Endangering reason and reproductive strategy of *Psathyrostachys huashanica* population

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Abstract: *Psathyrostachys huashanica* is perennial herb belongs to Psathyrostachys of hordeae of pooidae in Gramineae. Psathyrostachys distribute in center of middle Asia and Caucasus Mt., but Psathyrostachys huashanica are only located on the Qinling Mt. in China. At present, the amount of the population is much less than the past, being at the edge of extinction. Owing to distributing limitation and importance as breeding material for germplasm storage, it was listed into the first class of national protected rare plants and imperatively protected wild species in relation to crops. For this reason, the present study is significant in probing plant flora-origin and evolution of *Triticum* and crop breeding.

Having made a survey of community and habitat, soil analysis of plots and morphology observation and biomass measurement, the results of the paper were as follows:

*P. huashanica* was distributed narrowly and disconnectedly, ranging from alt. 350m to 1800m. It’s habitat often on roadside or cliff or rock hollow, was quite rigorous. Most of it grew strong in places full of sunlight, but did not exist basically in shadow places, and did not distribute under trees. The scale of population was small, that is, there were seldom of individuals in a population from more than 10 plants to the least of only 2. The community contained *P. huashanica* were always sparse brush or herbosa, and *P. huashanica* is companion species. Other companion species were relatively constant, frequent plants were *Indigofera bungiana*, *Lespedeza dahurica*, *Potentilla discolor*, *poa* spp., *Aquilegia incurvata*, *Artemisia gmelini*, *Sedum aizoom*, *Trachelospermum jasminoides*, *Tripogon chinensis*, and so on. Most of these plants are high stress resistance, i.e. species in *Sedum*, *Trachelospermum*, and *Artemisia*.

The places where *P. huashanica* grows is separated each other, and the characteristics of these places were similar on the whole, i.e. 8~10cm of soil layer thickness, covered by litters, and there were some un-
covered broken stones in it. *P. huashanica* grew on slightly acid soil (pH 6~7) where the nutrient contents are little and has the highest validity. Soil moisture of plots was relatively high but fluctuated intensively among the plots and seasons. In hollow of rock or edge of steep cliff, soil moisture mainly came from rainfall but thin soil layer checked water poorly because there are serious loss of water & soil. Uncertainty of rainfall and unevenness of water & soil erosion result in irregularity of soil moisture timely and spatially.

*P. huashanica* is perennial herb with long rhizome. Straw is adisperse with 2~3 mm in diameter and 40~60 cm of height. Like other plants of Gramineae, *P. huashanica* also developed in form of vegetative propagation by tiller. Valid spike per plant was lower. The number of valid flower per spike is basically constant. Consequently, the number of valid flower per plant depends on the number of valid spike and the number of small spicula per spike. It is concluded from data in tables that the number of valid spike was positively correlated with the number of tiller.

Fecundity of *P. huashanica* was much lower as compared to valid flower per plant. The mean number of grains was 10.13~11.36 per plant. Low fecundity of *P. huashanica* shows that many of valid flowers did not develop into grain. Viewed from biomass allocation to different living organs, assimilating organs (leaf and blade sheath) accounted for 79.3% of total fresh biomass, but sexual reproductive organ only 0.9%. In addition, total current annual assimilation product, percentage of standing dead leafs and straws was 24%.

Despite reproduction allocation among populations of *P. huashania* was different significantly, on the whole allocation to reproductive was quite tiny.

As far as vertical distribution is concerned, biomass declined greatly. Biomass decreased by 50% at interval of 10 cm with up to the top of plant. Moreover, more than part of biomass concentrated on the base (<10 cm of height) of the plant. In this way, the growth pattern restricted efficiency of sexual reproduction.

Tillers produced by *P. huashanical* were used in the two respects of vegetative and productive growth, but most of tillers became vegetative growth. Leaves were different on the two types of tiller. In general, leaves on sexual reproduction tiller were 2~5 cm longer than that of vegetative tiller, and amount of leafs on reproductive tiller were markedly larger than vegetative tiller, presumably because of energy translocation in the process of reproduction.

