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Investigation on morphology and cultural properties of a vegetative strain "Special Blue" (SB) of *Leymus chinensis* for its application in landscaping

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Abstract

A vegetative strain gained by single plant selection and propagation, the Special Blue (SB) of *Leymus chinensis*, has excellent bluish color and unitary growth. The strain was found in a natural vegetation ((35.11° N.Lat., 110.59° E.Long). In contrast to the normal type of *Leymus chinensis*, this strain has morphological characteristics as: ripen spike brown, inner lemma shorter than outer lemma. The results of six years investigation shows that flowering time begins at the end of May and it continues for one week. At the beginning of June the population has a density of 1852 culm/m^2 and a spiking rate of 14.3 % culms. The protein content of ground part is 12-21 %. The hey yield is calculated to 4.56 t/ha under conditions without irrigation. The plants can be transplanted at anytime during a vegetation season and the transplants are 100 % survival. Transplantation enhances the growth of rhizomes which extend outwards evenly after transplantation, reaching a distance of 2.09 m in average in one year and the rate of extending lowers thereafter. The maximal planting distance is calculated as 2.96 m. Mowing in the growing season disturbs the growth. In landscaping or gardening the plant gives unique beauty effect with its special bluish color in contrast to the fresh yellowish green background of the by-standing plants.

Keywords: Leymus chinensis, Special Blue, vegetative strain, landscaping

Untersuchungen zur Morphologie und Kultivierung der vegetativen Linie „Special Blue" (SB) von *Leymus chinensis* in der Landschaftsgestaltung

Zusammenfassung

Durch Einzelpflanzenselektion und entsprechender Vermehrung konnte eine vegetative Linie „Special Blue" (SB) von *Leymus chinensis* aus einem natürlichen Bestand (35.11° N.Lat., 110.59° E.Long) gewonnen werden. Die Linie zeichnet sich, wie sechsjährige Untersuchungen zeigen, durch eine intensive blaue Farbe mit einem einheitlichen Erscheinungsbild aus. Im Gegensatz zum normalen Typ von *Leymus chinensis* weist die gefundene Linie im ausgereiften Zustand eine braune Ähre aus und die inneren Deckspelzen sind länger als die Äußeren. Die Blütezeit beginnt Ende Mai und dauert eine Woche. Anfang Juni ist eine Pflanzendichte von 1852 Halmen/m^2 erreicht, wovon 14,3 % ährentragende Halme sind. Der Proteingehalt der Biomasse schwankt in einem Bereich von 12 % bis 21 %. Die Erntemasse beträgt (ohne zusätzliche Bewässerung) 4,56 t/ha. Die Pflanzen können während der gesamten Vegetationszeit etabliert werden und zeigen einen hundertprozentigen Anwuchserfolg. Im ersten Jahr der Transplantation erreicht das Rhizomwachstum 2,09 m, während es in den Folgejahren abnimmt. Eine Pflanzweite von maximal 2,96 m wird kalkuliert. Mähen während der Vegetationszeit schränkt das Pflanzenwachstum ein. Wird die Linie zur Landschaftsgestaltung oder im Gartenbereich eingesetzt, gibt sie einen schönen blauen Farbkontrast zu den meist gelb/grün gefärbten Grasbeständen ab.

Schlüsselworte: Leymus chinensis, „Special Blue", vegetative Linie, Landschaftsgestaltung

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1 Introduction

Leymus chinensis was ever named *Triticum chinense* Trin.ex Bunge (1832), *Elymus regelii* Roshev (1932), and *Aneurolepidium chinense* (Trin.) (Kitagawa, 1938, 1959, 1976), and had a synonym as *Elymus chinensis* (Trin.) T. (Koyama, 1987). Its current name has been confirmed as *Leymus chinensis* (Trin.) (Tsvelev, 1968, 1987). The genus *Leymus* is systematically organized to the Tribe Triticeae, Subfamily Pooideae, Family Gramineaea (IBAS, 1976).

