Generation Mean Analysis of Seed Yield and Pod Per Plant in Azuki Bean Growing on Highland Areas

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ABSRACT

Six basic generations, P_1, P_2, F_1, F_2, BC_1 and BC_2 of one azuki bean cross, Hondawase × Akatsukidainagon, were planted at two locations on the highland area of Chiang Mai province for two consecutive growing seasons. The objective of the study was to evaluate the gene action as influenced by environmental variations on seed yield per plant and number of pods per plant of azuki bean by using the generation mean analysis. Results of the study indicated that there were additive gene effect, dominance gene effect and interaction of both genes effects of these studied traits with environment. This study suggested that seed yield per plant and number of pods per plant were important agronomic characters which highly responded to environmental variations, thus, optimum environmental factors especially low temperature on highland areas should be selected for testing gene action in azuki bean.

Key words: Azuki bean, Gene action, Generation mean analysis, Highland

INTRODUCTION

Gene action of each quantitative trait such as seed yield and its yield components can be evaluated by generation mean analysis. Several models have been developed for analysis of generation mean which described by Anderson and Kempthorne (1954), Hayman (1958) and Gamble (1962). Procedures used to estimate mean and variance of quantitative traits were proposed by using six basic generations which included parents (P_1 and P_2), F_1, F_2 and first two backcrosses (BC_1 and BC_2). Additive (d) and dominance (h) are parameters of gene actions for additive-dominance model. Genotype and environment interaction of generation mean analysis was presented by Mather and Jinks (1982). Some important crops had been reported on generation mean analysis for evaluation of genetic effects of genes controlling quantitative traits such as mungbean (Chaitieng et al., 2003), peanut (Jogloy et al., 1999), wheat (Mullaney et al., 1982; Snijders, 1990), cotton (Quisenberry, 1975; Dani and Kohel, 1989), maize (Landi et al., 1990), tomato (Scott and Jones, 1990) and common bean (Checa et al., 2006). The objective of this work was to evaluate gene action as influenced by environmental variations by using generation mean analysis of seed yield per plant and number of pods per plant which these two traits were considered as important agronomic traits of azuki bean which were grown under different highland areas in the northern part of Thailand.

MATERIALS AND METHODS

The data of seed yield per plant and number of pods per plant for six basic generations; P_1, P_2, F_1, F_2, BC_1 and BC_2 were derived from crossing Hondawase × Akatsukidainagon azuki bean. In order to evaluate gene action as influenced by environmental variations, crops were grown under two different altitude levels of Chiang Mai province, northern Thailand, namely, Khunpae Royal Project Development Center (1,200 m above sea level, ASL) and Inthanon Royal Agricultural Station (1,300 m ASL) in 2005 and 2006 growing seasons. At harvesting time, seed yield per plant and number of pods per plant of individual plant were measured and calculated for mean and standard error of each generation by using the standard statistical method. The joint-scaling test, additive-dominance model and genotype × environment interaction analysis were used to estimate the genetic effect and generation means as proposed by Mather and Jinks (1982). Matrix algebra was used for calculating each model and used parameter coefficients of full model in Table 1 for analysis.

For joint-scaling test; if all values of A, B and C are not significantly different from zero by *t*-test, it implies that genetic effect is either additive or dominance gene action. In this case, analysis of genetic effect can be carried out by using additive-dominance model. The model is calculated by equation as follows (Kunkaew et al., 2008):-

$$\mathbf{M} = [\mathbf{B_1}' \times \mathbf{B}]^{-1} \times [\mathbf{B_1}' \times \mathbf{C}]$$
$$\mathbf{V} = \mathbf{D} \times \mathbf{V1}$$
$$SE = \sqrt{V}$$

Where, **M** is the matrix of the parameters
B is the matrix of parameter coefficients
$\mathbf{B}_1$ is the matrix of weight
C is the matrix of six generation means
V is the matrix of parameter variances
$\mathbf{V}_1$ is the matrix of six generation variances
D is the matrix of squared elements of the matrix $[\mathbf{B_1}' \times \mathbf{B}]^{-1} \times \mathbf{B_1}']$
SE is the standard error of parameters

Table 1. Genetic expectation for the generation means of generations P_1, P_2, F_1, F_2, BC_1 and BC_2 grown in two years and two locations.

