Effects of Fertilizer Applications on Seed Yield and Quality of *Elymus sibiricus* in a Rain-Fed Condition

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Introduction

Siberian wildrye grass (*Elymus sibiricus* L.) is widely used for reseeding as part of grassland improvement programs in Inner Mongolia. Shortage of seed supply has been a problem that limits wider use of *E. sibiricus* in Northern China steppes. In this research, we investigate the effects of fertilizer application on the seed yield and seed quality of *E. sibiricus* grown under rain-fed conditions in Inner Mongolia.

Materials and Methods

The experiment was located in the Experimental Farm of Duolun Grassland Station, Duolun County, Inner Mongolia. Fertilizer was applied to a three year old *Elymus sibiricus* seed crop with a row width of 25 cm. Urea (46% - N), calcium superphosphate (18% - P_2O_5) and a local potash fertilizer (54% - K_2O) was used as sources of N, P and K nutrients.

The impact of three different fertilizer strategies on *E. sibiricus* seed production was examined: (1) the main effects and interactions of N, P, K inputs (Table 1); (2) the effect of variable N application with basal P (Table 2); and (3) Basal P with N applied according to stage of growth (Table 3). The treatments were set out in a randomized block design with three replicates and a plot size of 15 m^2.

At peak flowering time (mid July), flowering tillers (FT) were counted in a 1 m^2 quadrat in each treatment plot. Spikelet number per raceme (SR) and floret number per spikelet (FS) were measured with 20 randomized collected racemes in each plot. At harvesting, seed weight (SW) was measured with 100 seeds of 8 replicates. Final yield was measured by harvesting the seeds in a 1 m^2 quadrat in the treatment plot in early September. Potential yield was calculated as the product of FT x SR x FS x SW. Data measured for the control plots (CK) were denoted as 1 for easy relative comparison with other treatments.

Results

Seed yield response to different fertilizers

Results of the first year assessment (Table 4) showed that in general none of the yield components showed significant response to the fertilizer applications. However, there was an increase (P<0.05) in yield measured with the NP and NPK combination treatments.

Seed yield responses to rated N and P applications

The significant effect of N and P on final yield was further investigated with results in Table 5 showing that there were significant responses to N and P applied alone. *E. sibiricus* final yield increased by 20% with application of N_{40} to

Table 1. Fertilizer application details of the trial (kg/ha).

Treatment	CK_0	N_{100}	P_{60}	K_{50}	$N_{100}P_{60}$	$N_{100}K_{50}$	$P_{60}K_{50}$	$N_{100}P_{60}K_{50}$
N applied	0	100	0	0	100	100	0	100
P_2O_5 applied	0	0	60	0	60	0	60	60
K_2O applied	0	0	0	50	0	50	50	50

Table 2. Treatment of different rated fertilizer applications (kg/ha).

Treatment	N-CK	N_{40}	N_{80}	N_{120}	N_{160}	P_{CK}	P_{30}	P_{60}	P_{90}	P_{120}
N		40	80	120	160	80	80	80	80	80
P_2O_5	60	60	60	60	60	0	30	60	90	120

Table 3. Treatments of N fertilizer application at different times (kg/ha).

Treatment	N-Early	N-Late	N-E_{20}-L_{60}	N-E_{40}-L_{40}	N-E_{60}-L_{20}
P_2O_5 applied at early growth stage	60	60	60	60	60
N applied at early growth stage	80	0	20	40	60
N applied at shooting stage	0	80	60	40	20

Table 4. Responses of different seed yield components to different fertilizer applications.

Treatment	CK	N	P	K	NP	NK	PK	NPK
Spikelet/Raceme	38.44	38.50	40.07	40.03	39.62	39.55	40.03	40.51
Standardized value	1.00	1.00	1.04	1.04	1.03	1.03	1.04	1.05
Floret/Spikelet	4.16	4.20	4.04	3.99	4.17	4.25	4.26	4.46
Standardized value	1.00	1.01	0.97	0.96	1.00	1.02	1.02	1.07
1000-seed weight (g)	3.71	3.77	3.62	3.68	3.83	3.85	3.85	3.99
Standardized value	1.00	1.01	0.98	0.99	1.03	1.04	1.04	1.06
Potential yield (kg/ha)	4503	4627	4448	4461	4803	4912	4983	5472
Standardized value	1.00	1.03	0.99	0.99	1.07	1.09	1.11	1.22
Final yield (kg/ha)	800	944	932	786	1091	930	922	1103
Standardized value	1.00	1.18	1.17	0.98	1.36*	1.17	1.15	1.39*

* significantly different at $P<0.05$ level.

