

Breeding rye (*Secale cereale* L.) for early fall-winter forage production

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Abstract: Rye (*Secale cereale* L.) is an important annual forage crop suitable for improved forage production in the southern Great Plains of USA. Early fall-winter forage production is of great value in this region as it allows producers better flexibility for earlier grazing or increased stockpiling. Livestock producers usually spend a dollar per day per cow for feed during the time from the last week of October to November. This paper gives an overview of the methodology and results from Noble Foundations small grain breeding program that has the aim of helping livestock producers overcome feed shortages and increase profitability. A particular objective of the small grain breeding programme is to develop rye cultivars with high early fall-winter forage yield potential. Parents with desirable traits are chosen from local cultivars and world collections. Single, double, and three-way crosses are made. Subsequent generations are evaluated in field trials and potential populations are evaluated in Noble Foundation farms. Advanced lines are tested in multi-location trials alongside standard check cultivars. In multi-location trials, total and early fall-winter yields varied from 4,281 to 7,650 and 1,063 to 4,219 kg of dry matter ha^{-1} , respectively. Early fall-winter forage yield constituted 25 to 62 % of the total forage potential. Advanced lines with better potential for early fall-winter production are being developed as new cultivars.

Introduction

Livestock and forage production are the largest contributors to agricultural income in the southern Great Plains. Small grains are grown primarily as cool-season forage for livestock when pasture growth is minimal. Distribution of forage yield is as important as total forage yield. The main focus of Noble Foundation's small grain breeding program is to develop improved cultivars with potential for early fall-winter forage. Early fall-winter forage allows producers better flexibility for earlier grazing or increased stockpiling. Rye is an important forage crop with potential for early fall-winter forage.

Small grains have the potential to provide fall-winter forage and extend the grazing period. The Noble Foundation is the only organization in the region concentrating efforts to the genetic improvement of rye, triticale and oat. The small grain breeding program of the Foundation was initiated in early 1950's for rye. Since then, five forage rye cultivars have been released from Foundation's breeding program. 'Maton' (Bates, 1979) and 'Oklon' (Bates and Baker, 1994) are two important cultivars widely grown by livestock and forage producers across the southern U.S. In early 1970's wheat, triticale, and oat were also included in the breeding program. Significant improvements have been made on the genetic stocks and several breeding lines with potential for release as improved cultivars have been identified. This paper describes the methods and results of the Noble Foundations breeding programme for rye cultivars with improved early-fall winter yield potential.

Materials and methods

Parents with desirable traits are chosen from local cultivars and world collections. Single, double and 3-way crosses are made among the selected parents in greenhouses. Most of the breeding lines are chosen from double crosses. Subsequent generations are evaluated in field trials at Ardmore and Bourneville, OK, USA. Seeds are sown during mid September to early October and standard cultural practices are followed. Plants are grown under dryland conditions. During the early generations, breeding lines are evaluated for early fall-winter forage potential in a 1-10 scale where 10 indicates the highest potential for early fall-winter forage yield. Lines in preliminary, advanced, and variety trials are also evaluated for forage yield. Plots are clipped three to four times during the growing season to ascertain distribution of forage yield. Besides yield, these lines are evaluated for reaction to common leaf and stem diseases. Advanced strains are evaluated for forage quality (dry matter, crude protein, ADF, NDF, TDN, IVDMD and mineral composition). Eight lines from preliminary and five from advanced strains trials are moved to their next generations on the basis of 2004-05 evaluations. In 2005-06, 10, 12, and 11 rye lines are planted for evaluation in variety, advanced, and preliminary trials, respectively. Separate seed increase blocks are maintained for all the material in preliminary, advanced and variety trials. Advanced lines with better potential are evaluated in the small grain variety trials alongside standard checks in Oklahoma, Texas and other neighboring states.

DNA isolation, PCR conditions, and amplification of SSR alleles are performed following the protocol suggested by Saha et al (2004). The PCR products are resolved on 2% agarose gels stained with ethidium bromide. SSR bands are scored as present or absent. Genetic similarity among rye genotypes is calculated according to DICE coefficients of the NTSYS-*pc* software package (version 2.1). The similarity coefficients are used to construct UPGMA dendograms using the SAHN module. The FIND module of the NTSYS-*pc* is used to identify all trees.

Results and discussion

Among the four small grains (rye, wheat, triticale, and oat) tested in our breeding program, rye has the highest potential for early fall-winter forage production. During 2004-05, a total of 1010 F₆ rye breeding lines were evaluated in head rows along with four check cultivars ('Maton', 'Oklon', 'Bates' and 'Wrens96') repeated after every 40 lines. Rye lines varied widely with score classes from 4 to 10. Several F₆ rye lines were identified with high early fall-winter yield potential in comparison to the check cultivars (Figure 1).

