Cities and the Environment

The Influence of Garden Size and Floral Cover on Pollen Deposition in Urban Community Gardens

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Abstract

Many cucurbits, such as cucumbers, squashes and pumpkins, depend on pollinating bees in order to set fruit. However, fruit yield and progeny vigor in these plants generally decreases as heterospecific pollen deposition increases. We studied how the spatial area dedicated to cucumbers (*Cucumis sativis*), versus other flowering plants, influenced the deposition of conspecific and heterospecific pollen on cucumber plants in New York City community gardens. We also examined the effect of garden size on conspecific and heterospecific pollen deposition on cucumber plants. Female flowers were collected from potted cucumber plants that had been experimentally placed into the gardens, specifically for this study, or that were established in raised beds by members of the community garden. In the laboratory, pollen grains were isolated from the flower by acetolysis, and the number of heterospecific and conspecific cucumber pollen grains were quantified.

Conspecific pollen deposition was positively and significantly associated with the size of a community garden, as well as with the area of each garden dedicated to non-cucumber, flowering plants (i.e. floral cover) and the area of each garden dedicated to cucumber plants (i.e. cucumber cover). Although floral cover explained a greater proportion of the variance, cucumber cover had the strongest effect on conspecific pollen deposition. Heterospecific pollen deposition was positively and significantly related to garden area. However, no significant relationship was found between heterospecific pollen deposition and floral cover, or cucumber cover. Based upon these results, we hypothesize that floral cover positively impacts conspecific pollen deposition by attracting a greater number of pollinators into an urban garden, and that total cucumber area positively impacts conspecific pollen deposition when pollinators are locally foraging within a garden. We suggest that the arrangement of plants within a garden can positively influence yield in fruit and vegetable-producing plants within urban community gardens. Due to the low availability of fruits and vegetables within the stores of the neighborhoods where this study was conducted, developing a better understanding of those factors that constrain or foster fruit and vegetable production are important to increasing food security and public health.

Keywords

Pollination; pollen deposition; urban community gardens; cucumbers; acetolysis; New York City

INTRODUCTION

Many studies have shown the negative effects of pollen limitation on fruit or seed production in angiosperms (reviewed in Knight et al. 2005). For animal-pollinated plants, the effects of pollen limitation on fruit or seed production may result from lack of suitable pollinators (Bierzychudek 1981), a lack of co-flowering conspecific plants (Ågren 1996) or an abundance of heterospecific pollen (i.e. pollen from a different plant species). Heterospecific pollen deposition can reduce fruit or seed production of the flowering plant being pollinated, especially if the heterospecific pollen arrives before conspecific pollen (i.e. pollen from a different flower or a different plant of the same species) arrives (Galen and Gregory 1989; Caruso and Alfaro 2000). Though heterospecific pollen may not limit the amount of conspecific pollen deposited, it competes for limited stigmatic space capable of hydrating conspecific grains. This has the same effect of decreasing the conspecific pollen load, in that space becomes less available to conspecific pollen that could potentially fill the stigma, germinate, and fertilize ovules. High conspecific pollen loads, on the other hand, are more likely to initiate fruit production (Bertin 1990) and increase seed production and weight (Winsor et al. 1987; Bertin 1990) in flowering plants.

Plant community structure is known to have effects on fruit production. However, it is sometimes unclear whether these effects are a direct result of the plant community, or indirectly mediated via heterospecific pollen deposition. For example, Bach and Hruska (1981) demonstrated that cucumber yield was highest when grown in low density monocultures, and was lowest when grown in high density polycultures. Although both density and diversity had an impact on yield, plant diversity had a larger effect on reproduction than did cucumber density. Although the authors attributed patterns in cucumber reproductive performance to competition for resources among plant species, it is possible that heterospecific pollen deposition also contributed to depressed yield in high density polycultures. However, the types of pollen (i.e. conspecific or heterospecific) deposited on cucumber stigmas was not examined in the study.

In addition to plant community structure, heterospecific pollen deposition on an insect pollinated species depends on pollinator abundance, activity and behavior. The generalist habits of many pollinator species (Waser et al. 1996) may play an important role in pollen limitation, and hence the reproductive success of plants (Galen and Gregory 1989). Generalist pollinators do not have a specialized relationship with one or a few flowering plant species within a particular genus or family. Thus, it is likely that promiscuous pollinators may deposit relatively large amounts of heterospecific pollen on the stigma of a given plant species. In this way, the floral community of the area immediately surrounding a flowering plant may affect the distribution of stigmatic pollen and serve as a major cause of conspecific pollen limitation.

