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PATTERNS OF FRUIT AND SEED PRODUCTION AND CHARACTERISTICS OF SOIL SEED BANK OF DESERT PLANT *HYPECOUM ERECTUM* L. (PAPAVERACEAE)

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Abstract

The fruiting and seed setting patterns and characteristics of soil seed bank of *Hypecoum erectum* L. were counted by field investigation statistics. The results showed that there was a significant positive correlation between the proportion of dichasium of different sizes in all inflorescence and its seed setting rate, among which the proportion of dichasium containing 4-10 flowers (medium number of flowers) and its seed setting rate were the highest. This distribution pattern can ensure the reproductive success. The fruiting pattern within inflorescence is shown the location of single flowering (counting from 1-order branch near stalk end) has a negative linear correlation with its seed setting rate. The 1st order branches at the base of the inflorescence had the highest seed setting rate, while the 4th order branches at the top had the lowest seed setting rate. The results of this study can explain the reasons for the difficulty of sexual renewal in natural populations, providing a theoretical basis for the conservation of this species. And there is a correlation between seed rate and seed location in the fruit. The seed rate was lowest at the base and top of the fruit and highest in the middle. The seed bank density showed that leeward sides of the shrub > smoothly sandy area > windward sides of the shrub in population A; bottom > lower > middle > top of dune in population B. The number of valid seeds distributed within the depth of 0 - 2 cm in the seed bank was decreasing gradually from June to May in next year. The vertical position of sand dunes and wind erosion are important factors affecting seed bank density.

Key words: *Hypecoum erectum* L.; Fruiting pattern; Seeding pattern; Soil seed bank.

Introduction

The flowers, inflorescence, fruits and seeds of plants and even the reproductive branches adhering these organs can be called reproductive modules (Fang, 1996), which show a certain distribution pattern and dynamic changes in quantity (Lovett, 1980; Cox, 1982; Ellstrand, 1984). The characteristic of fruiting and seed setting of plants not only occupies an important position in the life history of plants, but also is one of the important contents of plant reproductive ecology study (Stephenson, 1981; Lee & Bazzaz, 1982; Hossaert & Valero, 1988; Gómez & Zamora, 2003). The fruit distribution pattern of a plant, mainly includes the fruiting state at the level of the inflorescence and that of the branches at all levels (Fang & Zhang, 1996).

The fruiting pattern of plants is primarily influenced by three factors: Inside factors, external biological factors (pollinators and predators) and abiotic factors (light, water and temperature) (Fang & Zhang, 1996). Seeding pattern refers to the distribution of seeds in the fruit. In the fruiting and seeding pattern of seed plants, abortion of fruit and seeds can be divided into selective abortion and random abortion. In recent years, selective abortion of plants is not only a hot issue in the study of the pattern of fruit and seed production, but also one of the important aspects in the study of plant evolutionary biology (Casper, 1984; Sutherland, 1986). Selective abortion refers to the factors such as pollen source, pollination sequence, fruit position on the plant and number of seeds in the developing fruit, or the phenomenon of selective abortion of fruits or seeds during development based on a combination of these factors, which is commonly found in Leguminosae, Cruciferae and Lithospermum of the family Boraginaceae in the fruits having linear arrangement of seeds (Zhao & Tan, 2007). The seed in the fruit with linear arrangement, There are three types of seed selective abortion: the first is seed abortion at the end of pedicel or base of the fruit (Ganeshaiah & Uma, 1988; Arathi *et al.*, 1999); The second is the selective abortion of the seeds at the stigma end and base of the fruit, and the mature seeds in the middle of the fruit (Bawa & Buckley, 1989); The third type is selective abortion of seeds at the stigma end of the fruit (Horovita *et al.*, 1976; Hossaert & Valéro, 1988). By selectively aborting some fruits or seeds with selfing, or some fruits or seeds with poor genotypes, plants can increase the diffusion efficiency of fruits or seeds while improving the fitness of maternal plants and offspring (Zhao & Tan, 2007).

The soil seed bank is the sum of all viable seeds that are present in the soil surface for a given period of time, and is the potential plant community or population that provides a stable propagule for replenishing, renewing, perpetuating, and restoring damaged ecosystems (Guo *et al.*, 1998; Cabin & Marshil, 2000). Soil seed banks record the recent vegetative life of an area and potential future patterns of new seedling germination in the area, and play an important ecological role in linking past, present, and future plant community structure and dynamics (Xue & Lu, 2017). Under natural conditions, plant seeds are influenced by many ecological factors throughout their growth and development, mainly including the effects of dispersal of mature seeds, and the process of their continued germination and growth in the soil under ideal conditions.

