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**Original Article**

# Allometric Relationships in Field-Grown Annual Plant Species with Different Architectures as a Measure of Intraspecific Competition

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## ABSTRACT

Experiment was carried out to test the prediction of the Optimum Partition Theory (OPT) that plant will allocate biomass to maximize their capture of limited resources. Two annual species were grown with different branching pattern at different densities. One Species, *Hibiscus sabdarifa* was sown at inter-spacing distances of 5cm, 10cm and 20cm to represent High, Medium and Low density, respectively. The second Species, *Corchorus olitorius* was sown at inter-spacing distances of 5cm and 10cm to represent High and Low density, respectively. Both species were planted in different sections of the same field. For both species, treatments were laid in a completely randomized design with three replicates. Allometric relationships between leaf biomass and total biomass from three harvests for *Hibiscus sabdarifa* and two harvests for *Corchorus olitorius* was performed to test for significant differences in slopes of the relationship.
Results showed that for both species and at all harvest times, leaf biomass had linear relationship with total biomass. However, there were no significant differences in the slope of the relationships across treatments in both species. Our study did not suggest any evidence of an adaptive strategy to invest more biomass in leaves in response to high density as predicted by the OPT. Our data, however, suggest that high density may not adversely affect leave production in these species.

**Key words:** Allometric relationship, Adaptive Strategy, Density, Leaf biomass, Optimal partioning, Total biomass.

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## INTRODUCTION

The environment in which plants live is far from optimal, as resources fluctuate both spatially and temporally. How a plant allocates available limited resources to its various organs is a central question in plant ecology. A number of studies have demonstrated that plants will allocate more biomass to the organ responsible for the capture of the limited resource (Bloom *et al.,*, 1985; Levin *et al.,*, 1989; Dewar, 1993). For instance, under limited nutrient availability plants have been reported to allocate more biomass to roots at expense of the leaves (Mony*et al.*, 2007). Conversely, plants exposed to limited sunlight would be predicted to shift allocation of biomass to the leaves (Shipley and Meziane, 2002). This has long been considered as the theoretical basis for the assumption that plasticity in biomass allocation allows a plant to maximize their growth and confer adaptive advantage.
There is, however, a growing consensus amongst researchers that biomass allocation patterns changes with size, and as such, questions of plasticity in allocation patterns

are better analyzed from an allometric perspective (Wright and McConnaughay, 2002; Weiner, 2004; Wang *et al.,* 2006; Zhang *et al.,* 2008; Japhet *et al.,* 2009; Weiner *et al.,* 2009). Biomass allocation patterns may differ for plant growing at different rate when comparisons are made at a common time or plant age but would not differ when comparison are made at a common plant size (Weiner, 2004; Wang *et al.,* 2006). This phenomenon has been referred to as apparent plasticity (Wright and McConnaughay, 2002; Weiner, 2004), which is often misinterpreted as true plastic shift in biomass allocation patterns in response to the environment (Weiner *et al.,* 2009).Allometric analysis will help to correct for possible size differences for plants growing at different rates (Wang *et al.,* 2006; Weiner *et al.,* 2009).

Competitive interactions amongst individuals in a population could be influenced by their growth form (Weiner and Thomas, 1992; Weiner and Fishman, 1994; Salomonson *et al.,* 1994), and therefore, plants with different architecture or branching pattern may exhibit different allocation patterns. For instance, Zhang *et al.,* (2008), reported differences in meristem allocation in three species with different growth forms.In this study we grew two annual species with different branching pattern under different densities to address the following questions:

(1) Does leaf biomass allocation pattern changes with density in these species?

(2) Does these changes translate to true plastic investment in leaf biomass?

(3) Does species with different branching patterns show different allocation patterns?