Studies on heterospecific pollen transfer usually focus on the effect of the pollen load or pollen type on seed production and fruit size (Galen and Gregory 1989; Caruso and Alfaro 2000). These studies often include carefully controlled applications of different ratios of conspecific pollen, in which the amount of heterospecific pollen is known. Relatively few studies, by comparison, have examined how flowering plant abundance influences heterospecific pollen deposition on stigmas in the field. Furthermore, no study has yet explored the degree to which heterospecific pollen transfer occurs among plants within urban community gardens.

Urban community gardens are an ideal setting for investigating how flowering plant abundance impacts conspecific versus heterospecific pollen deposition, and ultimately, fruit production. Because these gardens are often utilized by local residents of diverse ethnic and cultural heritage (Shinew et al. 2004), a wide variety of ornamental flowers, fruits, and vegetables are cultivated. Thus, plant abundance and plant community structure is generally quite variable from garden to garden.

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We studied the degree to which plant abundance and plant community structure in urban gardens in East Harlem and the Bronx (New York City) affects pollen deposition on cucumbers (Curcurbitaceae: *Cucumis sativis*). Specifically, we measured the area within gardens occupied by non-cucumber, flowering plants to assess the potential for heterospecific pollen deposition. The area within gardens occupied by cucumber plants was also quantified, to assess the potential for conspecific pollen deposition. We expected that the abundance of heterospecific pollen deposited on cucumber flower stigmas would increase as the area within a garden occupied by non-cucumber flowering plants increased. Likewise, we expected that conspecific pollen deposition would increase as the area within a garden occupied by cucumber plants increased. Finally, both conspecific and heterospecific pollen deposition were expected to be highest in large, relative to small, gardens.

METHODS

Female flowers from cucumber (*C. sativis*) plants were sampled from three community gardens in the Bronx, NY and four community gardens in East Harlem, NY (Table 1). These seven gardens were chosen as study sites because they varied in several potentially important variables that may impact conspecific and heterospecific pollen deposition, such as total garden area, the total space occupied by plants in bloom (floral area) and the total area occupied by cucumber plants (cucumber area). In addition to these potentially important independent variables, garden access, permission to place cucumber plants in the garden and permission to harvest existing flowers from cucumber plants that were already established in a garden also influenced our choice of study sites.

Table 1. Pearson correlation coefficients, and associated P values, for the variables garden area (i.e. 'Garden Area'), area of a garden with flowering plants in bloom (i.e. 'Floral Cover'), and area of a garden planted with cucumbers (i.e. 'Cucumber Area'). P values are for the null hypothesis of no correlation among garden variables. Sample size is n=25 for Floral Area and Cucumber area, and n=29 for Garden Area.

	Garden Area	**Floral Cover**	**Cucumber Area**
Garden Area	1.00	0.96 P <0.0001	0.84 P<0.0001
Floral Area		1.00	0.96 P<0.0001
Cucumber Area			1.00

Cucumber Plants

We chose to examine pollen deposition on *C. sativis* flowers because cucumbers generally require insects to carry pollen from male flowers to female flowers in order to set fruit, although both parthenocarpy and, on rare occasion, self-pollination in the absence of insects have been known to occur (Gingras et at. 1999). In addition to requiring pollination to set fruit, cucumbers were especially well suited to this study because they can be successfully grown in pots in a manner that requires relatively little space.

In non-gynoecious varieties of cucumbers, male flowers outnumber female flowers about ten to one and open about ten days prior to females. Both male and females flowers produce nectar to attract pollinators. Flowers are usually open and receptive to pollination for about one day. Because cucumber flowers are a comparatively poor source of pollen or nectar, bees readily switch to other flowers present

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in the vicinity, when available (Delaplane and Mayer 2000). The characteristics of cucumber flowers, as well as the behavior of pollinators associated with cucumbers, suggest that heterospecific pollen may readily be deposited on the stigmas of cucumber flowers.

Sampling Protocol

Samples of whole, female flowers (including ovaries) were collected from each of the community garden study sites between July 12, 2006 and August 1, 2006. In all but two gardens (La Casita Community and East Harlem Council), the cucumber plants from which flowers were collected were planted in raised beds and tended to by community gardeners. No attempt was made to identify the variety of these cucumber plants. Fertilization and watering regimes were not standard, and were determined by the gardener that tended the plot in which the cucumbers were grown. Soils and compost superficially appeared to be similar among beds and among gardens. However, no attempt was made to identify the source or characteristics of the soils in which these cucumbers were growing.

