Article

Responses of Seed Yield Components to the Field Practices for Regulating Seed Yield of Smooth Brome grass (*Bromus inermis* Leyss.)

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Abstract: Agronomic practices improve seed yield by regulating seed yield components, and the relationship between seed yield and seed yield components is still unclear in smooth brome grass (*Bromus inermis*). To optimize seed production and yield in smooth brome grass, a five-year field trial was designed with split-split-plot to study the combined effects of row spacing (30, 45, 60, and 75 cm), phosphorus (0, 60, 90, and 120 kg P ha⁻¹) and nitrogen (0 and 100 kg N ha⁻¹) on seed yield and seed yield components including fertile tillers m⁻² (FTs), spikelets per fertile tiller (SFT), florets per spikelet (FS), and seeds per spikelet (SS). The results showed that FTs as a key factor had a positive effect to seed yield with the biggest pathway coefficient, while SS had a negative effect. Meanwhile, an interaction effect between FTs and SS was observed. FS and SS were increased with phosphorus application under the condition of sufficient nitrogen. In addition, sufficient precipitation at the non-growing season resulted in more FTs in the next year in rain-fed regions. Therefore, the optimum seed yield of smooth brome grass can be obtained with row spacing (45 cm), nitrogen (100 kg N ha⁻¹), and phosphorus application (60 kg P ha⁻¹).

Keywords: fertilization; row spacing; seed yield; seed yield component; smooth brome grass

1. Introduction

Field management practices including seeding, fertilization, irrigation, and weed control, etc., are important factors for a seed grower to improve seed yield. Research on cool-season grasses revealed that agronomic practices, such as plant density, fertilization, and residue management, influenced the level of seed yield and quality [1,2].

Seed yield components consist of fertile tillers m⁻² (FTs), spikelets per fertile tiller (SFT), florets per spikelet (FS), and seeds per spikelet (SS), which are significantly related to the seed yield of grass species [3]. Previous studies in smooth brome grass (*Bromus inermis* Leyss.), Russian wildrye (*Psathyrostachys juncea* Nevski), and Siberian wildrye (*Elymus sibiricus* L.) showed that there was a significant correlation between the FT and seed yield [4–6]. The range of variation for the SFT and FS of perennial ryegrass (*Lolium perenne* L.) is influenced by the genetic backgrounds during plant growth [7,8]. Additionally, agronomic practices can increase the number of FS in perennial ryegrass [9]. The number of SS is limited by self-incompatibility [10], weather at pollination [11], and lodging at flowering [12]. Therefore,

the relationship between seed yield and yield components needs to be explored further for grass seed production in certain areas.

Plant density is one of the key factors affecting plant growth and seed yield, mainly by regulating the demand for resources such as space, water, nutrient, and light [13,14]. The row spacing for the optimum seed yield is varied in different grass species, and even in different regions, as seed development and tiller growing depend on the closing time of the crop canopy [15,16].

Nitrogen, as a massive element restricting the growth and reproduction of crops [17,18], plays an important role in plant growth and seed development [19]. Nitrogen affects the photosynthetic capacity of leaves, tiller formation, spikelet differentiation, and grain quality [20,21]. Insufficient nitrogen application decreases the seed yield, while excessive nitrogen application might cause a low utilization rate, soil pollution, and plant lodging, which consequently decreases the seed yield and quality [22,23]. Application of an appropriate amount of nitrogen increases the seed yield through the improved number of FTs and SS in rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) [24,25]. Additionally, the variation of FTs in *Leymus chinensis* is regulated by the timing and rate of nitrogen application [26,27].

Plants take up phosphorus from the soil during the entire growth period and accumulate a large amount of phosphorus in their seeds [28]. Phosphorus deficiency inhibits plant photosynthesis mainly in terms of the reduction in ATP production, Rubisco activity, and RUBP regeneration rate [29,30]. Phosphorus deficiency also inhibits plant root growth and carbohydrate transport, so as to reduce the yield and stand age of perennials [31]. Appropriate phosphorus application can promote the development and growth of the root [32], regulate the distribution of assimilation products, and facilitate flowering and seed physiological maturation [33]. The application of phosphorus fertilizer is beneficial to the accumulation and transfer efficiency of phosphorus from stems and leaves to grains, which is conducive to increasing the seed yield [34]. It has been reported that an application of 18 kg P ha⁻¹ increased the seed yields of smooth brome grass in the soil with available phosphorus at a medium level under rain-fed conditions [35]. Moreover, phosphorus application can also improve the number of SFTs in Siberian wildrye [6]. However, how the seed yield components respond to the field practices for maintaining higher seed yield is still a focused point for the research of seed technological during grass seed production.

