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Yield stability of new elite lines of yardlong bean (*Vigna unguiculata* (L.) Walp. subsp. *sesquipedalis* Verdc.)

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Abstract The yield trials of new elite lines of yardlong bean under nine environments revealed that they differently responded to multi-environments for horticultural traits and yield. Genotype-environment interactions were significantly found ($P < 0.01$) for the days of anthesis, pod length, seeds per pod, pod weight and yield per hectare. Significant differences ($P < 0.01$) of yield were observed for genotypes, environments, and genotype-environment interaction. Stability analysis after Eberhart and Russell's model suggested that non-linear component was more important than linear component for determining the yield stability. Based on stability parameters, line No.30 was identified as stable for yield since it gave high yield (14.17 t/ha), high positive phenotypic index ($P_i > 0$), regression coefficient around unity ($b_i = 1$), and deviation from regression value around zero ($S_{di}^2 = 0$). Bangpra2 and No.25 lines also gave high yield but their deviations from regression were highly significant, it clearly shown that these 2 lines were unpredictable expected by linear regression. However, considering their yields from various environments, they were suitable for highly favorable environments but under poor environments. Environmental index which directly reflected the poor and rich environment in terms of negative and positive of yield revealed that environments 1 and 2 were rich environments, and environments 6 and 9 were poor environments.

Keywords: Asparagus bean, Environments, Elite lines, Yield stability

Introduction

Yardlong bean (*Vigna unguiculata*) L.) Walp. subsp. *sesquipedalis* (L.) Verdc.) is among the most important vegetable crops widely grown in all seasons throughout Thailand. According to the annual crop production situation report of the Department of Agricultural Extension, the 2017 planting year has approximately 4,701.12 hectares of yardlong bean plantations nationwide, with a total yield of approximately 22,444 tons (Department of Agricultural Extension, 2018). Yardlong bean is therefore an important vegetable that

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generates high income for farmers. Improving new yardlong bean cultivars possessing higher yields is still an ultimate goal of breeders, which is an important and beneficial for farmers who are growing vegetables in Thailand.

Plant cultivars often respond to growing environments by producing high or low yields when planted in different growing seasons or areas. Therefore, in addition to the yield potential, the stability of yields when grown in diverse environments is another issue that plant breeders need to consider. Some cultivars have a wide range of adaptability to the environment, with high productivity in many environments, whereas some cultivars may produce high yields specific to a particular environment only. Genotype-environment interaction is definitely significant in the development and evaluation of plant cultivars, because it affects yield performance of plant cultivars grown under various environments (Hebert *et al*., 1995; Detios *et al*., 2006). It also provides information about the effects of different environments on cultivar performance and plays a key role for assessment of performance stability of the breeding materials (Moldovan *et al*., 2003). In general, new cultivars that are recognized often have high yield potential and can be grown in a wide variety of environments where yields are still high. Therefore, it is necessary to pay attention to the breeding of plants that provide stable yields (Becker and Leon, 1988).

The stability of crop yields is an important feature and a desirable trait in plant breeding. This is an important characteristic of the cultivar in order to introduce it to farmers for cultivation in different areas, where the environment may differ. Therefore, newly developed cultivars should be tested for yield stability over several growing seasons and planting areas. Sometimes the unilocational trials can also serve the purpose provided different environments are created by planting experimental material at different dates of sowing, using various spacings and doses of fertilizers and irrigation levels etc. (Ottai *et al*., 2006). Pornsuriya *et al*. (2017) also reported the study on yield stability of yardlong bean lines/cultivars exposed to 6 modified environments using different doses of nitrogen fertilizer.

According to the university's yardlong bean breeding program, researchers crossed between two yardlong bean lines (Pornsuriya *et al*., 2013; Pornsuriya and Pornsuriya, 2016) to create genetic variability for line selection (Pornsuriya *et al*., 2019). Their progenies were selected for high yield and pod quality using pedigree method to obtain elite lines in the F_8 generation. Generally at the last stage of the breeding program, new elite lines will be tested in multiple environments to determine if they have wide adaptability or yield stability, or are specific to certain environments. In this research, they were conducted for yield trial under multi-environments (growing seasons, fertilizer rates and locations). Thus, the objective of the study was to evaluate genotype-environment interaction and yield stability of new elite lines in the F_8 generation of yardlong bean growing under multi-environments.

