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The Comparative Study on Diaspore Weights of 65 Plant Species in the Xianghai Natural Reserve of Jilin Province

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Abstract:

The comparative study on diaspore weights of 65 plant species in the Xianghai Natural Reserve of Jilin Province was conducted to have a better understanding of regeneration strategies of these species for purposes of improving the vegetation managements and restorations. Plant diaspores are usually referred to as seeds, even though many of them are in fact fruits. In the research, the air-dried weights of 50 diaspores were measured for each plant, and then the data on seeds and indehiscent, single-seeded fruits were analyzed. The results indicated that the weight per seed or fruit of the plant diaspores varied greatly, from 0.0096 mg for the lightest seed of Orobanche coerulescens to 131.50 mg for the heaviest fruit of Tribulus terrestris; and could be respectively divided into four groups (<0.1 mg, 0.1-1mg, 1-10mg, 10-100mg) or five groups (<0.1 mg, 0.1-1mg, 1-10mg, 10-100mg, 100-200mg). The plant species, such as Chenopodium aristatum, Agrostis Clavata, Typha minima, Artemisia lavandulaefolia, Chenopodium acuminatum, Setaria viridis, Taraxacum mongolicum, Calamagrostis epigejos, Saussurea amara, Ixeris chinensis, could distribute widely in the Xianghai Natural Reserve on account of the lighter weight of diaspores with the help of wind dispersal. Moreover, the plant species, such as Chenopodium aristatum, Orobanche coerulescens, Puccinellia tenuiflora, Potentilla discolor, Chenopodium acuminatum, Silene jenisseensis, Plantago depressa, Lythrum virgatum, Setaria viridis, Thymus serpylium, Polygonum thunbergii, Thalictrum simplex, Galium verum, Sium suave, could be of persistent soil seed banks on account of the lighter weight (<1 mg) and approximate spherosome shape of diaspores. In semi-arid sandy areas, plants formed special reproductive strategies with the help of diaspore morphology, which reduced the risk of population survival to a certain extent, and played an important ecological significance for sustainable population reproduction.

***Keywords**: Desertification; Diaspore; Soil seed bank; Vegetation restoration.*

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I. INTRODICTION

In the research of modern seed ecology, the relationship between the diaspore weight, as an important characteristic of plant diaspore morphology, and its ability to adapt to disturbance has always attracted much attention [1, 2]. A large number of studies have shown that the weight and shape of plant diaspores are closely related to the dispersal distance, the lifespan of soil seed bank, the success rate of plant settlement and plant reproductive capacity [3-6]. Small, nearly spherical seeds of plants are more likely to form persistent soil seed banks [1, 2], one of the mechanisms by which plants could be able to adapt to disturbance in arid environments [6-8].

Diaspore weights also affected the spatial distribution pattern of vegetation to a certain extent [1-4]. It has been reported that plants of small seeds could be able to bear a larger number of seeds, which gives them a strong ability to spread and diffusion and are easier to spread to distant places under the action of external forces such as wind, thus expanding the spatial and temporal distribution of the population [2, 4, 5]. Therefore, the diaspore weights are closely related to the dispersal of diaspores and spatial pattern of the population.

Liu *et al* conducted a comparative study on the diaspore morphology (weight, shape, etc.) of a large number of plants in Horqin Sandy Land, and discussed the relationship between diaspore morphology and psammophytic adaptability of plants [1, 2, 5-8]. However, there are few studies on the relationship between diaspore morphology and ecological significance in Xianghai Nature Reserve in the western Jilin Province.

The Xianghai National Nature Reserve is an extension of Horqin Sandy Land, the landform of which is characterized by sandy and salinized plains. With the aggravation of global climate warming, the desertification area of the Nature Reserve has a tendency to increase [9]. Therefore, vegetation restoration in Xianghai Nature Reserve, especially in desertified areas, is a serious and major issue to be addressed. The study on the restrictive mechanism of vegetation restoration in desertified areas of the Xianghai Nature Reserve from the perspective of seed ecology is an effective way of solving the problem.

In order to provide the references for vegetation restoration, the diaspore weights of 65 plant species in the flora of the Xianghai Nature Reserve were comparatively studied, and the relationship between the diaspore morphology and the adaptability of psammophytes was discussed.

