Theor. Appl. Genet. 58, 71-74 (1980)

Combining Ability Analyses of Stability Parameters and Forage Yield in Smooth Bromegrass

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Summary. Twenty-one progenies of smooth bromegrass (*Bromus inermis* Leyss.) from a 7 × 7 half diallel cross, with their parents, were evaluated for three years at four locations in Alberta for the genetic variation of stability in expression of their annual yield. The linear response and deviation from linear response for each genotype were the two stability parameters considered, together with mean performance in the evaluation of each genotype. Four high yielding genotypes, namely 12, 13, 16, and 26, had general adaptability, while genotype 23 was especially suited to a poor environment. Combining ability analysis showed that general combining ability (GCA) and specific combining ability (SCA) were both important in the expression of yield. Inheritance of linear regression was controlled predominantly by GCA whereas both GCA and SCA were equally important in the expression of deviation. The presence of a substantial proportion of variability due to the additive genetic component in the linear response suggests that it should be possible to exploit this fraction of variability in developing high yielding stable cultivars.

Key words: Regression coefficient – Deviation from regression – General combining ability – Specific combining ability – Genotype-environment interaction

Introduction

Genotype-environment (GE) interaction has been demonstrated to play an important role in the expression of forage yield in smooth bromegrass (Tan et al. 1979a). The regression technique of measuring GE interaction developed by Finlay and Wilkinson (1963) has been extensively used in many crops to quantify the response of a set of genotypes to the varying environments. The method was further elaborated by Eberhart and Russell (1966), where they considered regression coefficients and deviation mean squares with mean performances as criteria for stability. However, it is difficult to decide the relative weight to be attached to these three parameters while selecting material in a practical breeding program. Some workers (Eberhart and Russell 1966, 1969; Busch et al. 1976) have suggested that the deviation mean square is a more important stability parameter than linear regression.

In bromegrass, previous studies (Tan et al. 1979b) showed that both the heterogeneity among regressions and the residuals were highly significant for yield and most of the morphological characters. The relative magnitudes of mean squares suggested that in most cases where regressions were not significantly greater than their residuals, both linear regression and deviation mean square were suggested to be considered in selecting stable genotypes in bromegrass.

In the present study, the 21 single crosses and their seven parental bromegrass genotypes were screened for stability of yield performances by using the regression technique of Eberhart and Russell (1966). This technique partitioned GE interactions into linear and non-linear components for each genotype. The two estimates were used with mean yield performance to assess the potentialities of various genotypes. The mode of inheritance of these parameters was studied using the combining ability analysis as described by Griffing (1956). The combining ability effects of these parameters were then jointly considered with that of yield in selection of bromegrass genotypes which would not only combine high yield but also transmitted stability in differing Alberta environments.

Materials and Methods

The origins of the seven parental clones of smooth bromegrass (*Bromus inermis* Leyss.) used in this study were:

1. UA5, a random selection from 'Magna';

0040-5752/80/0058/0071/$ 1.00

2. UA9, a random selection from 'Carlton';
3. UA10, a random selection from S7388, a synthetic susceptible to *Selenophoma bromigena* (Sacc.) and *Pyrenophora bromi* (Dred.);
4. UA12, a random selection from 'Lincoln';
5. B40, selection provided by Drs. Smith and Knowles of Saskatoon;
6. B42, selection provided by Drs. Smith and Knowles of Saskatoon. Both B40 and B42 showed resistance to the above mentioned diseases; and
7. 43, a collection from an old auction yard on a farm near Sedgewich, Alberta.

The parents were coded from 1 to 7 and a single cross is a combination of the two parental codes, with the female parent appearing on the left.

The seedlings of the 21 single crosses and the clonal propagules of the parents were transplanted to four locations (Beaverlodge, Edmonton, Kinsella and Lethbridge) in Alberta in 1975 in a randomized block design with six replications. The environments were as previously described (Tan et al. 1979a). Each plot consisted of five plants spaced 120 cm within and between plots. The trials were harvested twice in each of the three years, 1976, 1977 and 1978. Spring harvest usually took place in late June and fall harvest around the end of August each year when the plants were near anthesis. Five whole plants from each plot were harvested in 1976 whereas a plot 60 cm X 450 cm was harvested in both 1977 and 1978. Forage yield was a total of the two harvests annually and was expressed as dry weight in grams per plot.

The regression approach as outlined by Eberhart and Russell (1966) was used for statistical analysis. This involved estimation of three parameters for each genotype, namely, mean yield, linear regression (b) of a genotype on an environmental index and deviation from regression (S_d^2). The environmental index was the deviation of the genotypic mean at one environment (a year-location combination) from the general mean over all genotypes and environments. Griffing's (1956), Method 2 was used for combining ability analysis and to provide estimates of combining ability effects for yield and stability parameters.

Results and Discussion

The environments are diverse in Alberta. Some of the environmental effects are obvious in forage yield (Table 1). Analyses of variance revealed that locations, years and their interactions were highly significant. Each location-year combination was consequently considered an environment in subsequent analysis. There are large differences between locations and between years. Generally, Edmonton and Lethbridge were recognized as higher yielding environments than either Beaverlodge or Kinsella, based on the annual forage production for the three years.