Materials and methods

Ten yardlong bean lines and cultivars: 6 new elite lines, 2 parental lines and 2 commercial cultivars, were planted for yield trial under 9 environments. For each environment, they were arranged in a randomized complete block design with 3 replications. Each experimental unit (plot size) was 1×3 m^2, 2 rows per plot, with 50 × 75-cm spacing (plant × row), 24 plants per plot (2 plant/hill). Plants were grown in beds using plastic mulch under a trellising system using bamboo stakes. The 9 environments were set for various conditions according to places, seasons and fertilizer applications as descrived in the Table 1.

Table 1. The nine modified growing environments set for the stability study of 10 yardlong bean lines and cultivars

Growing Environments[1/]	Planting Seasons	Planting Dates	Places	Fertilizer applications[2/]
1	1	Jan 13, 2020	RMUTTO, Chonburi	Chemical fertilizers
2	1	Jan 13, 2020	RMUTTO, Chonburi	Cow manure
3	2	Apr 30, 2020	RMUTTO, Chonburi	Chemical fertilizers
4	2	Apr 30, 2020	RMUTTO, Chonburi	Cow manure
5	3	Jul 30, 2020	RMUTTO, Chonburi	Chemical fertilizers
6	3	Jul 30, 2020	RMUTTO, Chonburi	Non-fertilizer
7	4	Nov 23, 2020	RMUTTO, Chonburi	Chemical fertilizers
8	5	Nov 28, 2020	Chanthaburi Land Development Station, Chanthaburi	Chemical fertilizers + Cow manure + spraying bio-extract from durian flowers
9	6	Dec 19, 2020	Uthaithani College of Agriculture and Technology, Uthaithani	Chemical fertilizers

[1/] Chemical fertilizers and cow manure or non-feritlizer were applied to modify the growing environments conducted in the same place and planting date.

[2/] Chemical fertilizers:- 15-15-15 (N-P-K) 500 kg/ha and 46-0-0 (N-P-K) 125 kg/ha; cow manure 11.13 ton/ha; bio-extract from durian flowers 225 ml/l, sprayed weekly, once a week.

Data were recorded for horticultural traits including days to first anthesis (day), pod width (cm), pod length (cm), seeds per pod, and pod weight (g) (averaged from 10 pods/plot). Pods per plant were averaged from pods per plot. Yield (t/ha) was calculated from the pod fresh weight of each plot. Fresh pods were harvested on alternate days for five weeks. Data of each environment were analyzed according to the experimental design (RCBD). Mean comparison between a pair of treatments was conducted by Duncan's new multiple range test at 0.05 level ($DMRT_{0.05}$). Homogeneity tests of error variance of all environments were determined using Bartlett' test (Little and Hills, 1978). Combined analyses were performed only for traits with having homogeneity of error variance to investigate genotype-environment (G x E) interactions (McIntosh, 1983). Stability parameters were calculated for traits possessing significance of genotype-environment interaction according to the model of Eberhart and Russell (1966) as illustrated by Sharma (2008) and Singh and Chaudhary (2012).

Results

Combined analysis of variance

Homogeneity of variance for all nine environments was discovered in days to first anthesis, pod length, seeds per pod, and pod weight, but was not detected for yield. However, when combined analysis of yield per hectare was performed for eight environments, homogeneity of variance was found, where the 8th environment was excluded because of its high variation in yield. Thus, from this reason the study of yield stability was determined from only eight environments, where the other characteristics were from nine environments. The results from combined analyses revealed that genotype-environment interactions were found significantly ($P < 0.01$) for days to first anthesis, pod length, seeds per pod, pod weight and yield per hectare. The stability analyses are elucidated for pod length, seeds per pod, pod weight and yield per hectare in this study.

Pooled analysis of variance

The pooled analyses of variance were conducted for pod length, seeds per pod, pod weight and yield per hectare as shown in Table 2. The results indicated that genotype-environment interactions were significantly different ($P < 0.01$) for all traits, implied that these cultivars had different genetic background and the various environments had different effects on yardlong bean lines and cultivars, which resulted the expression of the traits. The significance of environment (linear) for all traits ($P < 0.01$) indicated that variation among environments was linear. Genotype-environment (linear) interactions were significant for pod length ($P < 0.01$) and pod weight ($P <$

0.05), which revealed that there were genetic differences among genotypes for their regression on the environmental index. Pooled deviation from regression was detected for pod length, seeds per pod and yield ($P < 0.01$), suggested that the performance of different genotypes fluctuated significantly from their respective linear path of response to environments. Insignificant pooled deviation for pod weight signified that most genotypes were close to linear response (Table 2).