The majority of new seeds are lost due to necrosis, senescence, and use as fodder, with only a small percentage of viable seeds entering the soil to form a seed bank (Cabin & Marshil, 2000). During the seed maturation season, seeds reach the ground by dispersal. This process is influenced by a combination of factors such as wind, animal feeding, community or vegetation type, and microhabitats in arid ecosystems (Brown *et al*., 1979; Caballero *et al*., 2003). At the same time, these factors interact to form a particular spatial and temporal pattern of the soil persistent seed bank. As a result of the growing recognition of the ecological and evolutionary significance of seed banks, many field experiments have documented the distribution patterns of soil seed banks, and in particular have explored the importance of persistent soil seed banks in restoring desert vegetation populations or communities (Reichman, 1984; Gul & Weber, 2001).

Hypecoum erectum L. is an ephemeral plant of the Papaveraceae in *Hypecoum*, which is distributed only sporadically on the mobile - semi-mobile dunes of the southern margin of the Gurbantunggut Desert in Xinjiang Province, China. Focusing on the perspective of reproductive distribution of species, through observation and statistics of the number of fruit and seed setting in different parts of inflorescence, within infructescence and fruit, and soil seed bank. This paper intends to emphasize: 1. Fruit pattern between inflorescences of natural populations of *H. erectum*; 2. Fruit pattern in infructescence of natural populations of *H. erectum*; 3. Seed pattern in the legume of natural populations of *H. erectum*. 4. Characteristics of seed bank *H. erectum*. Meanwhile, further analyzes the ecological evolutionary significance of the pattern of fruit, seed setting and soil seed bank, which is conducive to the conservation of this species and the thorough understanding of the reproductive strategies of other desert plants.

Materials and Methods

Study site: Gurbantunggut Desert is the second largest desert in China (84°50′-91°20′ E, 49°15′-46°50′ N) The annual average temperature in this area is 6-10℃, and the extreme maximum temperature is over 40℃. The average temperature in May is 12-22℃, the annual precipitation is 80-160 mm, and the annual evaporation is 2000-2800 mm. Low precipitation, strong evaporation, long sunshine and variable temperature are the main climate types in Gurbantunggut Desert (Zhang & Chen, 2002). The observed natural population of *H. erectum* is located in the operation area of Cainan Oilfield on the southern margin of Gurbantunggut Desert (88°20'47.5"E, 49°59'18.2"N, elevation 676 m, area 50 m × 50 m). The dominant species in the population mainly include *H. erectum* and *Eremopyrum triticeum*, *Allium pallasii*, *Lepidiumperfoliatum*, *Ceratocarpus arenarius* and *Lappula semiglabra*.

Experimental design

Seed quality measurement and morphological observation: During the maturation date, seeds of 50 plants were randomly picked from the *H. erectum* population and stored them in a refrigerator at 4℃ for later use after air drying. In the experiment, 1000 seeds were randomly selected from the seed samples, and their 1000-grain weight was measured by an electronic balance of 1/10000. The mean value of 1000 ×5 groups was used as the average weight (± standard deviation). The seeds were sprayed with gold and observed under Leo 1430 scanning electron microscope (Changchun University).

Phenology observation at population level: From April to June 2023, the flowering phenology characteristics of *H. erectum* were observed and counted from the population level. The main flowering parameters observed and counted were the first flowering date, the peak flowering date, the duration time and the last flowering date. At the population level, the flowering time of 25% of the individuals is regarded as the first flowering date, the flowering peak of 50% of the individuals is regarded as the peak flowering date of the population, and the flowering end of 95% of the plants is regarded as the last flowering date of the population. The phenology observation of emergence date, maturation date and withered was carried out according to the methods of Wan & Liu (1987).

Fruiting pattern between inflorescence: In May 2023, 100 plants of *H. erectum* with basically the same development were randomly selected in the *H. erectum* population, from which 200 dichasium were randomly selected (2 dichasium per plant). At the beginning of the fruit development, the morphology of the fruit and the position in the inflorescence were observed every day, mature fruits in each inflorescence, and the number of flowers in each inflorescence were counted and proportion and seed rate of inflorescence of different sizes were calculated.

$$\text{Proportion} = \frac{\text{Number of inflorescences of different sizes}}{\text{Number of all inflorescence}} \times 100\ \%$$

$$\text{Seed rate} = \frac{\text{Number of fruit}}{\text{Number of flowers}} \times 100\ \%$$

