Inheritance of Seed Yield in Azuki Bean [*Vigna angularis* (Willd.) Ohwi and Ohashi]

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ABSTRACT

Six crosses of azuki bean, viz. Kamuidainagon × Hondawase, Kamuidainagon × Akatsukidainagon, Kamuidainagon × Erimo, Hondawase × Akatsukidainagon, Hondawase × Erimo and Akatsukidainagon × Erimo were studied on the inheritance of seed yield per plant. The study was conducted under three highland conditions in the northern Thailand during August to November, 2005. Genetic analysis using generation means revealed significant difference among generations. Dominance effect (h) was found to be more significant than the additive effect (d) in most crosses at all locations. The epistatic interactions (i, j and l) also played significant roles in controlling the inheritance of this trait. Seed yield per plant was controlled by genes with significant in additive, dominance, and epistatic effects suggesting that an effective selection to improve this trait should be mild in earlier generations and intense in later generations.

Key words: Azuki bean, Gene effects, Generation mean analysis

INTRODUCTION

Azuki bean [*Vigna angularis* (Willd.) Ohwi and Ohashi] is mostly grown on highland areas in the northern Thailand. This crop is anticipated to be a good potential cash crop for highland farmers. Some progress was made to improve the yield of this crop through employing a new variety, “Pangda” by the Royal Project Foundation (Julsrigival et al., 2007). Yield stability assessment of genotypes was reported by Kunkaew et al., (2004).

Since seed yield of field crops is a complex character, direct selection for this trait is oftenly not effective. Selection for yield components, especially seed yield per plant has been widely used as a possible method for seed yield improvement. For selection to be effective, information on genetic parameters associated with inheritance of the character is a prerequite for planning a good sound-breeding programme.

Although, emphasis was put on the role of additive and dominance components in the inheritance of quantitative characters to formulate a breeding programme for improving a trait. However, a number of breeders (Hayman, 1958; Brim and Cockerham, 1961; Stuber and Moll, 1974) pointed the role of epistatic gene interactions in conditioning a character. Hill (1966) concluded that epistatic interaction, even at digenic or trigenic level, were also important in inheritance of quantitative traits. Since only limited studies have been reported on the inheritance of seed yield per plant in azuki bean, a study was designed to find the effect of altitudes which may affect the results of such genetic investigations. A generation mean analysis using six generations of six crosses was field-trialed to provide information on the relative significance of different types of gene action conditioning seed yield per plant at different highland environments. Breeding methodologies can then be formulated for the improvement of seed yield per plant to further increase seed yield in azuki bean in Thailand.

MATERIALS AND METHODS

The experimental materials were generated from six crosses, viz. Kamuidainagon × Hondawase (K × H), Kamuidainagon × Akatsukidainagon (K × A), Kamuidainagon × Erimo (K × E), Hondawase × Akatsukidainagon (H × A), Hondawase × Erimo (H × E) and Akatsukidainagon × Erimo (A × E). The parental lines were chosen primarily on the basis of their diversity in seed yield and yield components. Six populations viz. P_1, P_2, F_1, F_2, BC_1 and BC_2 were developed and evaluated in a randomized complete block design with four replicates in three locations with different altitudes, namely Inthanon (1,300 m above sea level, ASL), Khunpae (1,200 m ASL) and Pangda (700 m ASL). Six generations of each cross were randomly assigned to complete each block. The plots of various generations had different number of rows. Each F_1 and backcross generation is planted to a single row, while each parent had two rows and F_2 had three rows. Each row was 2 m long with a row-to-row distance of 50 cm. One seed was planted per hill with a spacing of 20 cm apart. The data were recorded on the seed yield of each plant in all six generations.

Standard statistical method was used to calculate mean and variance for each generation and in environment. The variance was used to calculate a standard error for each generation mean in each environment. The joint-scaling test and additive-dominance model were used to estimate the generation means as proposed by Mather and Jinks (1982). Six genetic parameters viz. m, d, h, i, j and l, representing mean, additive, dominance, additive × additive, additive × dominance and dominance × dominance gene actions were estimated using non-allelic interaction model according to Hayman (1958). With this model, it is assumed that the inheritance of the trait under study must present non-allelic interaction of genes.

