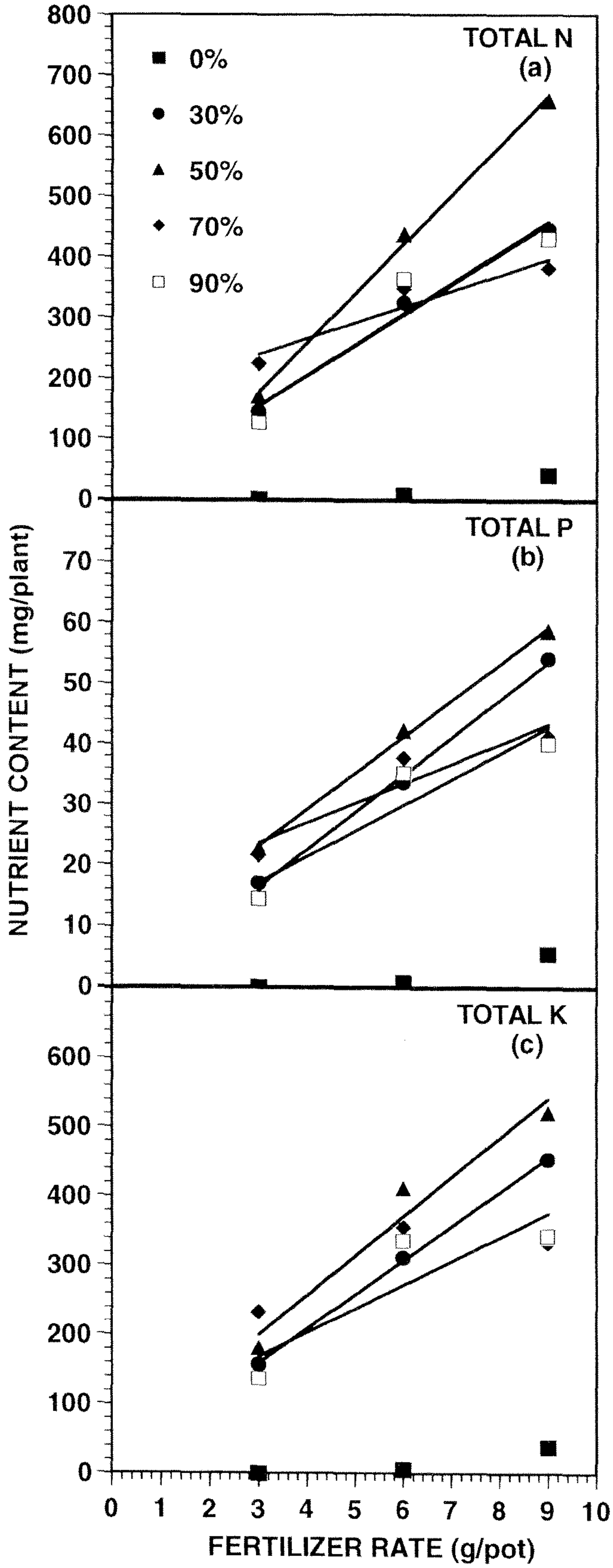

FIGURE 3. Total nutrient content of mangosteen plants as influenced by fertilizer rate. Absence of a curve denotes lack of a significant response.