Fruiting pattern in the infructescence: In May 2023, 25 plants of *H. erectum* with uniform development were randomly labeled in the population, and each plant with 4 branches with dichasium of 4-order branches was randomly labeled and the observation was continued until the fruit was mature. The seeding rate at different positions (1st order, 2nd order, 3rd order, 4th order) on a single infructescence was calculated by referring to the statistical method of ripe fruits among infructescences. The inflorescence type of *H. erectum* is dichasium, which first formed 1st order flower buds, and then developed a pair of branches on both sides of the 1st order flower buds at the same time, and then the branches continued to produce flower buds (called 2nd order flower order, 3rd order flower order, and so on) and branches. In dichasium of 1st order, the flower buds of 1st order were the first to open, followed by the flower buds of other orders, and the last to open was the flower buds formed by the branches of dichasium that were finally differentiated. The position of fruit in the infructescence formed by flower bud development of order 1 was denoted as 1; The position of fruit in the infructescence formed by flower bud development of order 2 was denoted as 2; The position of fruit in the infructescence formed by flower bud development of order 3 was denoted as 3; The position of fruit in the infructescence formed by ray flower was denoted as 4 (Fig. 1).

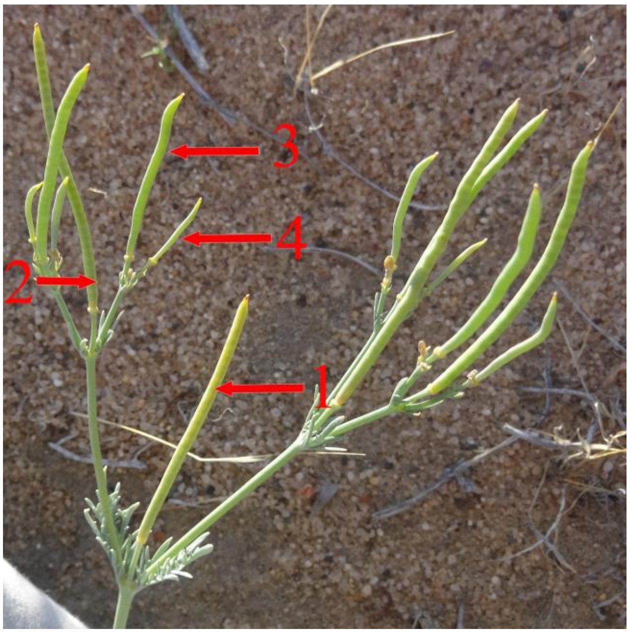

Fig. 1. The diagram of dichasium cyme in *H. erectum* (a principal axis).

Seeding pattern in legume: In May 2023, in the *H. erectum* population, 30 mature fruits were randomly selected, and the peel was opened with a scalpel under the microscope. The number and position of mature seeds and the number of ovules in each fruit was counted and recorded.

Soil seed banks

Sample plot setup and sampling time: Two germination strategies for *H. erectum* populations, fall and spring germination. Two *H. erectum* populations distributed in the hinterland of the Gurbantunggut Desert at the Cainan Petroleum Base were used as the study object, and two 50 m × 50 m plots were laid out. In order to investigate the spatial and temporal distribution characteristics of the *H. erectum* seed bank, the sample line method and the random method were adopted on July 6-9, 2022 (to determine the soil seed bank after the replenishment of new seeds in the current year), October 21-24 (to determine the soil seed bank renewed prior to the fall germination of the seeds), December 5-8 (to determine the soil seed bank renewed after the fall germination of the seeds), March 19-22, 2023 (to determine the soil seed bank renewed prior to spring germination of seeds), and May 1-4, 2023 (to determine the soil seed bank renewed after spring germination of seeds), and soil seed bank sampling was conducted for eight sample plots (four sample plots in Population A, and four sample plots in Population B) within the two *H. erectum* natural populations. The five sampling times cover all time points in the life cycle of *H. erectum* where the soil seed bank is replenished and depleted.

Sample line method for sampling the soil seed bank: The dune where Population A is located has a hight slope and few shrubs within the population, no sand accumulation. During each sampling, a parallel sample line was set at the upper, middle, lower and bottom of the dune, respectively. On each sample line, one small sample square of 20 cm × 20 cm (avoiding potholes and rat holes) was set up every 4 m, totaling five small sample squares. Inside the small sampling plots, a homemade soil stratification sampler (specifications: L × W × H = 20 cm × 20 cm × 10 cm; stratification: 0-2 cm, 2-4 cm, 4-6 cm, 6-8 cm, 8-10 cm) was used to collect sandy soil from an area of 20 cm × 20 cm, with depths of 0-2 cm, 2-4 cm, 4-6 cm, 6-8 cm, and 8-10 cm, and a total of five sampling profiles of sandy soil. The stratified soil samples were introduced into the sieve from the sampler from top to bottom layer by layer, and the seeds were separated by mesh sieve sorting method and put into cloth bags separately and brought back to the laboratory.