In the two gardens where cucumbers were not already present, or in which permission was not granted to collect flowers from growing cucumber plants, we placed potted cucumber plants into the gardens. Three 30 liter pots, with three plants per pot, were placed into each of these two gardens. Cucumber plants were sown in the glasshouse of Fordham University's Louis Calder Biological Field Station from Martha Stewart Everyday^{TM} 'Picklebush' Pickling Cucumber brand seeds. In early May 2006, two seeds were planted per three inch pot, in a 1:1 ratio of soil and vermiculite. Three pellets of Osmocote slow-release fertilizer were added to each pot. Seedlings were transplanted (three per pot) into 26 L (7 gal.) pots filled with a 3:1 mixture of Miracle-Gro^{TM} Garden Soil for Flowers and Vegetables (3:1:2 N:P:K) and ML Peat Moss manufactured by Nerom Peat Inc. A 2.5 cm layer of river pebbles were placed into the bottom of the pot, to aid with drainage. Plants were placed in the gardens on July 21, 2006, and were watered to saturation three times a week until flowers were collected on August 1, 2006.

Female flowers were collected at the first sign of petal senescence to assure that flowers had the opportunity to be visited by pollinating bees. Three to five flowers were collected from each of the 7 gardens. Flowers were separately placed in vials with 70% ethanol, and were stored in a freezer at -20° C until acetolysis (to separate pollen from other organic material) was performed.

Garden Variables

Because our garden study sites were relatively small and rectangular in shape, the area of all gardens was measured directly. Garden area was chosen as an independent variable in this study because the amount of vegetation as well as the number of pollinators was expected to vary with garden size.

The area of each flower bed within a garden was also measured. For the purposes of this study, a flower bed was defined as a discrete area, in which flowering plants were being deliberately grown and tended to, for the purposes of aesthetics and/or food production. During the time that cucumber flowers were being sampled within a garden, the percent space within each flower bed that was covered by non-cucumber plants in bloom was visually estimated. The area within each flower bed covered by these blooming plants was calculated as the product of the flower bed area and our visual estimate of the amount of space occupied by plants in bloom, summed across all flower beds within a garden, for each garden. This value is referred to as 'floral cover'. Within each garden, the total area covered by cucumber plants was measured directly, and is referred to as 'cucumber cover'. Due to our inability to gain access to the Garden of Happiness, to estimate and measure floral cover and cucumber cover, these variables were not determined for this garden.

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Acetolysis and Slide Preparation

Acetolysis, a technique adapted by G. Robinson of Fordham University from Erdtman (1960), was performed on collected flowers to dissolve all organic matter, except for the sporopollinen that composes pollen's outer layer (i.e. the exine). This procedure allowed for the separation of the pollen from the organic matter of the flower as well as the rest of the pollen grain which otherwise may obstruct view of dichotomous traits. Pollen contents from each sample were then mounted on slides, identified, and counted.

Acetolysis was carried out in 15 mL centrifuge tubes made of polypropylene that could resist reactivity with the reagents. The process consisted of a series of "washes" in which 7 mL of a given reagent was added, the sample was briefly vortexed and then centrifuged for ten minutes. The supernatant was then decanted and the next reagent was added. For each flower harvested, the stigma and the petals were removed from the ovary and included in the acid digest. The ovary was discarded, but the alcohol that each ovary was stored in was included in the digest, to include pollen that may have detached from the stigma during transportation. The first wash consisted of 5% KOH, followed by two washes in distilled water. Next, the sample was washed in glacial acetic acid, followed by an acetic acid mixture which consisted of a 9:1 ratio of acetic anhydride to sulfuric acid. Samples were then placed in boiling water for 5 minutes prior to centrifugation. Another wash in glacial acetic acid was performed, followed by two washes in distilled water. Samples were washed in 5%KOH once more, before being placed in boiling water for another 5 minutes. Centrifugation followed this step. Three more washes in distilled water were performed, followed by the final wash in 95% ethanol. The samples were then centrifuged for 20 minutes, to ensure that all pollen grains were forced into the pellet. After the final centrifugation, the supernatant was decanted and the pellet was left in a sterile hood until nearly dry (24-48 hours). Once the pellet had nearly dried, 40 μL of 95% ethanol was added and the solution was briefly mixed to homogenize the distribution of pollen within the ethanol. At this point, each sample was ready for slide preparation.

Five reference slides were prepared from each sample digested. Slides were prepared using 5 μL of ethanol/pellet solution, as well as one drop of molten glycerin jelly mounting medium with phenosafranin stain. The slides were examined using a compound microscope set at 100x total magnification. All pollen grains on each slide were counted, and their conspecificity or heterospecificity to cucumbers was noted.

To aid in determining whether field collected pollen grains were from cucumber plants or non-cucumber plants, a voucher slide was prepared from cucumber flowers that were hand-pollinated under glasshouse conditions, void of insect pollinators. Pollen was taken directly off of the anthers of male cucumber flowers using a clean, fine hair paintbrush. Pollen grains were then transferred to the stigma of a recently opened female flower. The stigma was removed immediately after hand-pollination, and stained with basic fucsin before being transferred to and compressed on a clean slide.