Smooth brome grass, originating from the Eurasian continent, is found in the temperate regions of Asia, Europe, and North America. It is a kind of perennial grass with a high tolerance for drought and cold, and is widely used for pasture cultivation, rangeland improvement, and soil and water conservation in semi-arid regions in China [36,37]. Compared with annual crops, perennial grass has poor performances of reproduction and seed yield [26], which largely depends on soil fertility, environmental factors, and varieties [38]. Previous research on seed production of smooth brome grass mostly focused on one single factor, for example, row spacing, phosphorus, or nitrogen treatments [16,35,39,40] and no interactive pattern among seed yield components was investigated. In this study, the experiments were designed with a split-split-plot factorial arrangement consisting of row spacing, nitrogen, and phosphorus application to evaluate the interaction pattern among seed yield components and their contributions to the seed yield in smooth brome grass.

2. Materials and Methods

2.1. Seed Field Location

The field trials were performed at the Yuershan farm in Hebei Province, China (41°44' N, 116°8' E; 1455 m elevation) during the growing seasons of 2014, 2015, 2016, 2017, and 2018. Seed field is located in the semi-arid continental monsoon climate zone, where the monthly mean temperature is stable among years, and precipitation is mainly enriched from May to October (Figure 1). There was 46.48 mg kg⁻¹ available nitrogen (N), 1.33 mg kg⁻¹ available phosphorus (P), 22.99 g kg⁻¹ total potassium (K), and 12.82 g kg⁻¹ organic matter in the soil (0~30 cm) before sowing.

Figure 1. Monthly means of precipitation (mm) and temperature ($^{\circ}\text{C}$) from 2013 to 2018 in the field located in Yuershan, Hebei Province, China. Bars indicate precipitation (P2013–P2018), and lines indicate temperature (T2013–T2018).

2.2. Trial Design and Treatments

Field trials were established by the seeding of Yuanye smooth brome grass (seeding rate 35.2 kg ha^{-1}) in July 2013 with a split-split-plot design, and the plots were arranged in a randomized complete block design with four replicates. Row spacing (R), nitrogen (N), and phosphorus (P) levels were arranged as main plot, subplot, and sub-subplot, respectively. The size of the sub-subplot experimental unit was $5 \text{ m} \times 4 \text{ m}$. Row spacing treatment had four levels, i.e., 30 (R1), 45 (R2), 60 (R3), and 75 (R4) cm. The four levels of P application were 0 (P1), 60 (P2), 90 (P3), and 120 (P4) kg P ha^{-1} with calcium superphosphate (12% P_2O_5) broadcasted together with seeds. The two levels of N application were 0 (N1) and 100 (N2) kg N ha^{-1} , and urea (46% N) was applied at the tillering stage, from 2014 to 2018. Seed development entered the milk stage in early July and the hard stage in late July. The field experiment ended in August 2018.

2.3. Seed Sampling and Analysis

2.3.1. Seed Yield Components

Fertile tillers m^{-2} were measured by randomly selecting a 1-m-row sample in each plot at milk stage. Thirty fertile tillers and thirty spikelets were selected randomly to determine the number of spikelets per fertile tiller, florets per spikelet, and seeds per spikelet at the milk stage.

2.3.2. Seed Yield

Mature seeds were carefully hand-harvested from 1-m-row plants in each plot at the end of July; after, they were air dried (at $20\text{--}25^{\circ}\text{C}$, for 2–3 days), threshed, and cleaned by hand. Seed yield (kg ha^{-1}) was calculated by weighing samples on the scale ($\pm 0.001 \text{ gr}$).

2.4. Statistical Analysis

Excel 2010 software was used for data input and collation. Experiment data from the split-split plot design were analyzed based on the generalized linear model (GLM) in SPSS version 23.0 (SPSS, IBM, Inc., Chicago, IL, USA). Treatment means were used for Duncan's new multiple range test, at a significance level of 0.05. The variables of year, row spacing, nitrogen, and phosphorus application were considered as fixed effects, and block was considered a random effect. Year was treated as a repeated measure variable. The variables were compared among different P application levels with a combination with N0 and N1,

in One-way ANOVA analysis at a significance level of 0.05. One-way ANOVA analysis was also conducted to assess the effect of harvested year. The relationships between seed yield and yield components were examined across years by using Pearson's correlation analysis across years. Multiple stepwise regression analysis was used to evaluate pathways from management factors to yield components and seed yield.