			Genetic parameter (full model)											
Generation	Year	Location	m	[d]	[h]	e_1	e_2	e_3	g_{d1}	g_{d2}	g_{d3}	g_{h1}	g_{h2}	g_{h3}
P_1	1	1	1	1	0	1	1	1	1	1	1	0	0	0
P_1	1	2	1	1	0	1	-1	-1	1	-1	-1	0	0	0
P_1	2	1	1	1	0	-1	1	-1	-1	1	-1	0	0	0
P_1	2	2	1	1	0	-1	-1	1	-1	-1	1	0	0	0
P_2	1	1	1	-1	0	1	1	1	-1	-1	-1	0	0	0
P_2	1	2	1	-1	0	1	-1	-1	-1	-1	1	0	0	0
P_2	2	1	1	-1	0	-1	1	-1	1	1	1	0	0	0
P_2	2	2	1	-1	0	-1	-1	1	1	1	-1	0	0	0
F_1	1	1	1	0	1	1	1	1	0	0	0	1	1	1
F_1	1	2	1	0	1	1	-1	-1	0	0	0	1	-1	-1
F_1	2	1	1	0	1	-1	1	-1	0	0	0	-1	1	-1
F_1	2	2	1	0	1	-1	-1	1	0	0	0	-1	-1	1
F_2	1	1	1	0	1/2	1	1	1	0	0	0	1/2	1/2	1/2
F_2	1	2	1	0	1/2	1	-1	-1	0	0	0	1/2	-1/2	-1/2
F_2	2	1	1	0	1/2	-1	1	-1	0	0	0	-1/2	1/2	-1/2
F_2	2	2	1	0	1/2	-1	-1	1	0	0	0	-1/2	-1/2	1/2
BC_1	1	1	1	1/2	1/2	1	1	1	1/2	1/2	1/2	1/2	1/2	1/2
BC_1	1	2	1	1/2	1/2	1	-1	-1	1/2	-1/2	-1/2	1/2	-1/2	-1/2
BC_1	2	1	1	1/2	1/2	-1	1	-1	-1/2	1/2	-1/2	-1/2	1/2	-1/2
BC_1	2	2	1	1/2	1/2	-1	-1	1	-1/2	-1/2	1/2	-1/2	-1/2	1/2
BC_2	1	1	1	-1/2	1/2	1	1	1	-1/2	-1/2	-1/2	1/2	1/2	1/2
BC_2	1	2	1	-1/2	1/2	1	-1	-1	-1/2	1/2	1/2	1/2	-1/2	-1/2
BC_2	2	1	1	-1/2	1/2	-1	1	-1	1/2	-1/2	1/2	-1/2	1/2	-1/2
BC_2	2	2	1	-1/2	1/2	-1	-1	1	1/2	1/2	-1/2	-1/2	-1/2	1/2

RESULTS AND DISCUSSION

The generation mean and standard error analysis for seed yield per plant and number of pods per plant of Hondawase × Akatsukidainagon azuki bean cross revealed significant differences among all six generation means, P_1, P_2, F_1, F_2, BC_1 and BC_2 at both locations and years as presented in Tables 2, 3, 4 and 5.

The results of joint-scaling test showed that neither A, B nor C-scale was significant for *t*-values in each location and year, indicating that the seed yield per plant and number of pods per plant of this cross fitted well to the additive-dominance model in all environments, except number of pods per plant grown at Inthanon station in 2005.

Table 2. Combined analysis of variance for seed yield per plant and number of pods per plant in azuki bean cross, Hondawase × Akatsukidainagon, grown at Khunpae and Inthanon station in 2005 and 2006 growing season.

Source of variance	df	Mean square	
		Seed yield per plant (gm./plant)	Number of pods per plant
Seasons	1	949.92**	1429.44**
Locations	1	666.55**	1600.34**
Season × location	1	9.59	656.26**
Reps within seasons and locations	12	39.50**	68.40**
Generations	5	46.23**	76.17**
Generation × season	5	3.40	12.71
Generation × location	5	1.14	1.74
Generation × season × location	5	17.04**	54.21*
Error	60	4.93	9.74
CV (%)		18.87	14.37

*, ** Significant difference at the P<0.05 and P<0.01 levels, respectively.

Table 3. Six basic generation mean, standard error, scaling test and components of gene action for seed yield per plant (gm./plant) of azuki bean cross, Hondawase × Akatsukidainagon, grown at Khunpae and Inthanon station in 2005 and 2006 growing season.