Table 2. Pooled analysis of variance of pod length, seeds/pod, pod weight and yield data for the response of 10 yardlong bean lines/cultivars exposed to 9 environments when stability parameters were estimated following Eberhart and Russell (1966)

		Mean Square			**Mean Square1/**	
SOV.	**D.F.**	**Pod length**	**Seeds/pod**	**Pod weight**	**D.F.**	**Yield**
Total	89				79	
Genotypes (G)	9	254.746 **	3.184 *	26.922 **	9	15.606 **
Env. (E)	8	489.637 **	9.719 *	522.605 **	7	553.256 **
G x E	72	29.925 **	3.966 **	29.820 **	63	11.233 **
Env. + (G x E)	80	25.299 **	1.514 ns	26.376 **	70	21.812 **
Env. (linear)	1	1305.562 **	25.928 **	1394.506 **	1	1,290.932 **
G x E (linear)	9	24.036 **	0.921 ns	16.474 *	9	5.101 ns
Pooled deviation	70	7.172 **	1.241 **	8.105 ns	60	3.166 **
BP Purple	7	5.838 ns	0.372 ns	4.260 ns	6	1.412 ns
Bangpra2	7	3.782 ns	2.415 **	4.302 ns	6	7.225 **
Lamnamch	7	2.354 ns	0.601 ns	7.569 ns	6	8.096 **
Tarntong	7	10.151 **	1.413 ns	22.766 **	6	5.800 **
Number 1	7	24.642 **	2.124 **	15.572 **	6	1.046 ns
Number 17	7	5.582 ns	0.975 ns	7.254 ns	6	1.137 ns
Number 18	7	8.630 *	1.786 *	2.366 ns	6	1.813 ns
Number 25	7	2.303 ns	0.550 ns	10.570 *	6	2.769 *
Number 30	7	4.432 ns	0.889 ns	3.971 ns	6	1.597 ns
Number 33	7	4.004 ns	1.287 ns	2.419 ns	6	0.768 ns
Pooled error	162	10.479	2.2648	14.322	144	2.987
Mean of MSE		3.493	0.755	4.774		0.996

^{ns} Not significant

*, ** Significant at *P < 0.05* and *0.01*, respectively.

1/ ANOVA for yield was analysed from 8 environments with homogeneity of variance.

Stability parameters

Stability parameters define that genotypes with positive phenotypic index ($P_i > 0$), regression coefficient around unity ($b_i = 1$), and deviation from regression around zero ($S^2_{di} = 0$) are considered highly stable. Stability study of the horticultural characteristics and yield of 10 yardlong bean genotypes are described below:

Pod length: Stability parameters were analyzed for pod length as illustrated in Table 3. The results showed that all genotypes had regression coefficient around unity ($b_i = 1$) except for No. 25 line that had regression coefficient lesser than 1 ($P < 0.01$). There were 3 genotypes; Tarntong, No.1 and No. 18, which had deviation from regression values greater than 0 ($P < 0.01$ and 0.05). Therefore, considering these stability parameters, Bangpra 2, No. 30, 33 and 17 with mean pod length of 63.43, 63.18, 62.46 and 61.70 cm, respectively, and with positive phenotypic index of 4.66, 4.41, 3.70 and 2.93 cm, respectively, are defined as stable genotypes in pod length. Their coefficient of determination (R_i^2) values were high as 83.1%, 86.5%, 75.2% and 83.8%, respectively, conforming their stability. Line No. 25 which had the greatest mean pod length (65.81 cm) with a deviation from regression not different from 0 but having a regression coefficient significantly less than 1, is therefore classified as a genotype that is less responsive to fertile environments, but still produces considerable pod length even when grown in low to medium fertile environments. In contrast, Tarntong, No. 1 and No. 18, which had a high deviation from regression, significantly different from 0, are therefore classified as genotypes in which their responses of pod length to environments are uncertain and unpredictable (Table 3).