Table 5. Responses of seed yield components to different rated N and P applications.

Treatment	N-CK	N_{40}	N_{80}	N_{120}	N_{160}	P-CK	P_{30}	P_{60}	P_{90}	P_{120}
Spikelet/Raceme	33.21	35.14	35.21	35.74	33.80	37.24	38.89	39.80	39.78	38.75
Standardized value	1.00	1.06	1.06	.1.08	1.02	1.00	1.04	1.07	1.07	1.04
Floret/Spikelet	4.07	4.25	4.22	4.34	3.97	4.24	4.08	4.32	4.35	4.06
Standardized value	1.00	1.04	1.04	1.07	0.98	1.00	0.96	1.02	1.03	0.96
1000-seed weight (g)	3.64	3.81	3.82	3.92	3.80	3.88	3.87	3.91	3.92	3.96
Standardized value	1.00	1.05	1.05	1.08	1.04	1.00	1.00	1.01	1.01	1.02
Potential yield (kg/ha)	3734	4318	4308	4580	3870	4650	4661	5103	5749	4729
Standardized value	1.00	1.15	1.15	1.23	1.04	1.00	1.00	1.09	1.24	1.02
Final yield (kg/ha)	736	879	890	972	756	757	743	823	1124	894
Standardized value	1.00	1.19*	1.21*	1.32*	1.03	1.00	0.98	1.09	1.48*	1.18

* significantly different at $P<0.05$ level.

Table 6. Seed yield responses to N application at different times.

Treatment	N-Early	N-Late	$N\text{-}E_{20}\text{-}L_{60}$	$N\text{-}E_{40}\text{-}L_{40}$	$N\text{-}E_{60}\text{-}L_{20}$
Spikelet/Raceme	38.15	36.15	36.15	36.88	38.48
Standardized value	1.06	1.00	1.00	1.02	1.06
Floret/Spikelet	4.17	4.11	4.10	4.21	4.20
Standardized value	1.01	1.00	1.00	1.02	1.02
1000-seed weight (g)	3.87	3.82	3.80	3.88	3.99
Standardized value	1.01	1.00	0.99	1.02	1.04
Potential yield (kg/ha)	4673	4308	4275	4572	4894
Standardized value	1.08	1.00	0.99	1.06	1.14
Final yield (kg/ha)	790	610	657	881	946
Standardized value	1.29*	1.00	1.08	1.44*	1.55*

N_{120}, but declined with the highest N rate. A clear optimum was detected for P at the application rate of 90 kg P_2O_5/ha (Table 5). At the higher rate of 120 kg P_2O_5/ha yield declined indicating that other nutrients rather than P were limiting production. The results suggest that *E. sibiricus* yield is enhanced with N and P inputs of 120 kg/ha and 90 kg/ha, respectively.

Seed yield response to separated application times

Results in Table 6 showed that when 80 kg/ha urea was applied only once, an early application at the growth initiating stage was superior in final yield to a late application at shooting stage. When the application was divided into two times, a heavy early rate plus a light late rate achieved the highest yield. A light early rate plus heavy late rate showed almost no effects on seed yield.

Effects of fertilizer application on seed quality

There was no significant difference between any two treatments, although all the fertilizer applications seemed beneficial to seed germination performance.

Discussion and conclusion

A combined fertilizer application of 90-120 kg/ha urea and 60-90 kg P_2O_5/ha was considered a suitable rate for seed production in the experimental conditions. An early application was much more effective than the late application.

The similarities in seed germinability and seed vigour index obtained from the various fertilizer treatments indicated that plant nutrition level may not be an important factor affecting seed quality.

Cost efficiency is the most important factor determining the management decision whether or not to use fertilizers. In the current study, a maximum 1.54 fold seed yield over the CK was obtained by fertilizer application. A 500 Yuan/ha minimum net profit is expected from the fertilizer application. However, in comparison with other crops and even with the production for herbage, this net income is still minimal. Furthermore, when considering the risk of unpredictable weather, the reluctance for any extra input, such as applying fertilizers into the field, was understandable.