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Identification of Indices for Empirical Selection of Dolichos Bean [*Lablab purpureus* (L.) Var. Lignosus] Genotypes for Tolerance to Terminal Moisture Stress

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ABSTRACT

Background: Detection and quantification of variability among germplasm accessions/segregating populations/advance breeding lines is a pre-requisite (among others) for breeding crop plants for drought tolerance. Indices that integrate yield under moisture stress free (MSF) and moisture stress (MS) have been developed and used for screening and selection of moisture stress tolerant genotypes in several crops. The present study was aimed at identifying desirable indices from among those reported for screening and selection of terminal moisture stress (TMS) tolerant genotypes.

Methods: Two experiments were conducted at experimental fields of Department of Genetics and Plant Breeding, University of Agricultural Sciences, Bengaluru during 2017 post rainy season. The first experiment consisted of 33 genotypes which included 31 selected genotypes from F_3 populations and two released varieties. The second experiment consisted of 13 genotypes which included 5 advanced breeding lines, 2 released varieties and 6 land races. The genotypes of both the experiments were evaluated for dry seed yield under two moisture regimes (MR), namely, MSF and TMS environments in separate trials following randomized block design.

Conclusion: Based on the criterion of significant correlation of indices with dry seed yield under both MSF and TMS environments, two indices namely, mean productivity (MP) and geometric mean productivity (GMP) were found desirable to identify TMS tolerant genotypes of both the experiments. Based on rank mean of the two indices, two F_3 selections and one released variety from first experiment; four landraces, one advanced breeding line and one released variety from second experiment were found TMS tolerant.

Key words: Dolichos bean, Correlation, Indices, Moisture stress tolerance, Selection.

INTRODUCTION

Dolichos bean is one of the ancient grain legumes grown in India for fresh beans for use as a vegetable and for dry grains as split dhal for use in various food preparations (Ramesh and Byregowda, 2016). It serves as an important source of protein to many people who depend on vegetarian diets. It is predominantly grown in rain-fed eco-systems in southern Karnataka and adjoining districts of Tamil Nadu, Andhra Pradesh and Maharashtra both as inter crop and pure crop (Ramesh and Byregowda, 2016).

Despite its multiple uses, dolichos bean is an 'underutilized' crop as evidenced by limited area planted to the crop, scale of consumption and efforts for its genetic improvement (Ramesh and Byregowda, 2016). Enhancement of its economic value through the development of widely adapted and stable high yielding varieties is expected to offer competitive edge to dolichos bean to enable its popularity and wider cultivation (Ramesh and Byregowda, 2016). As a result of shifts in rainfall pattern driven by climate change, the crop frequently experience moisture stress (MS) at pod filling and grain development stages, referred to as terminal MS (TMS). TMS significantly reduces grain yield in dolichos bean (Ramesh and Byregowda, 2016). Sustainable production of dolichos bean requires (among others) identification/ development and use of TMS tolerant varieties. Breeding dolichos bean for TMS tolerance is still in infancy. Crop breeding for TMS has been less effective. This is because, TMS tolerance is a complex quantitative trait with confounding effects of high temperature and soil physico-chemical factors (Blum, 2011).

Three approaches have been used to breed crop plants for tolerance to TMS (Mitra, 2001). In the first approach, direct selection for yield under moisture stress free (MSF) conditions is practiced. The basic axiom of this approach is that genotypes that perform well MSF condition do so under MS as well (Blum, 2011). Most often, this axiom is not necessarily true. In the second approach, direct selection for high yield under MS is practiced. Due to significant genotype × MS interaction coupled with low heritability, direct selection for yield potential under MS has been less effective

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resulting in low yield and hence, progress of breeding for tolerance to TMS is rather slow (Mitra, 2001). In third approach, the ability of high yielding genotypes to tolerate TMS is enhanced by transferring genes controlling morphological, physiological and biochemical traits contributing to tolerance to TMS. Even this approach proved less effective due to inadequate understanding of genetic basis of these traits contributing to TMS tolerance (Mitra, 2001). Considering the drawbacks of the three approaches, an alternative one which is the combination of the first two is suggested. In the alternative breeding approach, direct selection for high yield under MSF and stability of yield (with minimal reduction in yield) under MS is practiced (Mitra, 2001; Bennani *et al.,* 2017). This alternative approach is attempted in the present study.