The stability parameters, linear response (b) and deviation from regression, of each genotype, including parents and progenies, for forage yields are given in Figure 1. The graph shows the relationships between yield and linear response of genotypes, and is considered useful in selecting stable genotypes. The vertical line is the grand mean, whereas the horizontal line is the average slope (b = 1.0).

Forage yield varied from 2791 (genotype 4) to 3840 (genotype 6) grams per plot, and the regression coefficients ranged from 0.75 (genotype 23) to 1.17 (genotype 34) (Fig. 1). Seventeen genotypes had above average yield. Among these genotypes, eight (2, 6, 15, 17, 27, 34, 37, 67) had significant deviation mean squares. The stability parameters indicated that four genotypes (12, 13, 16, 26) produced high yield, and had average linear responses and non-significant deviations. Genotype 23, on the other hand, had shown maximum stability combined with low yield. The correlation coefficient between regression coefficients and mean yield of each genotype was not significant (r = 0.19). Therefore, it seems possible to select genotypes which have above average stability and high yield. These results are in contrast to those reported by Eberhart and Russell (1966) in maize, and by Fatunla and Frey (1976) and Eagles et al. (1977) in oats, where they obtained significant correlations between mean yield and regressions.

The diallel design of the present experiment permits

Table 1. Environmental means for forage yield of smooth bromegrass

Location	Yield (g/plot)		
	1976	1977	1978
Beaverlodge	2665 ± 396[a]	3324 ± 292	2435 ± 221
Edmonton	4044 ± 361	4737 ± 314	2745 ± 273
Kinsella	3451 ± 316	2181 ± 156	1853 ± 160
Lethbridge	5176 ± 451	3694 ± 265	4856 ± 280

[a] Standard error of the mean

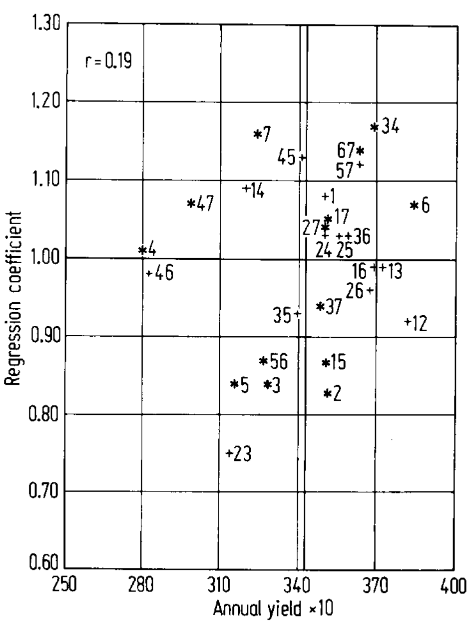

Fig. 1. The relationship between forage yield (g/plot) and stability of 28 bromegrass genotypes. * Deviation MS significant ($P < 0.05$); + Deviation MS not significant

Table 2. Mean squares for combining ability of forage yield and stability parameters: regression coefficients (b) and mean squares of deviation from regression

Source	df	Yield	b	Deviation MS
GCA	6	10,334,703[a]	0.0273[a]	1,935,576[b]
SCA	21	4,032,570[a]	0.0079[b]	1,889,658[a]
GCA x E	66	1,927,280[a]		
SCA x E	231	517,617[a]		
Error	1620	274,546	0.0035	665,171
GCA:SCA		2.56	3.46	1.02

[b,a] Significant at the 0.01 and 0.001 probability levels, respectively

the partition of the genotypic variances of the stability parameters, regression coefficients and deviation mean squares, into variances due to general combining ability (GCA) and specific combining ability (SCA). The combining ability of a genotype for both parameters and yield can, therefore, be jointly examined. This method had been used in examining the stability of grain yield in maize (Dhillon and Singh 1977). Combining ability analyses for the mean yield, linear regressions and deviation mean squares are given in Table 2. Variations in the expression of mean yield due to GCA, SCA and their interactions with environments were significant when compared with the pooled error. The relative magnitudes of GCA to SCA indicated that mean square due to GCA was greater than that of SCA for yield and regression coefficient; while for the deviation mean squares both GCA and SCA were equally important.

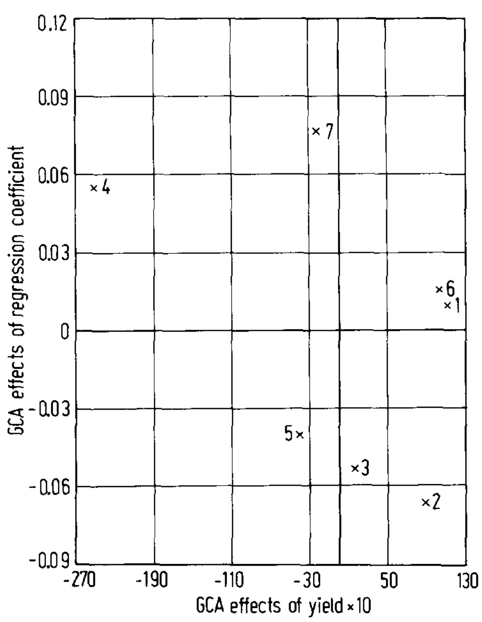

Fig. 2. The relationship between mean GCA effects for forage yield and regression coefficient for all environments. $S_{E_{gi}} = 0.028$ for regression; $S_{E_{gi}} = 96.$ for yield

