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Evaluation of Selection Indices for Identification of Productive Mungbean (*Vigna radiata* L. Wilczek) Genotypes Under Different Water Regimes

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Abstract: Seven mungbean genotypes were evaluated for their response to water-deficit stress and for different stress attributes for the selection of productive and stress tolerant genotypes. The results indicated that mean productivity (MP) and geometric mean productivity (GMP) would be useful selection indices to identify mungbean genotypes that have high seed yield potential across a range of environments. MP would best identify genotypes with high performance in nonstress environments and GMP would best identify genotypes with high performance in stress environments. High and negative correlation coefficients were found between stress susceptibility index (SSI) and seed yield in the driest condition both with Ys (r = -0.96) and Yc (r = -0.82). Stress tolerance index (STI), highly significantly correlated with Ys, Yc, MP and GMP at all stress intensities, may prove to be a useful index of yield potential and stress tolerance across a range of environments. Generally, choice of the most appropriate selection index will depend on the objective of selection and target areas.

Key words: *Vigna radiata* L. Wilczek, seed yield, selection indices, moisture stress

Introduction

Physiological processes leading to plant growth and development are affected by water stress. Growth reduction induced by water-deficit is particularly critical during early growth and grain-filling stages, ultimately reducing seed yield (Boyer, 1987). Plants are considered under stress when they experience a relatively severe shortage of an essential constituent, or an excess of potentially toxic or damaging substances. The field stress environment is characterized primarily by low inputs, suboptimal levels of irrigation, nutrients, temperature and plant protection measures (Blum, 1988). Significant genetic variation exists in a plant species and genotypes that differ in their ability to cope with stress and maintenance processes. Selection of genotypes that are adapted to both stress and on stress environments for yield or production traits is a problem which continues to perplex plant breeders.

The effect of soil moisture stress on beans has been well documented (Acosta-Gallegos and Shibata, 1989; Acosta-Gallegos and Adams, 1991; White *et al.*, 1994). Many studies have been attempted to partition the performance of common bean (*Phaseolus vulgaris*) under water stress into discrete components. These include morphological, physiological and phenological characteristics for which variation has been demonstrated (Acosta-Gallegos, 1988). Another mechanism contributing to increased performance under drought is phenotypic plasticity (Acosta-Gallegos and White, 1995). To improve seed yield and stability of mungbean genotypes, an understanding of a number of selection criteria have been proposed. Because seed yield is the most important economic trait, the most practical method to improve performance is the measurement of yield-related characteristics (Acosta-Gallegos and Adams, 1991). In the present study, Mean Productivity (MP), Geometric Mean Productivity (GMP), Tolerance (TOL), Stress Susceptibility index (SSI) and Stress Tolerance Index (STI) stress attributes along with yield variables including seed yield under stress(Ys) and nonstress (Ye) have been used in an attempt to their preliminary comparison for the closeness of associations with productivity to identifying genotypes exhibiting consistent performance with higher seed yields and relatively tolerant to both stress and nonstress environments.

Materials and Methods

The material consisting of seven mungbean genotypes viz. NM51, 55/1, 89/10, 259/1, 284/6, 285/1 and 324/2 collected from diverse ecological zones was grown in earthen pots lined with polyethylene bags to prevent evaporation. Each pot filled with five kg of light loamy soil and sand mixed in 1:1 ratio with a saturation percentage of 31.3 and electrical conductivity of 2.8 dS m^{-1}. The pots were located under net house covered with polyethylene sheet to avoid rain and irrigated each time after 3 days with 250 ml of water as nonstress. For the water stress treatments, the water supply was withheld at 6, 9 and 12 day watering intervals. A completely randomized design with three replications was used. The average yields of mungbean genotypes evaluated under stress and nonstress conditions are presented in tables 1, 2 and 3. The data were analyzed and the stress-attributes like Stress Intensity (Si), Mean Productivity (MP), Geometric Mean Productivity (GMP), Tolerance (TOL), Stress Susceptibility index (SSI) and Stress Tolerance Index (STI) were computed. The stress intensities (S1s) of the induced environments were 0.19, 0.37 and 0.48. Following the procedures adopted by Fernandez (1993), the stress attributes were estimated as follows.

Stress Intensity (SI) = 1- ($\bar{Y}s$/Yc) where $\bar{Y}s$ the mean seed yield in stress environment and Yc is the mean seed yield in nonstress environment. SI ranges between 0 and 1 and larger the value of SI, the more severe is stress intensity.

Mean Productivity (MP) = (Ys + Yc)/2 where Ys is the seed yield of a given genotype in stress environment and Yc is the seed yield of a given genotype in nonstress environment.

Tolerance (TOL) = Yc-Ys. A large value of TOL indicates more sensitivity to stress, thus a smaller value is favoured.