II. MATERIALS AND METHODS

2.1 Overview of the Study Area

The Xianghai National Nature Reserve (44°55′-45°09′N, 122°05′-122°31′E), where the ridge dunes are interlaced with interdune depressions, is a continental monsoon climate in the north temperate zone, and is

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windy and arid in spring. The annual average temperature is 5.1℃, and the annual average precipitation is 400 mm. The main soil types are aeolian sand soil and meadow soil.

2.2 The Research Methods

The plant diaspores (mature seeds or fruits) were collected from plants with different crown widths (large, medium and small) in proportion and from the upper, middle and lower parts of the plants during the seed maturity in the autumn of 2020 in the Xianghai Nature Reserve, and then were mixed all together. The intact diaspores were selected and measured after air-drying. The gramineous plants with lemmas and miscanthus were measured using an analytical electronic balance. The crested hairs, hooks or spines of other plants were retained during measurement. Due to the limitation of experimental materials, the diaspore weight is the air-dried weight of 50 grains [3-6]. Each measurement has five replicates. The measurement was carried out in the Integrated Technology Research Center of Environmental Protection and Ecological Engineering in western Jilin Province.

Latin names were quoted and biotypes and ecological groups of plants were identified on the basis of relevant literatures (TABLE I) [10-12].

TABLE I. The diaspore weights and classifications of 65 species of plants

Plant species	**Family**	**Biotype**	Ecological group	**Weight of 50 grains(mg)(±SE)**	**Propagandist type**
Chloris virgata Swartz	Gramineae	AH	W	29.14±0.92	Caryopsis
Aristida adscenionis Linn.		AH	ST	50.23±2.23	Caryopsis
Arthraxon hispidus (Thunb.) Makino		AH	M	39.20±2.03	Caryopsis
Oxytropis glabra (Lam.) DC.		PH	W	163.24±5.86	Caryopsis
Stipa krylovii Roshev		PH	ST	662.24±71.24	Caryopsis
Puccinellia tenuiflora (Griseb.) Scribn.et Merr.		PH	M	4.02±0.56	Caryopsis
Calamagrostis epigejos (L.) Reth.		PH	M	10.76±0.62	Caryopsis
Leymus chinensis (Trin.) Tzvel.		PH	M	143.28±5.40	Caryopsis

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Phragmites australis (Cav.) Trin.ex Steudel		PH	M	16.20±0.46	Caryopsis
Setaria viridis (L.) Beauv.		AH	W	28.78±2.07	Caryopsis
Miscanthus sacchariflorus (Maxim.) Hack.		PH	M	27.96±3.12	Caryopsis
Agrostis Clavata Trin.		PH	M	4.10±0.18	Caryopsis
Agropyron cristatum (L.) Gaertn.		PH	ST	112.32±2.42	Caryopsis
Spodiogon sibiricus Trin.		PH	M	56.84±2.65	Caryopsis
Pennisetum fraccidum Grseb.		PH	P	48.56±1.08	Caryopsis
Erigeron acer L.	Compositae	BH	W	8.10±0.69	Achene
Artemisia lavandulaefolia DC		PH	W	5.12±0.24	Achene
Cirsium setosum		PH	W	178.41±3.58	Achene
Eupatorium lindleyanum DC.		PH	M	15.85±0.42	Achene
Heteropappus altaicus (Willd.) Novopokr.		PH	ST	18.65±0.74	Achene
Inula britanica L. var.japonica (Thunb.) Franch.et Sav.		PH	M	6.59±0.88	Achene
Ixeris chinensis (Thunb.) Nakai		PH	W	13.08±0.32	Achene
Mulgedium tataricum (Linn.) DC		PH	M	32.26±1.54	Achene
Saussurea amara (L) DC.		PH	M	33.25±1.88	Achene
Saussurea runcinata DC.		PH	M	81.80±7.09	Achene
Scorzonera albicaulis Bunge		PH	M	161.15±8.13	Achene
Senecio argunensis Turcz.		PH	M	37.08±1.92	Achene
Taraxacum mongolicum Hand.-Mazz.		PH	M	45.11±3.22	Achene
Potentilla discolor Bunge	Rosaceae	PH	M	3.69±0.30	Achene