Randomized method of sampling the soil seed bank: The dune where population B was located had a relatively flat slope and there were more shrubs within the population. The sand surface locally showed a convex and concave undulation, local windward slopes were mainly affected by wind erosion, while local leeward slopes had obvious sand accumulation, and local scrub slopes, both wind erosion and sand accumulation were more obvious. Therefore, four sample plots were selected for soil seed bank sampling, namely, sand accumulation gentle, sand accumulation under scrub, wind erosion gentle and wind erosion under scrub. Five were randomly set up in each sample plot, and soil samplers and corresponding methods in Population A were used for sampling within the sample plots.

In this study, the size of *H. erectum* soil seed bank was expressed as the number of *H. erectum* seeds per square meter unit area of soil, and the number of viable seeds within a sampling area of 20 cm × 20 cm was converted to the number of seeds in an area of 100 cm × 100 cm as the size of the *H. erectum* seed bank.

Data analysis

SPSS 17 was used to analyze the obtained data, and Origin 8.5 was plotted; Bivariate Correlations was used for the correlation analysis between proportion of different size of inflorescence and seed setting rate; Linear Regression was used to establish a Linear Regression equation for the ratio of the fruiting mass to the total fruit mass in the infructescence from the 1st order branch near the stalk end to the 4th order branch at the top; The quadratic regression equation of seed location and number of seeds was established with Curve Estimation.

Research results

Seed quality and morphology: The 1000-seed weight of *H. erectum* was (0.2910 ± 0.0027) g. The seeds of *H. erectum* were black and brown, rectangular (Fig. 2A), with an "X" shape protrusion on its side, with a length of (0.96 ± 0.04) mm and a width of (0.69 ± 0.03) mm. Seeds were oblong, surface raised and reticulated. The mesh in the hollow of the surface of seed skin is mostly 5-6 angles, and there were cuboid protrusions in the middle of the mesh. The cuboid had a granular projection or network structure. At the same time, the pore structure was formed in other parts of the mesh, and the mesh ridge can be clearly seen (Fig. 2B).

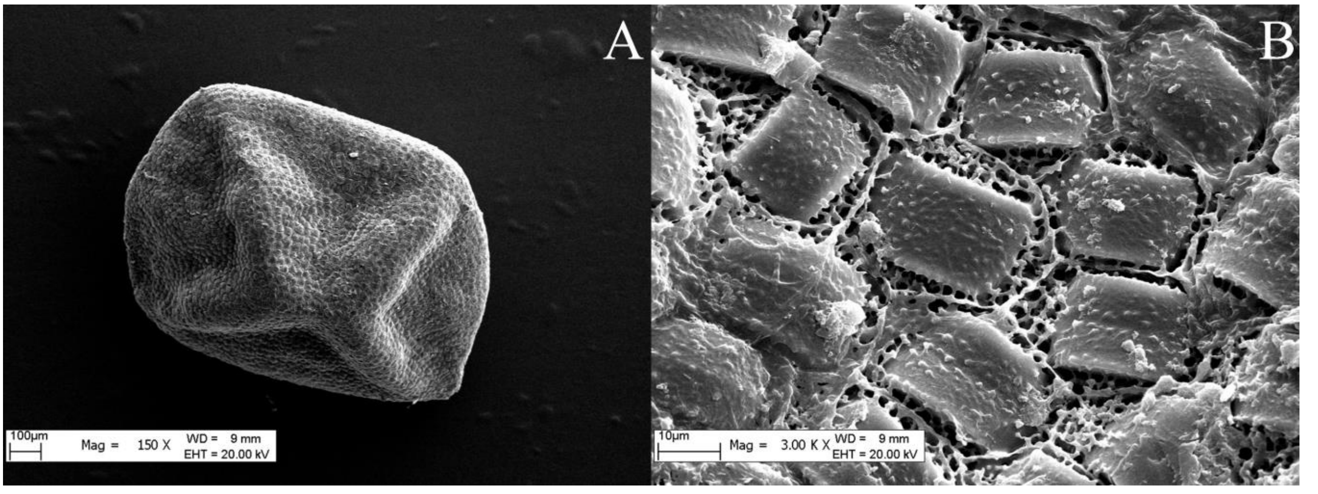

Fig. 2. SEM photomicrographs of the seed morphological of *H. erectum*.

Reproductive phenological characteristics: The flowering period of *H. erectum* population is from late April to early June. The flowering duration of the population level was 40 d and the life cycle was 68 d to 75 d. The flowering phenological characteristics of population level are shown in Table 1.

Table 1. Phenology of *H. erectum* at population level in 2022.