Geometric Mean Productivity (GMP) = $\sqrt{(Ys \times Yc)}$

where Ys is the seed yield of a given genotype in stress environment and Yc is the seed yield of a given genotype in nonstress environment.

Stress Susceptibility Index (SSI) = [1 - (Ys/Yc)]/SI. Smaller the value of SSI, greater will be the stress tolerance.

Stress Tolerance Index (STI) = (Yc/Yc)(Ys/$\bar{Y}s$)($\bar{Y}s$/Yc) =

I(Yc)(Ys))/(Yc)^2. STI is estimated based on GMP and thus the rank correlation between STI and GMP is equal to 1. Higher the value of STI for a genotype, the higher will be its stress tolerance and seed yield potential.

Results and Discussion

There were highly significant differences between genotypes for seed yield per plant under all water stress treatments as well as in the treatments. Lack of interaction between genotypes and environments showed that the genotypes behaved independently under all water stress treatments. The mean seed yield was 18%, 36% and 46% lesser in the water stress treatments with SIs of 0.19, 0.37 and 0.48 respectively than in the non-stressed treatment (Table 1-3). The range in seed yield among genotypes in stressed and normal conditions demonstrated that variation existed for productivity within and among soil moisture gradients. Different stress attributes for genotypes estimated from Ys and Yc under SIs of 0.19, 0.37 and 0.48 are presented in Table 1-3 and used to calculate correlation coefficients between the attributes and both Ys and Yc (Table 4).

The positive correlations between mean genotype performance in Ys and Yc across stress intensities (SI 0.19, r = 0.96**; SI 0.37, r = 0.92**; SI 0.48, r = 0.95**) indicated that seed yield performance of the genotypes retained a moderate level of consistency under different treatments. All correlation coefficients calculated between attributes and Ys and Yc were auto-correlated to some extent because Vs and Yc were used in the attributes calculations. Because the objectives of the research were to compare the attributes for the closeness of associations with productivity, comparisons between the magnitude of the correlation coefficients were justified. Correlations between stress attributes and seed yield performance can be partitioned into two groups based on their associations with Vs and Yc. The first group included MP and GMP which were highly correlated with both Ys and Yc. The second group included TOL, SS1 and STI and *were* not correlated with either Ys or Yc. These results concur with those of Abebe *et al*. (1998) in dry beans. MP had the highest correlation with Yc (r = 0.990**) while GMP had a higher correlation with Ys = 0.990**) at stress intensity of 0.19, MP had the highest correlation with Yc (r = 0.980**) while GMP had a higher correlation with Ys (r = 0.987**) at stress intensity of 0.37 and at the highest stress intensity of 0.48, NIP had the highest correlation with Yc (r = 0.985**) while GMP had higher correlation with Ys (r = 0.993**). Using simulated data, Rosielle and Hamblin (1981) reported positive correlations between MP and Yc and MP and Ys. Higher value of MP favours higher yield potential and lower stress tolerance. Thus selections based on MP generally increase the average performance in both stressed and non-stressed environments. However, MP fails to distinguish the genotypes who express uniform superiority in both stressed and non-stressed environments and those which perform favourably only under normal conditions. Since GMP showed higher values of correlation coefficients with Ys at all the levels of stress intensities, it may be concluded that selection based on GMP would Increase seed yield under more stress conditions. Because MP and GMP were highly significantly correlated with both Yc and Ys and appeared to be suitable stress attributes to select genotypes perform well under stress and nonstress environments. The choice of GMP to represent mean productivity is preferred because, when ranking genotypes (Table 1-3), GMP better accounts for large differences in performance under stressed and non-stressed conditions than does the simple arithmetic mean. While both MP and GMP ranked 259/1, the most productive genotype in the stress environments among the top, only GMP ranked in the same order as productivity. The similar ranking of genotypes by MP and GMP is substantiated by the high positive correlations 0_{019} = 1.000**; $r_{0.37}$ and $r_{0.48}$ = 0.999**) between the two attributes in different stress intensities. These results concur with the findings of Abebe *et al*. (1998), White and Singh, (1991) and Samper and Adams (1985) who showed that GMP is highly correlated with seed yield performance with water stress. These observations were similar to that noted by Schneider *et al*. (1997). MP and GMP selection indices should be useful for identifying productive genotypes under different stress intensities. The choice of the most suitable selection index would be based whether the preference should be placed on Vs or Yc.