Generation	2005 growing season		2006 growing season	
	Inthanon station	Khunpae station	Inthanon station	Khunpae station
P_1	7.17±0.45(72)b[1]	15.05±0.57(69)b	6.05±0.37(50)a	7.60±0.53(67)c
P_2	12.16±0.63(75)a	16.70±0.65(69)ab	5.33±0.47(61)a	11.82±0.61(68)ab
F_1	11.88±0.96(28)a	18.29±1.25(19)a	6.61±0.95(13)a	11.06±1.24(17)bc
F_2	12.81±0.91(105)a	16.73±0.73(105)ab	5.42±0.41(100)a	11.40±0.61(103)abc
BC_1	11.54±1.18(22)a	18.40±1.60(16)ab	6.68±0.88(21)a	9.11±1.05(23)bc
BC_2	16.02±2.35(15)a	19.26±1.85(13)a	7.67±2.01(6)a	14.82±3.15(4)a
Scaling test				
A	4.02 ± 2.58	3.46 ± 3.48	0.70 ± 2.03	-0.44 ± 2.50
B	8.00 ± 4.85	3.53 ± 3.97	3.40 ± 4.15	6.77 ± 6.44
C	8.15 ± 4.19	-1.43 ± 3.95	-2.92 ± 2.59	4.07 ± 3.58
Component				
m	9.88 ± 0.38**	15.89 ± 0.42**	5.63 ± 0.29**	9.81 ± 0.39**
[d]	-2.54 ± 0.38**	-0.81 ± 0.43	0.38 ± 0.29	-2.19 ± 0.40**
[h]	3.37 ± 0.93**	2.60 ± 1.09*	0.43 ± 0.74	2.11 ± 1.01*
X^2	7.163	2.258	2.978	2.567
df	3	3	3	3
P	0.066	0.520	0.395	0.463

Figure in parenthesis is the number of plant.
[1]Means within columns followed by the same letter are not significantly different based on Duncan's Multiple Range Test (p=0.05).
*, ** Significantly different from zero at the P<0.05 and P<0.01 levels, respectively.

Table 4. Six basic generation mean, standard error, scaling test and components of gene action for number of pods per plant of azuki bean cross, Hondawase × Akatsukidainagon, grown at Khunpae and Inthanon station in 2005 and 2006 growing season.

Generation	2005 growing season		2006 growing season	
	Inthanon station	Khunpae station	Inthanon station	Khunpae station
P_1	16.63±0.90(72)c[1]	24.36±0.90(69)a	11.53±0.60(49)a	20.56±0.94(50)c
P_2	23.99±1.13(69)b	24.55±0.89(75)a	9.88±0.66 (42)a	26.13±0.86(54)ab
F_1	23.91±1.69(22)b	29.69±2.07(16)a	11.47±1.15(15)a	24.75±1.62(12)bc
F_2	24.44±1.27(101)b	25.58±1.04(105)a	10.49±0.62(97)a	24.59±0.84(80)bc
BC_1	23.18±2.26(22)b	27.22±2.18(18)a	11.36±1.1 (22)a	22.83±1.51(18)bc
BC_2	31.38±2.94(16)a	24.60±2.46(15)a	10.71±2.08(7)a	29.50±3.69(4)a
Scaling test				
A	5.83 ± 4.90	0.39 ± 4.90	-0.27 ± 2.55	0.36 ± 3.56
B	14.86 ± 6.23*	-5.03 ± 5.42	0.08 ± 4.36	8.12 ± 7.60
C	9.31 ± 6.28	-5.96 ± 6.01	-2.37 ± 3.51	2.16 ± 4.85
Component				
m	20.75 ± 0.70**	24.31 ± 0.62**	10.64 ± 0.43**	23.43 ± 0.61**
[d]	-3.87 ± 0.71**	0.00 ± 0.62	0.83 ± 0.44	-2.84 ± 0.62**
[h]	5.45 ± 1.63**	3.89 ± 1.66*	0.38 ± 1.02	1.93 ± 1.44
X^2	7.441	1.655	0.493	1.230
df	3	3	3	3
P	0.059	0.646	0.920	0.745

Figure in parenthesis is the number of plant.
[1] Means within columns followed by the same letter are not significantly different based on Duncanís Multiple Range Test (p=0.05).
*, ** Significantly different from zero at the P<0.05 and P<0.01 levels, respectively.

The results of this study revealed that gene actions were influenced greatly by environmental variation, especially low temperature on the high altitude resulted in low yield and number of pods per plant as observed in both years at Inthanon station. The m values for seed yield per plant at Khunpae station were 15.89 and 9.81 gm. and at Inthanon station were 9.88 and 5.63 gm. in 2005 and 2006, respectively. For number of pods per plant at Khunpae station were 24.31 and 23.43 pods and at Inthanon station were 20.75 and 10.64 pods in 2005 and 2006, respectively. The additive gene effects (d) for seed yield per plant were observed significantly at Inthanon station in 2005 and at Khunpae station in 2006. As well, d effects for number of pods per plant were significantly exhibited in both locations and years. For dominance gene effect (h), significance was observed for seed yield per plant at both locations in 2005 but significance was observed only at Khunpae station in 2006. For number of pods per plant, h effects were observed significantly at both locations in 2005 but did not show any effects at both locations in 2006.

