Changes in plant growth, reproduction and offspring vigor with increasing distance from an urban center

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Abstract

Changes in propagule pressure may be a key factor driving the disproportionate abundance of invasive plants in urban compared to more rural areas. Yet, few studies have examined whether seed production or offspring vigor vary with urbanization. Complementary field and greenhouse studies were conducted to investigate how seed production, resource allocation to seeds, and offspring vigor vary in an annual, invasive plant, *Xanthium strumarium* L., with increasing distance from an urban center. Individuals of *X. strumarium* were planted at four sites ranging in urbanization from the urban Central Park in New York City to rural Ashokan in the Catskill Mountains. In general, vegetative dry mass production and reproductive output were highest at Central Park and lowest at Ashokan. To examine site-related environmental maternal effects on offspring vigor, fruit randomly collected from three representative maternal plants from each site were germinated and grown in a greenhouse. Each seedling was chosen at random to receive a high, intermediate or low water treatment for 45 days after emergence. Due to low germination percentages, offspring from the two most rural sites were combined as an "exurban" treatment. Seedlings from Central Park emerged, on average, four days earlier than those from the exurban sites. Decreasing water availability was associated with shorter shoots, fewer leaves, less aboveground dry mass and less belowground dry mass. Seedlings from Central Park maternal plants were significantly taller and had significantly more shoot dry mass, than seedlings from exurban maternal plants, suggesting that offspring vigor may differ between plants grown in urban and rural areas. Our results are consistent with other studies, which have shown that plants may grow faster, produce more seeds, and have increased offspring vigor when grown in environments with less distance from an urban center. Increases in growth rate and increased propagule production may increase the invasiveness of invasive plants in urban areas.

Figure 1. *Xanthium strumarium* L. (common cocklebur)

Introduction

- Invasive plants are particularly common in urban areas
- Altered disturbance regimes, reduced native species richness, and increased propagule pressure associated with human traffic may facilitate the spread of invasive plants in urban areas.
- Plants may be more productive in urban areas
- Urbanization may affect the growth of invasive plants through effects on environmental characteristics. Increased air temperatures, elevated atmospheric [CO_2] and nutrient deposition may increase plant growth, while comparatively high concentrations pollutants, such as ozone, may negatively affect growth. The net result of these environmental changes may be more beneficial for invasive plants than for native plants.
- Effects of urbanization on reproduction may not parallel effects on vegetative growth if there are inherited maternal environmental effects on offspring vigor. Because environmental factors may vary with urbanization, seeds may inherit different maternal environmental effects from maternal parents in urban and rural areas.
- The objective of this study was to assess the impact that urbanization may have on growth, reproduction and offspring vigor of an annual plant, *Xanthium strumarium* L., that is invasive in urban areas. We focused on four specific questions: 1) Does vegetative dry mass production change with distance from an urban center, 2) Does reproductive output change with distance from an urban center, 3) Does resource allocation to reproduction change with distance from an urban center, and 4) Does offspring vigor differ among maternal plants grown at different distances from an urban center?

Site	Latitude °N	Longitude °W	Elevation ± 5 meters	Population 2000 census	Temperatures °C Low	Average	High	Precipitation cm
Central Park	40.7927	73.9550	21	304008	28.3	25.0	21.7	7.0
LDEO	41.0053	73.9078	108	31698	28.6	23.0	18.4	10.5
BRF	41.4219	74.2475	112	24829	26.8	21.4	17.4	10.8
Ashokan	41.9249	74.2475	265	8463	26.9	22.2	17.7	14.5

Table 1. Latitude, longitude, elevation, population, summer daily temperatures and monthly precipitation for each site in 2006. Population is the total population of the zip code at the site and the nearest zip code each to the north, south, east and west. Summer temperatures and precipitation are the averages of June, July and August 2006 data from NWS stations located at NYC (Central Park), Palisades (Anton Court; LDEO), Cornwall (West Side; BRF) and Kingston (Ashokan).