Detection and quantification of genetic variability within working germplasm/released varieties/available segregating populations for responses to TMS is not only a prerequisite, but also a short-term strategy for identification of TMS tolerant dolichos bean genotypes for use as varieties to cater to immediate needs of the farmers. Development/identification of appropriate indices is essential for quantification of responses of the experimental genotypes and identification of TMS tolerant ones for use as cultivars. Indices such as stress tolerance index (STI) (Fisher and Maurer, 1978), mean productivity (MP) (Rosielle and Hamblin, 1981), geometric mean productivity (GMP) and hormonic mean productivity (HMP) (Fernandez, 1992), yield index (YI) (Gavuzzi, 1997), drought susceptibility index (DSI) (Lan, 1998), modified STI (K_1STI and K_2STI) (Farshadfar and Sutka, 2002), abiotic tolerance index (ATI) and stress non-stress production index (SNPI) (Moosavi *et al*., 2008) have been developed and frequently used in crop plants for quantification and selection of genotypes for tolerance to TMS. All these proposed indices are based on the extent of reduction in yield under MS condition relative to that under MSF condition. Identification of indices that enable empirical selection of genotypes with high yield under MSF conditions and acceptable stability of yield under MS conditions is the key (among others) for enhancing the progress in breeding for tolerance to TMS in any crop (Bennani *et al*., 2017) with no exception of dolichos bean.

The objectives of the present investigation were to (1) identify indices that most significantly correlated with seed yield under both MSF and TMS conditions and (2) identify TMS tolerant genotypes using the most significantly correlated indices.

MATERIALS AND METHODS

Material

Two separate experiments were conducted. The material for the first experiment consisted of 33 genotypes which included 31 selected plants with determinate growth habit and photoperiod insensitivity (PIS) from F_3 populations derived from two crosses, namely, HA 3 × Kadalavare (KA) and HA 4 × KA and their female parents, HA 3 and HA 4. HA 3 and HA 4 are high yielding determinate and PIS released varieties (Ramesh and Byregowda, 2016). While 20 of these 31 genotypes were selected from HA 4 × KA, the remaining 11 were selected from HA 3 × KA. KA, the common parent of the two crosses is a high yielding indeterminate photoperiod sensitive (PS) landrace. The material for the second experiment consisted of 13 genotypes, which included five advanced breeding lines (ABLs) two released varieties (RVs) and six landraces (LRs) (Table 1). The rationale behind conducting two experiments is to examine if similar/compare results obtained from different genetic backgrounds to enhance our confidence in research findings.

Field evaluation of experimental material

The 33 genotypes of the first experiment and 13 genotypes of the second experiment were evaluated under two moisture regimes (MR), namely, moisture stress-free (MSF) and

Table 1: The pedigree/source and salient characteristics of the material used in the second experiment.

Genotypes	Pedigree/source	Salient features
Advance breeding lines (ABLs)		
HA 11-3	HA 4 × GL 127	Determinate and Photoperiod insensitive (PIS)
HA 12-2	HA 4 × GL 121	Determinate and PIS
HA 12-3	HA 4 × GL 121	
HA 16-1	HA 4 × KA	Determinate and PIS
HA 16-2	HA 4 × KA	Determinate and PIS
Released varieties (RVs)		
HA 3	HA 1 × US 67-3	Determinate and PIS
HA 4	HA 3 × Magadi local	Determinate and PIS
Landraces (LRs)		
GL 6	Tamil Nadu	Indeterminate and Photoperiod sensitive (PS)
GL 12	Karnataka	Indeterminate and PS
GL 66	Karnataka	Indeterminate and PS
GL 142	Karnataka	Indeterminate and PS
GL 147	Karnataka	Indeterminate and PS
KA	Karnataka	Indeterminate and PS

terminal moisture stress (TMS) environments in separate trials at the experimental plots of the Department of Genetics and Plant Breeding, University of Agricultural Sciences (UAS), Bengaluru, during 2017 post-rainy season. In the first experiment, both trials (MSF and TMS) were laid-out in Randomized Block Design (RBD) with two replications, while the second experiment was laid-out in RBD with three replications. In both the experiments, each entry was sown in a single row of 3.0 m length with 0.6 m between rows. A total of 20 plants were maintained per entry in each replication. In both the experiments, one trial was maintained MSF by regular irrigation through-out the crop life cycle. In the second trial, TMS was maintained by withholding irrigation from pod-filling stage until pod harvesting stage. All the other recommended crop production and protection practices were followed to maintain the crop free from other abiotic stresses and biotic stresses in both the experiments.