Table 3. Estimates of stability parameters for pod length of 10 yardlong bean lines and cultivars under 9 environments

Lines/Cultivars	**Pod length (cm) 1/**	**Phenotypic index (Pi)**	**Regression coefficient (bi) 2/**	**Coefficient of determination (Ri2)**	**Deviation from regression (S_{di}^2) 3/**
BP Purple	55.67 c	-3.10	0.640	0.567	2.344
Bangpra2	63.43 ab	4.66	0.997	0.831	0.289
Lamnamchee	51.14 d	-7.62	0.835	0.847	-1.139
Tarntong	50.62 d	-8.14	0.605	0.402	6.658 **
Number 1	56.54 c	-2.22	1.660	0.676	21.149 **
Number 17	61.70 b	2.93	1.246	0.838	2.089
Number 18	57.10 c	-1.66	1.603	0.847	5.137 *
Number 25	65.81 a	7.04	0.375 **	0.533	-1.190
Number 30	63.18 ab	4.41	1.234	0.865	0.938
Number 33	62.46 b	3.70	0.807	0.752	0.511
F-test	**				
CV. (%)	5.01				

*, ** Significant at $P < 0.05$ and 0.01, respectively.

[1/] Means in a column followed by the same letter are not significantly different at $DMRT_{0.05}$

[2/] Test for $b_i = 1$, [3/] Test for $S_{di}^2 = 0$

Seeds per pod: The results showed that only BP purple line had a regression coefficient different from 1 (*$P < 0.01$*), while all the rest of the genotypes had a regression coefficient of 1 (*$P > 0.05$*). The deviation from regression values of Bangpra2, No.1 and No.18 lines were significantly different from 0, while the rest were not different from 0 (*$P > 0.05$*) (Table 4). According to the stability parameters, No.25 is considered as a stable genotype for this characteristic, whereas BP purple may be suited to poor environments since it had positive phenotypic index and its regression coefficient was significantly less than 1 (*$P < 0.05$*). However, both genotypes had very low coefficient of determination values, indicated that their linear regression models were not fit to predict these data.

Table 4. Estimates of stability parameters for seeds per pod of 10 yardlong bean lines and cultivars under 9 environments

Lines/Cultivars	**Seeds/pod (seeds) 1/**	**Phenotypic index (Pi)**	**Regression coefficient (bi) 2/**	**Coefficient of determination (Ri2)**	**Deviation from regression (S^2_{di}) 3/**
BP Purple	16.96 abc	0.29	-0.131 *	0.017	-0.383
Bangpra2	17.20 abc	0.53	1.400	0.231	1.660 **
Lamnamchee	16.16 bc	-0.51	1.624	0.619	-0.154
Tarntong	16.06 bc	-0.60	1.263	0.295	0.659
Number 1	15.98 c	-0.69	0.494	0.041	1.369 **
Number 17	16.30 bc	-0.37	1.638	0.505	0.220
Number 18	17.26 ab	0.59	1.316	0.264	1.031 *
Number 25	17.61 a	0.95	0.514	0.151	-0.205
Number 30	16.17 bc	-0.50	1.325	0.423	0.134
Number 33	16.96 abc	0.29	0.557	0.082	0.532
F-test	*				
CV. (%)	9.03				

*, ** Significant at *$P < 0.05$* and *0.01*, respectively.

[1/] Means in a column followed by the same letter are not significantly different at $\text{DMRT}_{0.05}$

[2/] Test for $b_i = 1$, [3/] Test for $S^2_{di} = 0$

Pod weight: All genotypes had regression coefficient around unity ($b_i = 1$) except for No.25 line that had regression coefficient lesser than 1 (*$P < 0.05$*). Tarntong, No.1 and No.25 showed large degree of fluctuations from linearity because their deviation from regression values were significantly greater than 0 (*$P < 0.01$* and *0.05*). When considering the stability parameters, it was found that Lamnamchee and Bangpra2 possessing average pod weight of 32.51 and 30.91 g, respectively, and positive phenotypic index of 3.25 and 1.65 g, respectively, therefore, are classified as highly stable genotypes in pod weight characteristic. Their coefficient of determination (R_i^2) values were high as

72.1% and 86.8%, respectively, conforming their stability. Tarntong cultivar also had high average pod weight of 30.88 g but the deviation from regression differed significantly from 0, it is therefore classified as a genotype with an unpredictable environmental response (Table 5).