Leymus chinensis is an important forage grass species which has been studied and utilized for grazing and feeding purposes for long times (NAC, 1980). Besides its high nutritional quality, it has properties to tolerate cold, drought and salinity, and has an especially strong ability of vegetative propagation through its rapidly growing and extending rhizomes, giving the ground surface an ideal coverage with its steady density of culms (Xiao, 1986). Furthermore, there is a blue type of *Leymus chinensis*, that increases, with its unique bluish appearance, the sight diversity and beauty of the landscapes. However, investigations on *Leymus chinensis* concerning its uses in ecological landscaping have never been reported.

The natural distribution areas of *Leymus chinensis* include northern and north-eastern China, Mongolia and the east part of Russia. *Leymus chinensis* dominant meadows in north-eastern China count to over 3 million ha (Su 1983), of which near to 1.29 million ha are in Songnei-Plain (Li et al., 2002). Large amounts of investigations on the biology and ecology of *Leymus chinensis* have been carried out on the above mentioned natural, or sometimes cultivated, populations. Information from various authors showed that in natural populations *Leymus chinensis* varies in its ecological types, morphological characteristics and biological properties (Zhang, 2000). There are mainly two types of *Leymus chinensis*, the bluish grey-type and the green type, and the former type has more tolerance against salinity and drought than the latter. In natural populations of *Leymus chinensis*, it is mostly the green type (Chen and Jia, 2002). The fact that different ecological types and strains are in mixed growth hinders the realization of maximal production potential of some stronger strains, as well as the accuracy of many investigations and observations. It is therefore necessary to select and to purify the varieties of *Leymus chinensis* in order to improve its quality and production. A few artificially selected and bred varieties have been occurred and increased strongly the hey and seed yields of *Leymus chinensis* (Chen and Jia, 2002). This shows a great potential for the success of the work in selection and breeding of *Leymus chinensis*.

The seeding rates of *Leymus chinensis* are generally as low as between 20-40 %, even there are no seeds to be yielded. The seed germination rates of *Leymus chinensis* are between 30-40 % (Chen and Jia, 2002). Therefore the efficiencies of propagating and breeding *Leymus chinensis* through seeds are much limited. On the other hand, it is very easy to propagate *Leymus chinensis* with its rhizomes and by such a vegetative method it is easier to keep its genetic purity and characteristic evenness. It is proved to be an effective way to breed *Leymus chinensis* through resource collection, selection and successive strain propagation.

In the investigation and collection work of ecological and landscaping grass resources the author has found a valuable strain of *Leymus chinensis* which has excellent blue-color and highly adversity-resistant properties. Through successive non-sexual breeding for eight years, it has formed an cultivated population of pure strain with definite characteristics and high evenness. This paper presents the morphology, ecological adaptability and cultivation property of the above cultivated strain, looking into its possibility to be used as an ecological landscaping grass material.

2 Materials and Methods

The starting material of *Leymus chinensis* for successive vegetative propagation is a single plant collected from the natural vegetation of Shanxi-Yuncheng (35.11° N.Lat., 110.59° E.Long.). The plant showed an obvious blue-color characteristic, in contrast with other plants in its surrounding. It was transplanted on 31. May 1996 to a base-field in Yuncheng (35.14° N.Lat., 110.57° E.Long.) where it was grown and vegetative propagated for six years. On 27. March 2002 the propagated plant materials were transplanted to the Experimental Base-field of Beijing R & D Center for Grasses and Environment in Beijing-Xiotangshan (40.10° N.Lat., 116.22° E.Long.). For transplantation the rhizomes were dug off and, after one week in the process of transportation, were buried in a depth of ca. 20 cm in row with a row-distance of 2 m. After one year's growth, till June 2003, it has formed a cultivated population with an unique blue-color appearance, showing a quite evenness in its culms density, plant height, development stage, spiking and flowing times. Upon this population the author has carried out the following observations and measurements:

1. Basic morphological characteristics of this vegetative strain of *Leymus chinensis*.
2. Growth and development stages.
3. Plant height and culms density.
4. Fresh matter and dry matter of ground and underground part.
5. Basic nutritional components analysis of the plant.
6. Outward-extending distance of the rhizomes within a certain period.
7. Effects of transplantation and mowing at different times.