Observation items	Population level
First flowering date	4-28
Emergence date (month-day)	4-1～4-7
Duration	40
Peak flowering date	5-17
Last flowering date	6-2
Maturation date (month-day)	5-27～6-13
Withered (month-day)	6-7～6-20
Living circle (d)	68～75

Fruiting patterns between inflorescence: The results showed that dichasium in *H. erectum* had a total of 3-4 orders of branches, with the highest proportion of dichasium containing 3 orders of branches, the lowest proportion of dichasium contained 2 orders of branches, and the lowest proportion of dichasium contained 1 orders of branches and 4 orders of branches.

The dichasium size of *H. erectum* was concentrated between 2-16 flowers. Statistics showed that dichasium with more than 10 flowers and less than 4 flowers was less prevalent in common inflorescence than those that tended to produce dichasium with 4-10 flowers; Moreover, the proportion of dichasium of different sizes in plants in common inflorescence had a significantly positive correlation with its seed setting rate (p = 0.021) (Fig. 3).

The fruiting pattern in the infructescence: The flowering position of *H. erectum* (counting from 1st order branch near the stem end) had a negative linear correlation with its setting rate (R^2=0.92), the first-order branches at the base had the highest seed setting rate (93.17 ± 1.79) %, and the fourth-order branches at the top had the lowest seed setting rate (66.72 ± 1.03) % (Fig. 4).

Seed setting in fruit: The results showed that there were 26.32 ± 0.31 ovules within a fruit, of which 24.69 ± 0.31 can form seeds, the seed setting rate in a fruit was (93.81 ± 0.68) %，which can increase the number of seeds in the seed bank. There was a linear correlation between seed setting rate and seed position in the fruit, the seed setting rate was lowest at the base and top of the fruit, and highest in the middle of the fruit (Fig. 5).

Soil seed bank: There were dynamic changes in the distribution of viable seeds within the soil seed bank of *H. erectum* both in time and space. In terms of temporal distribution, from June, October, and December 2022 to March and May of the following year, the densities of the seed bank of population A were (9438 ± 235) grains/m^{-2}, (8020 ± 273) grains/m^{-2}, (7300 ± 251) grains/m^{-2}, (6713 ± 236) grains/m^{-2}, and (5908 ± 229) grains/m^{-2}, respectively, and the seed bank of population B The seed bank densities of population B were (10103±323) grains/m^{-2}, (8868±373) grains/m^{-2}, (8173±549) grains/m^{-2}, (7408±394) grains/m^{-2}, and (6375±246) grains/m^{-2}, respectively, and decreased gradually in both populations. The spatial distribution was mainly divided into horizontal and vertical distribution.

Horizontally distributed, there were significant differences in seed bank densities between the four sample plots all five sampling periods for the *H. erectum* A population (F_7 = 31.380, p = 0.000; F_{10} = 55.062, p = 0.000; F_{12} = 73.239, p = 0.000; F_3 = 68.210, p = 0.000; F_5 = 48.566, p = 0.000), while seed bank density showed lower dune > bottom dune > middle dune > upper dune (p<0.05) during all five sampling periods (Fig. 6A).

Horizontally distributed, there were significant differences between seed bank densities in all four sample plots during the five sampling periods of Population B (F_7 = 35.537, p = 0.000; F_{10} = 35.406, p = 0.000; F_{12} = 13.422, p = 0.000; F_3 = 40.706, p = 0.000; F_5 = 44.675, p = 0.000), meanwhile, seed bank density during all five sampling periods showed that cumulus scrub > cumulus gently > wind erosion scrub (p<0.05), while there was no significant difference (p>0.05) between seed bank density under wind erosion scrub and at wind erosion gently (Fig. 6B).

The results showed that within the two populations, from June 2022 to May 2023, *H. erectum* seeds were mainly distributed in the depth range of 0-6 cm, the number of seeds distributed in the seed was bank decreased with the time, the number of seeds distributed at 0-2 cm as a proportion of the total number of seeds at 0-10 cm within the *H. erectum* seed bank was decreasing (Fig. 7).

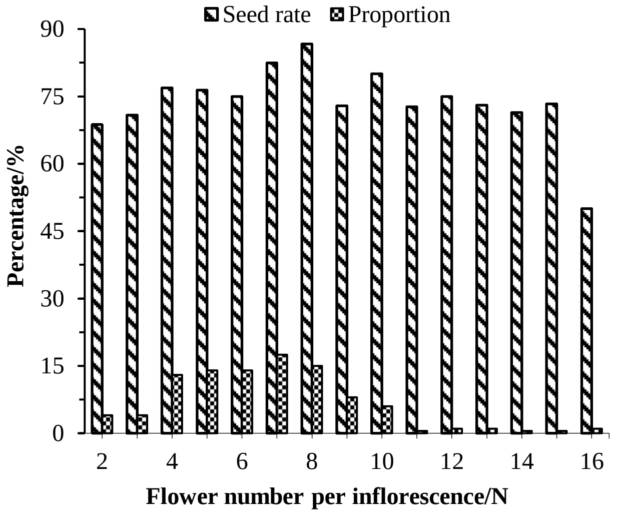

Fig. 3. The correlation between the proportion of flower number in inflorescence and and the seed set rate in *H. erectum*.