There was a lack of correlation between TOL and Ys and Yc under all stress intensities and TOL and 551 and STI except for stress intensity of 0.19. 551 was negatively correlated with `I's and Yc (r = -0.958** and r = -0.817*, respectively) and with STI only at the highest stress intensity (r = -0.949**) indicating that larger seed yields were associated with higher levels of drought tolerance or with high stability. In other terms, the highest yielders under moisture stress had a below average seed yield under more favourable conditions. These results coincided with those of Ceccarelli (1987) in barley, while the correlations at stress intensities of 0.19 and 0.37 showed nonsignificant effects between SSI and Ys and Yc, although the extent of negative correlations to Ys at all stress intensities were much greater than that to Yc which are similar to those observed by Lazar *et al*. (1995) in wheat. Negative correlations between Ys and SSI were expected because genotypes having less decline in seed yield from the nonstress to stress environments also tend to have high seed yield in the stress environments. Based on SSI nonsignificant differences among genotypes were observed at stress intensities of 0.19 and 0.37 whereas at the highest stress intensity of 0.48, genotypes exhibited differences among themselves (Table 1-3) that showed non-consistent performance of the genotypes. The inherent problem with SSI for assessing drought tolerance is the emphasis placed on the change in genotype performance across environments, rather genotypic performance per se. This can be explained by comparing genotypes 259/1 and 284/6 that had very similar SSI of 0.81 and 0.82 respectively, but 259/1 had higher seed yield than 284/6 at SI of 0.19, whereas at SIs of 0.37 and 0.48, SSI did not differentiate the genotypes. Genotypes 285/1 and 55/1 that had SSI of 1.04 and 1.05 very close but their seed yields were also nonsignificant. However, at SI of 0.48, genotype 259/1 had low value of SSI (0.52) and exhibited higher seed yield under stress and nonstress conditions. Abebe *et al*. (1998) also observed that susceptibility index evaluated change in genotype performance across environments rather than genotype performance in either treatments and Fernandez (1993) showed that selection based on SSI favours genotypes possessing low yield potential under non-stressed conditions and high yield under stress conditions.

STI was highly correlated with Ys and Yc under all treatments. These results were expected because STI was designed specifically for use in both stressed and non-stressed environments. STI ranged from 0.23 to 1.58 among the genotypes thus reflecting a wide range in drought response. Higher the value of STI for a genotype, the higher its stress

Table 1: Estimates of stress tolerance attributes from the seed yield/plant in non-stressed and the stressed conditions for mungbean genotypes evaluated under water stress (SI =0.19)

Genotype	Yc	Ys	MP	GMP	TOL	SSI	STI
NM 51	2.71[a]	2.19[a]	2.45[a]	2.44[d]	0.52[a]	1.01[a]	0.38[b]
324/2	3.64[ab]	3.29[b]	3.47[b]	3.46[bc]	0.35[a]	0.51[a]	0.77[b]
259/1	5.71[a]	4.83[a]	5.27[a]	5.25[a]	0.88[a]	0.81[a]	1.78[a]
285/1	3.60[ab]	2.59[a]	3.10[b]	3.05[c]	1.01[a]	1.48[a]	0.60[b]
55/1	3.72[ab]	3.04[b]	3.38[b]	3.36[bc]	0.68[a]	0.96[a]	0.73[b]
284/6	3.91[b]	3.30[b]	3.61[b]	3.59[bc]	0.61[a]	0.82[a]	0.83[b]
89/10	4.30[b]	3.20[b]	3.75[b]	3.71[b]	1.10[a]	1.35[a]	0.89[b]
Mean	3.94	3.24	3.58	3.55	0.74	0.99	0.85
S	0.92	0.83	0.86	0.86	0.27	0.33	0.44

SI = Stress Intensity; Yc = Yield in nonstress; Ys = Yield In stress; MP = Mean Productivity; GMP = Geometric Mean Productivity; TOL = Tolerance; SSI = Stress Susceptibility Index; STI = Stress Tolerance Index
Means within a column designated by same superscript(s) are not significantly different at 5% level of probability

Table 2: Estimates of stress tolerance attributes from the seed yield/plant in non-stressed and the stressed environments for mungbean genotypes evaluated under water stress (SI = 0.37)

Genotype	Ye	Ys	MP	GMP	TOL	SSI	STI
NM 51	2.71[a]	1.83[b]	2.27[c]	2.23[a]	0.88[a]	0.88[a]	0.32[b]
324/2	3.64[ab]	2.31[b]	2.98[b]	2.90[b]	1.33[a]	0.99[a]	0.54[b]
259/1	5.71[c]	4.44[a]	5.08[a]	5.04[a]	1.27[a]	0.60[a]	1.63[a]
285/1	3.60[ab]	2.27[b]	2.94[b]	2.86[a]	1.33[a]	1.00[b]	0.63[b]
55/1	3.72[ab]	2.26[b]	2.99[b]	2.90[b]	1.46[a]	1.06[a]	0.54[b]
284/6	3.91[b]	2.21[b]	3.06[b]	2.94[b]	1.70[a]	1.18[a]	0.56[b]
89/10	4.30[b]	2.25[b]	3.28[b]	3.11[b]	2.05[a]	1.29[a]	0.62[b]
Mean	3.94	2.51	3.23	3.14	1.43	1.00	0.68
S	0.92	0.87	0.87	0.88	0.37	0.22	0.43

