Urban gardens found to have higher pollination success than rural gardens

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Abstract: Recent decline in wild pollinators have been reported and studies have found a connection to increasing urbanisation, larger homogenous landscapes and increased pesticide usage. The pollinators are important to preserve for various ecosystem services, such as plant reproduction, however the effects on pollination success has not been thoroughly studied in relation to urbanisation. In this study the aim is to examine how much the seed set is influenced by method of pollination (hand or open pollination), type of landscape and the surrounding vegetation cover. Brown knapweed, *Centaurea jacea* plants were placed in rural and urban gardens, and were allowed to flower for 1-2 weeks. There was a variation in the vegetation cover surrounding the urban gardens, where the brown knapweed plants were distributed to. Thereafter the seeds and unfertilized ovules were counted. The urban gardens had higher mean seed set and vegetation cover did not influence seed set. In conclusion, the rural areas were negatively affecting pollinators and the urban areas may have the potential to act as a source of pollinators to peri-urban and rural areas nearby.

Introduction

Pollination is an important ecosystem service, contributing to plant reproduction (Lin et al., 2018), however declines of pollinator populations have been observed in recent years (Carvalheiro et al., 2013). Changes in habitats, as a result from modern farming practises, have had a big connection to pollinator declines (Goulson et al., 2015). By converting pollinator habitats into crop fields the consequences for the pollinators are habitat loss, resulting in food sources becoming more scarce and the use of systemic pesticides and herbicides, potentially killing or decreasing the fitness from the exposure of chemicals (Goulson et al., 2015). Soil nesting is also negatively affected by the soil mixing in crop fields (Verboven et al., 2014). Urbanization also alters habitats greatly and may cause a threat for pollinators (Bates et al,. 2011), with the increase in coverage of sealed of areas to pollinators, such as asphalt, buildings etc. (Williams et al., 2005). However some studies have shown cases where urban areas are favorable for wild pollinators (Saure et al. 1998; Goulson et al. 2008; Baldock et al. 2015, etc.). A possible way to preserve wild pollinator populations is to create habitats as refuges for the pollinators within cities by constructing urban areas with green areas, parks and flowerbeds (Hall et al., 2017).

This study evaluates two aspects of pollination in urban areas, i) a comparison between urban and rural gardens, ii) an analysis of the effect of amount of surrounding vegetation cover in the urban sites. To measure pollination, potted plants were placed in domestic gardens and were allowed to flower. The native species Brown knapweed *Centaurea jacea,* was used in the study. The percentage of fertilized was used to evaluate pollination success. Only a few other studies have observed the reproductive success from pollination in urban areas and compared it with rural areas (Verboven et al. 2014). Therefore it might be interesting to further study the subject in order increase the knowledge to preserve self-incompatible plants, for example.

Study plant

The brown knapweed, *Centaurea jacea*, was chosen to be the studied plant in this project. It is a perennial plant commonly found in the studied area, Scania in southern Sweden, and flowers between July and September (Mossberg et al., 1992). It was suitable because it has been observed to be very attractive to pollinators (Ohashi and Yahara, 1999), due to its relatively big, open floral display and because it is high in resources for pollinators, i.e nectar (Rusterholz and Erhardt, 1998) and pollen (Anna Persson, personal communication). Figure 1 shows a picture of *C. jacea*

Figure 1. *Centaurea jacea.* Photo: Wikipedia

Method

Selection of sites and field work

The fieldwork and planning was conducted by Anna Persson and colleagues. The urban sites were located within Malmö, Sweden. Sites had been chosen based on information from GIS, the proportion of vegetation and the number of people in a 1 km x 1 km area surrounding the gardens. The sites were selected to get a variation between different sites based on these factors, resulting in 20 sites where 2 gardens were used for each site. The rural areas were chosen within a 1 km distance from Malmö but was distinct from densely populated areas. A total of 7 sites were used for the rural areas and two gardens for each site. One limitation was that only sites with someone nearby who was willing to help water the plants could be chosen. All sites can be viewed on the map in the appendix, fig. 1 and the urban sites can be seen on the map in appendix, fig 2.
Two pots (7,5 l) with one Brown knapweed plant each were placed in each garden between 19-20 June 2017. Plants were placed in or adjacent to flower beds, vegetable patches or similar