Materials and Methods

Maternal Plant growth and reproduction

- Fruit from a single plant of *Xanthium strumarium* L. (common cocklebur; Fig. 1) were planted at four study sites located in southern New York State. Listed in order of increasing distance from an urban center (NYC, NY), the sites were located at Central Park, Columbia University at Lamont Dougherty (LDEO), Black Rock Forest (BRF) and Ashokan. Site locations and characteristics are listed in Table 1.
- Fruit were planted in topsoil in 9 L pots in an unshaded exclosure located in an open field at each site. The plants at each site received natural precipitation supplemented with tap water. Plants did not receive supplemental nutrients or light. Individual plants were harvested after complete senescence. Pots with seeds that did not emerge, plants that flowered shortly after emerging, and plants that died before fruit production were eliminated from analysis. Dry mass was measured for the leaves, shoots and fruit of each plant.

Offspring vigor

- Nine fruit from each of three maternal plants were planted in pots in soil from the Louis Calder Center of Fordham University (Armonk, NY) and placed in the greenhouse at the Calder Center. The fruit were watered every day until emergence, after which seedlings were watered every other day. Due to low emergence rates for seedlings from BRF and Ashokan, and because these locations represented the two most rural locations, seedlings from these two locations were combined into a single Exurban site for analysis. Plants were harvested 45 days after emergence.

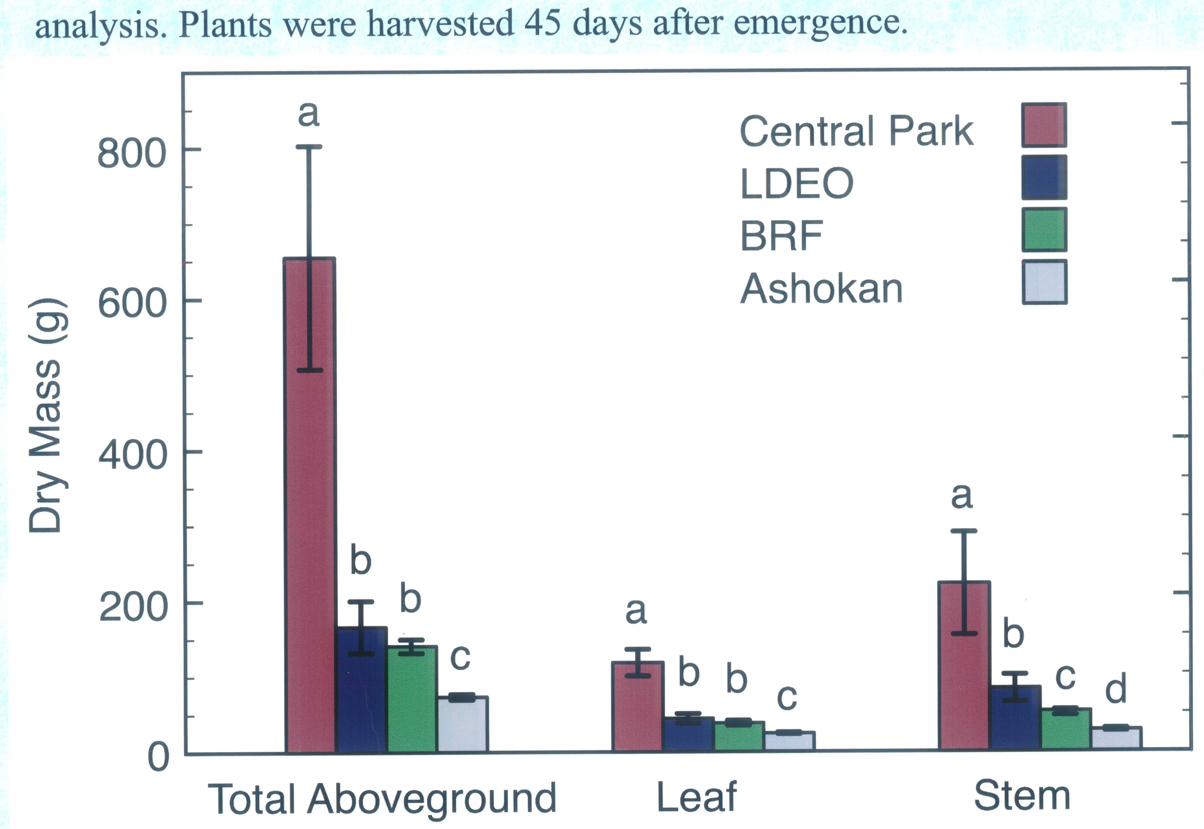

Figure 2. Total aboveground dry mass, leaf dry mass and stem dry mass of maternal plants (mean ± SE).