The experiment was conducted on the highland area in Chiang Mai province, Thailand, during August to November, 2005.

RESULTS AND DISCUSSION

Generation mean and standard error analyses for seed yield per plant revealed significant difference among the six generation means, indicating the presence of genetic variability of this trait in the materials studied.

The joint-scaling test was used to estimate genetic parameters related to seed yield per plant assuming the presence of epistatic interaction. The value of A, B and C scales should not be different from zero as compare to their standard errors. The significance of any scale indicates the presence of non-allelic interaction of genes, revealing that the estimate of genetic parameters of the trait does not fit to the additive-dominance model.

Results of the joint-scaling test, as shown in Table 1, indicated that the crosses of K × H and H × A showed non-significant *t*-values at Inthanon and Khunpae stations. This revealed that the epistatic interaction of genes played a significant role in controlling the inheritance of seed yield per plant in azuki bean at these two locations. Both crosses showed significant *t*-value at only Pangda Station, indicating that the expression of gene interaction of seed yield per plant might be masked by environmental condition at this location. Thus, genetic variation among generations of these two crosses are quite limited. It should be pointed out that the other four crosses of azuki bean included, K × A, K × E, H × E and A × E which showed significant *t*-values of any scale-test in all three locations indicated that the additive-dominance model is not sufficient to explain the genetic inheritance of yield trait for these four crosses. In addition, it may be postulated that this trait is controlled largely by non-allelic interaction of genes and gene effects are expressed consistently to diverse environments.

The analysis of gene effects of seed yield per plant among the four inter-varietal crosses of azuki bean are presented in Table 2. The results indicated that F_2 population mean or mean effect (m) of each cross at all locations was significantly observed, revealed difference in this trait among the parents. The additive gene effect (d) was significant in the crosses K × A and A × E at Khunpae Station, while K × A, H × A and A × E; and K × H, K × E, H × E and A × E were significant at Inthanon and Pangda, respectively.

The dominance gene effect (h) was significant in all crosses and locations, except for K × A and A × E at Khunpae Station.

The epistatic interactions (i, j and l) revealed that additive × additive effect (i) was observed in K × A and H × E at Inthanon and in K × E and H × E at Khunpae, while all crosses except K × E at Pangda Station.

The additive × dominance effect (j) showed less number of significant crosses than in the i effect. The crosses A × E; K × A and A × E; and K × H, H × E and A × E were observed significantly at Inthanon, Khunpae and Pangda stations, respectively. Whereas dominance × dominance effect (l) is significant in most crosses, except K × E at Pangda Station. Only K × A and H × E at Inthanon and K × E and H × E at Khunpae stations showed significant l effect.

Table 1. Generation means and joint-scaling test of seed yield per plant in azuki bean crosses, grown at three highland locations in 2005 growing season.