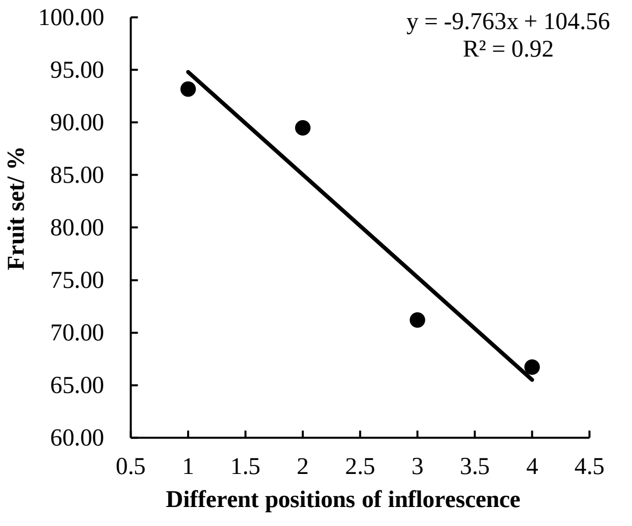

Fig. 4. Fruit setting rates at different positions of inflorescence of *H. erectum*.

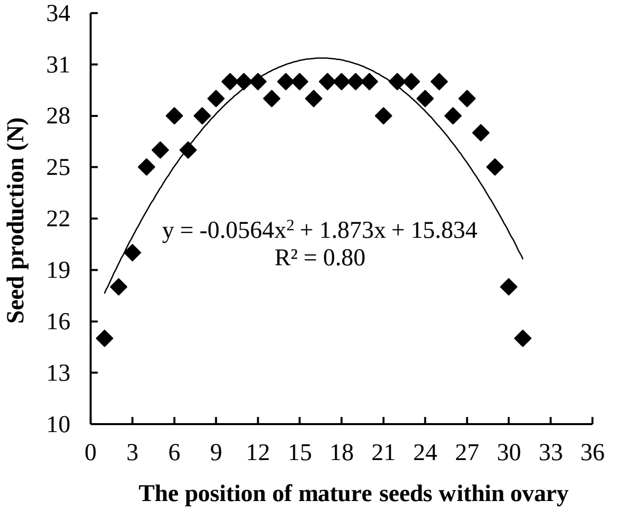

Fig. 5. The variation of seed production from basal position to distal position within the fruit in *H. erectum* under natural condition.