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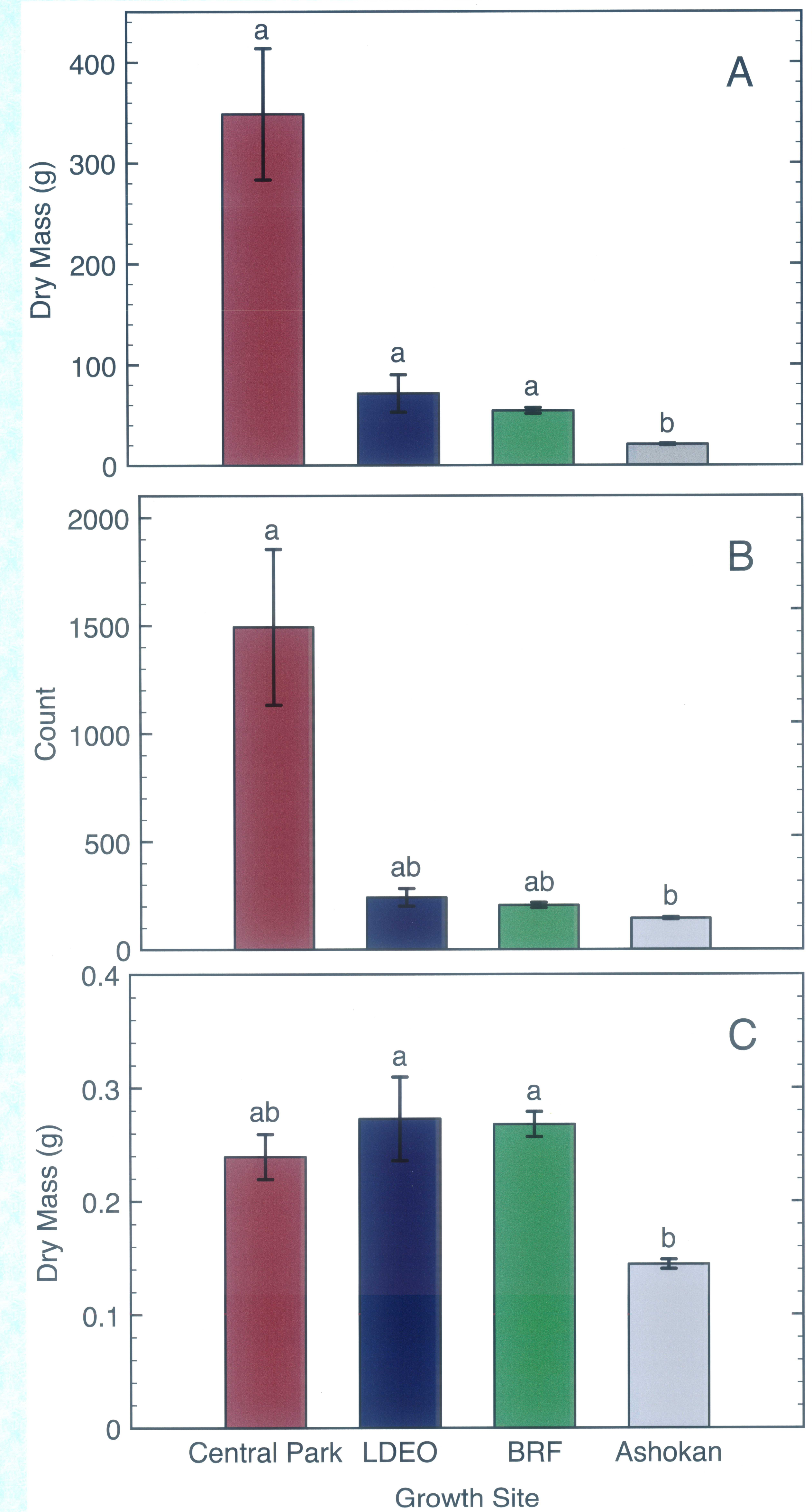

Figure 3. Total dry mass of fruit (A) total number of fruit (B) and mass per fruit (C) mass per fruit (mean 1 ± SE) of maternal plants

Conclusions

- As distance from an urban center decreases, plant fitness may increase through increases in vegetative mass, fruit production and offspring that emerge earlier and grow differentially larger.
- Urbanization may increase the invasiveness of *Xanthium* by increasing propagule pressure through increased seed production, seed germinability, and inherited environmental effects on offspring
- Altered urban environmental factors such as increased temperature, N and CO_2 in and near cities may make urban environments more favorable to invasive plants, giving an increased competitive advantage to these plants.