Table 5. Estimates of stability parameters for pod weight of 10 yardlong bean lines and cultivars under 9 environments

Lines/Cultivars	**Pod weight (g) 1/**	**Phenotypic index (Pi)**	**Regression coefficient (bi) 2/**	**Coefficient of determination (Ri2)**	**Deviation from regression (S^2_{di}) 3/**
BP Purple	27.82 bc	-1.44	0.912	0.796	-0.514
Bangpra2	30.91 ab	1.65	1.191	0.868	-0.472
Lamnamchee	32.51 a	3.25	0.991	0.721	2.795
Tarntong	30.88 ab	1.62	0.463	0.158	17.992 **
Number 1	28.15 bc	-1.11	1.062	0.591	10.798 **
Number 17	26.99 c	-2.27	1.293	0.821	2.480
Number 18	27.88 bc	-1.38	1.197	0.924	-2.408
Number 25	29.32 abc	0.06	0.340 *	0.179	5.796 *
Number 30	29.59 abc	0.33	1.361	0.903	-0.803
Number 33	28.53 bc	-0.73	1.189	0.921	-2.355
F-test	**				
CV. (%)	12.94				

*, ** Significant at $P < 0.05$ and 0.01, respectively.

1/ Means in a column followed by the same letter are not significantly different at $\text{DMRT}_{0.05}$

2/ Test for $b_i = 1$, 3/ Test for $S^2_{di} = 0$

Yield per hectare: Considering the yield stability parameters of 10 yardlong bean lines/cultivars in Table 6, No.30 is considered as a stable genotype that is suitable over all environmental conditions or suitable for general adaptation, because it possesed high yield (14.17 t/ha), high positive phenotypic index ($P_i > 0$), regression coefficient around unity ($b_i = 1$), and deviation from regression value around zero ($S^2_{di} = 0$). Its coefficient of determination (R_i^2) was also the highest value as 95.5%, conforming its stability. Bangpra2 and No.25 lines also gave high yield (15.24 and 14.49 t/ha, respectively) but their deviations from regression were significantly high ($P < 0.01$ and 0.05), it became clear that these 2 lines were unpredictable by linear regression. However, considering their yields from various environments, they were suitable for highly favorable environments but under poor environments they rather gave low yield (Figure 1). BP purple line yielded lower than the mean of all genotypes, with a negative phenotypic index (-0.26) and a low coefficient of regression, which was significantly less than 1. As shown in Fig. 1, BP purple yielded below the average of all genotypes in almost all environments. It is therefore identified as a poor sensitive line that is less responsive to the environment.

Adaptive specificities for yield of 10 yardlong bean genotypes are shown in Figure 2. Genotypes falling in the right-top quarter of the distribution chart are classified as high yield and high sensitivity, which are suitable for fertile environments. Genotypes falling in the left-lower quarter are classified as low yield and poor sensitivity, which may be not suitable for all environments.

Table 6. Estimates of stability parameters for yield per hectare of 10 yardlong bean lines and cultivars under 8 environments

Lines/Cultivars 1/	**Yield (t/ha) 2/**	**Phenotypic index (Pi)**	**Regression coefficient (bi) 3/**	**Coefficient of determination (Ri2)**	**Deviation from regression (S^2_{di}) 4/**
BP Purple	11.33 c	-1.60	0.703 *	0.883	0.416
Bangpra2	15.24 a	2.30	1.144	0.796	6.223 **
Lamnamchee	11.68 c	-1.25	0.872	0.669	7.100 **
Tarntong	11.26 c	-1.67	0.838	0.723	4.804 **
Number 1	13.01 bc	0.07	0.874	0.940	0.050
Number 17	13.16 abc	0.23	1.057	0.955	0.142
Number 18	11.82 c	-1.11	0.858	0.897	0.817
Number 25	14.49 ab	1.56	1.303	0.930	1.773 *
Number 30	14.17 ab	1.23	1.250	0.955	0.601
Number 33	13.18 abc	0.25	1.100	0.971	-0.227
F-test	**				
CV. (%)	13.36				

*, ** Significant at $P < 0.05$ and 0.01, respectively.

1/ All values were calculated from 8 environments (Env.8 was excluded because of heterogeneity of variance).

2/ Means in a column followed by the same letter are not significantly different at $\text{DMRT}_{0.05}$

3/ Test for $b_i = 1$, 4/ Test for $S^2_{di} = 0$

Environmental index (I_j)

Environmental index of yield directly reflects the poor or rich environment in terms of negative and positive I_j, respectively. As shown in Table 7, environments 1 and 2 are identified as rich environments, environments 3, 4, 5 and 7 as moderate, and environments 6 and 9 are poor environments. The results from yield comparison of environments revealed that environments 1 and 2 gave the highest yield of 18.16 and 18.66 t/ha, respectively, whereas environments 6 and 9 provided the lowest yield of 7.82 and 6.48 t/ha, respectively.