Pollen grains on this voucher slide all presented a single morphology. Because the flower from which this sample was prepared was pollinated under controlled conditions, where the possibility for heterospecific pollen deposition was excluded, it was concluded that the pollen grains were conspecific to cucumbers. The morphology of these pollen grains as being those of *C. sativis* was further confirmed by comparison to a photo taken by Halbritter (2000). Grains from the voucher sample differed from grains prepared from acetolysis, in that basic fucsin stained the grains dark purple so as they were opaque, while acetolysis combined with the phenosafranin stain dyed cucumber grains pink and transparent. Nonetheless, in both sample types, the basic size and morphology of the cucumber pollen grains was evident.

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Pollen grains were identified as either conspecific or heterospecific based on their size and their morphology, as confirmed by the voucher slide. Cucumber pollen grains range from 51-100 μm in diameter (Halbritter 2000), and are triangular-ellipsoid in shape, with three pores per grain, such that a single pore occupies each triangular angle. Heterospecific pollen grains were not identified to species, but instead were identified as those pollen grains whose size or morphology was visibly different from cucumber pollen grains.

Statistical Analyses

Pearson's correlation coefficient was computed to assess the correlation of garden area, floral cover and cucumber area with one another. Because each of the three garden variables was positively and significantly correlated with one another (Table 1), the effect of these variables on pollen deposition was independently assessed.

Least squares regression was used to independently assess the influence of garden area, floral cover, and cucumber area within gardens on the mean number of conspecific pollen grains deposited on cucumber stigmas per garden. A companion set of least squares regressions was used to independently assess the influence of garden area, floral cover and cucumber area on the mean number of heterospecific grains deposited on cucumber stigmas per garden. The pollen counts from the five reference slides prepared from each flower were averaged prior to analysis. These data were blocked by garden, for each analysis. To meet the regression assumption of homogeneity of residual variance, all data were square root transformed prior to analysis. Because we conducted a total of six linear regressions, and to control for type I error, alpha was set to $P \leq 0.008$ for rejection of the null hypothesis (Bonferroni adjustment for multiple comparisons). All analyses were performed using SAS v 9.0 (2002).

RESULTS

The urban gardens where this study was conducted varied in their total area (range = 181 to 1651 m^2), floral cover (range = 4.61 to 94.37 m^2) and cucumber area (range = 0.73 to 15.47 m^2). However, the area of gardens was more equitably distributed among garden study sites than were floral cover or cucumber cover (Table 2).

Garden area had a positive and significant effect on conspecific ($F_{1,22}=33.30$, $P<0.0001$) and heterospecific ($F_{1,22}=9.12$, $P=0.0063$) pollen deposition on cucumber stigmas (Figure 1). Floral cover had a positive and significant effect on conspecific ($F_{1,19}=35.89$, $P<0.0001$), but not on heterospecific, pollen deposition ($F_{1,19}=1.58$, $P=0.22$) on cucumber stigmas (Figure 2). Similarly, cucumber area had a positive and significant effect on conspecific pollen deposition ($F_{1,19}=34.78$, $P<0.0001$), but not on heterospecific pollen deposition ($F_{1,19}=0.82$, $P=0.38$) on cucumber stigmas (Figure 3). Relative to garden area and floral cover, cucumber area had the strongest effect on conspecific pollen deposition (regression coefficient = 1.05; Table 3). Cucumber area explained roughly 66% of the variation in conspecific pollen deposition on cucumber stigmas ($r^2=0.66$; Table 3).

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Because the concentration of data points towards the lower range of floral cover and cucumber area resulted in Tremont Community Garden having a large influence on the outcome of regression analyses, the effects of garden area, floral cover and cucumber area on pollen deposition were re-analyzed, with data from Tremont removed. Removal of this data influenced the outcome of regression analyses (Table 4). The effects of cucumber area ($F_{1,15}$=3.99, P=0.064) and floral cover ($F_{1,15}$=2.81, P=0.11) on conspecific pollen deposition were no longer significant with the data from Tremont removed. The effect of garden area on conspecific ($F_{1,18}$=12.73, P=0.002) and heterospecific ($F_{1,18}$=17.03, P=0.0006) pollen deposition remained significant, with the data from Tremont removed. The effects of cucumber area ($F_{1,15}$=5.05, P=0.04) and floral cover ($F_{1,15}$=2.02, P=0.18) on heterospecific pollen deposition remained non-significant (at P=0.008 to reject H_0) with the data from Tremont removed.

