

## Record of Plasticity Gynomonoecy in *Taraxacum*

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### Abstract

Gynomonoecy is the sexual system in which individual plants bear both female and bisexual flowers. Little attention has been paid to the adaptive significance of this sexual system, which is particularly prevalent in the Asteraceae. Nevertheless, the sexual system of some dandelions currently remains vaguely characterized as having “bisexual and female flowers.” The present study investigates the significance of female flowers in *Taraxacum antungense* Kitage. It's confirmed that *T. antungense* is gynomonoecy in nature and greenhouse. In addition, sexual dimorphism is found in floral morphology in *T. antungense*, namely a red syngenesious stamen in female compared to a yellow one in bisexual flowers. A position effect on floral sex was presented in *T. antungense*. At the inflorescence level, central florets were predominantly female while lateral florets were mainly bisexual, which were opposite to other reports of gynomonoecious in Asteraceae. The observation can improve our knowledge of sexual systems in plants and document relevant evolutionary patterns in sexual dimorphism and position effect of floral sex. Nutrient stress produced fewer bisexual flowers and a higher ratio of female flowers in dandelion capitulum. *T. antungense* has a phenotypically plastic in floret morphology. While the floral-sex ratio responses of gynomonoecious plants may be more complicated than other breeding systems of plants, and they offer the potential to test and refine the already rich body of sex-allocation theory.

**Keywords:** Floret size; Gynomonoecy; *Taraxacum*; Position effect; Sexual dimorphism.

### 1. Introduction

Although the impressive diversity of sexual systems in angiosperms has long intrigued botanists since Darwin, little progress has been made to understand gynomonoecious species [1-3], which have both female and bisexual flowers co-occurring on the same plant. In gynomonoecious species of Asteraceae, a cluster of bisexual flowers is surrounded by peripheral female flowers, while this is not true for *T. antungense*.

Intra-inflorescence variations in floral characteristics and fruit investment of plants may provide a unique opportunity to understand the evolution of sexual systems [4]. The modular growth of plants allowed the modular subunit (i.e. flower and inflorescence), which is regarded as a semiautonomous structure, to act as a primary player in the interaction between genotype and environment. However, few studies have examined the possible variations of floral characteristics and fruit investment within individuals in gynomonoecious species.

Many studies have been devoted to the importance of resource competition and architectural effects for the reduction of investment allocated to flowers or fruits among different positions along the inflorescence [5]. The resource competition hypothesis suggests that the strength of internal constraints is depended upon the limited amount of available resources. With limited resources, the mean number of pollen grains and ovules per flower was found to decrease from early to late blooming flowers [6,7].

Several other factors, such as flower longevity [8] and pollination directionality have also been suggested to play a role in intra-inflorescence variations of floral allocation and female success.

Therefore, we used a field and greenhouse observational and experimental study to investigate capitulum variations of floral sex ratio in the plots of *T. antungense*, a common apomixes perennial herb in Northeast China. In the present paper, we answer the following questions: (1) quantify to what extent female flowers are present in the plots and whether they occur together with bisexual flowers on the same individual or not; (2) investigate the size of the female flowers compared to the bisexual ones; (3) recorded whether female flowers were arranged in specific positions within the inflorescences; (4) what is the possible potential mechanism and adaptive significance of these floral sex investment variations? Specifically, we explore the roles of architectural effects, resource competition and achene spread on capitulum variations in reproductive patterns of gynomonoecy *T. antungense*. All in all, our work sheds light on the sexual system in *Taraxacum* and can guide other botanists dealing with similar problems.

## 2. Materials and methods

### 2.1. Study species and sampling sites

The roots of *T. antungense* collected from Dandong city in Liaoning province were transplanted in the greenhouse and filed of Shenyang Agricultural University in June, 2008, and the classification was based on Herbaceous Flora of Northeast China and Flora of China. This species had been identified by Professor Li Jiyun from Shenyang Experimental Station of Ecology, Chinese Academy of Sciences (SYAB), and this specimens was preserved and planted in the Herbarium of Shenyang Agricultural University. The plants were studied during the flowering and fructification periods.