Generations	K x H	K x A	K x E	H x A	H x E	A x E
Inthanon station						
P1 ± SE	8.52±0.43(47)c[1]	7.79±0.48(54)c	8.94±0.45(67)c	7.17±0.45(72)b	6.31±0.33(61)c	13.59±0.63(63)b
P2 ± SE	8.36±0.46(55)c	10.56±0.45(54)b	11.93±0.96(72)bc	12.16±0.63(75)a	9.62±0.48(56)c	10.61±0.52(66)b
F1 ± SE	18.62±1.51(5)a	14.37±1.27(6)a	24.45±1.99(20)a	11.88±0.96(28)a	20.05±1.47(6)ab	19.28±1.40(13)a
F2 ± SE	12.49±0.55(57)b	9.39±0.48(100)bc	13.59±0.94(100)bc	12.81±0.91(105)a	17.18±1.01(84)b	15.09±0.85(82)b
BC1 ± SE	12.91±1.15(10)b	11.46±1.00(16)b	17.20±1.61(23)b	11.54±1.18(22)a	22.64±1.85(12)a	12.50±1.79(6)b
BC2 ± SE	11.57±1.30(9)b	15.12±1.20(13)a	16.22±1.99(24)b	16.02±2.35(15)a	19.44±2.10(13)b	23.47±2.40(11)a
Joint-scaling test						
A ± SE	-1.32 ± 2.78	0.75 ± 2.41	1.01 ± 3.82	4.02 ± 2.58	18.92 ± 4.00**	-7.87 ± 3.89*
B ± SE	-3.84 ± 3.04	5.31 ± 2.75	-3.94 ± 4.55	8.00 ± 4.85	9.20 ± 4.48*	17.05 ± 5.04**
C ± SE	-4.16 ± 3.80	-9.53 ± 3.25**	-15.39 ± 5.56**	8.15 ± 4.19	12.69 ± 5.03*	-2.38 ± 4.49
Khunpae station						
P1 ± SE	16.13±0.86(54)ab	16.37±0.58(49)b	15.58±0.67(53)c	15.05±0.57(69)b	16.11±0.82(70)b	21.13±0.66(51)b
P2 ± SE	14.68±0.85(55)b	17.72±0.60(50)b	15.52±0.64(64)c	16.70±0.65(69)ab	16.56±0.61(63)b	16.98±0.56(63)b
F1 ± SE	19.68±1.94(15)a	18.51±1.73(8)b	27.42±1.60(13)a	18.29±1.25(19)a	22.74±2.06(10)a	24.27±2.09(15)b
F2 ± SE	16.24±0.89(94)ab	18.07±0.67(68)b	16.73±0.75(88)c	16.73±0.73(105)ab	19.51±0.97(94)ab	19.62±0.94(93)b
BC1 ± SE	18.35±1.56(17)ab	24.59±1.39(12)a	20.27±1.30(20)b	18.40±1.60(16)ab	28.21±1.91(18)a	19.78±2.01(11)b
BC2 ± SE	18.44±1.90(22)ab	15.00±1.41(14)b	22.75±1.42(23)b	19.26±1.85(13)a	22.68±2.53(11)a	28.32±2.94(9)a
Joint-scaling test						
A ± SE	0.89 ± 3.77	14.31 ± 3.33**	-2.45 ± 3.12	3.46 ± 3.48	17.57 ± 4.43**	-5.83 ± 4.58
B ± SE	2.52 ± 4.34	-6.24 ± 3.36	2.55 ± 3.32	3.53 ± 3.97	6.06 ± 5.50	15.39 ± 6.27*
C ± SE	-5.19 ± 5.40	1.17 ± 4.47	-19.01 ± 4.47**	-1.43 ± 3.95	-0.10 ± 5.75	-8.15 ± 5.70
Pangda station						
P1 ± SE	10.42±0.34(72)c	10.95±0.37(79)b	9.59±0.38(70)c	10.93±0.41(72)c	10.58±0.41(69)c	11.62±0.39(73)cd
P2 ± SE	10.82±0.32(69)c	11.88±0.40(70)b	8.42±0.42(57)c	12.52±0.45(67)bc	6.97±0.43(63)d	9.30±0.48(57)d
F1 ± SE	17.93±0.65(13)b	16.14±0.92(16)a	17.34±1.04(20)a	13.44±0.72(27)abc	14.60±0.77(20)ab	17.64±0.80(20)ab
F2 ± SE	11.39±0.39(113)c	11.82±0.39(101)b	12.56±0.50(106)b	12.03±0.48(113)bc	10.34±0.42(110)c	12.92±0.50(117)cd
BC1 ± SE	23.71±1.23(5)a	15.58±0.70(26)a	15.89±1.00(17)a	15.74±0.98(21)a	12.00±0.79(25)bc	20.70±1.43(10)a
BC2 ± SE	18.95±1.27(12)b	15.72±1.12(12)a	12.56±0.93(28)b	14.35±1.08(19)ab	15.35±1.16(12)a	15.04±1.26(17)bc
Joint-scaling test						
A ± SE	19.06 ± 2.56**	4.06 ± 1.71*	4.85 ± 2.29*	7.12 ± 2.13**	-1.18 ± 1.80	12.12 ± 3.00**
B ± SE	9.14 ± 2.64**	3.40 ± 2.46	-0.65 ± 2.18	2.74 ± 2.32	9.13 ± 2.48**	3.13 ± 2.69
C ± SE	-11.55 ± 2.09**	-7.82 ± 2.47**	-2.47 ± 2.95	-2.22 ± 2.49	-5.36 ± 2.37*	-4.51 ± 2.64