3. Results

3.1. Effects of Harvested Year, Row Spacing, and Fertilizer Application on Seed Yield and Yield Components in Smooth Brome grass

The results of variance analysis showed that there were significant ($p < 0.05$) effects for the harvested year, row spacing, and N/P application on seed yield and all the seed yield components, but there was no significant effect for P application on SFT (Table 1). The interaction of row spacing and N application ($R \times N$) significantly affected the seed yield components of FTs ($p < 0.05$), SFT ($p < 0.05$), and SS ($p < 0.01$). FS, SS, and seed yield were significantly ($p < 0.01$) affected by the interaction of N and P application ($N \times P$). However, there were no significant effects for the interaction of row spacing and P application ($R \times P$), and $R \times N \times P$ on seed yield and yield components.

Table 1. ANOVA results for harvested year, row spacing, and N/P application on seed yield and seed yield components in smooth brome grass.

Source of Variation	Fertile Tillers m ⁻² (FTs)	Spikelets Per Fertile Tiller (SFT)	Florets Per Spikelet (FS)	Seeds Per Spikelet (SS)	Seed Yield (kg ha ⁻¹)
Harvest year	**	**	**	**	**
R	**	**	**	**	**
N	**	**	**	**	**
P	*	ns	**	**	**
$R \times N$	*	*	ns	**	ns
$R \times P$	ns	ns	ns	ns	ns
$N \times P$	ns	ns	**	**	**
$R \times N \times P$	ns	ns	ns	ns	ns

* significant at 0.05 level; ** significant at 0.01 level; ns, no significance.

3.2. Effects of Different Treatments of Row Spacing, and N/P Application

The FT values decreased significantly ($p < 0.05$) with the increase in row spacing from 30 to 75 cm, while SFT, FS, and SS presented the increasing tendency (Table 2). The FT values in the treatments of R1 (30 cm) and R2 (45 cm) were significantly ($p < 0.05$) higher than those in R3 (60 cm) and R4 (75 cm). The seed yield, with a similar trend to FTs, firstly increased and then decreased, with the highest (527.67 kg·ha⁻¹) at the R2 treatment. Furthermore, there was a significant increase in the seed yield and yield components with more N and P application (Table 2). All the seed yield components significantly ($p < 0.05$) increased with N1 application (100 kg N ha⁻¹) compared to those with N0 (0 kg N ha⁻¹). P application significantly ($p < 0.05$) increased the seed yield and improved FTs, FS, and SS, except for SFT, but there were no significant differences among P2, P3, and P4.

Table 2. Effects of row spacing and N/P application on seed yield and seed yield components in smooth brome grass.

Treatments	Fertile Tillers m ⁻² (FTs)	Spikelets Per Fertile Tiller (SFT)	Florets Per Spikelet (FS)	Seeds Per Spikelet (SS)	Seed Yield (kg ha ⁻¹)
Row spacing (cm)					
R1 (30)	328 a, [†]	15.61 d	5.10 b	3.27 b	498.51 a,b
R2 (45)	331 a	17.37 c	5.12 b	3.34 b	527.67 a
R3 (60)	289 b	18.03 b	5.35 a	3.52 a	496.98 ab
R4 (75)	222 c	18.80 a	5.38 a	3.54 a	477.76 b
N application (kg N ha ⁻¹)					
N0 (0)	201 b	16.00 b	4.88 b	3.07 b	265.44 b
N1 (100)	382 a	18.76 a	5.59 a	3.75 a	741.94 a
P application (kg P ha ⁻¹)					
P1 (0)	272 b	17.36 a	5.06 b	3.31 b	407.36 c
P2 (60)	293 a	17.24 a	5.34 a	3.45 a	511.12 b
P3 (90)	298 a	17.57 a	5.25 a	3.42 a	526.84 ab
P4 (120)	308 a	17.60 a	5.30 a	3.49 a	555.12 a

[†] mean values within each treatment ($n = 4$) followed by different letters are significantly different at 0.05 level.