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Polygonum lapathifolium Linn.	Polygonaceae	AH	M	89.42±5.89	Achene
Polygonum thunbergii Sieb.et Zucc		AH	M	47.85±2.40	Achene
Polygonum divaricatum L.		PH	M	428.44±15.94	Achene
Thalictrum simplex L.	Ranunculaceae	PH	M	38.23±2.54	Achene
Typha minima Funck	Typhaceae	PH	M	2.44±0.21	Nutlet
Typha angustata Bory et Chauberd		PH	M	3.42±0.13	Nutlet
Thymus serpylium L. var. mongolicus Ronn.	Labiatae	SS	ST	14.80±3.28	Nutlet
Stellera chamaejasme L.	Thymelaeaceae	PH	ST	60.40±1.23	Nutlet
Galium verum L.	Rubiaceae	PH	ST	32.21±2.47	Twin fruit
Saposhnikovia divaricata (Turc z.) Schischk.	Umbelliferae	PH	M	132.32±7.80	Twin fruit
Sium suave Walt		PH	M	56.44±2.45	Twin fruit
Tribulus terrestris L.	Zygophyllaceae	AH	P	6575.84±289.92	Aggregate fruit
Euphorbia humifusa Willd.	Euphorbiaceae	AH	W	53.62±1.05	Capsule
Linaria vulgaris Mill.	Scrophulariaceae	PH	P	8.49±0.56	Capsule
Polygala tenuifolia Willd.	Polygalaceae	PH	P	211.25±13.27	Capsule
Atriplex patens (Litv.) lljin.	Chenopodiaceae	AH	W	405.30±9.95	Utricle
Corispermum candelabrum lljin		AH	P	112.26±2.85	Utricle
Chenopodium acuminatum Willd	Chenopodiaceae	AH	W	20.09±0.17	Seed
Chenopodium aristatum		AH	W	4.86±0.12	Seed

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L.					
Orobanche coerulescens Steph.	Orobanchaceae	AH	M	0.48±0.09	Seed
Linum stelleroides Planch	Linaceae	ABH	M	24.52±1.53	Seed
Hyoscyamus niger L.	Solanaceae	BH	W	29.65±1.48	Seed
Thermopsis lanceolata R.Br.	Leguminosae	PH	M	823.60±15.57	Seed
Oxytropis ramosissima Kom.		PH	P	94.45±1.24	Seed
Cynanchum paniculatum (Bunge) Kitagawa	Asclepiadaceae	PH	M	213.35±17.57	Seed
Cynanchum chinense R. Br.		PH	W	236.69±18.39	Seed
Periploca sepium Bunge		S	ST	654.18±47.43	Seed
Asparagus dauricus Fisch.ex Link	Liliaceae	PH	P	854.84±9.15	Seed
Allium japonicurn Regel		PH	M	95.96±1.19	Seed
Lilium pumilum DC		PH	M	65.12±3.88	Seed
Silene jenisseensis Willd.	Caryophyllaceae	PH	M	7.98±0.18	Seed
Dianthus chinensis Linn.		PH	ST	28.62±0.79	Seed
Plantago depressa Willd.	Plantaginaceae	PH	W	11.80±0.12	Seed
Lythrum virgatum Linn.	Lythraceae	PH	M	8.71±0.23	Seed
Salix mongolica	Salicaceae	S	M	7.96±0.26	Seed
Salix microstachya Turcz.		S	M	19.23±1.08	Seed

AH: Annual Herbs, ABH: Annual or Biennial Herbs, BH: Biennial Herbs, PH: Perennial Herbs, S: Shrubs, SS: Subshrubs, W: Weeds, ST: Steppe Plants, M: Meadow Plants, P: Psammophytes.

III. RESULTS AND ANALYSIS

Among the 65 species of plants collected in Xianghai Nature Reserve, the diaspores of 19 species were seeds and the ones of 46 species were fruits. The fruits included caryopsis of 15 Gramineae plants and

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achenes of 13 Compositae plants. All the diaspores of Legume (2 species), Asclepiadaceae (3 species), Liliaceae (3 species), Salicaceae (2 species) and Caryophyllaceae (2 species) were seeds (TABLE I).

3.1 The Analysis of Single-Grain Weight of Plant Diasporas

The weight per grain of the plant diaspores varied greatly, from 0.0096 mg for the lightest seed of *Orobanche coerulescens* to 131.50 mg for the heaviest fruit of *Tribulus terrestris*.