K = Kamuidainagon, H = Hondawase, A = Akatsukidainagon and E = Erimo variety In parenthesis, is the number of plant

[1] Means followed by the same letter are not significantly different based on Duncan's Multiple Range Test (*p*=0.05) SE is the standard error value

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

Table 2. Estimation of genetic effects of seed yield per plant in azuki bean crosses, grown at three highland locations in 2005 growing season.

parameters	K x H	K x A	K x E	H x A	H x E	A x E
Inthanon station						
m ± SE	8.37 ± 0.31**	9.39 ± 0.48**	16.50 ± 0.68**	9.88 ± 0.38**	17.18 ± 1.01**	16.39 ± 0.65**
d ± SE	0.12 ± 0.31	-1.84 ± 0.41**	-	-2.54 ± 0.38**	-	-10.97 ± 3.02**
h ± SE	8.72 ± 0.95**	20.78 ± 3.88**	13.39 ± 1.78**	3.37 ± 0.93**	27.51 ± 6.91**	7.65 ± 1.30**
i ± SE	-	15.59 ± 3.66**	-	-	15.43 ± 6.91*	-
j ± SE	-	-	-	-	-	-12.46 ± 3.03**
l ± SE	-	-21.66 ± 7.03**	-	-	-43.56± 12.28**	-
X^2 (df)	2.0063 (3)	0.1728 (1)	1.1500 (4)	7.1631 (3)	0.9319 (2)	0.5292 (2)
Probability	0.5711	0.6776	0.8862	0.0668	0.6275	0.7675
Khunpae station						
m ± SE	15.33 ± 0.58**	18.38 ± 0.47**	16.73 ± 0.75**	15.89 ± 0.42**	19.51 ± 0.97**	21.64 ± 1.29**
d ± SE	0.70 ± 0.59	9.59 ± 1.98**	-	-0.81 ± 0.43	-	-8.54 ± 3.56*
h ± SE	3.66 ± 1.50*	-	30.98 ± 4.89**	2.60 ± 1.09*	30.14 ± 7.46**	7.27 ± 4.88
i ± SE	-	-	19.10 ± 4.87**	-	23.73 ± 7.44**	1.55 ± 3.24
j ± SE	-	10.27 ± 2.02**	-	-	-	-10.61 ± 3.59**
l ± SE	-	-	-19.20 ± 8.90*	-	-47.36±13.94**	-
X2 (df)	2.2280 (3)	0.4346 (3)	0.1422 (2)	2.2583 (3)	0.6066 (2)	0.6401 (1)
Probability	0.5264	0.9330	0.9313	0.5205	0.7383	0.4236
Pangda station						
m ± SE	11.39 ± 0.39**	11.82 ± 0.39**	13.44 ± 0.36**	12.03 ± 0.48**	10.34 ± 0.42**	12.92 ± 0.50**
d ± SE	4.76 ± 1.77*	-	1.14 ± 0.35**	-	-3.35 ± 1.40*	5.66 ± 1.91**
h ± SE	47.06 ± 3.92**	20.01 ± 3.08**	8.51 ± 0.93**	13.80 ± 3.51**	19.14 ± 3.38**	26.95 ± 4.39**
i ± SE	39.76 ± 3.86**	15.28 ± 3.07**	-	12.09 ± 3.50**	13.32 ± 3.28**	19.77 ± 4.31**
j ± SE	4.96 ± 1.78**	-	-	-	-5.15 ± 1.43**	4.50 ± 1.93*
l ± SE	-67.96 ± 7.37**	-22.75 ± 5.84**	-	-21.95 ± 6.35**	-21.27 ± 6.09**	-35.02 ± 8.07**
X^2 (df)	-	0.0392 (2)	0.3952 (3)	0.1729 (2)	-	-
Probability	-	0.9805	0.9412	0.9171	-	-