structures. The plants had flower buds, but no opened flowers, at the time when they were placed in the gardens. Flowering ranged from 4 to 7 weeks after they were transferred to the gardens. Circa 2 flower heads per plant were hand pollinated by gently rubbing two flower heads from different plants against each other, in order to facilitate cross-pollination. The plants were brought back to the university garden week 31. Flowerheads were collected once they had matured, each flowerhead were color coded based on time of flowering. The flowers were then dried and stored.

Seed counting

There were two people involved in the seed counting, I counted all from rural sites and 4 urban sites, where as Julia Weber counted 11 urban sites for a separate project. Due to limited time 4 urban sites were not counted as of making this report.

The size of the flower heads were measured, then we counted the seeds and unfertilized ovules for all flowers. A comparison between fertilized seeds and unfertilized ovules can be seen in figure 3, in appendix. We calculated the seed set (%) to get a measurement on how successful pollination had been. Seed set was obtained by the number of seeds divided by the total number of seeds and unfertilized ovules.

Statistical analyses

I used the SPSS program to conduct univariate analysis of variance (ANOVA), where the H_0 hypothesis is that seed set % will not differ: i. between gardens; ii. whether they are hand pollinated or open pollinated; iii. rural or urban or iv. with different degrees of vegetation cover among the urban sites.

Results

The gardens differed significantly from each other in terms of seed set ($F = 19.923$, $p < 0.000$, $df = 41$), as shown in figure 2. To distinguish which differences between gardens affected the seed set further analyzes were made, first when the variables are tested separately. When comparing urban and rural gardens, the seed set was significantly higher in the urban gardens ($F = 64.688$, $p < 0.000$, $df = 1$), see figure 3. In a similar manner the influence of whether the flowers had been open pollinated or hand pollinated had on seed set. There was a significance between pollination method and seed set ($F = 7.890$, $p = 0.05$, $df = 1$), where hand pollination favored higher seed set, see figure 4. The proportion of vegetation coverage in a 1 x 1 km area around the urban gardens did not influence the seed set ($F = 1.977$, $p = 0.161$, $df = 1$). This can be observed in figure 4 in appendix. Although some gardens had very low or close to 0 % seed set, they were not removed in the analyzes due to lack of time.