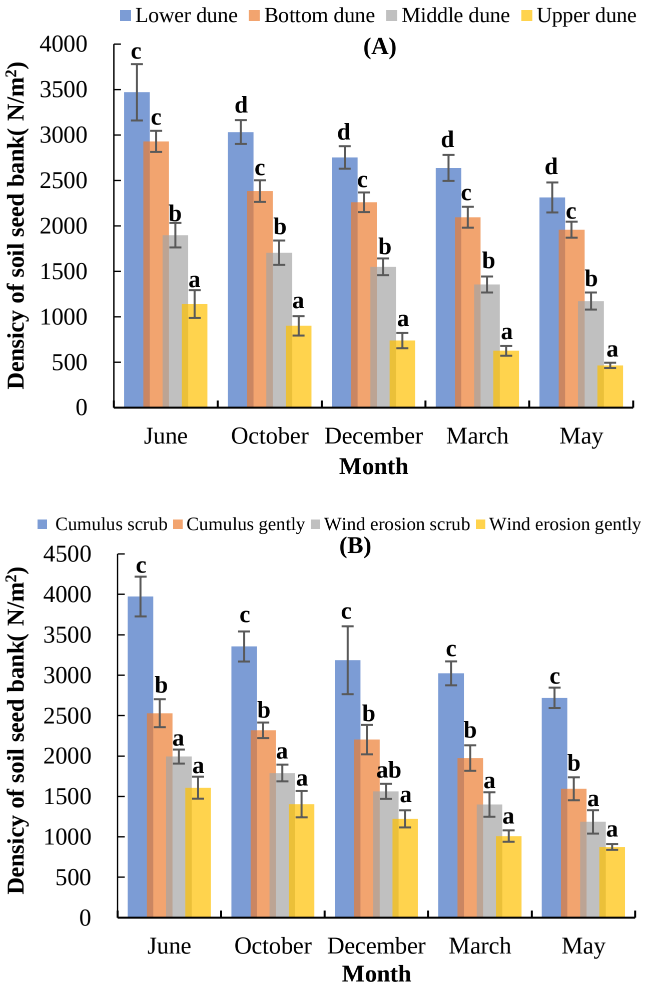

Fig. 6. Comparison of soil seed bank density of *H. erectum* of different sampling time in different micro-sites for two populations. (Note: The different lowercase letters show significant differentiation under the different topographic conditions at the 0.05 level)

Discussion

Fruiting pattern between inflorescence: If the size of the plant's inflorescence is based on a tradeoff between the resources available for producing attractive structures and those available for ripening fruit, the plant prefers to produce large flowers to improve the efficiency of pollen transfer (Willson *et al*., 1979; Schemske, 1980; Firmage & Cole, 1988). Resource constraint is one of the important reasons affecting the fruit of *H. erectum*, and large flowers will inevitably increase the utilization of resources. Therefore, under the circumstance of limited resources, *H. erectum* tend to choose to generate dichasium containing 4-10 flowers (medium number of flowers) (the inflorescence of this size also has a higher seed setting rate). This distribution pattern can effectively attract pollinators, improve seed setting rate, and to some extent ensure the successful reproduction of *H. erectum*. This result is consistent with that of Shi *et al*., (2011).

The fruit-set pattern in the infructescence: In a single infructescence of *H. erectum*, the seed setting rate of the level 1 top flower was significantly higher than that of it in other positions, which was consistent with the first type of fruit selective abortion, the single flower closest to the main axis of the plant had a higher seed setting rate than the single flower at the middle or top of the inflorescence. This agrees with the research results of Casper (1984), Nicholls (1987) and Susko (1998) and Lovett (1980). In dichasium of *H. erectum*, the flowers at the top of level 1 were closest to the branches of the plant Branches are semi-spontaneous construction of plant resource allocation, and resources in branches were preferentially allocated to single flowers near the axial end (Siqin *et al*., 2005). Because in dichasium, the flowers at the top of level 1 was the first differentiation, and compared with flowers at the top in other locations, the flowers at the top of level 1 had advantages in resource competition in terms of time and space, and could obtain more mother resources in the growth and development process, thus making fruit ripening easier.

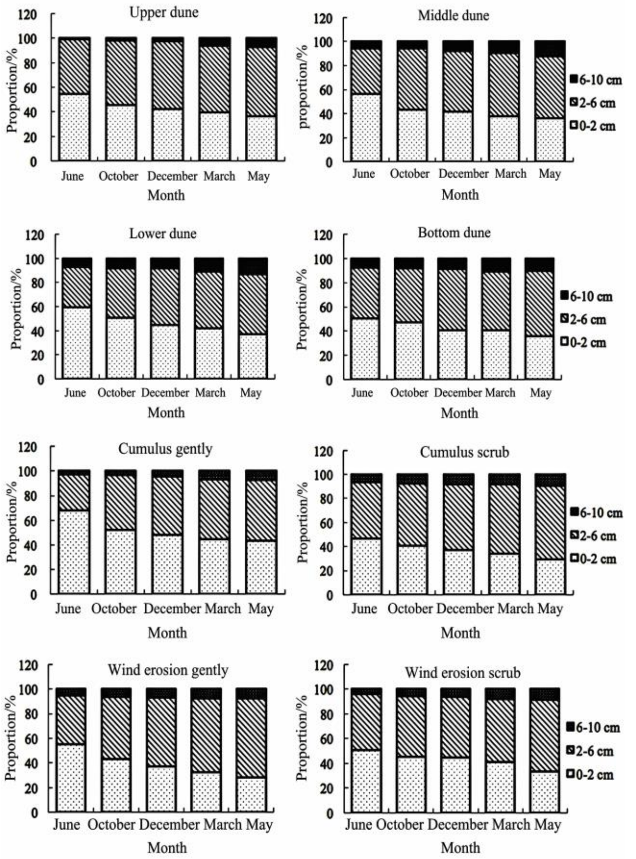

Fig. 7. Depth distribution of *H. erectum* seed under different micro-sites in two populations from different sampling time.