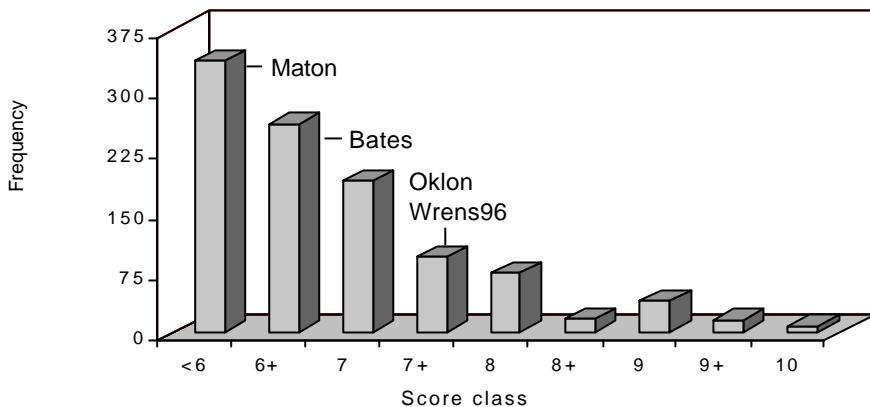


Figure 1. Frequency distribution of rye F₆ lines evaluated for early fall-winter forage potential at Ardmore, OK, USA.

In previous trials, rye has always performed better than other small grains in the light textured soils of Red River valley. In 2004-05 variety trials at Bourneville, OK, average dry forage yield of rye lines was 7,109 kg ha⁻¹ and those of triticale, wheat and oat were 6467, 6300, and 5718 kg ha⁻¹, respectively. Dry forage yield of our advanced rye lines varied from 7956 to 6573 kg ha⁻¹. Advanced lines that consistently perform better in variety trials are developed as new cultivars. Considering superior performance in the last seven year of evaluation, the rye breeding line NF65 has been selected to be released as a new cultivar in 2005.

NF65 is developed from a cross between 'Polish 3' x 'Maton' made in 1990. 'Polish 3' is an early fall-winter forage selection from germplasm originating from Poland. 'Maton' is an established cultivar with superior total forage production, disease resistance, winter hardiness and tillering capacity in the southern Great Plains. NF65 is a winter rye adapted well to southern Oklahoma, north and east Texas, and Louisiana conditions. Leaf size and plant height were significantly higher over 'Elbon' but were similar to 'Maton' and 'Wrens96' (Table 1). Stem diameter, node number and internode length at maturity were similar to other check varieties.

Table 1. Morphological characteristics of NF65 rye in comparison to the standard checks in Ardmore and Bourneville, OK, USA.

Line/ Cultivar	Leaf Length (cm)	Leaf Width (mm)	Stem Diameter (mm)	Internode Length (cm)	Plant Height (cm)	Number of Nodes
NF 65	[†] 21.06a	12.01a	4.67a	12.86a	153a	5.40a
'Elbon'	17.05b	10.56b	4.50a	12.73a	143b	5.04a
'Maton'	18.42ab	10.79b	4.38a	13.47a	150ab	4.99a
'Wrens96'	-	-	4.55a	12.97a	157a	4.93a

[†] For each column, mean values followed by the same letters are not significantly different (P= 0.05)

In multi-location trials, total and early fall-winter yield of rye lines and cultivars varied from 4,281 to 7,650 and from 1,063 to 4,219 Kg of dry forage ha⁻¹, respectively. During seven years of testing (1997-2004) at Ardmore and Bourneville, OK, the total and fall-winter dry forage yield of NF65 was 7,207 and 3,825 kg ha⁻¹ (Figure 2). NF65 produced

55% more fall-winter forage and 6% more total forage over 'Maton'. During the same period, early forage yield of NF65 was 10% higher than 'Oklon' with 9% more total forage production. Seed production averaged 10% less than 'Maton' but 1% more than 'Oklon'. The total forage yield of NF65 was the highest in the southern Oklahoma, Texas and Louisiana trials. In two out of three location trials in Georgia, dry forage yield of NF65 was significantly lower than some of the elite cultivars (e.g. Elbon, Gurley CG187) in 2005 evaluations (un-published data). However, state wide average yield in 2005 and past three years mean yield is similar to other elite cultivars. In Alabama and Florida trials, though the total forage yield of NF65 is significantly lower than few other cultivars, the early fall-winter yield was similar (un-published data). It is especially suitable for the light textured soils and out-yielded check varieties on sandy-loam soils of Red River valley.

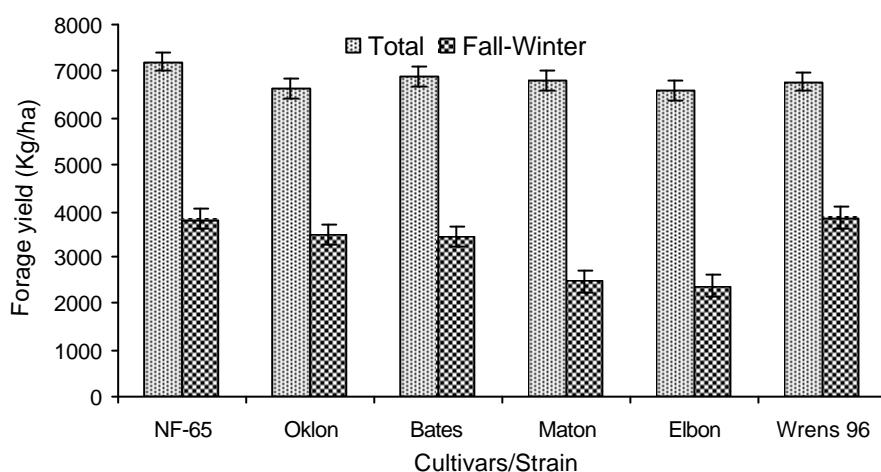


Figure 2. Total and fall-winter yield potential of rye cultivars in Oklahoma. Yields were averaged across seven years performance at two locations, Ardmore and Bourneville. The bars indicate the standard error of the mean.