Table 2. Name, location, size, and ownership of garden study sites located in New York, NY. Floral cover and cucumber cover were not determined in Garden of Happiness, due to issues with garden access.

Community Garden Name	Location	Garden Area (m²)	Flower bed Area (m²)	Floral Cover (m²)	Cucumber Cover (m²)
Los Amigos	326 Pleasant Ave, Harlem	181	37.84	7.32	1.29
Peaceful Valley	E. 117th St., Harlem	224	40.20	4.61	1.90
La Casita	223 E 119th St., Harlem	312	78.35	14.59	0.73
East Harlem Council	E. 117th St., Harlem	525	181.03	36.13	7.57
Fordham Bedford Lot Busters	2593 Bainbridge Ave. Bronx	1036	221.09	34.61	2.76
Garden of Happiness	2156 Prospect Ave., Bronx	1440	616.62	Not Determined	Not Determined
Tremont	Corner of E. Tremont Ave. and Lafontaine Ave., Bronx	1651	453.40	94.37	15.47

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Figure 1. Mean number of conspecific and heterospecific pollen grains (± standard error bars) deposited on cucumber flowers, as a function of the area of the garden in which the cucumber flower was in bloom. The regression line modeling the effect of garden area on conspecific pollen deposition (y=0.01X+6.11) was significantly different from 0 (P<0.0001). Similarly, the regression line modeling the effect of garden area on heterospecific pollen deposition (y=0.002X+2.87)was significantly different from 0 (0.0063).
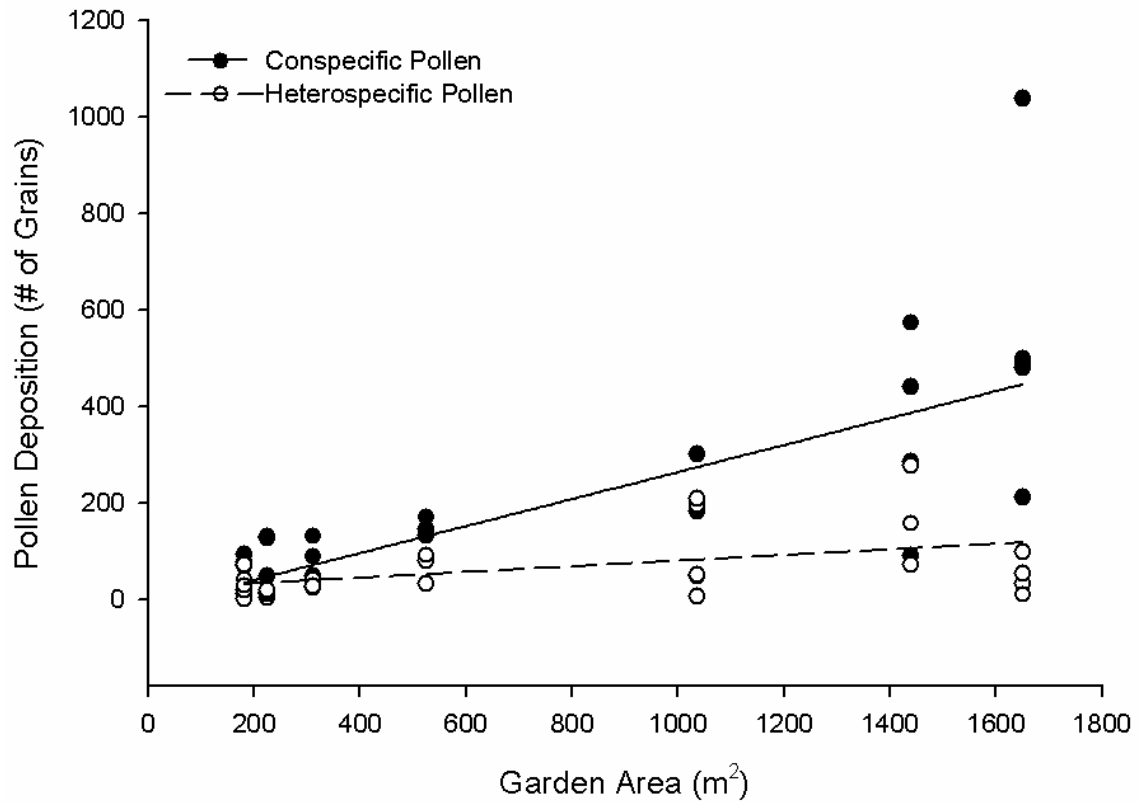