For the measurement of the outward-extending distance of the rhizomes within a certain period, the following formula is applied to calculate the coefficient of the variation (*cv*):

$$cv\ (\%) = s / \bar{x} \bullet 100 \qquad s = \sqrt{[\Sigma x^2 - (\Sigma x)^2 / n] \bullet 1/n}$$

In which

s: standard deviation,
$\bar{x}$: mean value,
x: value of individual measurement,
n: number of measurements.

The soil conditions of the experimental base-fields are listed in Table 1 and Table 2. No irrigation and fertilization methods were applied in the whole process of propagation and cultivation of this grass. The tolerance of the grass to drought and poor soils were thus tested to a certain extent.

In addition to the above experiment, the author has collected and observed *Leymus chinensis* in the natural flora of Beijing, taking it as a comparison of the strain Special Blue in description of its special characteristics.

3 Results and Discussion

3.1 Description of basic morphology of the Strain Special Blue of Leymus chinensis and observation of its growth and development stages

This grass is perennial, with rhizomes. Fibrous root with sand sheath. Culms are dispersal, erect, 50-80 cm high (leaf tip 50 cm high, spike tip 80 cm high). Spiked culms are with 4 internodes, non-spiked culms with more than 4 internodes, mostly 5-6 internodes. Leaf sheath is smooth, the remnant leaf sheaths at the base part of the plant appear fibrous, yellow and withered. Ligules are truncate, usually with a split in the middle of the top, paper-like, 0.5-1 mm long. Leaf blade bluish green, with white wax powder on the surface. Flag leaves are 6-8 cm long, 3 mm wide; other leaves 10-33 cm long, mostly between 20-30 cm long, 3-6 mm wide. Leaf blade flat, rolls inwards when dried out. The extent of inward-rolling of the leaves shows the extent of drought from which the plant is suffering at the moment. Leaves have glandular spots in rows on both sides. Older leaves have cilia in rows on their upper sides. Leaf margins are rough, with fine teeth. Inflorescence is an erect spike, 8-15 cm long, 3-5 mm wide at the widest position of the spike. Spike-axis has two ridges with fine teeth; inter-node of the spike is 6-10 mm long, and the base inter-node of the spike 10-19 mm long. Spikelets are 8-13 mm long, each normally with 5-7 florets, two florets on one node usually, except those growing singly on the top part or on the base part of the spike. The spikes are whitish green at the beginning, and turned brown when

Table 1:
Soil conditions of the base-field for the first transplantation of the strain Special Blue of *Leymus chinensis* (Shanxi-Yuncheng)

Depth of the soil (cm)	pH	Mg (mg/100g)	K_2O (mg/100g)	P_2O_5 (mg/100g)	NO_3-N (kg/ha)
0-30	8.05	27.7	25.4	4.1	57.8
30-60	8.17	27.1	18.1	2.8	28.9
60-90	8.10	24.3	6.9	1.2	16.4

Fein loess soil, from the base-field of Shanxi-Yuncheng on 05.05.1998. Analysis of the soil samples was carried out by Mr. Arnemann in FAL in Germany on 30.06.1998

Table 2:
Soil conditions of the base-field for the second transplantation of the strain Special Blue of *Leymus chinensis* (Beijing-Xiaotangshan)

Depth of the soil (cm)	pH	Mg (mg/100g)	K_2O (mg/100g)	P_2O_5 (mg/100g)	NO_3-N (kg/ha)
0-30	7.67	46.6	20.4	2.5	97.8
30-60	7.69	58.7	20.6	2.4	66.3
60-90	7.64	88.5	28.1	1.1	86.4