## MATERIALS AND METHODS

### Description of Studied Species

*Hibiscus sabdarifa* is an annual or perennial herb or woody base sub-shrub, growing to 2-2.5m tall. The leaves are deeply three-to five lobed, 8-15cm long arrange alternately on the stem. The flowers are 8–10 cm (3–4 in) in diameter, white to pale yellow with a dark red spot at the base of each petal, and have a stout fleshy calyx at the base, 1–2 cm (0.39–0.79 in) wide, enlarging to 3–3.5 cm (1.2–1.4 in), fleshy and bright red as the fruit matures. It takes about six months to mature. It branches profusely along the length of stem (Cobley, 1976). *Corchorus olitorius* is an annual herb reaching a height of 2-4m. The leaves are alternate and simple. The flowers are small and yellow with five petals. The plant is usually unbranched or with only a few side branches. Both species are grown in tropics for their leaves and fibres. In both species a high planting density is desirable for optimum yield (Cobley, 1976).

### Study Area and Experimental Design.

The study was conducted in the Botanical Garden of Ahmadu Bello University Zaria (11°N, 38°E) Northwest, Nigeria in 2010. Seeds of both Species were sown in plots measuring 3x3 metres on the 23$^{rd}$ of June, 2010. In *Hibiscus sabdarifa*, seeds were sown at inter-planting distances of 5cm, 10cm and 20cm to represent High, Medium and Low density, respectively, while for *Corchorus olitorius,* seeds were sown at an inter-planting distance of 5cm and 10cm to represent High and Low density respectively. Both species were planted in different sections of the same field. For both species, treatments were laid in a completely randomized design with three replicates. Weeds were control mechanically by hand picking or hoeing.

### Measurements

To control for ontogeny, we performed three sequential harvests for *Hibiscus sabdarifa* and two sequential harvests for *Corchorus* *olitorius*. Harvests were performed every two weeks beginning from the 7th of August 2010. We randomly selected 10 plants per replicate per treatment, making a total of 30 plants per treatment. For each plant, data on leaf biomass and total biomass were recorded after oven drying at 65$^0$C for 48 hours.

## Data Analysis

All analysis was conducted using the SPSS Statistical software (version 17). The allometric relationship between total biomass and leaf biomass was tested using the reduce major axis regression analysis (Wang *et al.,* 2006; Japhet *et al.,* 2009). Allometric analysis has been used to correct for probable size effect in the interpretation of plasticity (Wright and McConnaughay, 2002; Wang *et al.,* 2006; Weiner *et al.,* 2009). Significant differences in allometric slope of the regression analysis would indicate a true plastic investment in leaf biomass in response to density (Weiner, 2004). By contrast, non significant differences in slopes of the regression analysis would indicate apparent plastic response (Weiner, 2004).Significant differences in slope of the allometric relationship in response to density were tested following Bonser and Aarssen, (2003).

## RESULTS AND DISCUSSION

The effect of density on the allometric relationship between leaf biomass and Total biomass are summarized in Table 1 and illustrated in Figures 1 and 2. For both species, the relationship between leaf biomass and total biomass was linear at all harvest times (positive allometric slope and regression coefficient). However, there was no significant difference in the slopes of the relationship when compared across treatments (Table 1).The Optimal Partitioning Theory predicts that plants will shift allocation of biomass to the organ responsible for the capture of the most limiting resource (e.g. Shipley and Meziane, 2002). High density is associated with diminishing light supply as a result of shading (Schmitt and Wulff, 1993; Ballaré and Scopel, 1997), and therefore, such plants are predicted to allocate comparatively more biomass to leaves to mitigate the effect of the reduced supply of light. In this study, we expected that plants sown at high densities, would allocate comparatively more of the total biomass to leaves compared with the plants sown at lower densities consistent with the Optimal Partitioning Theory. Analysis of the slope of the allometric relationships, did not, however, show any significant differences in slopes (Table 1). This shows that the biomass allocation pattern was not altered by competition in this study. Allocation of biomass to leaves increased linearly in all species irrespective of variations in density at all harvest times (Figures 1 and 2). Similarly, differences in plant form did not alter the biomass allocation patterns in this study. This suggests that the two species seems to commit a constant amount of biomass to leaves with or without competition.Without considering the effect of plant size, most studies have misinterpreted "apparent" plasticity for "true" plasticity (Weiner, 2004; Wang *et al.,* 2006). Furthermore, majority of studies have only conducted one harvest, which is at the final development stage (e.g. Wang *et al.,* 2006; Japhet *et al.,* 2009). This approach may ignore other developmental changes that could provide more information about the plant strategy. In this study, we performed more than one harvest to give a more detail information of the plants response to intra-specific competition.