SI = Stress Intensity; Yc = Yield in nonstress; Ys = Yield in stress; MP = Mean Productivity; GMP = Geometric Mean Productivity; TOL = Tolerance; SSI = Stress Susceptibility Index; STI = Stress Tolerance Index
Means within a column designated by same superscript(s) are not significantly different at 5% level of probability

Table 3: Estimates of stress tolerance attributes from the seed yield/plant in non-stressed and the stressed environments for mungbean genotypes evaluated under water stress (SI =0.48)

Genotype	Ye	Ys	MP	GMP	TOL	SSI	STI
NM 51	2.71[a]	1.32[c]	2.02[a]	1.89[c]	1.39[a]	1.07[a]	0.23[b]
324/2	3.64[ab]	1.83[bc]	2.74[b]	2.59[b]	1.81[a]	1.04[a]	0.43[b]
259/1	5.71[c]	4.30[a]	5.01[a]	4.96[a]	1.41[a]	0.52[b]	1.58[a]
285/1	3.60[ab]	1.81[bc]	2.71[b]	2.55[b]	1.79[a]	1.04[a]	0.42[b]
55/1	3.72[ab]	1.85[bc]	2.79[b]	2.62[b]	1.87[a]	1.05[a]	0.44[b]
284/6	3.91[b]	1.66[bc]	2.79[b]	2.55[b]	2.25[a]	1.20[a]	0.42[b]
89/10	4.30[b]	2.20[b]	3.25[b]	3.08[b]	2.10[a]	1.02[a]	0.61[b]
Mean	3.94	2.14	3.04	2.89	1.80	0.99	0.59
S	0.92	0.99	0.94	0.98	0.32	0.22	0.45

SI = Stress Intensity; Yc = Yield in nonstress; Ys = Yield in stress; MP = Mean Productivity; GMP = Geometric Mean Productivity; TOL = Tolerance; SSI = Stress Susceptibility Index; STI = Stress Tolerance index
Means within a column designated by same superscript(s) are not significantly different at 5% level of probability

Table 4: Correlation coefficients between seed yield in stress (Ys) and nonstress (Yc) and between seed yield and stress attributes under different stress

	Stress intensity	Ys	Yc	MP	GMP	TOL	SSI
Yc	0.19	0.957**					
	0.37	0.917**					
	0.48	0.946**					
MP	0.19	0.988**	0.990**				
	0.37	0.978**	0.980**				
	0.48	0.988**	0.985**				
GMP	0.19	0.990**	0.988**	1.000**			
	0.37	0.987**	0.969**	0.999**			
	0.48	0.993**	0.977**	0.999**			
TOL	0.19	0.184	0.462	0.333	0.318		
	0.37	-0.074	0.33	0.137	0.087		
	0.48	-0.381	-0.06	-0.231	-0.272		
SSI	0.19	-0.406	-0.123	-0.26	-0.276	0.819**	
	0.37	-0.727	-0.393	-0.567	-0.608	0.62	
	0.48	-0.958**	-0.817*	-0.903*	-0.921**	0.62	
STI	0.19	0.983**	0.978**	0.991**	0.992**	0.308	-0.272
	0.37	0.996**	0.943**	0.990**	0.995**	0.002	-0.673
	0.48	0.998**	0.948**	0.988**	0.993**	-0.369	-0.949**

SI = Stress Intensity; Yc = Yield in nonstress; Ys = Yield in stress; MP = Mean Productivity; GMP = Geometric Mean Productivity; TOL = Tolerance; SSI = Stress Susceptibility index; STI = Stress Tolerance Index, **Significant at 0.01, *Significant at 0.05

tolerance and seed yield potential. One of the seven genotypes 259/1 had the highest STI of 1.78 at SI of 0.19, 1.63 at SI of 0.37 and 1.58 at SI of 0.48 retaining a high level of consistency under all treatments. The STI indicated that this genotype had no specific response to drought. The genotype 259/1 with the highest STI values was also ranked at the top for Ys and Yc across all stress environments. The strong correlations of STI with Ys and Yc indicated that STI may be used as an index of yield potential and stress tolerance to identity genotypes across a range of environments. Same was the case with Fernandez (1993) in mungbean.

Present study indicated that MP would best identify genotypes with high average performance in nonstress environments and GMP would best identify genotypes with high performance in stress environments. If the objectives of the selection programme are to identify genotypes across normal and soil moisture-deficit environments, STI selection index, proposed by Fernandez (1993), may prove to be a useful index of yield potential and stress tolerance. In general, the most appropriate selection index will depend on the objective of selection and target areas.

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