Soil samples from the base-field of Beijing-Xiaotangshan on 11.08.2003. Soil layer near to ground surface is loess soil. 30-60 cm layer is mainly dark clay. 60-90 cm layer is dark clay mixed with lime pebbles or granules. Analysis of the soil samples was carried out by Mr. Liu in Beijing R & D Center for Grasses and Environment on 26.08.2003

ripen. Axis of the spikelets smooth, 1-1.5 mm long. Glumes are cone-shape, the first glumes 4-5 mm long, the second glumes 5-6 mm long. The glumes much shorter than the first floret, and leaving the base part of the first lemma uncovered. The glumes are hard, with three unclear veins and smooth backside. The lower part margins of the glumes are membranous, the upper part margins of which are rough and with fine teeth. Outer lemma is lanceolate, with narrow and membranous margins, and with a gradually sharpening or an awn-like tip, five unclear veins on the backside. Basal pad of the lemma smooth. The first outer lemma at the base of the spikelet is 8-9 mm long. Inner lemma is shorter than outer lemma, frequently split as two tips at the top, with sparse and fine teeth on the upper part of the ridge. Anthers are ca.5 mm long.

For *Leymus chinensis* in Beijing conditions, the time of sprouting from the ground is at the end of February. The Spikes grow out at the end of March and flower at the end of May. Flowering period is about one week. Each part of the flower develops completely. To the beginning of July, the spikelets will dry out and turn to brown color, only the glumes remain slight green. The plant grows vigorously and evenly during July-October, and dries out in November, along with the drastic downturn of the temperature.

This vegetative strain of *Leymus chinensis* differs from the normal types of *Leymus chinensis* (e.g. the local type in Beijing flora) in their morphological characteristics:

(1) The spike color of the normal type of *Leymus chinensis* will turn yellow when it ripens, whereas which of the Special blue will turn brown.
(2) The inner lemma is as long as the outer lemma in the normal type of *Leymus chinensis*, whereas the inner lemma is obviously shorter than the outer lemma in the strain Special Blue.

Besides, in comparison with normal types in the wild, the strain Special Blue grows and develops much more evenly in plant height and spiking time. Its flowering time is within only one week, whereas that of the wild *Leymus chinensis* is as long as to eight weeks or so (IMAHC, 1981). This explains to a certain extent that the genetic pureness of this strain is much higher than that of the wild populations of *Leymus chinensis*.

Table 3:
Culms densities, spiking rate of culms and yields in a certain area in the cultivated population of the strain Special Blue of *Leymus chinensis*

Time of sampling	Items of measurements	Values of measurements
30.05.2003, 17:00	Fresh matter of the whole plant (g)	51.65
	Dry matter of the whole plant (g)	18.12
	Dry mater/Fresh matter (%) of whole plant	35.1
	Water content of the whole plant (%)	64.9
03.06.2003, 12:00	Culms/m^2	1852
	Spike numbers/m^2	264
	Rate of the spike bearing culms (%)	14.3
	Fresh matter of the whole plant (g/m^2)	1600
	Dry matter of the whole plant (g/m^2)	772
	Dry matter/Fresh matter (%) of whole plant	45.8
	Water content of the whole plant (%)	54.2
	Whole fresh matter of spikes (g/m^2)	30
	Whole dry matter of spikes (g/m^2)	24.0
	Whole dry matter of spikes/Whole fresh matter of spikes (%)	80.0
	Fresh matter of the ground part (without spikes) (g/m^2)	1030
	Dry matter of the ground part (without spikes) (g/m^2)	432
	Dry matter/Fresh matter of the ground part (without spikes) (%)	41.9
	Fresh matter of the ground part (with spikes) (g/m^2)	1060
	Dry matter of the ground part (without spikes) (g/m^2)	456
	Dry matter/Fresh matter of the ground part (with spikes) (g/m^2) (%)	43.0
	Fresh matter of the underground part (g/m^2)	540
	Dry matter of the underground part (g/m^2)	316
	Dry matter/Fresh matter of the underground part (g/m^2) (%)	58.5
11.08.2003, 14:00	Culms/m^2	2134
	Dry matter/Fresh matter (%) for whole plant	51.3
	Water content of the whole plant (%)	48.7

Samples from the base-field of Beijing-Xiaotangshan

Table 4:
Main nutritional Components of the strain Special Blue of *Leymus chinensis*