Results

- Total mass, leaf mass, and stem mass decreased with increasing distance from an urban center (Fig. 2).
- Total fruit mass (Fig. 3a) and total number of fruit (Fig. 3b) increased, while mass per fruit generally decreased (Fig. 3c), with increasing distance from an urban center.
- Seedling emergence date was later with increasing distance of maternal growth site from an urban center (Fig 4).
- Seedling height and shoot mass decreased with increasing distance of maternal growth site from an urban center (Fig 5).

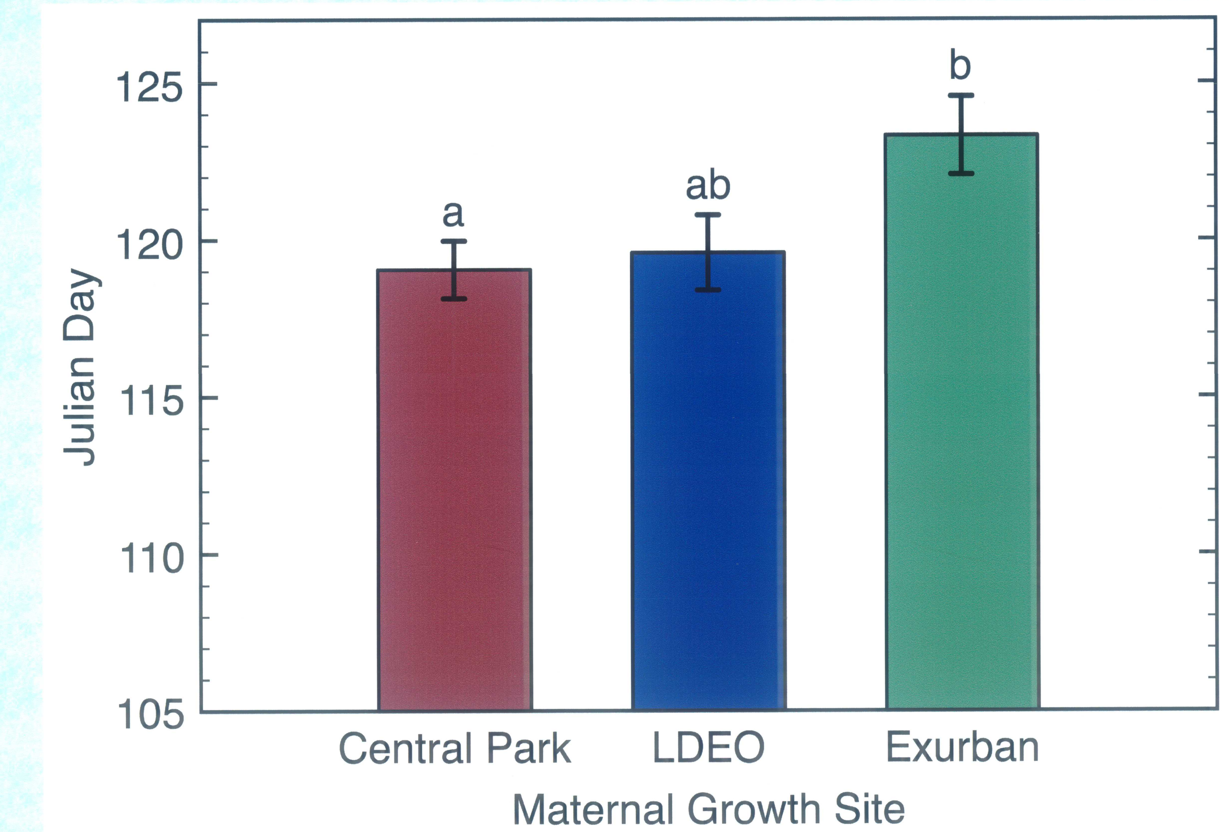

Figure 4. Emergence date, in Julian day, of offspring (mean ± 1 SE).