Table 5. The analysis of the generation mean for seed yield per plant and number of pods per plant of azuki bean cross, Hondawase × Akatsukidainagon, grown at two different locations, Inthanon (INT) and Khunpae (KP) station in 2005 and 2006 growing season.

Generation	Year	Location	Mean ± SE	
			Yield (gm./plant)	No. of pods/plant
P_1	2005	INT	7.17±0.45	16.63±0.90
P_1	2005	KP	15.05±0.57	24.36±0.90
P_1	2006	INT	6.05±0.37	11.53±0.60
P_1	2006	KP	7.60±0.53	20.56±0.94
P_2	2005	INT	12.16±0.63	23.99±1.13
P_2	2005	KP	16.70±0.65	24.55±0.89
P_2	2006	INT	5.33±0.47	9.88±0.66
P_2	2006	KP	11.82±0.61	26.13±0.86
F_1	2005	INT	11.88±0.96	23.91±1.69
F_1	2005	KP	18.29±1.25	29.69±2.07
F_1	2006	INT	6.61±0.95	11.47±1.15
F_1	2006	KP	11.06±1.24	24.75±1.62
F_2	2005	INT	12.81±0.91	24.44±1.27
F_2	2005	KP	16.73±0.73	25.58±1.04
F_2	2006	INT	5.42±0.41	10.49±0.62
F_2	2006	KP	11.40±0.61	24.59±0.84
BC_1	2005	INT	11.54±1.18	23.18±2.26
BC_1	2005	KP	18.40±1.60	27.22±2.18
BC_1	2006	INT	6.68±0.88	11.36±1.10
BC_1	2006	KP	9.11±1.05	22.83±1.51
BC_2	2005	INT	16.02±2.35	31.38±2.94
BC_2	2005	KP	19.26±1.85	24.60±2.46
BC_2	2006	INT	7.67±2.01	10.71±2.08
BC_2	2006	KP	14.82±3.15	29.50±3.69

Component	Value ± SE	
	Yield (gm./plant)	No. of pods/plant
m	10.31±0.19**	19.78±0.30**
[d]	-1.29±0.19**	-1.47±0.30**
[h]	2.13±0.48**	2.91±0.73**
e_1	2.58±0.19**	2.75±0.30 **
e_2	-2.55±0.19**	-4.09±0.30**
e_3	-0.46±0.19*	2.31±0.30**
g_{d1}	-0.39±0.19*	-0.47±0.30
g_{d2}	0.21±0.19	-0.05±0.30
g_{d3}	-1.08±0.19*	-1.89±0.30**

g_{h1}	0.85±0.48	1.76±0.73*
g_{h2}	-0.23±0.48	0.00±0.73
gh_3	0.62±0.48	0.78±0.73
X^2	14.975	10.850
df	12	12
P	0.242	0.541

*, ** Significantly different from zero at the P<0.05 and P<0.01 levels, respectively.

Genotype and environment interaction analysis for gene effects on seed yield per plant and number of pods per plant of azuki bean cross suggested that X^2-test was not significant, indicating that the full model can be fitted for analysing genotype × environment interaction in seed yield per plant and number of pods per plant of this cross. The analysis showed that an additive-dominance model was satisfactory for analysing each set of generation means in each environment as well as for the generation means averaged over environments (Mather and Jinks, 1982). The average m value of seed yield per plant and number of pods per plant were observed significantly for 10.31 gm. and 19.78 pods, respectively. The d and h values were observed significantly, indicating that both additive and dominance gene actions were involved in the inheritance of these two traits. These similar results were reported by Alghamdi (2009) and Joshi et al., (2004). The effects of years (e_1), locations (e_2) and interaction of years with location (e_3) were statistically evident for seed yield per plant and number of pods per plant of Hondawase × Akatsukidainagon azuki bean cross. The interaction of additive with years (g_{d1}) and with years × locations (g_{d3}) of seed yield per plant, additive with years × locations (g_{d3}) and dominance with years (g_{h1}) of number of pods per plant were found significantly, indicating that both additive and dominance gene effects were involved obviously in controlling these two traits and were influenced greatly by the environmental variations. These results were supported by the works of Alghamdi (2009).

CONCLUSION

The work on generation mean analysis of seed yield per plant and number of pods per plant of azuki bean cross, Hondawase ? Akatsukidainagon, pointed out that both additive and dominance gene effects were influenced by environmental variations, suggesting that optimum environmental factors should be selected carefully for improving seed yield per plant and number of pods per plant of azuki bean.

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