African Crop Science Journal, Vol. 2, No. 1, pp. 23–27, 1994
Printed in Kenya.

1021-9730/94 $ 10.00 + 0.00

USE OF SAFETY FIRST RULE IN SELECTING STABLE BARLEY CULTIVARS

M.A. MGONJA, N.I. MAMUYA and E.J. MAEDA
Selien Agricultural Research Institute
P.O. Box 6024, Arusha, Tanzania

(*Received* 13 *June* 1993; *accepted* 17 *December* 1993)

ABSTRACT

The presence of genotype environment interaction is of major concern to plant breeders, since large interactions can reduce gains from selection and complicate identification of superior cultivars. In order to attain sustainability in barley productivity, the Safety First Rule was used in 10 barley cultivars tested in two locations for four years (1984–1987). An Index that incorporated mean yield and stability was developed for each of the four different definitions of stability. B3072 was identified as a superior cultivar with the highest mean yield of 2. 95 t ha^{-1} and ranked first by all the four selection indices. The line B3072 was released as Kibo in 1991 and the usefulness of the Safety First selection rule in situations where poor yields have severe adverse consequences has been realised.

Key Words: **Barley, Safety First Rule, stable cultivars**

RÉSUMÉ

L'interaction genotype-environement constitue une préoccupation des sélectionneurs, puisque de grandes interactions peuvent réduire les avantages de la sélection et compliquers l'identification de meilleurs cultivars. Afin d'avoir une stabilité dans la production d'orge, la Règle Première de Sécurité est utilisée pour dix cultivars de blé testées dans deux sites sur 4 ans (1984–1987). Un index intégrant le rendement moyen et stabilité est développé pour chacune des 4 différentes définitions de la stabilité. B 3072 est identifié comme le meilleur cultivar avec le rendement le plus élevé de 2,95 t/ha et se place en tête pour les 4 indices de sélection. La lignée B 3072 a été vulgarisée sous l'appelation Kibo en 1991. L'utilité de la Règle Première de Sécurité dans des situations où les faibles rendement ont des conséquence défavorables graves a pu être démontrée.

Mots Clés: **Orge, Régle Premiére de Sécurité, cultivars stables**

INTRODUCTION

Barley (*Hordeum vulgare*) is a crop with tremendous potential because of its three unique characteristics: (i) broad ecological adaptation; (ii) utility as a feed and food grain; and (iii) superiority of barley and malt for use in brewing.

In Tanzania, the main use of barley is in the brewing industry; it has, however, developed a secondary use as a dairy feed in form of barley

straw and malt extract especially in Northern Tanzania where crops and livestock integrate.

Several researchers have found that most yield improvements in barley have been achieved by selecting for yield itself at the same time balancing for the physiological and morphological characteristics (Poehlman, 1985). Lack of moisture during the critical stages of floral initiation and anthesis can greatly affect the productivity of barley. However, barley is better adapted to drought conditions than other small grains and one reason for its drought resistance is early maturity. With the current threats of frequent droughts, unpredictable weather conditions and total dependence on rainfall for barley production, stability of production in different environments is an important consideration in crop breeding programmes in Tanzania. Numerous stability methods are available to aid the plant breeder with identifying superior cultivars in the presence of GxE interactions (Eskridge, 1990). It is assumed that a breeder prefers a cultivar with a small probability of low yields or is concerned with the avoidance of disaster. This paper illustrates how a decision making theory concept known as Safety First Rule can be used to model the GxE behaviour. An index incorporating mean and stability was developed for each of the four different definitions of stability and the indices were used to identify a superior barley cultivar.

MATERIALS AND METHODS

Ten barley genotypes were evaluated for stability in two locations of Tanzania for four years, 1984–1987. The two sites were Basotu in the Hanang Wheat Complex (HWC) and the Selian Agricultural Research Institute at Arusha. The genotypes were evaluated in a Randomised Complete Block Design with four replications. Each plot consisted of six rows 2.5 m long. Rows were spaced 0.23 m apart, with 0.15 cm between individual plants.

The statistical analysis consisted of a combined and separate year and locations analysis to determine effects of years, locations and genotypes as well as their two and three way interactions. The Safety First Selection Rule was used in the presence of GE interactions. Cultivar stability was based on four different models:

(i) the variance of a cultivar across environments (EV),
(ii) Finlay and Wilkinson's (1963) regression coefficient (FW),
(iii) Shukla's (1972) stability variance (SH), and
(iv) both Finlay and Wilkinson's regression coefficient and Eberhart and Russel's (1966) deviation parameter (ER) (Table 1).

To illustrate how the indices were obtained let Yij represent the yield of cultivar i (i = 1- - -p) in environment j (j = 1- - -g) with Yi, Yj, and Y denoting the marginal means of cultivar i and environment j, and the overall mean, respectively. The stability definitions are shown in Table 1 and procedures for working out the values are detailed by Eskridge (1990).