Table 7. Mean yield and environmental index of each environment when combined analysis of 10 yardlong bean genotypes was performed under 8 growing environments

Environments[1/]	**Mean yield of each environment (t/ha)**	**Environmental index (I_j)**
Env. 1	18.16 a	5.23
Env. 2	18.66 a	5.73
Env. 3	13.49 b	0.55
Env. 4	13.19 b	0.25
Env. 5	13.44 b	0.51
Env. 6	7.82 c	-5.12
Env. 7	12.23 b	-0.70
Env. 9	6.48 c	-6.45
	Mean = 12.93	Sum = 0.00
F-test	**	
CV. (%)	13.36	

** Significant at $P < 0.05$ and 0.01, respectively.

Means in a column followed by the same letter are not significantly different at $\text{DMRT}_{0.05}$

[1/] Env.8 was excluded because of heterogeneity of variance.

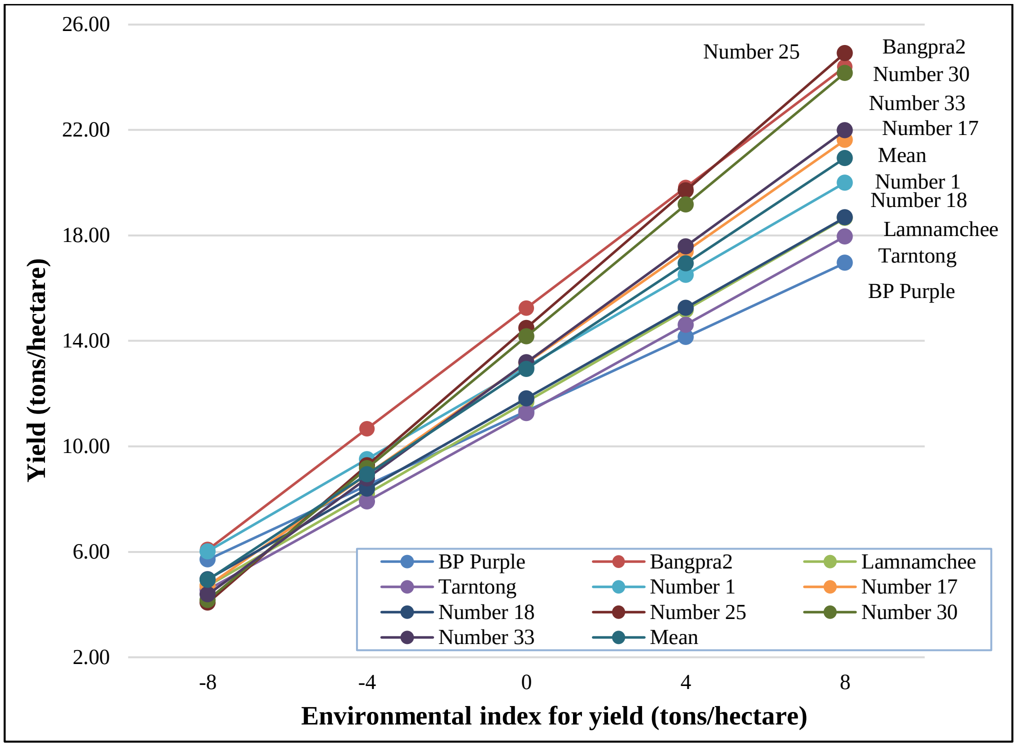

Figure 1. Reaction norms for yield of 10 yardlong bean lines/cultivars under varying environments