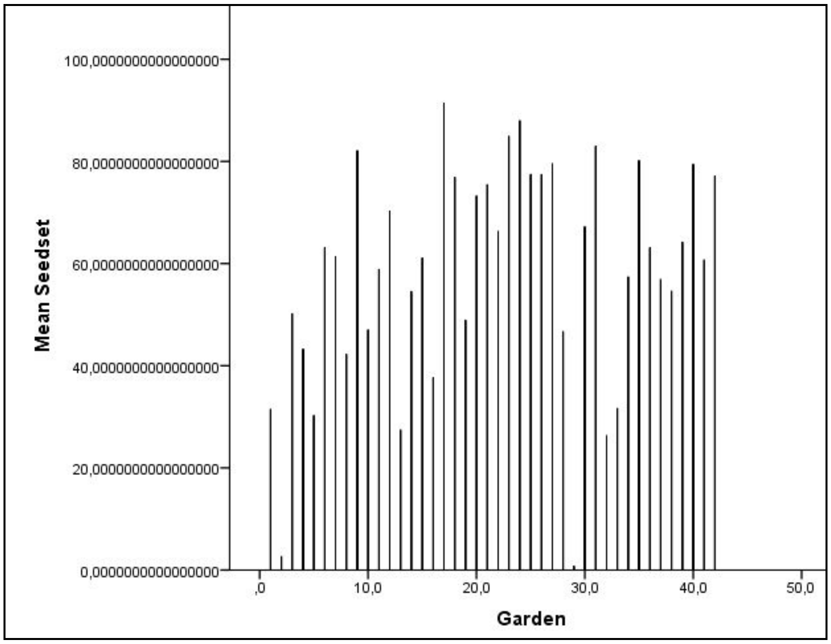

Figure 2. The difference in gardens in seed set

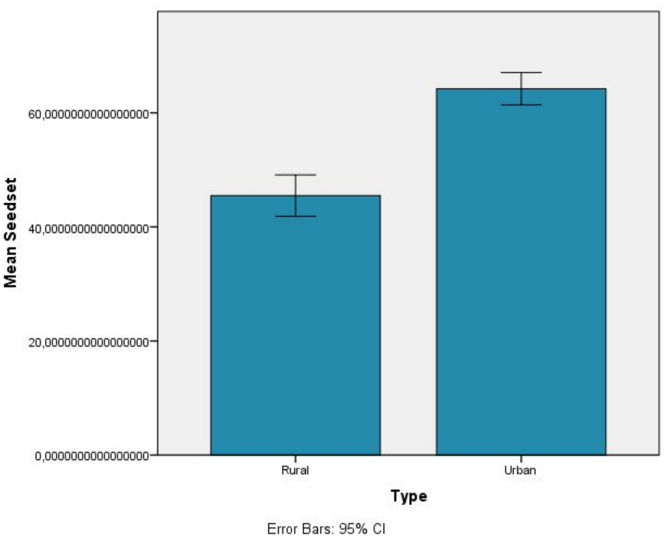

Figure 3. The mean seed set in urban and rural gardens, where urban gardens have significantly higher seed set

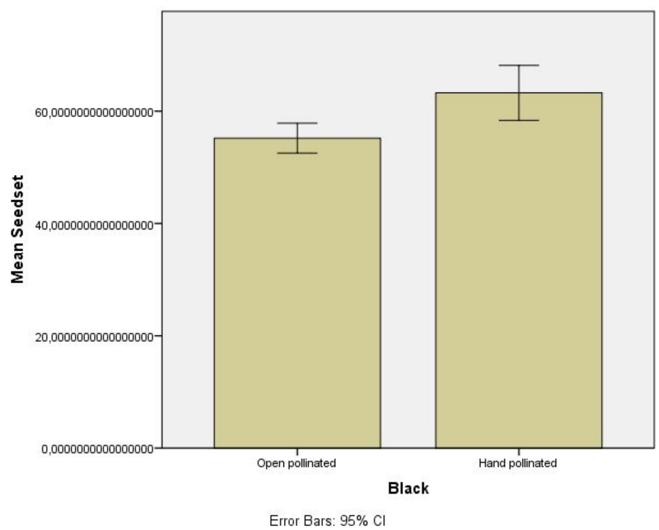

Figure 4. The mean seed set increases with hand pollination

When testing multiple models together the pollination method (”Black”) remains significant with different gardens (”Garden”) ($p = 0.023$), as seen in table 1. Pollination method is also significant when tested together with the rural/urban types (”Type”) ($p = 0.003$), see table 2. Both garden and type were significant when tested with black and had p-values below 0.001, which can be seen in tables 1 and 2.