While some allometric relationships were altered by competition in some other studies, e.g. Weiner and Thomas, (1992);

Weiner and Fishman (1994), that in this study were not, and this may reflect constrains in the expression of plasticity in response to competition (Weiner and Fishman 1994; Van Kluenen *et al.,* 2000).Our study has some practical implications in relation to the growth and economic importance of these species. These two species are grown for their leaves in most African Countries. With the interest among researchers to grow plants at high density for increased light interception and weed control (Andrade *et al.,*2002), results from this study suggests that growing these plants at high density may not adversely affect the plants.

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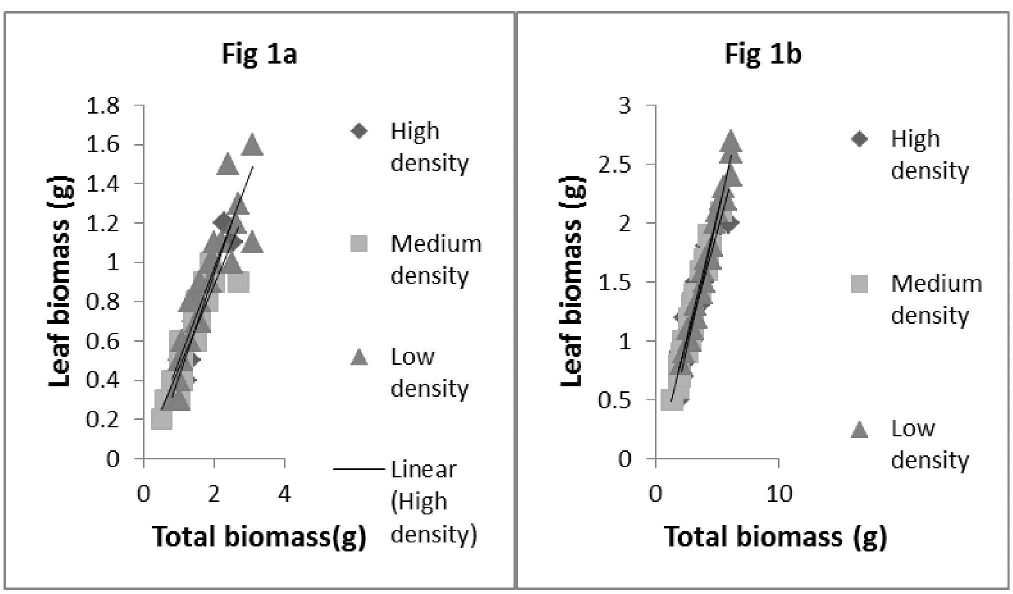
Table 1: Slope of the allometric relationship between Leaf biomass and Total Biomass in *Hibiscus sabdarifa* and *Corchorus olitorius*

| *H.sabdarifa* | 1st Harvest | | 2nd harvest | | 3rd harvest | | *C.olitorius* | 1st harvest | | 2nd harvest | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Density | Slope | $R^2$ | Slope | $R^2$ | Slope | $R^2$ | Density | Slope | $R^2$ | Slope | $R^2$ |
| High | 0.52 | 0.90 | 0.38 | 0.87 | 0.47 | 0.95 | High | 0.54 | 0.98 | 0.58 | 0.92 |
| Medium | 0.42 | 0.81 | 0.43 | 0.95 | 0.47 | 0.92 | | | | | |
| Low | 0.54 | 0.90 | 0.45 | 0.98 | 0.44 | 0.97 | Low | 0.49 | 0.86 | 0.43 | 0.93 |
| Significance | NS | | NS | | NS | | | NS | | NS | |

Note: $R^2$ denotes regression coefficient, NS denotes non significance differences in allometric slopes across treatments.