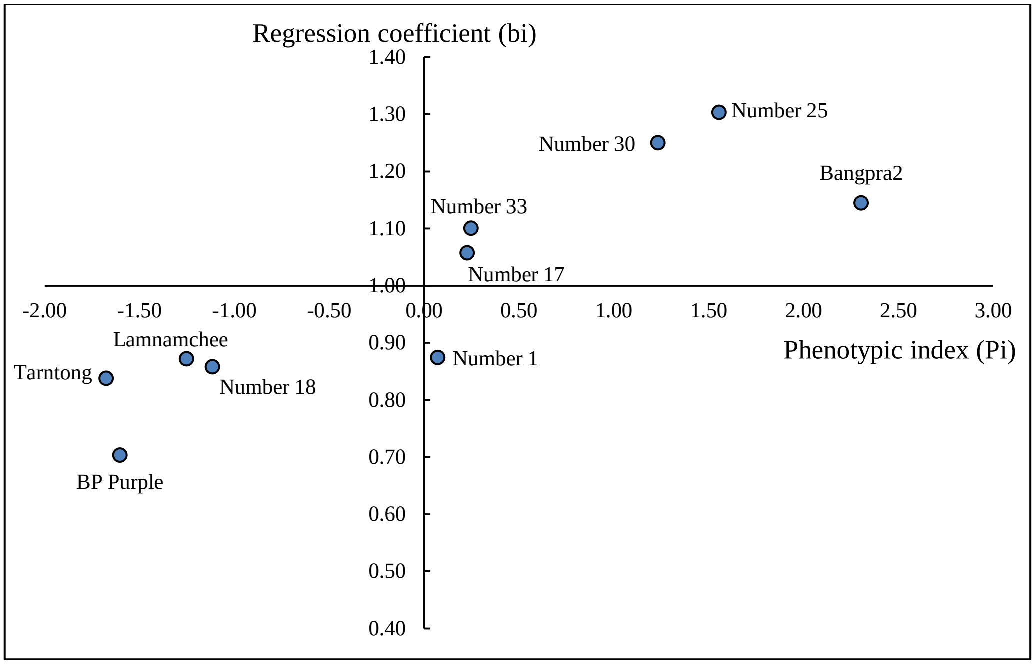

Figure 2. Adaptive specificities for yield of 10 genotypes of yardlong bean lines/cultivars exposed to 8 growing environments when stability parameters are estimated following Eberhart and Russell (1966)

Discussion

The performance of a genotype mainly depends on environmental interaction. Estimation of phenotypic stability has proved to be a valuable technique for assessing the response of various genotypes under changing environmental conditions. The development of cultivars with high yield potential is the definitive goal in a plant breeding program, thus this discussion is focused on the yield stability of the yardlong bean genotypes tested in the experiment.

The results of yield trial revealed that variances due to genotypes (G) and environments (E) were highly significant. This clearly signifies presence of substantial variation in the mean performance of all 10 genotypes over environments and in the environmental means over test genotypes. Significant G x E interaction variance indicates that particular genotypes tended to rank differently in yield at different environments. The significance of E (linear) indicates that variation among environments is linear. A linear environmental variance would signify unit changes in environmental index for each unit change in the environmental conditions (Sharma, 2008). G x E (linear) interaction was not significant, whereas pooled deviation from regression was significantly detected, suggests that performance of different genotypes fluctuated significantly from their respective linear path of response to environments. However, on the analyzing of the individual genotype fluctuation from linearity, there were four genotypes (Bangpra2, Lamnamchee, Tarntong and No.25) that fluctuated significantly. Regression coefficient (b_i), which was the linear regression of the performance of each cultivar under different environments on the environmental means over all the genotypes (Singh and Chaudhary, 2012), ranged from 0.703 to 1.303. The variation in regression coefficient indicates the different responses of genotypes to environmental changes (Akcura *et al*., 2005).

Eberhart and Russell (1966) emphasized that both linear (b_i) and non-linear (S_{di}^2) components of genotype-environment interaction are necessary for judging the stability of a genotype. A regression coefficient approximately 1.0, along with deviation from regression equal to zero and positive phenotypic index, indicated average stability (Sharma, 2008). According to this criteria, Line No.30 is classified a stable genotype and will be extended to farmers as a new elite line with high yield and general adaptation. Bangpra2 and No.25 had highly positive phenotypic index and regression coefficient around 1, but the deviation from regression values were significantly different from zero. The high value of deviation from regression signifies that there is high sensitivity to environmental changes, thus these lines quite give high yield performance when environmental conditions were conductive (Arshad *et al.*, 2003). Zubair *et al.* (2002) also suggested that if regression coefficients of the genotypes are not significantly different from 1, the stability of these genotypes should be judged upon other two parameters i.e. genotypic mean (as represented by phenotypic index; P_i) and the value of deviation from regression. BP purple with a negative phenotypic index and a regression coefficient below 1.0, provides a measurement of greater resistance to environmental change (above average stability), may be not suitable for both poor and rich environments.

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