K = Kamuidainagon, H = Hondawase, A = Akatsukidainagon and E = Erimo variety
SE is the standard error value
*, ** Significant at the $P<0.05$ and $P<0.01$, respectively

The over all estimation of genetic effects in this study showed that dominance effect (h) is generally much larger than additive effect (d) for seed yield per plant of azuki bean in most crosses in all locations. Similar results were reported in soybean (Kunta et al., 1997), azuki bean (Kunkaew et al., 2007) and in peanut (Jogloy et al., 1999) that dominance gene effects were always greater than additive gene effects if two diverse parents were crossed. In addition, epistatic interaction of additive × additive (i) as well as additive × dominance (j) and dominance × dominance (l) were integral components of the genetic formation of this trait. Hence, estimation and consideration of this gene effect component are important for the formation of azuki bean breeding programme. Consequently the magnitude of interaction of non-fixable gene effects were greater than the fixable ones, indicating that non-additive gene effects played the major role in controlling the trait. Such a condition, successful breeding methods will be those that accumulate the genes to form a specific genotype interacting in a favorable manner. A possible breeding programme is to do a bi-parental or multiparental mating followed by selection until desirable genotypes are observed. These breeding strategies are useful for exploitation of both fixable and non-fixable types of gene-action were recommended by many breeders (Hayman, 1958; Allard, 1960; Falconer, 1989; Kearsey and Pooni, 1996). This study also further demonstrated that the inheritance of seed yield per plant of azuki bean is quite affected by environmental factors, suggesting that an appropriate choice of the environments should be considered for improving this trait.

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REFERENCES

Allard, R. W. 1960. Principle of plant breeding. John Wiley & Sons, New York.

Brim, A. C., and C. C. Cockerham, 1961. Inheritance of quantitative character in soybean. Crop Sci. 1:187-190.

Falconer, D. S. 1989. Introduction to quantitative genetics, 3rd edition, Longman, UK.

Hayman, B. I. 1958. The separation of epistatic from additive and dominance variation in generation mean. Heredity 12:371-390.

Hill, J. 1966. Recurrent backcrossing in the study of quantitative inheritance. Heredity 21:85-120.

Jogloy, S., V. Pensuk, A. Patanothai, and S. Wongkaew. 1999. Generation mean analysis of late leafspot and rust resistance in peanut (*Arachis hypogaea* L.). Thai J. Agric. Sci. 32(3):423-433.

Julsrigival, S., S. Smutkupt, V. Sriwatanapong, W. Kunkaew, and V. Punsupa. 2007. Pangda azuki bean variety. Royal Project Journal 11(2):3-9.

Kearsey, M. J., and H. S. Pooni. 1996. The genetical analysis of quantitative traits. Chapman & Hall, London, UK.

Kunkaew, W., S. Julsrigival, N. Boonkaew, V. Punsupa, and K. F. Chen. 2004. Yield stability of azuki bean grow under highland conditions. Royal Project Journal 8(5):6-9.

Kunkaew, W., S. Julsrigival, C. Senthong, and D. Karladee. 2007. Combining ability analysis of yield and yield components in azuki bean under highland conditions of northern Thailand. CMU. J. Nat. Sci. 6(1):121-126.

Kunta, T., L.H. Edwards, and K.R. Keim. 1997. Heterosis, inbreeding depression and combining ability in soybean (*Glycine max* L.). Sabrao Journal 29(1): 21-32.

Mather, S. K., and J. L. Jinks. 1982. Biometrical genetics. Chapman & Hall, London, UK.

Stuber, C. W., and R. H. Moll. 1974. Epistasis in maize (*Zea mays* L.). Crosses among lines selected for superior inter-variety single cross performance. Crop Sci. 14:314-317.