There was a significant ($p < 0.01$) effect interaction for $N \times P$ on the increase in the seed yield (Table 1). N application was beneficial to promoting the effectiveness of P application on seed yield and yield components (Table 3). At N1, the seed yield and yield components of FS and SS increased significantly ($p < 0.05$) in treatments of P2, P3, and P4 compared with P1, although there were no significant ($p > 0.05$) differences between P2/P3/P4 and P1 at N0. Furthermore, there were no significant ($p > 0.05$) differences among P2, P3, and P4 at both N0 and N1. Finally, the highest seed yield of smooth brome grass was obtained with an optimum combination of R2 (45 cm), N1 (100 kg P ha⁻¹), and P4 (60 kg P ha⁻¹).

Table 3. Effects of P application on seed yields and seed yield components in smooth brome grass under certain N application levels during.

P Treatment (kg P ha ⁻¹)	Fertile Tillers m ⁻² (FTs)	Spikelets Per Fertile Tiller (SFT)	Florets Per Spikelet (FS)	Seeds Per Spikelet (SS)	Seed Yield (kg ha ⁻¹)
N0 (0 kg N ha ⁻¹)					
P1 (0)	195 a, [†]	16.31 a	4.92 a	3.12 a	264.21 a
P2 (60)	200 a	15.81 a	4.93 a	3.07 a	262.09 a
P3 (90)	211 a	16.07 a	4.82 a	3.00 a	273.23 a
P4 (120)	207 a	16.16 a	4.92 a	3.12 a	262.22 a
N1 (100 kg N ha ⁻¹)					
P1 (0)	350 b	18.48 a	5.21 b	3.51 b	555.94 b
P2 (60)	390 a,b	18.70 a	5.78 a	3.84 a	769.48 a
P3 (90)	385 a,b	19.05 a	5.69 a	3.83 a	782.49 a
P4 (120)	409 a	19.03 a	5.67 a	3.85 a	846.27 a

[†] mean values within each treatment ($n = 4$) followed by different letters are significantly different at 0.05 level.

3.3. Changes of Seed Yield and Yield Components of Smooth Brome grass during Different Harvested Year

The data from 2014 to 2018 presented a significant ($p < 0.05$) influence of the harvested year on the seed yield and yield components, and all exhibited the gradually declining trend with the prolonging of the harvested year (Table 4). Interestingly, the FT in 2015 was significantly ($p < 0.05$) lower than those in the other years; while the FS and SS attained the highest level, the seed yield went down to the lowest in 2015. The seed yields harvested in 2014 and 2016 were significantly ($p < 0.05$) higher than those in other years. Since 2017,

the seed yield began to decline significantly ($p < 0.05$) and was down to the lowest level of $256.96 \text{ kg ha}^{-1}$ in 2018.

Table 4. Changes in seed yield and seed yield components of smooth brome grass from 2014 to 2018.

Harvested Year	Fertile Tillers m^{-2} (FTs)	Spikelets Per Fertile Tiller (SFT)	Florets Per Spikelet (FS)	Seeds Per Spikelet (SS)	Seed Yield (kg ha^{-1})
2014	496 ^{a,†}	24.48 ^a	5.12 ^b	3.77 ^b	681.01 ^a
2015	170 ^d	17.87 ^b	6.00 ^a	4.04 ^a	319.58 ^c
2016	344 ^b	16.03 ^c	5.10 ^b	2.97 ^d	758.84 ^a
2017	227 ^c	14.42 ^d	5.19 ^b	3.41 ^c	459.14 ^b
2018	215 ^c	13.85 ^d	4.73 ^c	2.83 ^d	256.96 ^c

[†] mean values in each column followed by different letters are significantly different at 0.05 level ($n = 128$).

3.4. Correlation and Pathway Analysis

Pathway and correlation analysis were performed for the contribution of row spacing, N, and P treatments to the seed yield and yield components. The pathway analysis showed that the increased row spacing had a direct negative influence on FTs and a direct positive influence on SFT, FS, and SS (Figure 2). The factor of N application had a direct positive influence on all the seed yield components, and P application had a direct positive influence on FS and SS.

Figure 2. Pathway analysis of row spacing and N/P application on fertile tillers m^{-2} (FTs), spikelets per fertile tiller (SFT), florets per spikelet (FS), and seeds per spikelet (SS) in smooth brome grass. The numbers on the lines indicate pathway coefficient.