The 46 species of plant diaspores as fruits and the 19 species of plant diaspores as seeds were respectively divided into 5 groups (<0.1 mg, 0.1-1mg, 1-10mg, 10-100mg, 100-200mg) and 4 groups (<0.1 mg, 0.1-1mg, 1-10mg, 10-100mg) by weight per grain (TABLE II).

TABLE II. The weight groups of the plant diaspore per grain

Groups		Plant Species
＜0.1 mg	Seed	Chenopodium aristatum L., Orobanche coerulescens Steph.
	Fruit	Puccinellia tenuiflora (Griseb.), Agrostis Clavata Trin., Potentilla discolor Bunge,Typha minima Funck, Typha angustata Bory et Chauberd
0.1-1 mg	Seed	Artemisia lavandulaefolia DC, Chenopodium acuminatum Willd, Salix mongolica, Salix microstachya Turcz., Dianthus chinensis Linn., Silene jenisseensis Willd., Hyoscyamus niger L., Plantago depressa Willd., Lythrum virgatum Linn., Linum stelleroides Planch
	Fruit	Erigeron acer L., Eupatorium lindleyanum DC., Heteropappus altaicus (Willd.) Novopokr., Inula britanica L. var.japonica (Thunb.) Franch.et Sav., Ixeris chinensis (Thunb.) Nakai, Mulgedium tataricum (Linn.) DC, Saussurea amara(L)DC., Senecio argunensis Turcz., Taraxacum mongolicum Hand-Mazz., Chloris virgata Swartz, Setaria viridis (L.) Beauv., Calamagrostis epigejos (L.) Reth., Phragmites australis (Cav.), Miscanthus sacchariflorus (Maxim.) Hack., Aristida adscenionis Linn., Arthraxon hispidus (Thunb.) Makino, Pennisetum fraccidum Grseb., Thymus serpylium L. var. mongolicus Ronn., Polygonum thunbergii Sieb.et Zucc, Thalictrum simplex L., Euphorbia humifusa Willd., Galium verum L., Sium suave Walt, Linaria vulgaris Mill.
1-10 mg	Seed	Oxytropis ramosissima Kom., Cynanchum paniculatum (Bunge) Kitagawa, Cynanchum chinense R. Br., Allium japonicurn Regel, Lilium pumilum DC
	Fruit	Cirsium setosum, Saussurea runcinata DC., Scorzonera albicaulis Bunge, Oxytropis glabra (Lam.) DC., Leymus chinensis (Trin.) Tzvel., Agropyron cristatum (L.) Gaertn., Spodiogon sibiricus Trin., Atriplex

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		patens (Litv.) lljin., Corispermum candelabrum lljin, Polygonum thunbergii Sieb.et Zucc, Polygonum lapathifolium Linn., Stellera chamaejasme L., Saposhnikovia divaricata (Turc z.) Schischk., Polygala tenuifolia Willd.
10-100 mg	Seed	Thermopsis lanceolata R.Br., Periploca sepium Bunge, Asparagus dauricus Fisch.ex Link
	Fruit	Stipa krylovii Roshev
100-200 mg	Seed	
	Fruit	Tribulus terrestris L.

Moreover, the fruit weights of *Puccinellia tenuiflora (Griseb.)* (0.0804 mg), *Agrostis Clavata Trin.* (0.082 mg), *Potentilla discolor Bunge* (0.0738 mg), *Typha minima Funck* (0.0488 mg), *Typha angustata Bory et Chauberd* (0.0684 mg) were lightest, less than 0.1 mg; the fruit weight of *Tribulus terrestris* were heaviest, 131.50 mg, more than 100mg. The seed weights of *Orobanche coerulescens* (0.0096 mg) and *Chenopodium aristatum L.* (0.0972 mg) were lightest, less than 0.1 mg; the seed weights of *Thermopsis lanceolata R.Br.* (16.472 mg), *Asparagus dauricus Fisch.ex Link* (17.096 mg), and *Periploca sepium Bunge* (13.0836 mg) were heaviest, but less than 20 mg.

3.2 The Analysis of Single-Grain Weight of Plant Diaspore of Different Life Forms

In the annual weeds, the fruit weights per grain were medium, such as *Chloris virgata Swartz* (0.5828 mg), *Setaria viridis (L.) Beauv.* (0.5756mg), *Euphorbia humifusa Willd.* (1.0724mg), *Atriplex patens (Litv.) lljin.* (8.106mg); the seed weights per grain were just light, such as *Chenopodium aristatum L.* (0.0972 mg), *Chenopodium acuminatum Willd* (0.4018 mg).