Pattern of seed setting in fruit: As for the study of seed abortion pattern in the fruit, there are no reports on seed formation and ovule position in plants of *H. erectum*. The seed setting pattern of *H. erectum* manifests that the ovules in the middle position of the fruit fruit are more likely to form seeds, which is in line with the results of Shi (2011) on the legumes *Eremosparton songoricum*. According to some scholars, pollen tube always has priority to reach certain ovules after entering ovary, and seed formation is connected with the ovule position (Zhang & Zhu, 2005). With respect to the result of the lowest seed rate at the base and top of the fruit, the author speculates that this is due to the spatial limitation of the base and top of the fruit in *H. erectum*, which impacts the growth and development of the ovules in the fruit of *H. erectum*.

Horizontal variation of soil seed bank density under different microtopographic conditions: Soil seed bank density under different habitat conditions reflects the spatial distribution pattern of soil seed banks (Wang *et al*., 2005). Within population A, seed bank densities of *H. erectum* were usually higher in the lower and bottom parts of dunes within the desert, and the highest seed bank densities usually appeared in the lower parts of dunes. One of the reasons for this phenomenon is due to the fact that most of the *H. erectum* in the population were distributed in the lower and middle parts of desert sand slopes and at the bottom of the slopes where the sand accumulated (Yang *et al*., 2015), and the plants within the population drop their fruits onto the sand surface when they were riped, causing the number of seeds replenished in the lower part of the slope and at the bottom of the slope to be significantly higher than that replenished in the middle of the slope and on the upper part of the slope. Although *H. erectum* seeds have a thousand-seed weight of only (0.2910±0.0027) g and can be dispersed by wind, the effect of wind on seed dispersal is more limited because the dunes in the Gurbantunggut Desert are mostly fixed dunes with high vegetation density. Therefore, the density of the seed bank at the bottom and bottom of the slope will remain higher than the density of the seed bank in the middle and top of the slope during the continuous dispersal of *H. erectum* seeds. The wind speed starts to intensify from the middle and lower part of the windward slope of the dune until it reaches the highest in the upper part of the dune. Seeds in the upper part of the dune can be dispersed by strong winds, slipped by the effect of slope, or dispersed or slipped by animal or human trampling (Ha *et al*., 1999), whereas the sand in the lower part of the dune will be more stable due to the lower gradient (Wang *et al*., 2005). Therefore, wind has less effect on the seeds of *H. erectum* in the lower part of the dune, and it is more likely to accumulate the seeds.

Wang *et al* (2005) investigated the seed bank distribution pattern of feathery needlegrass and found that the seed bank distribution pattern of feathery needlegrass was influenced by other plants in the desert. Shi *et al* (2011) investigated the seed bank distribution characteristics of a rare desert species, Junggar leafless bean, and found that the highest seed bank density was found under the sandy scrub within the population. The vegetative scrub within the desert significantly affects the distribution pattern of the seed bank of plants around it. Our results indicate that within Population B, hornbeam can retain more seeds in the lower layers of the scrub, and the seed bank density under sand-accumulating scrub is significantly higher than the other three habitat conditions within this population. This phenomenon has been observed and explored by various scholars within arid regions and desert environments (Cabin & Marshil, 2000; Caballero *et al*., 2003), where scrub not only facilitates the accumulation of dead leaves and soil, but at the same time facilitates the accumulation of seeds and provides the opportunity for seed germination and seedling establishment (Happer, 1977). Within the B population of *H. erectum*, the seed bank density of *H. erectum* was relatively low in two microtopographies, under the wind erosion scrub and on the wind erosion flats, and this phenomenon occurred because *H. erectum* seeds on the wind erosion sites were able to be dispersed over a wider area when the wind and sand activities were stronger, while the scrub on the sand accumulation sites had a significant role in wind and sand stabilization. The results of this study are consistent with those of Zhao *et al*., (2007) and Ren *et al*., (2009).

Conclusion

Phenology of the *H. erectum* population is from late April to early June, with a duration of 40 d at the population. The frequency distribution of inflorescence size and fruit set was positively correlated. This distribution pattern ensures reproductive success to the greatest extent. There was a linear negative correlation between the location of single flower and its fruit set. The fruit set of the first branch at the base of inflorescence was the highest (93.17 ± 1.79) % and that of the fourth branch at the top was the lowest (66.72 ± 1.03) %. There was a correlation between the position of mature seeds within ovary and seed production, and the seed set in the middle of the fruit was the highest. The top flowers can compensate for the loss of base flower. This spatial effect may be a compensatory effect to resist the disturbance of early fruit development caused by desert strong wind and high temperature weather. Meanwhile, the vertical position and wind erosion of sand dunes in the Gurbantunggut Desert are important factors affecting seed bank density. Research on soil seed banks, analyzea the reasons for the difficulty of sexual regeneration in natural populations, and provides theoretical basis for the conservation of *H. erectum*.

Acknowledgements

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