The correlation analysis showed that the seed yield was extremely significantly ($p < 0.01$) correlated with FTs, SFT, FS, and SS, and the maximum correlation coefficient of 0.744 was achieved for FTs (Table 5). The multiple stepwise regression analysis showed that the FT, FS, and SS made significant ($p < 0.05$) direct contributions to the seed yield with direct pathway coefficients of 0.777, 0.434, and -0.182 , respectively (Table 6). Further analysis among the seed yield components showed that the component of SS imposed the strongest indirect influence on seed yield (indirect coefficient = 0.5446), followed by SFT (indirect coefficient = 0.4510). Finally, the structural equation was modeled through pathway analysis as follows: $Z = -715.45 + 1.56Y_1 + 205.43Y_3 - 92.63Y_4$ (Z : seed yield, Y_1 : FTs, Y_2 : SFT, Y_3 : FS, Y_4 : SS).

Table 5. Pearson correlation coefficients among seed yield and seed yield components in smooth brome grass from 2014 to 2018.

Seed Yield Components	FTs	SFT	FS	SS	Seed Yield (kg ha ⁻¹)
Fertile tillers m ⁻² (FTs)	1	0.544 **	0.021	0.206 **	0.744 **
Spikelets per fertile tiller (SFT)		1	0.278 **	0.507 **	0.461 **
Florets per spikelet (FS)			1	0.847 **	0.294 **
Seeds per spikelet (SS)				1	0.346 **
Seed yield (kg ha ⁻¹)					1

** significant at the 0.01 probability level.

Table 6. Pathway analysis for direct and indirect effects of seed yield components on seed yield in smooth brome grass.

Seed Yield Components	Direct Pathway Coefficients	Indirect Pathway Coefficients				
		FTs	SFT	FS	SS	Total
Fertile tillers m ^{−2} (FTs)	0.777		0.0180	0.0091	−0.0375	−0.0104
Spikelets per fertile tiller (SFT)	0.033	0.4225		0.1207	−0.0923	0.4510
Florets per spikelet (FS)	0.434	0.0163	0.0092		−0.1541	−0.1287
Seeds per spikelet (SS)	−0.182	0.1600	0.0167	0.3679		0.5446

4. Discussion

4.1. Effects of Row Spacing and N, P Application on Seed Yield and Yield Components in Smooth Brome grass

Seed yield is a quantitative trait influenced by genotype and environment. Seed yield components, such as fertile tillers m⁻² (FTs), spikelets per fertile tiller (SFT), florets per spikelet (FS), and seeds per spikelet (SS), are, with direct factors, contributions to seed yield, and affected by rainfall [41], flowering time, growth period, and plant growing rate [42]. In addition, agronomic managements are also important factors affecting the seed yield components [16,24–27].

In terms of seed yield per unit area, the maximum yield is bound to occur in narrow rows generally. In this study, the number of FTs was limited at the wider rows, and the maximum seed yield was achieved at row spacing of 45 cm, while there were no significant differences in the seed yield among row spacing treatments of 30, 60, and 75 cm. A previous study on perennial ryegrass reported that the row spacing from 12 to 48 cm had a negative effect on FTs but had no effects on seed yield [43]. A compensation effect for seed yield components was observed in smooth brome grass, as the seed yield with a loss caused by a lowered FT had been rebalanced by the increase in SFT, FS, and SS under wider row spacing (Table 2, Figure 2). It might be explained that wider row spacing provided much light and space for the plants, which resulted in the increase in SS [44] and FS [16,45], albeit a reduction in FTs.

The structural equation model revealed that the seed yield of smooth brome grass increased by 1.56 kg ha⁻¹ when the number of FTs increased by each unit. Meanwhile, the seed yield decreased by 92.63 kg·ha⁻¹ for the increase in one SS unit. Additionally, a significant positive correlation between FTs and SS ($p < 0.01$) was identified under the condition of no nitrogen application, and significant negative correlations were present under N application (Table 7). These results indicated that the complementary effects

between FTs and SS could limit the efficiency of nitrogen application. Additionally, the combination of N and P application significantly improved the seed yield, mainly through promoting FS and SS and depressing this complementary effect.

Table 7. Correlation analysis of seed yield and yield components in smooth brome grass under N application.