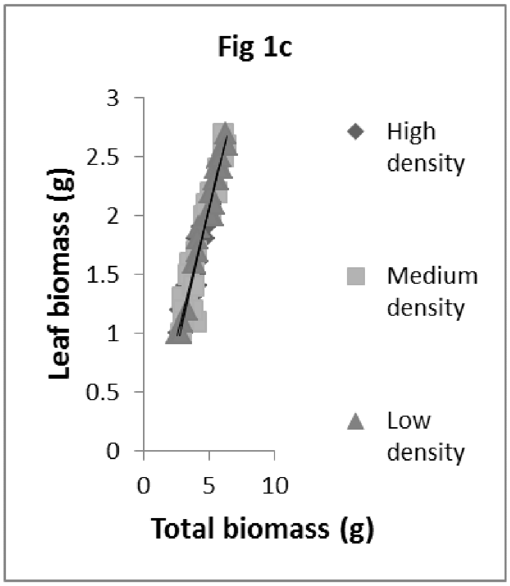



Figure 1: Allometric relationships between Leaf biomass and Total biomass of *Hibiscus sabdarifa* in response to density at (1a) first harvest, (1b) second harvest and (1c) third harvest.

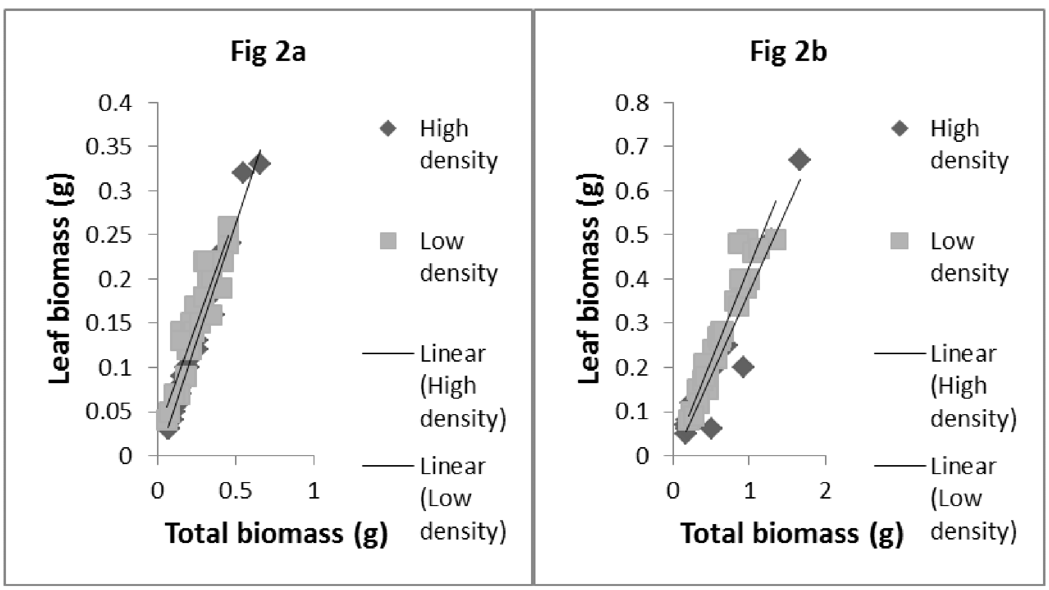



Figure 2: Allometric relationship between Leaf biomass and Total biomass of *Corchorus olitorius* in response to density at (2a) first harvest and (2b) second harvest.

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