The main advantage of NF65 is its early fall-winter forage potential. More than 53% of its total yield is produced during early season. Fall-winter yield of late maturing rye cultivars 'Maton' and 'Elbon' was only 33-34% of total production. In one evaluation, 'Wrens96' produced up-to 62% of its total yield as early forage. NF65 out yielded all the cultivars except 'Wrens96' for early fall-winter forage production in the southern Great Plains (Figure2). In two out of three comparisons in Oklahoma and Georgia-Florida, NF65 out-yielded 'Wrens96'. Early production of 'Wrens96' fluctuated widely but NF65 was fairly stable over seven years of testing at Bourneville, OK.

Rating for disease in Oklahoma indicated that NF65 has the same level of disease tolerant attributes compared to 'Maton' and 'Oklon'. Winter hardiness of NF65 was similar to both 'Maton' and 'Oklon' at Ardmore and Bourneville. NF65 forage contains approximately the same amount of dry matter, higher crude protein but had lower ADF and NDF than both check cultivars (un-published data). In vitro digestibility of NF65 was at least 1.2% higher than check cultivars. No consistent differences were found in lodging, and insect resistance between NF65 and the 'Maton' or 'Oklon'.

Molecular markers were used to identify genetic variations within genotypes of all four small grains. Tall fescue EST-SSRs developed at the Foundation and found to have

higher cross species trans ferability (Saha *et al.* 2004), were used to screen a set of genotypes. Several primer pairs (PPs) were found monomorphic across all genotypes of four crops (Figure 3A). Some of the PPs were crop specific and did not amplify well in other crops (Figure 3B). A set of tall fescue EST-SSR markers have been identified which can distinguish most of the genotypes. Amplification of a higher proportion (75.2%) of barley EST-SSRs in rye was reported by Varshney *et al.* (2005). In-silico comparative mapping also showed the presence of barley SSR-EST orthologues in the rye genome. Assaying of more markers is in progress with the objective of getting several markers which can clearly distinguish each of the genotypes.

A phylogenetic analysis of the rye cultivars was made with the SSR marker profile. All the Noble Foundation cultivars formed a distinct cluster with similarity coefficient of 0.78, which is clearly different from AGS104, a cultivar released by University of Florida. NF65 made a diverse node within the Foundation's genotype cluster and 'Elbon' was the closest relative. 'Maton', the late maturing parent of NF65, was in a distant node. Results indicated that NF65 is genetically different from 'Maton' which might occur due to several recombinations during the development process.

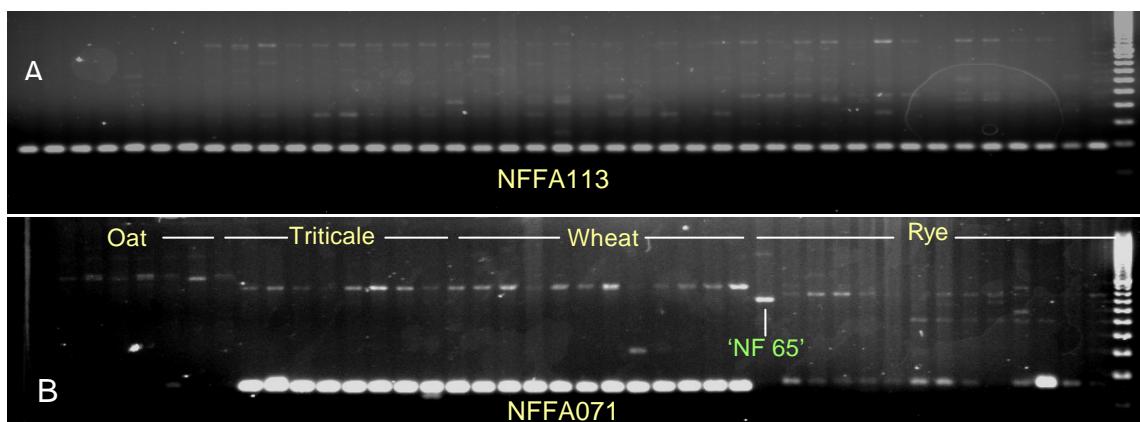


Figure 3 (A and B). Amplification of tall fescue EST-SSR primer pairs in selected genotypes of oat, triticale, wheat and rye. Primer pairs NFFA071, is able to distinguish NF65 rye from the other rye genotypes.

NF65 has the greatest potential in the southern Oklahoma, Texas and Louisiana for early fall-winter forage production when farmers do not have many choices for grazing their animals. We are in the process to release NF65 through a commercial partner.

References

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