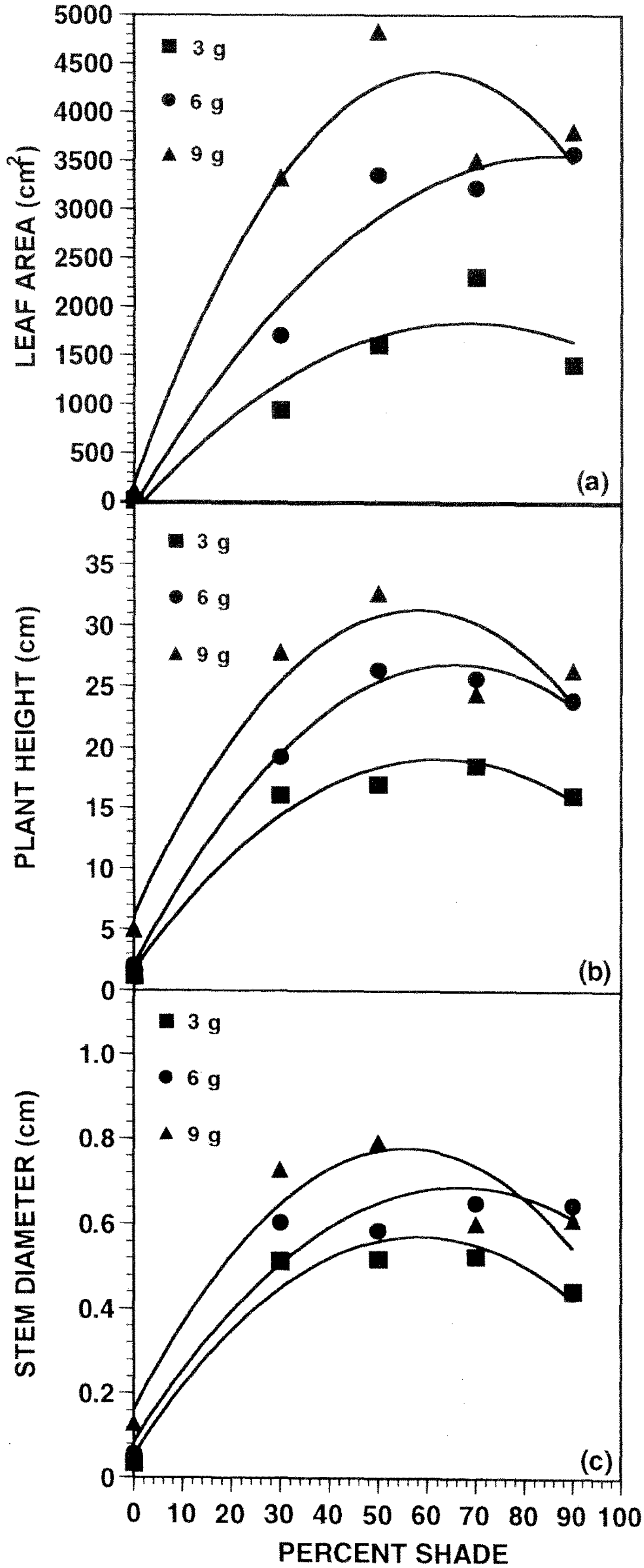

FIGURE 4. Leaf area (a), plant height (b) and stem diameter (c) of mangosteen plants as influenced by levels of shade and fertilizer.

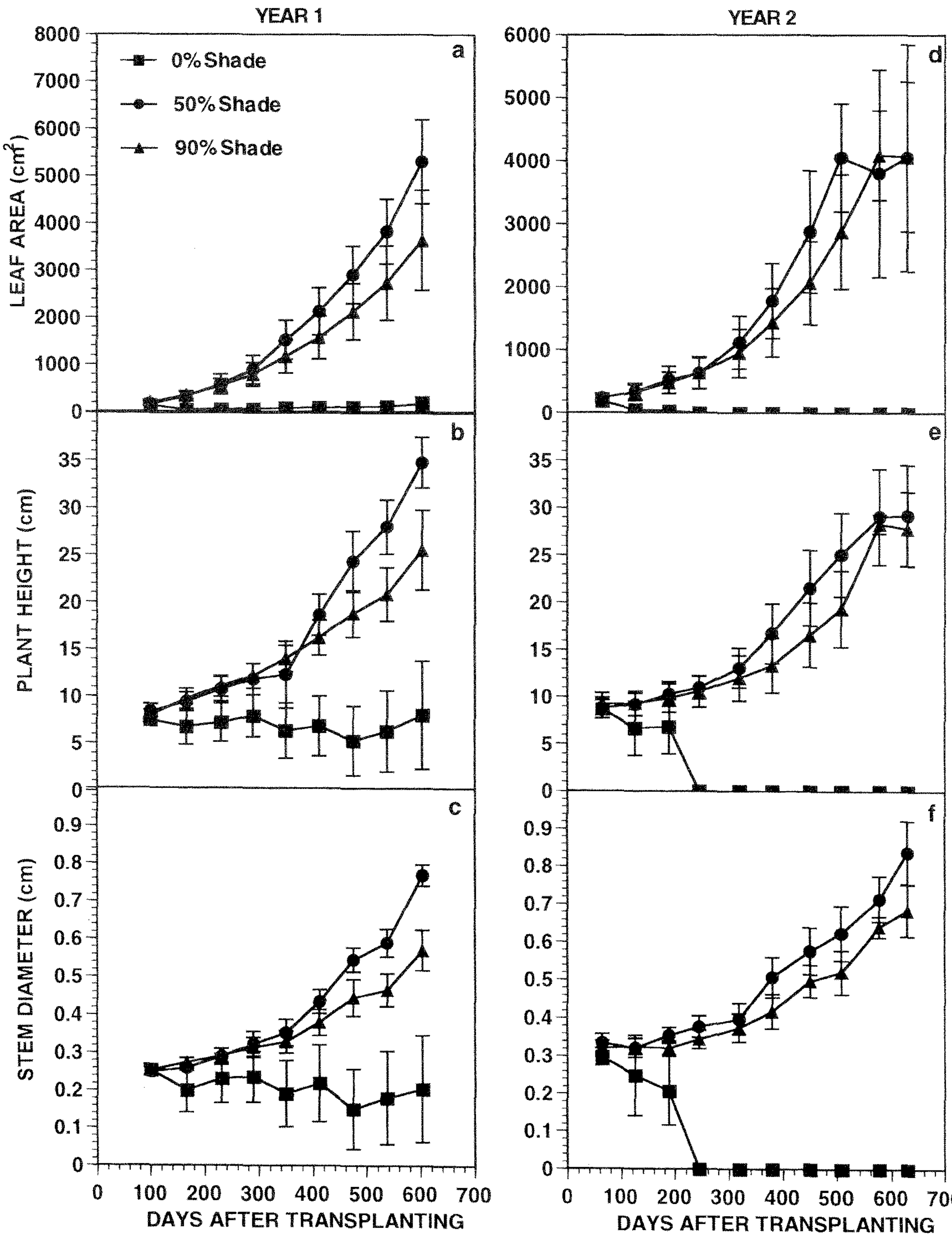

FIGURE 5. Leaf area (a, f), plant height (b, e) and stem diameter (c, f) of mangosteen plants grown under three shade levels and as influenced by plant age. Bars denote standard deviation of the mean.

and 70% shade fell between those obtained for plants grown under 50 and 90% shade (data not shown). In plants grown under full sunlight (i.e., 0% shade) leaf area, plant height and stem diameter either did not change appreciably (Figure 5a-d) or declined (Figure 5e-f) with increases in DAT. During the first 300 DAT, plants grown under 50% and 90% shade had low growth rates. Thereafter, leaf area, plant height and stem diameter increased almost linearly until the end of the experimental period (Figure 5a-e).

Few experiments characterizing the interrelationship between growth and development and nutrient uptake of young mangosteen have been reported in the literature. The results of this study demonstrate that 50% shade and fertilization at a rate of 9 g per pot of a 15-4.8-10.8% (N-P-K) fertilizer provide adequate conditions for mangosteen growth during the first two years of development in the nursery.

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