Table 1. Models for gardens and pollination types are tested together with mean seed set. Black = type of pollination (open pollination and hand pollination). Both were significant when tested together

Tests of Between-Subjects Effects

Dependent Variable: Seedset

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	310252,315[a]	80	3878,154	10,757	,000
Intercept	1213355,965	1	1213355,965	3365,457	,000
Black	1863,918	1	1863,918	5,170	,023
Garden	197785,562	41	4824,038	13,380	,000
Black * Garden	11712,738	38	308,230	,855	,717
Error	182789,861	507	360,532		
Total	2400897,944	588			
Corrected Total	493042,176	587			

a. R Squared = ,629 (Adjusted R Squared = ,571)

Table 2. Models of type of pollination and type of garden was tested together. Type = type of garden (urban or rural). Both variables were significant

Tests of Between-Subjects Effects

Dependent Variable: Seedset

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	55737,490[a]	3	18579,163	24,812	,000
Intercept	1245836,989	1	1245836,989	1663,757	,000
Black	6715,210	1	6715,210	8,968	,003
Type	28847,535	1	28847,535	38,525	,000
Black * Type	476,109	1	476,109	,636	,426
Error	437304,687	584	748,809		
Total	2400897,944	588			
Corrected Total	493042,176	587			

a. R Squared = ,113 (Adjusted R Squared = ,108)

In a study on the same site, occurring alongside this study, the number of pollinator visits had been observed for both the rural and urban gardens and compared different flowers. In the study by Svensson (unpublished data), found that there were no significant difference between rural and urban gardens in the numbers of times per minute the pollinators visited the brown knapweed flowers ($F_{1, 25} = 0.311$, $p = 0.582$ with humidity as a covariate). The mean visitation rate, all pollinator species included, was 0.65 visitors/min in urban gardens and 0.59 visitors/min in rural.

Discussion

Although the results showed that brown knapweed flowers in urban areas had a more successful pollination, which is contrary to the belief that urbanization destroys the pollinators habitats and food sources, it does not necessarily mean that the pollinators are better suited for urban environments. In this study rural areas were only represented by sites consisting of or sites near arable land. The pollinators could therefore have been negatively affected by large areas used for crop production, and therefore less available sources of food for pollinators; soil mixing and pesticide use, which was not present in the urban gardens. Furthermore the temperature was not measured but it was most likely warmer in the urban gardens compared with the rural. In theory the increase in temperature and wind shelter in the urban sites could be one explanation as to why the mean seed set was higher in urban gardens, contributing to earlier flowering and possibly a more favorable environment for pollinators. The surrounding vegetation could have spread out the pollinator populations in rural areas, where as the pollinators were more limited in urban sites, and therefore aggregated in the gardens. However, because no difference in pollinator visitation could be found it suggests that pollinators were equally abundant. The results do however further emphasises that greenery within cities can act as habitats for pollinators. Similar results have been found where urban sites hold a more diverse and abundant population of native bees than rural sites nearby (Saure et al. 1998; Goulson et al. 2008; Baldock et al. 2015, etc.). By having green areas within cities we can benefit from the ecosystem services that pollinators contribute to, preserve pollinator populations and increase public interest in nature, etc.

In a study by Söderman and Smith (2016) they found the number of pollinators visiting *C. jacea* to not affect the seed set. They suggested that it could be a more complex relationship and that visitation rates could not explain all. The behaviour of pollinators might also affect the seed set, i.e. the time spent on each flower (Goulson, 2000). Therefore as pollination rates were not significantly different, the difference in pollinator's behaviour might be the reason why pollination was more successful in the urban gardens.

The amount of surrounding vegetation did not affect pollination, which was only studied in the urban sites. It might have been because of competition for pollinators between plants, however since the brown knapweed is attractive for pollinators the competition should not affect it greatly.
Some flower heads did not have any developed seeds or only very few, which was far from the mean seed set for majority of the plants. One possible explanation would be that the smaller flowers were seen as less attractive for the pollinators, and where therefore outcompeted. Another likely theory would be that the plant aborted the seeds in order to allocate more resources for other seeds or self survival. Since both hand pollinated and open pollinated flowers had low numbers of seeds at some of the sites, the cause was most likely plant stress. The most probable stress would be drought stress, as several people outside of the project were asked to help water the plants.