In the biennial weeds, such as the fruit of *Erigeron acer L.* (0.162 mg) and the seed of *Hyoscyamus niger L.* (0.593 mg), the weights were lighter. The seed weight of the Annual and Biennial Meadow Plant, such as *Linum stelleroides Planch* (0.4904mg) was also lighter. The diaspore weights of perennial weeds were different greatly, some were light, such as the fruit of *Artemisia lavandulaefolia DC* (0.1024mg) and the seed of *Plantago depressa Willd.* (0.236 mg); the others were heavier, such as the fruit of *Cirsium setosum* (3.5682 mg) and the seed of *Cynanchum chinense R. Br.* (4.7338 mg).

3.3 The Analysis of Single-Grain Weight of Plant Diaspore of Different Families and Genera

The diaspores of the 15 gramineae species are caryopsis, but their weights varied greatly, the weights of *Puccinellia tenuiflora (Griseb.)* and *Agrostis Clavata Trin.* were lightest, respectively 0.0804 mg and 0.082 mg; the weight of *Stipa krylovii Roshev* was heaviest, 13.2448mg.

The diaspores of 13 compositae plants are achenes, the weights per grain of which were all heavy. The weight of *Artemisia lavandulaefolia DC* was 0.1024mg, the one of *Cirsium setosum* was 3.5682mg. Their difference was relatively small.

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3.4 The Analysis of Single-Grain Weight of Plant Diaspore of Different Ecological Groups

The diaspore weights of steppe plants varied greatly. The single-grain weight of nuts of *Thymus Serpylium L.* was light, 0.296mg; while that of seeds of *Periploca sepium Bunge* was large, 13.0836mg.

There were 35 kinds of meadow plants among the 65 species of plants collected in Xianghai Nature Reserve. Their diaspores, whether fruit or seed, vary widely in weight. In the plant diaspores as fruits, the weight of *Typha minima Funck* was light, only 0.0488 mg; that of *Polygonum thunbergii Sieb.et Zucc* was heaviest, 8.5688mg. In the seeds, the one of *Orobanche coerulescens Steph.* was light, 0.0096 mg; the one of *Thermopsis lanceolata R.Br.* was heaviest, 16.472mg.

In psammophytes, except the capsule of *Linaria Vulgaris Mill.* was smaller, only 0.1689mg per grain, the diaspores of other plants, whether fruits or seeds, were heavier, such as the caryopsis of *Pennisetum fraccidum Grseb.* (0.9712 mg), the aggregate fruit of *Tribulus terrestris L.* (131.50 mg), the capsule of *Polygala tenuifolia Willd.* (4.225 mg), the utricle of *Corispermum candelabrum lljin* (2.2452 mg), the seed of *Oxytropis ramosissima Kom.* (1.889 mg), and the seed of *Asparagus dauricus Fisch.ex Link* (17.0968 mg).

IV. DISCUSSION

Among the 65 plant species collected in Xianghai Nature Reserve, the weight per seed or fruit of the plant diaspores varied greatly, from 0.0096 mg for the lightest seed of *Orobanche coerulescens* to 131.50 mg for the heaviest fruit of *Tribulus terrestris*. There were as many as 34 species of diaspore weights between 0.1 mg and 1 mg, including 10 plant diaspores as seeds and 24 plant diaspores as fruits; 19 species of diaspore weights between 1 mg and 10 mg, including 5 plant diaspores as seeds and 14 plant diaspores as fruits. There are fewer diaspores that are too small or too large; only 7 species of diaspore weights less than 0.1mg and 5 species of diaspore weights more than 10 mg.

The effective dispersal and spread of diaspores are a fragile and critical stage in the plant's life history, undergoing not only unpredictable disturbances but also the risk of the inactivation [13]. Studies have shown that in the process of plant reproduction and evolution, the optimal diaspore size of plants is the result of trade-offs with the number of diaspores [14].