Various factors are involved in *P. huashanica* endangering. First of the reason is its habitat where many other plants cannot live. Its scattered distribution and small size of population suggest that *P. huashanica* had stress resistance, i.e. drought resistance and salinity resistance and that the species had weak competitive ability with other plants. Limited soil water and other resource become bottle-neck factors restricting population development. When scale of population exceeds capacity of environment, mortality of population has to increase, some populations in community will disappear or migrate to form small population. This is an important symbol indicating plants endangering.

In population development process, plants must get over difficulties and dangers caused by environment pressure, competition, predation, disease, and so on. In accordance with different essence and intensity of these difficulties, plants adopt different reproductive strategy. *P. huashanica* is perennial herb, apart from sexual reproduction, also having vegetative propagation by tillers. Allocation to sexual reproduction of *P. huashanica* is quite small and unstable. Apart from indigenous genetic character, environment pressure has impact on sexual reproduction level. In order to increase surviving rate, *P. huashanica* had to strengthen vegetative propagation to increase fitness at the cost of reproduction. As a result, percentage of fruiting and head sprouting was low, assimilation product allocated to reproduction was low, so coefficient of reproduction became lower and lower. In addition, the trend was further explained by biomass vertical distribu-
Biomass of *P. Huashanica* is mainly distributed at the base under 10cm, suggesting that it had to strengthen vegetative propagation to increase the number of tiller in order to adapt to surroundings as soon as possible. On the other hand, spike position is 5~10cm higher than leaves. It is impossible for *P. huashanica* to allocate energy to sexual reproduction based on degree of biomass decreasing vertically. So, low percentage of sexual reproduction resulted in low genetic variation of population. It is harmful to population development in the future.

There exist another phenomenon that leaves on vegetative tiller were different from that of reproductive tiller. It reflects presumably that energy translocation in *P. Huashanica*. In generally, reproductive allocation of perennial plants is less than annuals. *P. huashanica* cannot provide tillers with enough energy for differentiation and growth of spikes within one year, as a result, some last/year leaves stand withering and dead sticking to straw. It indicates that *P. huashanica* adopt K-strategy in life history to an extent.

Some humanity factors such as tourism and exploiting mount to build road, are also responsible for *P. huashanica* endangering.

**Key words:** endangering reason; reproductive strategy; *Psathrostachys huashanica*

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1. **Location**

   *P. huashanica* is distributed at 34°25'~34°30', 109°57'~110°05'. Mainly distributed at 2000m (2.0~0.65%).

2. **Soil analysis**

   From above 9 samples, we collected samples at 0~10cm, 10~20cm, 20~30cm, 30~40cm, 40~50cm, 50~60cm, 60~70cm, 70~80cm, 80~90cm. 902.7mm, 20.7C, 5.9C, 27.7C, 13.4C, -1.2C, 27.3C, 2300h, 600mm, 2200d, 325mm, 53d.

3. **I**

   3.1

   40~50cm 370m (1.4); 50~60cm 580m (2.3); 350m (3.4); 410m (4.4)

4. **2.2**

   0~25cm 0.5

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**Ecological Journal**
华山新麦草的形态学观察

在以上各个样地中再各建立一个10cm×10cm的小样方，采集该小样方中的华山新麦草数株进行形态学特征的观察，测量并统计每株华山新麦草的高度、分蘖数、有效穗数、每个穗上的小穗数及每个小穗上的小花数。

华山新麦草生物量的测定

将采集到的华山新麦草烘干，一部分分离其各器官，根、茎、叶、穗分别称重，统计分析。另一部分将地上部分按一段剪裁，进行垂直生物量分配的测定分析。

结果

华山新麦草的分布及群落特点

华山新麦草为狭域间断分布，海拔120~450间都可能有生长，但多分布于路边及峭壁的岩石凹陷或空隙中，生境比较严酷。华山新麦草具有喜光的特点，向阳地段植株生长旺盛，而背光处则明显分蘖减少，林下一般没有分布。