### 2.2. Variables measured

Anthers were clearly visible because female and bisexual flowers have different color. We found that the perennial *T. antungense* capitulum had some red anthers, which no pollen, deprive the male's function, only have the female function, so we called it "female flowers", the whole capitulum have both female and bisexual flowers. So we collect seeds, and sowed in cold tent (fertile soil) and greenhouse (poor soil) in September and December 2011, respectively, to investigate the gynomonoecy in *T. antungense*. We measured external shape of the female and bisexual flowers, and compared to the plants between gynomonoecy and hermaphroditic. We measured the diaspore traits when those two kinds of florets formed mature achene to check whether they have different dispersal potential.

### 2.3. Statistical analysis

All the analyses were performed with the programme package SPSS v.13.00 (SPSS Inc., Chicago, IL, USA). Pairwise differences among morphological were detected using Generalized Linear Model Here, and below, the figures are means  $\pm$  SE and N refers to the sample size.

## 3. Results

Compared to style length and ovary width, bisexual flowers was significantly larger than female flowers, in addition, compared to other parameters, although female flowers were shorter than bisexual flowers, did not had the significant difference (Table.1).

Within an inflorescence (Fig.1A), a strong position effect was found. In the case of female and bisexual flowers (Fig.1B), careful observation was distinguished. The central flower was female and the remaining flower was bisexual. No case with central female and lateral bisexual flowers was found.



Fig. 1 A. capitulum of gynomonoeocy; B, bisexual (left) and female (right) flower

Table.1. Distribution of variation in floral characteristics between female and bisexual flowers of *T. antungense*

	Stigma length	Style length	Ovary length	Ovary width	Petal length	Petal width
female	0.165±0.028 (15)	0.963±0.035 (15)	0.156±0.018 (15)	0.065±0.009 (15)	0.919±0.089 (15)	0.152±0.021 (15)
bisexual	0.147±0.028 (15)	1.058±0.060 (15)	0.170±0.029 (15)	0.077±0.020 (15)	0.971±0.080 (15)	0.174±0.043 (15)
F	3.128	28.322**	2.495	4.330*	2.900	3.178
P	0.088	0.000	0.125	0.047	0.100	0.085

\* P<0.05; \*\* P< 0.01.

We found that significant variation in head number per plant occurred within populations. The more heads, the higher incidence of gynomonoeocy plants. In this species examined, gynomonoeocy plants bore more heads length than did hermaphroditic plants, in those cases significantly so (Table 2). Both the number of leaves per plant and the height of a branch on its stem had an effect on the proportion of female flowers (Table 2). Proportions of gynomonoeocy plants were affected by plant size in this species. In every analysis, there was a significant added variance component among plants.

Table.2. the comparison between gynomonoeocy and hermaphroditic

	No. of heads per plant	NO.of Leaves per plant	Scape height
gynomonoeocy	5.286±1.380 (7)	27.143±5.047 (7)	25±2.432(7)
hermaphroditic	3.571±0.787 (7)	17.571±3.599 (7)	21±2.533 (7)
F	8.151*	16.688**	9.081*
P	0.014	0.002	0.011

\* P<0.05; \*\* P< 0.01.

Table.3. Proportion of gynomonoecy plants in population and female flowers within capitulum in greenhouse.

Flowering date	percentage of gynomonoecy plants in population(89)	Percentage of variation in proportion of female flowers
February 29, (early flowering season)	0	0
March10, (early full bloom stage)	1.12	19.02 ± 1.87(3)
March 20, (late full bloom stage)	8.99	34.41 ± 7.69(8)
March 30, (late florescence)	18.0	55.4 ± 11.84(13)

Flowering date had a significant effect on the average number of gynomonoecy plants and female flowers in population and within capitulum examined (Table 3). For the most part, gynomonoecy occurred later in the season contained more plants than early in the season. The proportion of female flowers was affected by sampling date in this species.

Table.4. Comparisons of diaspore traits between female and bisexual flowers of *T. antungense*

	achene length	achene width	beak length	pappus width
Female- seeds	0.359±0.019(15)	0.099±0.010(15)	0.789±0.074(15)	0.999±0.113(15)
Bisexual-seeds	0.331±0.022(14)	0.111±0.006(15)	0.998±0.124(14)	1.15±0.069 (14)
F	14.413**	12.417**	28.160**	20.226**
P	0.001	0.002	0.000	0.000

Terminal velocity was found to be a linear combination of achene length, achene width, beak length and pappus length. Mean and CV values for each trait, both female-seeds and bisexual-seeds, are given in Table 4. There were significant diaspore traits for the four dependent variables submitted to an analysis of variance. Compared to female-seed, bisexual-seed had lower predicted terminal velocity. Pappus length was significantly larger in bisexual-seed than female-seed.