In the wind-sand environment, the light diaspores of plants are more likely to disperse to distant places by means of wind, and more beneficial for the spreading of the plant population [13-16], which may be the main reason for the wide distribution of the plants with small-grained diaspores in Nature Reserve, such as *Chenopodium aristatum L., Agrostis Clavata Trin., Typha minima Funck, Artemisia lavandulaefolia DC, Chenopodium acuminatum Willd, Setaria viridis (L.) Beauv., Taraxacum mongolicum Hand-Mazz., Calamagrostis epigejos (L.) Reth., Saussurea amara (L)DC., Ixeris chinensis (Thunb.) Nakai*. In addition, plants with small-size diaspores tend to produce more seeds, which is an effective defense against the predation of birds [1, 2, 5-7].

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The weight and shape of diaspores of plants are closely related to the lifespans of soil seed banks [2]. Studies have shown that small, nearly spherical seeds tend to form persistent soil seed banks [5, 17]. Of the 41 plants with diaspore weight less than 1 mg in this study, the plants with nearly spherical seeds, such as *Chenopodium aristatum L., Orobanche coerulescens Steph., Puccinellia tenuiflora (Griseb.), Potentilla discolor Bunge, Chenopodium acuminatum Willd, Silene jenisseensis Willd., Plantago depressa Willd., Lythrum virgatum Linn., Setaria viridis (L.) Beauv., Thymus serpylium L. var. mongolicus Ronn., Polygonum thunbergii Sieb.et Zucc, Thalictrum simplex L., Galium verum L., Sium suave Walt,* may be equipped with persistent soil seed banks, which means they have evolved reproductive strategies to resist the drought disturbances. Active but dormant seeds in the persistent soil seed banks could empower plants the potential to adapt to future unpredictable disturbances [14, 16, 18-20].

Moreover, the weights of the diaspore, whether fruits or seeds, of psammophytes, are generally large, which makes them difficult to be blown by the wind and enhances the ability to settle down in the wind-sand environment. Studies have shown that psammophytes not only have a large diaspore weight, but also have evolved a mechanism to reduce the displacement of diaspores and adapt to the wind-sand activities [5, 7, 8].

In arid and semi-arid regions, the natural environment is relatively harsh and the wind-sand activities are frequent. In the long-term evolution process, plants have evolved various reproductive strategies to cope with the disturbances [17-20]. The study of plant reproduction strategies and relevant vegetation processes in arid and semi-arid regions has important reference and guiding significance for vegetation management and vegetation restoration in this region [1, 2, 5-8]. The research on seed ecology in Xianghai Nature Reserve in western Jilin Province is still less, the comparative study on plant diaspore weight is the beginning of this research. In the future, in order to provide evidence for local vegetation restoration, further studies on the shape of plant diaspores, seed germination and propagation, and the relationship between soil seed banks and above-ground vegetation will be conducted one after another.

V. CONCLUSIONS

(1) The weight per seed or fruit of the plant diaspores varied greatly, from 0.0096 mg for the lightest seed of *Orobanche coerulescens* to 131.50 mg for the heaviest fruit of *Tribulus terrestris*; and could be respectively divided into four groups (<0.1 mg, 0.1-1mg, 1-10mg, 10-100mg) or five groups (<0.1 mg, 0.1-1mg, 1-10mg, 10-100mg, 100-200mg).

(2) The plant species, such as *Chenopodium aristatum, Agrostis Clavata, Typha minima, Artemisia lavandulaefolia, Chenopodium acuminatum, Setaria viridis, Taraxacum mongolicum, Calamagrostis epigejos, Saussurea amara, Ixeris chinensis*, could distribute widely in the Xianghai Natural Reserve on account of the lighter weight of diaspores with the help of wind dispersal.

(3) Moreover, the plant species, such as *Chenopodium aristatum, Orobanche coerulescens, Puccinellia tenuiflora, Potentilla discolor, Chenopodium acuminatum, Silene jenisseensis, Plantago depressa,*

Lythrum virgatum, *Setaria viridis*, *Thymus serpylium*, *Polygonum thunbergii*, *Thalictrum simplex*, *Galium verum*, *Sium suave*, could be of persistent soil seed banks on account of the lighter weight (<1 mg) and approximate spherosome shape of diaspores.

(4) In semi-arid sandy areas, plants formed special reproductive strategies with the help of diaspore morphology, which reduced the risk of population survival to a certain extent, and played an important ecological significance for sustainable population reproduction.

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