N1\N0	FTs	SFT	FS	SS	Seed Yield (kg·ha ^{−1})
Fertile tillers m ^{−2} (FTs)	1	0.676 **	−0.060	0.276 **	0.882 **
Spikelets per fertile tiller (SFT)	0.264 **	1	0.403 **	0.685 **	0.794 **
Florets per spikelet (FS)	−0.361 **	−0.020	1	0.787 **	0.125 *
Seeds per spikelet (SS)	−0.272 **	0.190 **	0.831 **	1	0.432 **
Seed yield (kg·ha ^{−1})	0.563 **	0.152 **	0.011	−0.074	1

* significant at the 0.05 probability level, ** significant at the 0.01 probability level.

4.2. Effects of Local Climate and Harvest Year in Seed Yield and Yield Components of Smooth Brome grass

In addition to nutrient requirements, temperature and water are also important factors to influence seed yield. Suitable temperature and precipitation are the basic requirements for the vegetative and reproductive growth of forage plants in arid and semi-arid regions. Only after a period of low temperature (vernalization), can the tillers of smooth brome grass develop into fertile tillers [46]. The growth and development of plants are greatly affected by the amount and distribution of precipitation [47]. The mean monthly temperature from 2013 to 2018 was relatively stable in our field (Figure 1). The total precipitation at the growing season was relatively stable from 2013 to 2017, as the total precipitation in the non-growing seasons (i.e., from August to April of the following year) varied from 97.2 mm in 2015 to 203.9 mm in 2017. Interestingly, with the least precipitation in the non-growing season in 2015, the lowest seed yield was harvested (Table 4), which was mainly due to the insufficient FTs. Therefore, it was important for the grower to pay attention to the variation of precipitation in the seed field under rain-fed conditions.

The FT mainly depends on the tillers that came out in the previous year. The declining FT number in 2015 might be caused by the lower amount of precipitation from August to October in 2014. It was also found that precipitation in the post harvesting stage was helpful for the FT formation of sheepgrass (*Leymus chinensis* L.) in the next year [48]. In addition, with stand age prolonged in seed fields, there was similar declining tendency of seed yield for some perennial grasses. In this study, we found that the seed yield of smooth brome grass began to decline significantly ($p < 0.05$) after the third harvested year, which was consistent with the previous reports on slender wheatgrass (*Elymus trachycaulus* L.), smooth brome grass, and Siberian wildrye [16,45]. The seed yield components also presented a gradual decreasing tendency with the prolonging of stand age.

4.3. Relationship between Seed Yield and Yield Components in Smooth Brome grass

As there were significant ($p < 0.05$) correlations among the seed yield components, simple linear regression analysis was not accurate to determine a single important component correlated with seed yield. Path analysis is a good way to determine the relationship between the seed yield and the yield components. It divides the total effects into direct and indirect ones and provides determination coefficients of each seed yield component [49]. Our results of path analysis revealed that FTs, significantly affected by nitrogen application and row spacing, had strong direct effects on seed yield in smooth brome grass. It was consistent with the previous studies on smooth brome grass [50] and Russian wildrye [5].

Interestingly, the direct effects of FS and SS on seed yield were positive and negative, respectively. The negative effect of SS on seed yield might be partly related to FTs. SS was correlated positively and negatively with FTs under N0 and N1, respectively. This relationship might be partly explained by the competition of photoassimilates between stem and ear [51].

There were complementary effects among the seed yield components to maintain the seed yield of smooth brome grass. When the seed yield of smooth brome grass was influenced by precipitation or other agronomic practices, the complementary effects of the seed yield components were always employed to balance the seed yield.

5. Conclusions

Fertile tillers m^{-2} was the primary factor to determine seed yield in smooth brome grass. Meanwhile, there were interaction effects between fertile tillers m^{-2} and seeds per spikelet. Therefore, a combination of seed yield components should be selected to promote seed production, rather than using one or two. Fertile tillers m^{-2} was significantly affected by row spacing, N application, and precipitation in the post harvesting stage, while seeds per spikelet were significantly affected by P application. The optimum seed yield in smooth brome grass under rain-fed conditions was obtained with row spacing (45 cm), nitrogen application (100 kg P ha^{-1}), and phosphorus application (60 kg P ha^{-1}).

Author Contributions: C.O. analyzed the data and wrote the manuscript; M.W. designed and performed the experiments and revised the manuscript; P.M. designed and supervised the research and edited the manuscript; L.H., Y.Z., and C.O. were involved in performing the experiments; M.S. and S.S. were involved in data analysis; and S.J. edited the manuscript. All authors have read and agreed to the published version of the manuscript.

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