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Figure 2. Mean number of conspecific and heterospecific pollen grains (± standard error bars) deposited on cucumber flowers, as a function of floral cover within the garden where the cucumber flower was in bloom. The regression line modeling the effect of floral cover on conspecific pollen deposition (y=0.16X+7.61) was significantly different from 0 (P<0.0001). There was no significant relationship between floral cover and heterospecific pollen deposition (P<0.0401; Bonferroni adjusted P to reject ≤0.008).
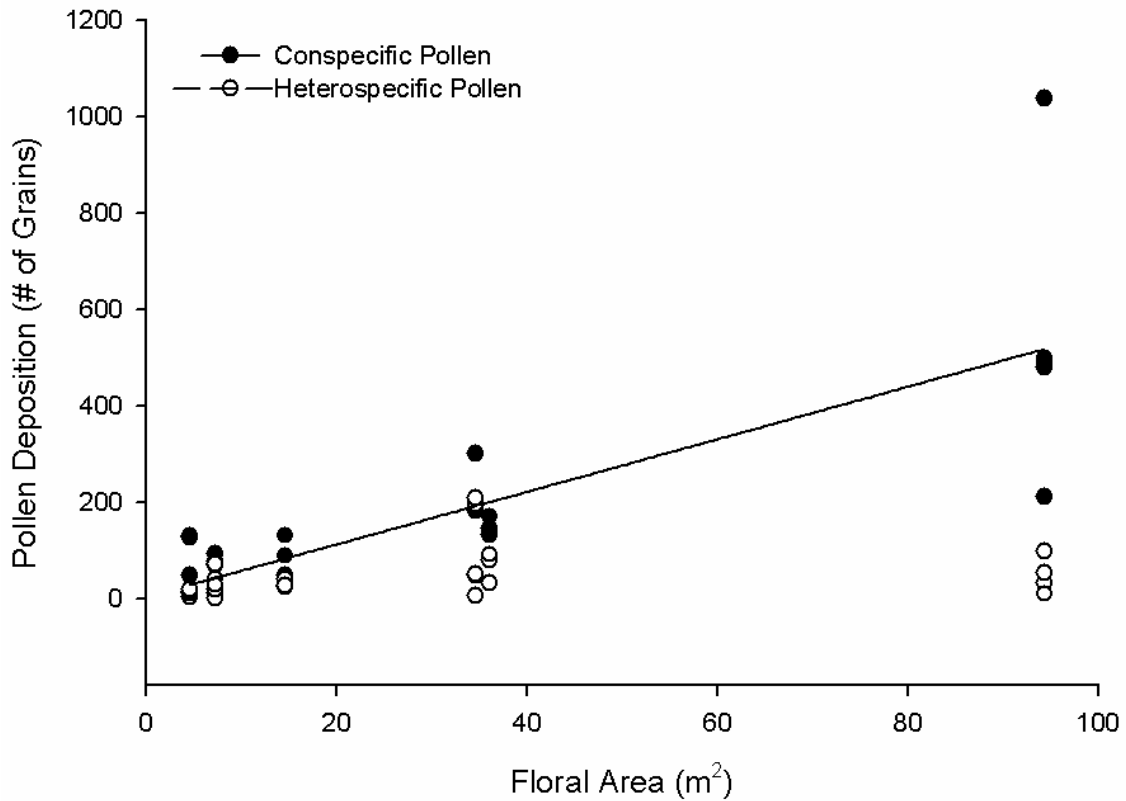
Figure 3. Mean number of conspecific and heterospecific pollen grains (± standard error bars) deposited on cucumber flowers, as a function of the area of cucumber plants growing within the garden where the sampled cucumber flower was in bloom. The regression line modeling the effect of cucumber area on conspecific pollen deposition (y=0.92X+0.38) was significantly different from 0 (P<0.0001). There was no significant relationship between cucumber area and heterospecific pollen deposition (P=0.53).
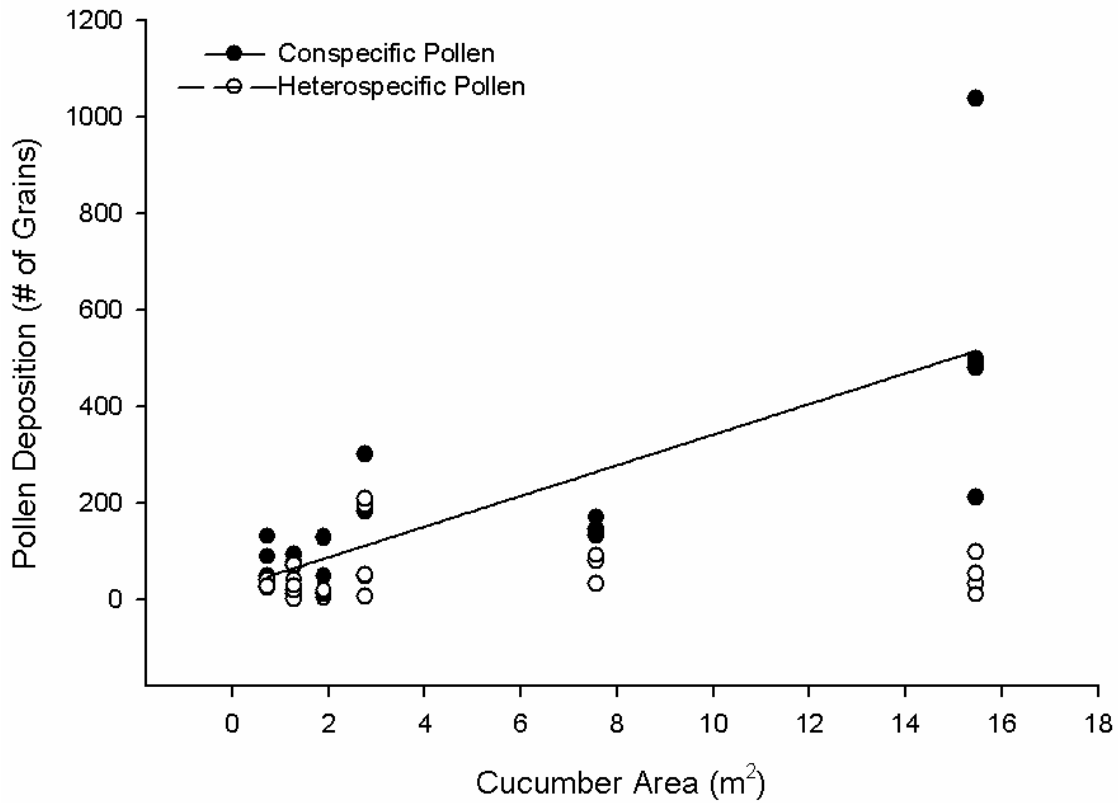
Table 3. Least squares regression results for the effect of garden area (i.e. 'Garden Area), area of a garden with flowering plants in bloom (i.e. 'Floral Cover'), and area of a garden planted with cucumbers (i.e. 'Cucumber Area) on conspecific, heterospecific and total pollen deposition on cucumbers. Prior to analysis, the data were square root transformed to meet the regression assumptions of homogeneous variance. To protect against Type 1 error, alpha was set to $P \leq 0.008$ for rejection of the null hypothesis (Bonferroni adjustment for multiple comparisons). Those predictive variables that significantly influenced pollen deposition are marked with an asterisk(*).