华山新麦草居群规模一般很小，居群中个体数量很少，常仅数株，最少的一个居群仅有两株。据调查，华山新麦草所处的群落多为稀疏的灌草丛，在调查的12个样地中华山新麦草的多度级都为1，相对密度小于0.6，相对频度小于3.6，重要值小于7.6，属于群落中的次要物种。与华山新麦草伴生的物种种类相对比较稳定，常见者有本氏木蓝，达乌里胡枝子，翻白委陵菜，早熟禾，秦岭漏斗菜，白莲蒿，费菜，络石，中华草沙蚕等。而且多数物种抗逆性较强，例如景天属、络石属和蒿属等属的植物。

华山新麦草分布地段土壤状况

华山新麦草主要生长在路边及峭壁的岩石凹陷或空隙中，大多数个体植株生长的地段彼此相对隔离，但其土壤总的特征基本一致，土层厚度常只有5~10cm，土壤中夹杂着许多大小不均一的碎石粒，土层表面覆盖着少许腐败或死亡的植物器官，土壤营养条件一般，如表1所示。从表中数据可以看出，华山新麦草生长在土壤pH值3.0~4.5的微酸性条件下，土壤养分的有效性最高，所以植株的生长条件应该是比较适宜的。由于特殊的生长位置，土壤中有机质的来源主要是土壤微生物分解土层表面的腐败的植物脱落或死亡器官形成的腐殖物质，这些物质构成了植物营养的重要碳源和氮源。水对植物维持生命活动起着重要作用，但从表中数据可以看出，土壤含水量虽不低但各样地差异很大，造成这种现象的主要原因是华山新麦草特殊的生长位置，华山新麦草多生长在岩石凹陷或空隙处，这决定了其土壤中的水分主要依靠降水，同时由于土层浅薄，拦蓄降水的能力较差，而且小地形起伏较大，这样降水的不稳定性及地表水土流失状况的不均一性就导致了其区域土壤含水量在时间和空间上的不规律性。

表1 华山新麦草分布地段的土壤条件

<table>
<thead>
<tr>
<th>Plot</th>
<th>Water content (%)</th>
<th>pH</th>
<th>Organic matter (%)</th>
<th>CaCO₃ (%)</th>
<th>Available P (mg/L)</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>44.71</td>
<td>6.24</td>
<td>5.95</td>
<td>1.88</td>
<td>9.9</td>
<td>0.30</td>
</tr>
<tr>
<td>2</td>
<td>20.00</td>
<td>6.63</td>
<td>5.61</td>
<td>2.03</td>
<td>11.4</td>
<td>0.28</td>
</tr>
<tr>
<td>3</td>
<td>63.91</td>
<td>5.98</td>
<td>4.12</td>
<td>1.28</td>
<td>8.6</td>
<td>0.21</td>
</tr>
<tr>
<td>4</td>
<td>31.94</td>
<td>6.87</td>
<td>4.77</td>
<td>2.60</td>
<td>10.5</td>
<td>0.24</td>
</tr>
</tbody>
</table>

3. 2

华山新麦草的生物量结构与繁殖特征

华山新麦草为多年生草本植物，具延长根茎，秆散生，直径7~31mm，植株高度1.7~3.1mm，和其他禾本科植物一样，也通过分蘖来进行营养繁殖。可以看出不同样地植株的有性繁殖指标差异很大，但总体上单株有效穗数很低，表3中单株有效穗数及可育花数是确定华山新麦草有性生殖能力大小的重要指标。由于每个小穗中的可育花数基本恒定，为7~31枚，因此单株可育花数主要依赖于其有效穗数和每穗小穗数。
把