Time of sampling	Plant part	Raw protein %	Raw fat %	Raw ash %	Raw fiber %	Soluble sugar %
30.05.2003, 17:00	Whole plant	21.22	5.18	6.36	28.00	2.975
03.06.2003, 12:00	spike	12.58	3.80	3.70	34.30	1.675
	Ground part (without spike)	14.04	3.61	4.79	34.05	2.875
	Underground part	7.08	1.40	17.69	45.45	4.250

Samples from the base-field of Beijing-Xiaotangshan. Analysis of the samples was carried out by Mr. Liu in Beijing R & D Center for Grasses and Environment on 14.07.2003

The appearance of the Special Blue is whitish blue, or thick sky-blue if seen at a distance. But more irrigation will decrease its blue color.

For descriptions of the normal *Leymus chinensis*, see Flora China Vol. 9 (3) listed in the literature (IBAS, 1987).

3.2 Culm density, yield and nutritional composition of the Special Blue in cultivated population

At the beginning of June, this vegetative strain of *Leymus chinensis* has a culm density of 1852 culms/m^2, and a culms spiking rate of 14.3 %. The yield of the ground part counts to 1060 g/m^2 as fresh matter or to 456 g/m^2 as dry matter. It is calculated that the fresh grass yield will be 10.2 t/ha and the hey yield be 4.56 t/ha (Table 3). It can be seen from these data that the yield potential of the Special Blue is very large, considering that the cultivated *Leymus chinensis* ever produced fresh grass up to 15 t/ha or hey to 4.5 t/ha in conditions without irrigation, and produced fresh grass up to 30 t/ha or hey 9 t/ha in conditions with irrigation (IMAHC 1981).

In the middle of August, this strain of *Leymus chinensis* has a culm density of 1852 culms/m^2, with 15.2 % increase in culms number compared to the data from the beginning of June.

The result shows that this vegetative strain of *Leymus chinensis* has a mean culms density of around 2000 culms/m^2 during one growing season. About 90 % of culms have already formed around the time of spike ripening, little increase occurs thereafter.

It can be seen in Table 3 that the plant has a rather low water content, lower than 55 % or 50 %, under intensive solar radiation in the noon. Its water content increases gradually, nearly reaches 65 %, along with the weakening of solar radiation in the afternoon. In this trend the plant must have even higher water content in the night. Low water content and its changing rhythms reflect strong abilities of the strain Special Blue against drought.

The nutritional components of this vegetative strain are analyzed and shown in Table 4. The results show that this strain has also rather high nutritional values with high protein content of 12-21 % in the ground part of the plant, though the contents of different nutritional components could vary to some extent in samples taken at different times or from different parts of the plant. The fact that the grass *Leymus chinensis* has so high protein content is due to the existence of nitrogen-fixing Spirilla in its root system (Chen and Jia, 2002). These nitrogen-fixing Spirilla are strongly active and host-specified. Their efficiency of nitrogen-fixation is almost comparative with that of root nodule bacteria (Rhizobia) in legume plants. This also explains the high tolerance of Special Blue to poor soils.

3.3 Extending rate of rhizomes of the strain Special Blue in cultivated population

This vegetative strain grows very evenly, and so is the extending rate of its rhizomes. At the time of transplantation at the end of March 2002, the row distance was 2 m and there were defects of different length vacancy in the rows. Till October 2002, the area of the plot was covered almost completely by the cultivated population, the Special Blue of *Leymus chinensis*. In the spring of 2003, new sprouts grew out from the area which was roughly the same size as covered by this grass in the last autumn. Till July 2003, the grass-covered area showed no obvious enlargement. On 12 July 2003, 12 points along the outline of the grass-covered area were measured to record the distances of the current margin of the population to the original planting position of the outline-rows. The result showed that the plant had extended outwards for 1.9-2.3 m, averagely 2.09 m (Table 5). This is to say that the outward-extending radius of the rhizomes of a single plant of *Leymus chinensis* is about 2.09 m within one growing season. The whole grass-covered area by a single plant after extending is about 13.72 m^2. In practice, we can taken a square form inscribed to this area as the effective extend-