Predictive Variable	Regression Line Equation	df	F value	P value	r^2
Conspecific Pollen Deposition					
Garden Area*	y=0.01X+6.11	1,22	33.3	<0.0001	0.64
Floral Cover*	y=0.16X+7.61	1,19	35.89	<0.0001	0.66
Cucumber Area*	y=1.05X+6.35	1,19	34.78	<0.0001	0.66
Heterospecific Pollen Deposition					
Garden Area*	y=0.002X+2.87	1,22	9.12	0.0063	0.50
Floral Cover	y=0.04X+3.21	1,19	1.58	0.2243	0.24
Cucumber Area	y=0.24X+2.92	1,19	0.82	0.3766	0.24

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Table 4. Least squares regression results for the effect of garden area (i.e. 'Garden Area), area of a garden with flowering plants in bloom (i.e. 'Floral Cover'), and area of a garden planted with cucumbers (i.e. 'Cucumber Area) on conspecific, heterospecific and total pollen deposition on cucumbers, with the data from Tremont Community garden excluded from the analysis. Prior to analysis, the data were square root transformed to meet the regression assumptions of homogeneous variance. To protect against Type 1 error, alpha was set to $P \leq 0.008$ for rejection of the null hypothesis (Bonferroni adjustment for multiple comparisons). Those variables that significantly influenced pollen deposition are marked with an asterisk(*).

Predictive Variable	Regression Line Equation	df	F value	P value	r^2
Conspecific Pollen Deposition					
Garden Area*	y=0.01X+6.60	1,18	12.73	0.0022	0.47
Floral Cover	y=2.85X+2.94	1,15	69.60	0.0644	0.25
Cucumber Area	y=0.08X+7.97	1,15	1.27	0.3239	0.25
Heterospecific Pollen Deposition					
Garden Area*	y=0.01X+1.50	1,18	17.03	0.0006	0.52
Floral Cover	y=5.46X-6.99	1,15	5.05	0.0401	0.26
Cucumber Area	y=0.16X+2.66	1,15	2.02	0.1761	0.26

DISCUSSION

Because we were not able to estimate floral cover and cucumber cover in one of the larger gardens in this study (e.g. Garden of Happiness), we only had an estimate of these predictive variables for a single large garden. Consequently, most data were clustered towards the lower range for floral cover and cucumber cover, and the data from Tremont garden had a large influence on the outcome of regression analyses. The results from this observational experiment should thus be interpreted with caution.