Sampling, collection and statistical analysis of data

Dry pods were harvested from 10 randomly selected plants from each genotype of the two trials of both the experiments. The pods were hand-threshed, sundried and weighted and the data was recorded as seed yield plant^{-1}. Replication-wise means of dry seed yield plant^{-1} were used for statistical analysis. Homogeneity of error mean squares as indicated from Bartlett test ($P<0.05$) (Bartlett, 1937) provided statistical validity to pool the data from the two experiments. Pooled analysis of variance was performed to detect significance/ otherwise of mean squares attributable to genotypes, MR and genotypes × MR interaction for of dry seed yield plant^{-1} in both experiments. The analysis was implemented using Microsoft (MS) excel software's statistical analysis option.

Quantification of responses of genotypes to TMS

Previously developed and reported 10 indices (Table 2) were calculated to quantify the responses of genotypes to TMS environment for dry seed yield plant^{-1}. All the indices were calculated based on the extent of reduction in dry seed yield plant^{-1} of the genotypes evaluated under TMS environment relative to those evaluated under MSF environment. Correlation coefficients of these 10 indices with dry seed yield plant^{-1} of genotypes evaluated under MSF and TMS environments were calculated. All these statistical analyses were implemented using Microsoft (MS) excel software's statistical analysis option.

Criteria to identify indices for selection of TMS tolerant genotypes

The indices which were significantly correlated (with high magnitude >0.80) with mean dry seed yield plant^{-1} of genotypes evaluated under both MSF and TMS environments were considered as desirable for selection of TMS tolerant genotypes from both the experiments. As more than one desirable index was identified and that the TMS tolerant genotypes varied with the indices, rank mean (RM), a slightly modified version of rank sum (RS) method (Farshadfar and Javadinia, 2011; Farshadfar and Elyasi, 2012) was used to identify TMS tolerant genotypes. The rank mean effectively combines the desirable indices into one index.

RESULTS AND DISCUSSION

Analysis of variance

Genotypes differed significantly for dry seed yield plant^{-1} in both the experiments (Table 3) as revealed from significant mean squares attributable to genotypes evaluated under both MSF and TMS environments. These results justified the selection of the genotypes for the study. Further, the genotypes in both the experiments performed differentially across the two MR for seed yield plant^{-1}, as indicated from significant mean squares attributable to genotype × MR interaction.

Identification of desirable indices based on their significant correlation with seed yield under both MS and MSF

Only those drought tolerant varieties with high yield under MSF production environments would receive immediate and wider acceptance by the farmers (Ramesh and Byregowda, 2016). Hence, indices, which exhibit significant positive and high magnitude of correlation (>0.8) with dry seed yield plant^{-1} under both MSF and TMS environments, were considered desirable. Based on this criterion, two (MP and GMP) and seven (MP, GMP, HMP, STI, K_1STI, K_2STI and YI) of the 10 indices with high magnitude of significant correlation (>0.8) with dry seed yield plant^{-1} (Table 4) were identified desirable for selection of TMS tolerant genotypes of the first and second experiment, respectively. Thus, two common indices

Table 2: The formulae of the reported indices used to quantify the responses of genotypes to terminal moisture stress (TMS) environment.

Indices	Code	Formula	Reference
Mean productivity	MP	$(Yp+Ys)/2$	Rosielle and Hamblin (1981)
Geometric mean productivity	GMP	$\sqrt{(Yp \times Ys)}$	Fernandez (1992)
Harmonic mean productivity	HMP	$2^* (Yp \times Ys) / (Yp+Ys)$	Fernandez (1992)
Stress tolerance index	STI	$(Yp \times Ys)/\bar{Y}p^2$	Fischer and Maurer (1978)
Abiotic tolerance index	ATI	$[(Yp-Ys)/(\bar{Y}p/\bar{Y}s) \times \sqrt{(Yp \times Ys)}]$	Moosavi *et al.* (2008)
Stress non-stress production index	SNPI	$[\sqrt[3]{Yp+Ys}/(Yp-Ys)] \times [\sqrt[3]{Yp \times Ys \times Ys}]$	Moosavi *et al.* (2008)
Yield index	YI	$(Yp/\bar{Y}s)$	Gavuzzi (1997)
Modified STI 1	K_1STI	$Yp^2/\bar{Y}s^2$	Farshadfar and Sutka (2002)
Modified STI 2	K_2STI	$Ys^2/\bar{Y}s^2$	Farshadfar and Sutka (2002)
Drought resistance index	DI	$(Ys \times (Yp/Ys))/\bar{Y}s$	Lan (1998)

Table 3: Pooled analysis of variance of genotypes evaluated under moisture stress free (MSF) and managed terminal moisture stress (TMS) environments in the two experiments for dry seed yield plant^{-1}.