个样地

个样本合在一起分析时

分蘖数与有效穗数间表现出一定的正相关关系

表（华山新麦草不同居群的形态及繁殖特征）

<table>
<thead>
<tr>
<th>Plot</th>
<th>Tillers per plant</th>
<th>Spikes per plant</th>
<th>Spikelets per spike</th>
<th>Flowers per plant</th>
<th>Flowers per plant</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60.2</td>
<td>4.4</td>
<td>6.73</td>
<td>74.78</td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>86.9</td>
<td>0.5</td>
<td>11.90</td>
<td>13.75</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>15.5</td>
<td>2.8</td>
<td>9.43</td>
<td>66.80</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>46.4</td>
<td>5.2</td>
<td>10.72</td>
<td>139.36</td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>

对华甫峪和仙峪两地华山新麦草结实状况的调查显示

华山新麦草的结实力很低

平均每株籽粒数分别为只有

与单株可育花数相比

很低的结实力说明有相当一部分的可育花最终没有能够发

育成果实

对这两地

株华山新麦草结实情况的统计分析表明

如图（华山新麦草的结实力的频度分布）

其中华甫峪

株

仙峪

株

两地均有

以上的植株的籽粒数在

而每株籽粒数超过

粒的还不到统计株数的

图（华山新麦草生物量结构）

从华山新麦草生物量在不同的活器官中的分布情况看

图（华山新麦草同化器官叶茎叶鞘所占比例很高

而有性繁殖器官则极低

另外在当年全部同化产物中有

的立枯茎叶

繁殖分配

指一株植物一年所同化的资源中用于生殖的比例

实际指总资源供给生殖器官的比例

常常采用将植物的干重分为生殖部分和非生殖部分的方法

虽然在不同居群中其繁殖分配变化显著

但总体来说

其繁殖分配值相当微小

图（华山新麦草的生物量垂直分布情况）

可以发现其生物量随高度的递减幅度相当大

每一等级递减幅都在

而且有一半的生物量都集中在基部

这种生长模式在一定程度上限制了其有性繁殖的效率

华山新麦草所产生的分蘖有两个用途

其中大部分分蘖是用

生态学报

卷万方数据
于营养生长，其他少数分蘖是通过产生穗状花序进行有性繁殖。华山新麦草在这两种分蘖上的叶片着生情况上存在着差异。一般说来，有性繁殖分蘖上的叶片要比营养生长分蘖上的叶片长。同时在叶片数目的上，两者的差异非常明显。造成这种现象的原因可能与华山新麦草繁殖分配中的能量转移情况有关。

不同的华山新麦草的繁殖分配系数。包括立枯物的生物量和不包括立枯物的生物量。表中的数字包括立枯物的生物量。

图华山新麦草地上生物量垂直分布。图华山新麦草地上生物量垂直分布。

表华山新麦草不同分蘖上叶片着生数目

<table>
<thead>
<tr>
<th>累计叶片数</th>
<th>活叶片数</th>
<th>死叶片数</th>
</tr>
</thead>
<tbody>
<tr>
<td>营养生长分蘖</td>
<td>81/12</td>
<td>19/12</td>
</tr>
<tr>
<td>有性繁殖分蘖</td>
<td>79/12</td>
<td>15/12</td>
</tr>
</tbody>
</table>