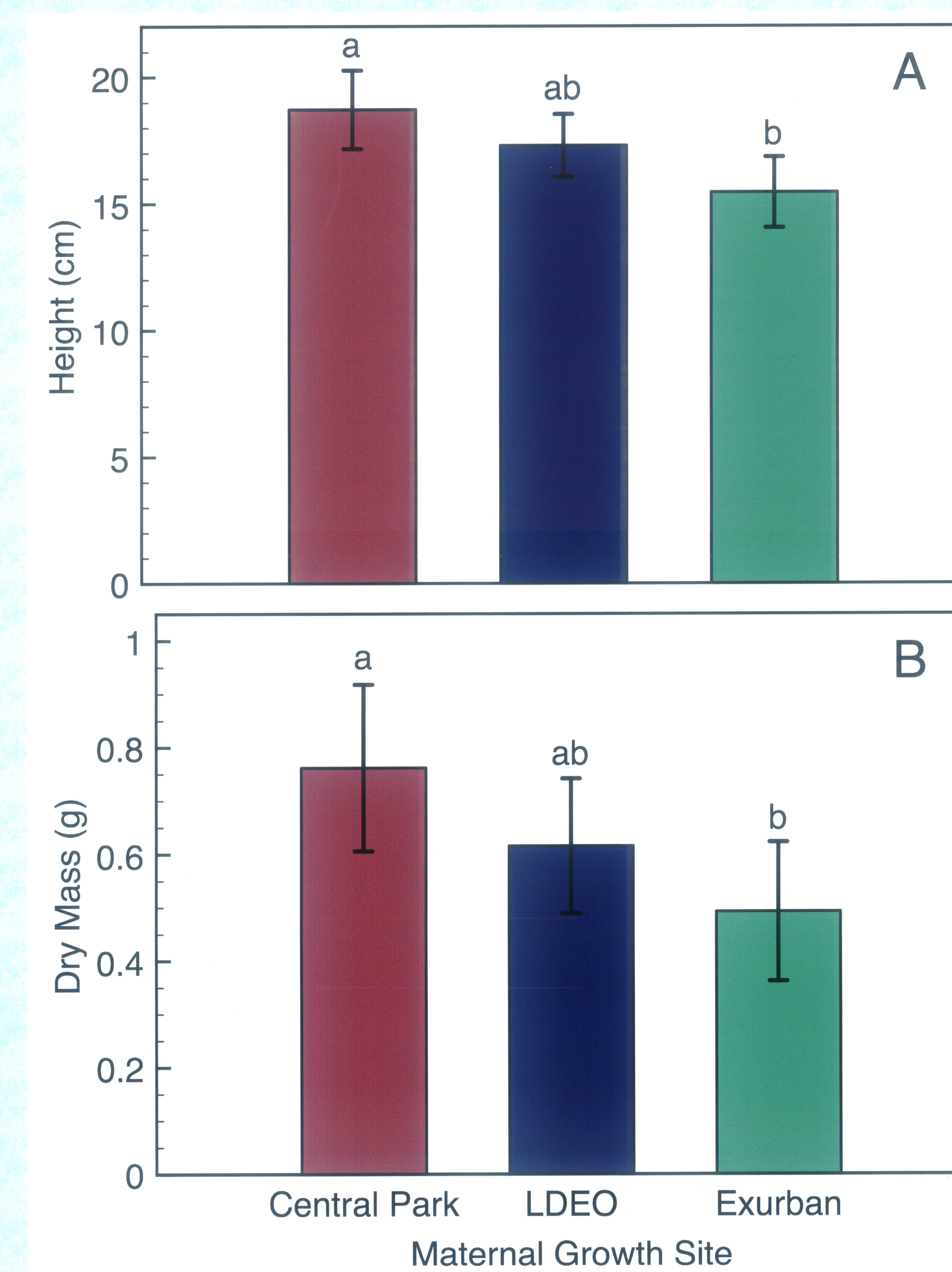

Figure 5. Mean (± SE) height (A) and mass (B) of offspring. Different letters indicate significant differences between maternal growth sites.