Since the brown knapweed is attractive for pollinators and has pollination that is possible from both generalists and specialists, the results can not tell anything about how species richness of pollinators is affected by urban and rural landscapes. Therefore, it can not suggest any actions to preserve biodiversity. Furthermore the rural gardens did not include nature reserves or other large areas of other non-crop habitats, which would have been interesting to study how pollinators differ in their native environment compared to landscapes altered by mankind. However this study can support the hypothesis that urban areas can be used as habitats and maybe also refuges for insect pollinators, even though further studies are needed to attain a more complete picture of how urbanisation affects pollinators and pollination success. As more and more land is needed for crop production, the knowledge of how urban areas can include sustainable habitats for pollinators, is important for future urban planning. The plants that will be most affected are those dependant on outcrossing with specialized pollinators for reproduction. Therefore further studies can involve a plant species with pollination from specialized pollinator and include areas more similar to the native pollinators' habitats, in order to attain a broader view on how different types of land use affects pollination success.

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Appendix

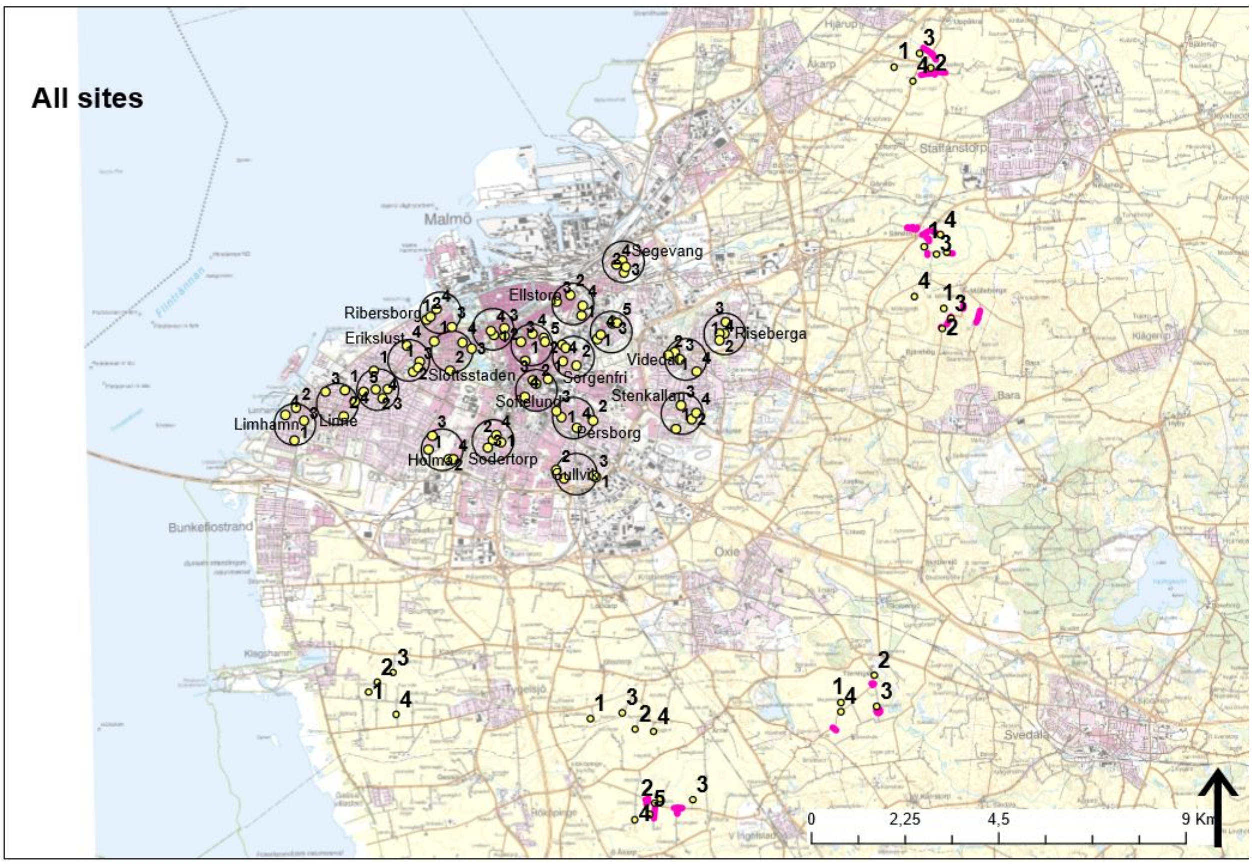

Figure 1. A map of all sites within and around Malmö. The pink lines are transects that were used for another study.

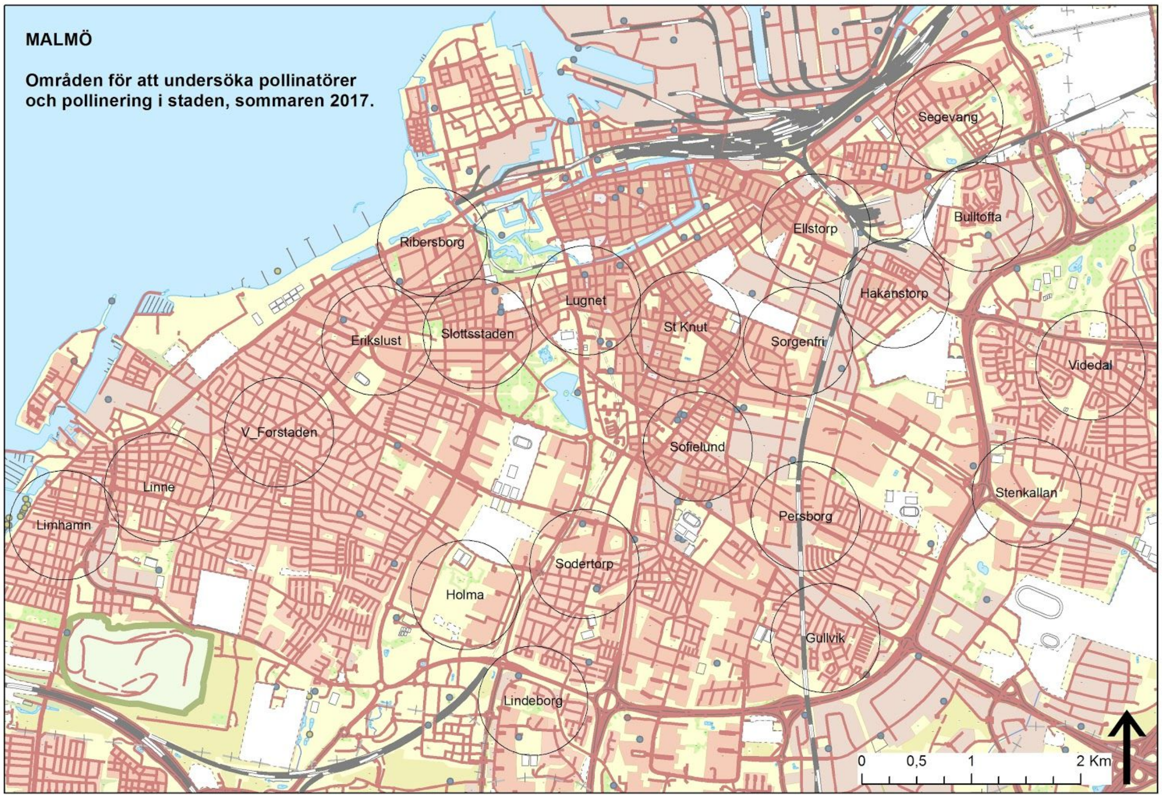

Figure 2. A map showing the locations of the urban gardens in Malmö, where brown knapweed plants were planted

Figure 3. Comparison between an unfertilized ovule (left) and a seed (right)