Pollen deposition, both conspecific and heterospecific grains, increased as garden size increased. This result was robust to the removal of the Tremont garden data. In addition, conspecific pollen deposition increased as the area of a garden planted with cucumbers increased. Unexpectedly, abundant floral cover (i.e. heterospecific plants) within a garden increased conspecific pollen deposition on cucumber plants.

That conspecific pollen deposition increases as floral cover increases suggests that heterospecific plants can have a positive effect on cucumber yield. A likely mechanism for this result is the positive effect of greater floral resources on pollinators, which may in turn have a positive effect on conspecific pollen deposition. In general, as floral abundance increases within an area, pollinator abundance and diversity increase (Potts et al. 2003; Fontaine et al. 2006; Herro 2006; Biesmeijer et al. 2006). It seems as if flowering plant abundance is important for attracting pollinators into the local vicinity of a garden. Once pollinators are attracted into a garden, cucumber plant abundance likely becomes an important factor dictating conspecific pollen deposition.

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We hypothesize that the immediate area surrounding a given flower will have a large impact on the types of pollen deposited on cucumber stigmas, relative to the effects of plant community composition within the garden, as a whole. Monocultural patches have been shown to increase cucumber yield (Bach and Hruska 1981) which also suggests that if cucumber flowers are immediately surrounded by other cucumber flowers, more conspecific pollen will be deposited. Clumping groups of plants together, in species-specific patches, may optimize fruit and vegetable yield in urban gardens. Although this arrangement may seem obvious, in urban community gardens (where several gardeners independently manage small areas of the garden) fruit and vegetable plantings tend to be diffuse and scattered among garden plots, rather than clumped into single species beds. Whether such an arrangement indeed optimizes the effectiveness of insects as pollinators of these plants warrants further study.

The number of bee visits required for optimal fruit set in cucumbers varies from study to study, and may be dependant on cucumber variety (Delaplane and Mayer 2000). However, multiple bee visits generally increases fruit set and the number of seeds per fruit (Collison 1976). Bumblebees are the most effective pollinators of cultivated cucumbers, although honey bees are also known to be effective (Gingras et al. 1999; Stanghellini et al. 1997, 2002). In urban gardens, sweat bees (*Lasioglossum sp.)* and bumble bees (*Bombus sp.)* are the most common visitors to cucumber flowers (Morath 2008; Langellotto unpublished data). Because foraging range generally scales with pollinator size (Gathmann and Tscharntke 2002), clumping plants into 'mini-monocultures' may enhance the effectiveness of smaller pollinators, such as the sweat bee.

Whether or not gardeners are able to clump their plants into 'mini-monocultures' is likely to be dictated by the total area of an individual garden. In gardens where more area was provided to individual gardeners (i.e. gardens with greater overall area) large patches of 'monoculture' were present, and larger amounts of conspecific pollen were deposited (Figs. 1 & 3). For example, gardeners working in the largest garden, the Tremont Community Garden, were able to plant cucumbers in monoculture patches averaging 2.58 m^2. Gardeners in the smallest garden, Los Amigos, only used patches averaging 0.65 m^2. Based on the results of this study, it may be beneficial for gardeners, especially those in smaller gardens, to work cooperatively and utilize the entire garden's available space to plant single monocultural patches for each crop, which could increase the amount of conspecific pollen received by flowers and increase yield.

In addition to serving as vital centers of social (Shinew et al. 2004) and civic (Schmelzkopf 1995) life in urban neighborhoods, community gardens can support local food production, and thus provide urban residents with access to a diversity of affordable produce (Baker 2004). This is particularly important in urban neighborhoods, where many community gardens were founded on vacant or abandoned lots in low to moderate-income neighborhoods (Pottharst 1995; Linn 1999). Local food production and access to a diverse array of quality and affordable produce is especially important in low income neighborhoods, where access to fresh food can be limited. For example, a survey of bodegas (i.e. small grocery stores) in the East Harlem neighborhood (where 4 of our study gardens were located) revealed that 40% failed to stock green vegetables and 26% failed to stock fresh fruit of any kind (Horowitz et al. 2004). Furthermore, quality and selection was variable in those stores that did stock fresh produce (Horowitz et al. 2004). Only 18% of East Harlem stores carried all foods recommended for a healthy diet compared to 58% of store in the prosperous Upper East Side (Horowitz et al. 2004). Studies that help improve the production of fruits and vegetables in urban community gardens may thus result in better access to healthy food choices.

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