First experiment			Second experiment		
Source	Df	MSS	Source	Df	MSS
Replication	01	5.84	Replication	02	5.99
Genotype	32	86.06**	Genotype (G)	12	417.21**
Moisture regimes (MR)	01	420.16**	Determinate (D)	06	106.00**
Genotype × Stress	32	63.97**	Indeterminate (ID)	05	393.68**
Error	65	6.13	Moisture regimes (MR)	01	1218.66**
			G × MR	12	32.23*
			Error	50	12.56

Df: degrees of freedom; *Significant @ P=0.05; **Significant @ P=0.01.

Table 4: Estimates of correlation coefficients of drought tolerant indices with dry seed yield plant^{-1} under under moisture stress free (MSF) and managed terminal moisture stress (TMS) environments in the two experiments.

Index	First experiment		Second experiment	
	MSF	TMS	MSF	TMS
Mean productivity (MP)	0.90**	0.88**	0.97**	0.96**
Geometric mean productivity (GMP)	0.82**	0.94**	0.95**	0.98**
Hormonic mean productivity (HMP)	0.73**	0.98**	0.93**	0.99**
Stress tolerance index (STI)	0.75**	0.95**	0.92**	0.97**
Stress non-stress production index (SNPI)	0.30	0.92**	0.56*	0.88**
Yield index (YI)	0.58**	1.00**	0.87**	1.00**
Modified STI (K_1STI)	0.98**	0.61**	0.98**	0.89**
Modified STI (K_2STI)	0.57**	0.98**	0.84**	0.98**

*Significant @ P=0.05; **Significant @ P=0.01.

Table 5: Terminal moisture stress tolerant genotypes based on rank sum method using desirable indices for dry seed yield plant^{-1} selected in the two experiments.

Genotypes of the first experiment	MP	Rank	GMP	Rank	Rank mean (RM)
F_3 Selection '27'	25.20	1	25.05	1	1
HA 4	24.67	2	24.59	2	2
F_3 Selection '16'	22.24	3	22.22	3	3
Genotypes of the second experiment	MP	Rank	GMP	Rank	Rank mean (RM)
Indeterminate					
Kadalavare	40.19	1	39.95	1	1
GL 447	29.29	2	29.16	2	2
GL 66	25.24	3	24.14	3	3
GL 6	22.00	5	21.01	5	5
Determinate					
HA 4	22.33	4	22.25	4	4
HA-12-3	18.48	7	18.19	7	7

namely MP and GMP were found desirable for selection of TMS tolerant genotypes of both the experiments. Researches such as Moosavi *et al.* (2008) in wheat, Seyyed *et al.* (2014) in soybean, Uday *et al.* (2016) in chickpea and Bennani *et al.* (2017) in wheat have also used this criterion and identified MP and GMP as most desirable indices for selection of drought tolerant genotypes.

Selection of TMS tolerant genotypes based on the combination of two desirable indices

TMS tolerant genotypes differed with the two identified desirable indices (MP and GMP). Based on rank mean (RM) method, which effectively combines the two desirable indices (MP and GMP) into one index, F_3 selection '16', F_3 selection '27' and HA 4 from the first experiment and GL 6, GL 66, GL 447 and Kadalavare (landraces), HA 12-3 (ABL) and HA 4 (released variety) among the released varieties in the second experiment (Table 5) were identified as TMS tolerant. The four landraces (Vaijayanthi *et al.,* 2016) and HA 12-3 and HA 4 (Ramesh *et al*., 2018) are widely adapted across locations in eastern dry zone of Karnataka. We suggest

using these identified landraces, ABL and HA 4 in effecting crosses for generating variability for selection of high yielding TMS tolerant varieties. Further, F_3 selections '16' and '27' need to be stabilized and tested for their seed yield potential under MSF and TMS environments. Meena *et al*. (2014) could also identify drought tolerant chickpea genotypes using drought susceptibility index and yield stability index. Development of a large numbers of breeding populations using crosses between drought-tolerant landraces and high yielding genotypes has proved effective in combining high yield potential with TMS tolerance in rice (Kumar *et al.* 2008).

CONCLUSION

Based on the criterion of correlation, two indices namely, mean productivity (MP) and geometric mean productivity (GMP) were found effective for identifying TMS tolerant genotypes with high seed yield under moisture stress free (MSF) and terminal moisture stress (TMS) environments in dolichos bean. Based on rank mean of genotypes, F_3 selection '16', F_3 selection '27' and 'HA 4' of the first experiment and GL 6, GL 66, GL 447 and Kadalavare (landraces), HA 12-3 (advanced breeding line) and HA 4 of the second experiment were found TMS tolerant with high seed yield under both MSF and TMS environments.

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