讨论
华山新麦草之所以濒危首先从其生境得到体现。华山新麦草处于十分恶劣且其他大多数物种很少生长的环境中，分布零散而不连续，同时种群数量很小。一方面体现出华山新麦草具有较强的抗逆性，如抗旱性和耐盐性，另一方面也反映出华山新麦草的竞争力十分脆弱。华山地区山势陡峭，水土流失比较严重，土壤水分变化很大，这限制了植物的分布，也加剧了密集生长的植物间的互相竞争，这样有限的土壤水分资源就成为制约植物种群数量进一步扩大的瓶颈因素。当种群数量超过种群的负荷能力时，为了重新恢复这种负荷平衡，达到一个稳定的状态种群的死亡率必然要增加，这就意味着群落中的有些种群必然要迁出或消亡，这势必会产生一些小种群，而小种群的产生是植物濒危的一个重要标志。植物再生依赖于繁殖过程，该过程要经过受精、成熟、扩散、休眠、发芽、幼苗建成的每一个阶段。每一植物体都必须克服由环境压力、竞争、捕食和疾病造成的危险。最终成活的个体是很少的。各种植物所经历的各阶段的障碍的性质与强度是不同的，因为有这些差异，因此可以推测每一种植物都有其特定的繁殖对策。华山新麦草是多年生草本植物，和大部分禾本科植物一样，除了进行有性繁殖外，还可以通过分蘖来进行营养繁殖。有性繁殖对不同环境的适应能力方面存在着优越性，其子代种群具有较高的遗传可变性。而营养繁殖产生的每一个后代的资源投资较高，而且每次产生的无性系分株后代数量很少，但其存活率比由种子形成的幼苗高得多。在长期而稳定的环境压力下，营养繁殖在选择上有优势，因为这种环境中的植物处于强烈竞争下，无性系分株比种子形成的幼苗更易存活。华山新麦草的有性繁殖分配非常低，而且不稳定。这正是华山新麦草在严酷的生境中长期进化适应的结果，这有利于其种群的维持和生存。当然除固有的遗传特性外，环境压力也影响着种群有性繁殖的水平。华山新麦草为了增加在恶劣环境条件下存活的机率，要不断加大营养繁殖来尽可能提高适应度，这样就势必以牺牲一部分有性繁殖来作为补偿，这表现在其较低的抽穗比例和结实力上，在同化产物分配上也表现。
出极低的繁殖分配系数。另外，从华山新麦草生物量的垂直分布也可以发现这一趋势。华山新麦草的生物量主要分布在基部以下，表现出该种为了生存不得不加大营养繁殖分蘖的强度，以便于更快的适应环境。同时，由于有性繁殖穗的高度一般要高出叶片，根据生物量垂直递减锐度推断，华山新麦草已不可能给繁殖分配更多的能量了。而有性繁殖比例的减少也使其种群遗传变异性不断变小。这对华山新麦草的种群繁育是非常不利的。华山新麦草植株出现了营养分蘖和有性繁殖分蘖上叶片的数量不同的现象，这一现象可能反映了华山新麦草体内的能量转移情况。一般多年生植物的繁殖分配要比一年生植物的繁殖分配少得多。可能在一年中，华山新麦草不足以给分蘖提供足够的能量来进行有性繁殖花穗的生长，或无法保证产生的种子能够成活。于是为了确保繁殖效率，除了从根部吸收能量外，还将一部分叶片中的能量转移来进行有性繁殖花穗的形成和成长。这使得一部分叶片逐渐枯死，未脱落前依然附着在茎秆上。从这里不难发现华山新麦草在生活史对策上偏重采取的是策略。华山新麦草的濒危还涉及到一定的人文因素。华山因道路险恶，为保证上山游客的安全，政府扩修了山道，并在险要处如悬崖边加修了栏杆等一系列防护措施。这一行动无疑严重影响了多分布在路边和悬崖边的华山新麦草的生长，甚至妨碍到某些地段华山新麦草的存活。几年前，为了解决旅游高峰期游客上山下山道路冲突的问题，在皇甫峪炸山修路，增设缆车，开辟了上华山的第二条路。这对本来生存就比较困难的华山新麦草来说无疑是雪上加霜。在充分发掘旅游资源，2的思想引导下，当地政府已准备对仙峪进行开发，新的炸山修路计划正在准备实施。可想而知，该区域的华山新麦草又将面临一次考验。旅游业作为增加国民收入的一个来源，也造成了生态环境的破坏可能加速大量珍稀植物的濒危灭绝。所以合理计划旅游景点的开发，大力提倡生态旅游已成为当务之急。