Table 5:
Statistical analysis of measured data of extending distances of the rhizomes in cultivated population of the strain Special Blue of *Leymus chinensis* within one growing season

Extending distance (m) (χ)	Number of measured points (n)	Sum of distances ($\Sigma\chi$)	Average ($\bar{\chi}$)	Square value of sum $(\Sigma\chi)^2$	Sum of square value ($\Sigma\chi^2$)	Standard deviation (S)	Coefficient of deviation (c v %)
2.0 2.2 2.3 1.9	6 3 2 1	25.1	2.09	630.01	52.21	0.0289	1.38
Data from the base-field of Beijing-Xiaotangshan							

ing area of a single plant, then the extended grass-covered area of the strain Special Blue will be $(2.09 \times 2) \times 2.09 = 8.74$ m^2. The maximal distance between single plants at the time of transplantation should be $8.74^{1/2} = 2.96$ m. On the other hand, the rate of rhizome-extending is also dependant on the soil conditions. The plant distance for transplantation could thus be designed with a plus or a minus value in reference to the above calculated data. However, the outward-extending rate of the rhizomes of the strain Special Blue is relatively stable with little variations under the same soil conditions (Table 5).

3.4 Effects of transplantation at different times and mowing on the growth of the plant of the strain Special Blue

This vegetative strain of *Leymus chinensis* has a very high viability through transplantation. Generally speaking, it can be transplanted at anytime in a growing season. Its growth will be restarted about one week after transplantation. In addition, transplantation can enhance the rate of propagation and the rate of extending of the rhizomes. The results of experiments showed that the plant had always a survival rate of 100 % through transplantations in March, May or in July, and the transplanted grass could restart growth soon. Along with restarting growth, the rhizomes of the plant started to extend outwards. On the contrary, the rhizomes grew slowly without obvious extending in the area of the population in the second growing season, when no further transplantation had been done.

Mowing has significant effect on the growth of *Leymus chinensis*. In the experiment, a small plot of culms was mowed on 18. July 2003. The new sprouts were scarcely to see and the ground of the mowed plot had not been recovered after three weeks, on 05. August 2003. The rhizomes of the mowed plant did not show any clear signs of outward-extending in more than three weeks. Although mowing during a growing season might keep or increase the total yields of hey products in this year, it decrease the accumulation of nutritional materials in the rhizomes and leaves a negative effect on the successive growth of the grass.

The results of the above experiments and observations show that the vegetative strain Special Blue of the grass *Leymus chinensis* has a relatively high yield and good nutrition values. It can be cultivated as a good grass species for grazing or for forage production. At the same time, this vegetative strain of *Leymus chinensis* has an excellent blue color appearance which is attractive or charming, a high viability in transplantation, a high rate of rhizome extending shortly after transplantation, a high culms density and thus a good effect of ground-coverage. In this context the strain Special Blue is also suitable to be used for roadside soil protection against erosion, and as a component plant for ecological landscaping. The prosperous experimental population, cultivated by the author in the base-field of Beijing R&D Center for Grasses and Environment, shows its blue color appearance with a yellowish-green background of a higher grass *Triarrhena* population, and has attracted much attentions and interests of visitors from Beijing City and from many places of the country.

4 Conclusion

The vegetative strain Special Blue of *Leymus chinensis* is a good grass material obtained through artificial selection and single plant successive propagation. It has good tolerance to drought and cold, and can be used for grazing or for forage production. More important is that this grass strain has an excellent blue color, high evenness in plant height, high and steady culms density, high survival rate in transplantation, high extending rate of the rhizomes shortly after transplantation but lower rate of that one year after transplantation. All these properties make this grass very suitable as a new plant component for ecological landscaping. The cultivation costs of this grass strain is low. Usually it does not need any irrigation in the whole growing season. Its dense rhizomes protect the ground very well. Its blue color appearance can match or fit to the green color of other plants in its surrounding and thus bring about a unique decorate or ornamental effect to the landscaping vegetation.

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