The average GCA effects of the seven parental clones for yield and regression coefficient are shown in Fig. 2. Four parents, 1, 2, 3 and 6, had average GCA effects greater than zero for yield; parents 1, 2 and 6 being the best combiners. Parent 4 had the highest GCA effect for regression coefficient; while parent 1 had near zero GCA effect. The lowest GCA effect for regression was obtained for parent 2, followed by parent 3. When the average GCA effects of mean yield and the GCA effects of regression coefficient for each parent were jointly considered (Fig. 2), both parents 1 and 6 seemed promising since they had high average GCA effect for yield and near zero GCA for regression.

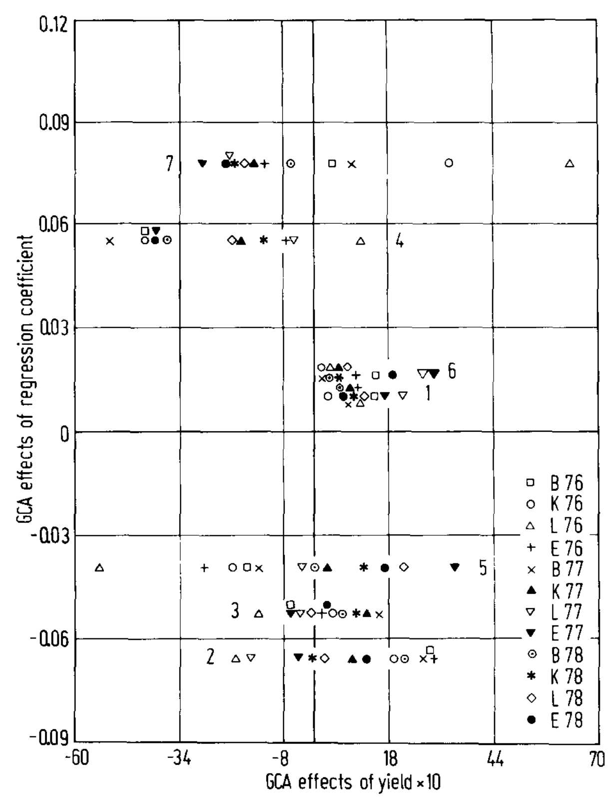

Fig. 3. The relationship between GCA effects for forage yield and regression coefficient for twelve individual environments (B: Beaverlodge; K: Kinsella; L: Lethbridge; E: Edmonton)

Thus, both parents 1 and 6 would transmit high yield and average stability to their progenies. Parent 2 transmitted above average stability to its progenies and had positive GCA estimates for yield.

The association of GCA effects between yield and regression coefficient with respect to individual environments are illustrated in Figure 3. The figure showed apparent GCA x environment interactions by the different ranking of the environments within each genotype. It revealed that environmental mean of a genotype as shown in Fig. 2 was not as informative as that shown by individual environments where genotype × environment interaction existed. For example, parent 3 was a positive combiner for yield when average GCA for all environments was considered (Fig. 2). When individual environments were examined (Fig. 3), it had positive GCA effects only in six of the twelve environments. Parent 2 transmitted to its progeny high yield and above average stability in eight of the twelve environments. Both parents 1 and 6 consistently had positive GCA effects for yield at all environments, and a near average stability.

Joint consideration of the GCA effects of yield and stability indicated that parent 1, a random selection from 'Magna', and parent 6, a disease resistant selection, have the highest potential among the seven clones. Parent 2 demonstrated the lowest GCA effects for regression coefficient (i.e. highest stability) of all parents; however, it did not combine high yield in some of the favourable environments (Fig. 3). Parent 3 transmitted above average stability but rather low yield to its progenies in many of the environments tested.

A predominance of additive effects in the inheritance of linear responses was reported by Eberhart and Russell (1966, 1969) and Patanothai and Atkins (1974). Both additive and non-additive effects were involved in inheritance of deviations from regression (Eberhart and Russell 1969; Dhillon and Singh 1977). Busch et al. (1976), however, indicated that deviation from regression was simply inherited and could be predicted from the parents. In contrast, Patanothai and Atkins (1974) concluded that the inheritance of deviations from regression was complex. The present study indicated that the mean square of regression coefficients due to GCA was 3.4 times as great as those due to SCA in bromegrass. The results suggested that it should be possible to exploit this fraction of variability in developing high yielding stable cultivars. However, the yield differences among the genotypes were ascribable to both additive and non-additive genetic variance (Tan et al. 1979a). Therefore, a more complicated approach, such as recurrent selections involving multi-environmental testing, would be necessary.

Acknowledgement

The authors gratefully acknowledge the cooperation provided by Agriculture Canada at Lethbridge and Beaverlodge.

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Received January 24, 1980
Communicated by R.W. Allard

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