The Kendalls' tau rank correlations (Snedecor and Cochram, 1967) between the mean and index ranking was used to quantify how similarly the indices ranked the genotypes. However, the four models were each based on several parametric statistics:

1. The variance of a cultivar across environments. This approach uses the variance of a cultivar across environments (Si) and the true mean of a cultivar across environments Yi. These estimates are substituted in the first equation to give the index EV in Table 1. Cultivars with large means and small standard deviations across environments are preferred.
2. The Finlay and Wilkinson's approach uses the i^{th} cultivar slope coefficient (Bi) obtained by regressing its yield on the mean yield of all cultivars for each environment (Environment Index). The predicted yield values are adjusted for the average yield response to environment with population mean estimated Y i and the variance with $[(b-1)^2 S^2_y(1^{-1}/q)]$ where b is the slope and S^2_y is the environmental variance. The estimated variance is substituted in equation 2, (Table 1) to give the FW index.
3. The Shukla's stability variance (Shukla, 1972) estimates a stability variance component for each of "p" cultivars and $\delta^2_e + \delta^2_1$ are variance of random effects of environment + Shukla's population variance for the i^{th} cultivar. Substitution of $\delta^2_e + \delta^2_1$ for variance is used for equation 3 to determine the SH index.
4. Eberhart and Russel's approach was used and it utilised three parameters: the mean yield, Finlay and Wilkinson's regression coefficient (B_1) and the mean square deviations about regression ($\delta^2 b_1$). The substitution of equation 4 are done to give the ER index. The estimates

TABLE 1. Safety First selection indices with four definitions of stability

Stability definition	Index form for cultivar i	Abbreviation
Variance across environments	Yi-Z (1-α) Si	EV2
Finlay and Wilkinson's regression coefficient	Yi-Z (1-α) $[b_1\text{-}1)\ ^2S^2_y\ (1^{-1}/_q)]^{1/2}$	FW
Shukla's stability variance	Yi-Z (1-α) $(\delta^2_{\bullet} + \delta^2_i)^{1/2}$	SH
Finlay and Wilkinson's regression coefficient and Eberhart and Russel's residual MS about regression	Yi-Z (1-α)$[\ (b_1\text{-}1\ )\ ^2S^2_Y\ (1\text{-}1/q) + S_{b1}{}^2]^{1/2}$	ER

of each entry's mean yield and stability, the Safety First Selection index for a particular definition of stability (Table 2) were used to rank the entries. The alpha level = 0.05 used translates into a willingness to accept a one in 20 chances of a low yield in a particular environment. Such small values of alpha are used when high costs such as starvation and/or bankruptcy are associated with low yields, which likely is the case for subsistence farmers.

RESULTS

The indices as well as the mean yield indicated the high yielding potential for B3072 as well as its stability, the low yielding and less stable lines were also indicated (Tables 2 and 3).

The EV, FW and SH indices produced similar rankings (rank correlation > 0.90) and the Kendall rank correlation coefficients were high and significant (Table 4). The EV indices produced rankings which were unexpectedly similar to the mean although the EV index defines stability as across environment yield variance. The EV index was thus not much affected by the environment probably because the lines evaluated were all in the early maturity group (44–65 days to 50% flowering) and this would result into low yield but also produce a smaller across environment variance. B3072 was ranked first by the mean and the four selection indices and was released in 1991 by the name Kibo. All indices as well as the mean ranked B3074 and 6014 lowest.

DISCUSSION

The different safety first selection indices produced different rankings of the ten barley lines. An alpha level of 0.05 was used in this trial because we were concerned about the low yields which would have affected entry rankings. Subsistence farmers risks as well as farmers severe consequences of bankruptcy have necessitated breeders to use Z (1-α) between 0.5 and 1.5, assuming normality of

TABLE 2. Mean yield (Yi), variance across environments (Si^2), Finlay and Wilkinson's regression coefficient (bi), Shukla's stability variance (δ^2_i) and Eberhart and Russel deviation from mean square for genotypes (S^2_{bi}) for 10 wheat genotypes in eight environments of Tanzania, 1984–1987[a]

Accession	Yield (t ha^{-1})	Si^2	b_i	(δ^2_i)	(S^2_{bi})
B3066	2.136	0.132	1.426	0.168	0.018
B3069	2.536	0.301	0.811	0.263	0.308
B3071	2.214	0.085	0.757	0.073	0.065
B3072	2.948	0.147	0.887	0.129	0.172
B3073	2.108	0.086	0.944	0.075	0.041
B3074	1.302	0.228	0.914	0.199	0.210
B6014	1.135	0.136	1.144	0.119	0.072
B8216	2.022	0.08	0.732	0.098	0.078
B9159	2.502	0.215	1.542	0.180	0.093
B9390	1.653	0.262	1.818	0.229	0.085

[a]Variance of experimental means (S^2_y) = 0.057; and experimental variance component (δ^2_a) = 0.157.