#### 4. Discussion

We found sexual dimorphism in floral morphology in *T. antungense*, namely a red syngenesious stamen in female compared to yellow stamen in bisexual ones. Information for gynomonoecious taxa is very scarce. In addition, we found a position effect on floral sex for *T. antungense* at the inflorescence level. Broad evidence exists for a decrease in allocation to female sexual structures and/or increase in allocation to male sexual structures along linear inflorescences in hermaphroditic species [9]. Position effect on floral sex at the inflorescence level seems easier to explain. In *T. antungense*, the lateral florets would also have first access to resources, and this could have influenced its central florets as a female flower. Nevertheless, a proper test of this hypothesis would require documenting the relative probability of position effect for female and bisexual flowers.

In the current study, we found that sexual allocation can indeed vary flexibly within-capitulum positions. By contrast, in the examination of most gynomonoecious species, Bertin found no large or consistent effects of within-individual position, plant size and resource availability on floral sex allocation were observed [4]. This lack of variation may be species-species. For instance, the monoecious *Tussilago farfar* shows a large variation in the number of female flowers [10]. As also suggested by Wise et al. [3], intra-inflorescence variation of floral sex ratio may vary remarkably, depending on the type of

environmental stress, or on the different morphological traits in flowers of different sexes. Thus, to evaluate the clear-cut selective advantage of gynomonoeocy, more empirical studies are needed.

The within-capitulum terminal velocity showed in the present study supports the hypothesis that gynomonoeocy might be a response to differences spread ability. Torices et al.[10] have proposed that resource competition and architectural effects between flowers and fruits within capitula produce a decreasing resource gradient from the outermost to the innermost flowers. Thus, it is common in Asteraceae that outer flowers can reach larger seed sizes than inner flowers. Nutrient stress caused a significant shift toward greater relative femaleness in *T. antungense*, since asexual dandelions do not require pollination to trigger endosperm development[11], pollen production has been seen as a pure waste of resources. The fact that stress from nutrient shortage on floral-sex ratio is interesting, but not easily explained. The resources used to production pollen shift to produce the female flowers to guarantee the number florets of head, meanwhile increase the scape height to promote the spread of seeds.

Plasticity has been defined as the ability of an organism to adjust its performance by altering its morphology and/or physiology in response to varying environmental conditions. However, there are complications for gynomonoeocious plants that do not occur in other breeding systems. Gynomonoeocious plants could potentially shift to more male-biased reproduction by increasing the number of perfect flowers relative to female flowers. But because perfect flowers are likely to be more expensive, this change would only make adaptive sense with a concomitant reduction in the total number of flowers. A second option to save resources would be to shift the focus from perfect to female flowers, with or without a reduction in the total number of flowers. This second option would cause a somewhat counterintuitive increase in phenotypic femaleness in response to environmental stress, but it still makes adaptive sense.

In conclusion, we have documented for the first time the presence of gynomonoeocy in *Taraxacum*, gynomonoeocious plants offer interesting opportunities to test predictions of sex-allocation theory. Nevertheless, further assessment of the sexual system within *Taraxacum*, is required before we can properly assess the commonness of gynomonoeocy in this genus. This research suggests that gynomonoeocy has evolved independently from hermaphroditism within this genus. It is tempting to suggest a connection between gynomonoeocy and apomixis, as has been proposed for the evolution of dioecy. In addition, gynomonoeocy in *T. antungense* is coupled to a clear sexual dimorphism in anther color and a position effect on floral sex. Floral sex ratio showed a significant variability among positions within capitulum. Our study can improve our knowledge of sexual systems in plants and document relevant evolutionary patterns in sexual dimorphism and position effects of floral sex. A fuller consideration of gynomonoeocious plants will enable a more comprehensive and more robust development of the already rich body of sex-allocation theory.

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