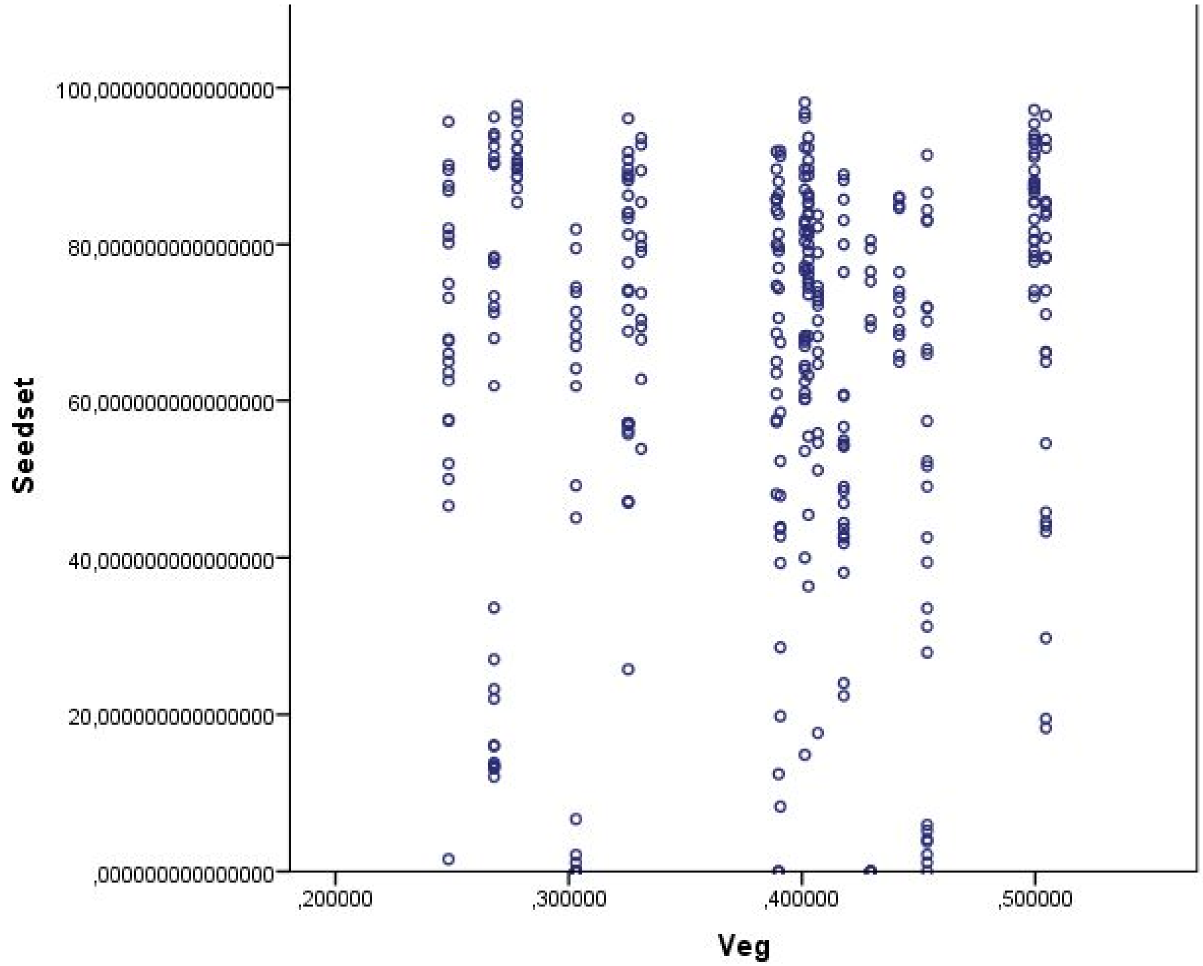

Figure 4. The influence on seed set the coverage of surrounding vegetation (Veg) has. Vegetation coverage was not significant