TABLE 3. Genotypes mean yields and the values of four Safety First selection indices with the associated rankings (in parentheses)[a]

Accession	Yield (t ha^{-1})	EV+	FW	SH	ER
B3066	2.136 (5)	1.539 (7)	1.979 (6)	1.278 (6)	1.620 (5)
B3069	2.536 (2)	1.633 (4)	2.466 (2)	1.470 (3)	1.601 (6)
B3071	2.214 (4)	1.736 (3)	2.215 (4)	1.426 (4)	1.718 (4)
B3072	2.948 (1)	1.818 (1)	2.549 (1)	2.069 (1)	2.259 (1)
B3073	2.108 (6)	1.626 (5)	2.088 (5)	1.316 (5)	1.769 (2)
B3074	1.302 (9)	0.518 (10)	1.270 (9)	0.321 (9)	0.543 (10)
B6014	1.135 (10)	0.528 (9)	1.130 (10)	0.271 (10)	0.666(8)
B8216	2.022 (7)	1.540 (6)	1.924 (7)	1.192 (7)	1.476(7)
B9159	2.502 (3)	1.739 (2)	2.303 (3)	1.548 (2)	1.723(3)
B9390	1.653 (8)	0.811 (8)	1.353 (8)	0.632 (8)	0.633(9)

[a]EV+ = Safety-first index with variance across environments as stability parameter.
FW = Safety-first index with Finlay and Wilkinson's regression coefficient as stability parameter.
SH = Safety-first index with Shukla's stability variance as stability parameter.
ER = Safety-first index with Finlay and Wilkinson's regression coefficient and Eberhart and Russell's deviation mean square as stability parameter.

TABLE 4. Kendall rank correlations between entry rankings from four selection indices

	Mean yield	EV	FW	SH
EV[b]	0.91*[a]			
FW	0.94*	0.94*		
SH	0.98*	0.96*	0.95*	
ER	0.77*	0.87*	0.83*	0.84*

[a]Significant at P = 0.05
[b]EV = Safety-first index with variance across environment as stability parameter.
FW = Safety-first index with Finlay and Wilkinson's regression coefficient as stability parameter.
SH = Safety-first index with Shukla's stability variance as stability parameter.
ER = Safety-first index with Finlay and Wilkinson's regression coefficient and Eberhart and Russel's deviation mean squares as stability parameter.

yield (Dillon and Scandizzo, 1978; Hazel, 1982). This is particularly important with barley farmers who are contracted by the Tanzania Breweries Ltd. (TBL) and are given credits on inputs like seed, herbicides and land cultivation as well as harvesting equipment. These costs are then deducted from the value of their barley produce. The stability indices are also very relevant in Tanzania because of a lack of funds to justify breeding cultivar(s) for particular environments.

The four selection indices identified a high yielding and stable barley cultivar. The Safety-First approach is based on the assumption that the plant breeder is concerned with avoiding disaster or total crop loss, i.e., sustainable productivity. The safety first selection indices explicitly weigh the importance of stability relative to yield. Breeders can, however, select the stability indices to use depending on the diversity of the environments their materials are tested in. Based on mean yield, safety first selection indices rankings and the malting quality characteristics, B3072 was released in 1991 and was thereafter named Kibo. It has maintained its high yield and stability characters in the 1990/91 and 1991/92 cropping seasons. These results justify the use of Safety First Rule in selection for identifying stable barley cultivars.

REFERENCES

Dillon, J.L. and Scandizzo, P. L. 1978. Risk attitudes of subsistence farmers in Northeast Brazil. A sampling approach. *American Journal of Agricultural Economics* 50: 425–435.

Eberhart, S.A. and Russell, W.A. 1960. Stability parameters for comparing varieties. *Crop Science* 6: 36–40.

Eskridge, K.M. 1990. Selection of stable cultivars using a Safety-First Rule. *Crop Science* 30: 369–374.

Finlay, K W. and Wilkinson, G.N. 1963. The analysis of adaptation in a plant breeding program. *Australian Journal of Agricultural Research* 14: 742–754.

Hazell, P.B.R. and Norton, R.D. 1986. *Mathematical Programming for Economic Analysis in Agriculture*. Macmillan, New York.

Poehlman, J.M. 1985. Adaptation and distribution. In Barley No. 26. Rasmusson, D.C. (ed.), pp. 2–16. American Society of Agronomy, Madison.

Shukla, G.K. 1972. Some statistical aspects of partitioning genotype-environmental components of variance. *Heredity* 29:237–245

Snedecor, G.W. and Cochran, W.G. 1967. *Statistical Methods*. 6th ed. Iowa State University press, Ames, IA.