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The Efficiency of Pedigree and Single Seed Descent Selections for Yield Improvement at Generation 4 (F_4) of Two Yardlong Bean Populations

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ABSTRACT

The efficiency of the selection procedure during succeeding generations is the most important role of any breeding program. There are many selection methods, but no method is perfect for general use with all crop plants. Breeders must carefully consider which method will be the most effective for their purposes. This study was conducted to compare the effectiveness between the pedigree selection (PS) and single seed descent (SSD) methods in two yardlong bean crosses. Both procedures started from the same F_2 population in each cross. In 2004, 15 F_4 progenies were selected by each selection method from each population. Thirty F_4 progenies and the parents of each population were tested in separate experiments with two check cultivars at the Songkhla Field Crop Research Station, Songkhla Province. Selected-PSU and VU135 were grown as check yardlong bean cultivars. Narrow sense heritability (h^2) for the pod yield and yield components were estimated through regression analysis of the F_4 progenies on F_3 parental plants. Correlations among yield and yield components were also estimated. The results showed that the mean pod yield and yield components of selected F_4 progenies derived from both PS and SSD were not significantly different in both the 4501 and 4502 populations. Low heritability for pod yield per plant was found in both the 4501 and 4502 populations at 4.62 and 2.96%, respectively, which indicated why selection for yield improvement in early generations had been ineffective. The highest positive correlation was found between the number of pods per plant and pod yield in both the 4501 and 4502 populations, with correlation coefficients of 0.7540 and 0.9229 ($p<0.01$), respectively. This study shows that PS and SSD are equally effective for yield improvement in yardlong bean.

Keywords: pedigree selection, single seed descent, heritability, yardlong bean

INTRODUCTION

Cultivar improvement in self-pollinated species, such as yardlong bean, is accomplished by inducing genetic variability and then selectively recombining desirable genotypes. Selection is a process based on selecting individuals or groups of plants during suitable generations by inbreeding to increase homozygosity. There are many methods of selection, and breeders need to consider carefully which method will be most effective for their purposes. The efficiency of

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selection depends not only on the selection method, but also on the heritability of different characters in different species. There have been many reports on the effectiveness of different selection approaches for improvement in different crops. The most commonly used selection methods are PS, SSD and the bulk method (BM). PS is well known and its success in creatively improving many cultivars has been widely acclaimed. However, Padi and Ehlers (2008) reported that the PS method for grain yield in cowpea was ineffective. De Pauw and Shebeski (1973) and Inakaki *et al*. (1998) have also pointed out that single-plant selection in early generations is ineffective for certain quantitative traits, such as yield in wheat (*Triticum aestivum* L.). The same limitation has been confirmed in barley (*Hordeum vulgare* L.) (Hanson *et al*., 1979). Simmonds (1979) reported that PS was effective in early generations only for traits with high heritability, such as grain size. In contrast, many groups of researchers have reported successful individual selection for yield in F_2 populations in various plant species, such as durum wheat (Michell *et al*., 1982), spring wheat (Lungu *et al*., 1987) and faba bean (Roupakias *et al*., 1997) and cotton (Batzios, 1997). By contrast, Sakai (1951) and Nakai (1962) have also suggested that rigorous PS in early generations might result in the loss of desirable genotypes, leading to the possibility that in some situations, BM might be preferable to PS. In related research, no significant difference was found between selection methods for yield in blackgram (Arshad, 2004), soybean (Boerma and Cooper, 1975), wheat (Knott and Kumar, 1975) and mungbean (Gill *et al*., 1995). One advantage of the SSD method is the reduced requirement for land needed to segregate generations. The plants can be grown in dense populations and larger numbers can be kept under controlled conditions to speed up the generation time, since no selection is made until homozygosity has been achieved. Haddad and Muehlbauer (1981) studied three lentil (*Lens culinaris*) populations and reported that the SSD method was an efficient and cost-saving method for advancing lentil populations and recommended it for lentil breeding. Ntare *et al.* (1984) compared selection methods, including PS, SSD and BM, in two crosses of cowpea and concluded that the grain yields of lines derived by the SSD procedure were as good as those derived from early selection.

The objectives of this study were to compare the efficiency of two selection methods (PS and SSD) for yield and yield components in two yardlong bean populations in the F_4 generation and to estimate the correlation coefficients among yield and yield components.

MATERIALS AND METHODS

Yardlong bean, which is grown in Southern Thailand, produces a relatively low pod yield because of unfavorable environmental conditions, such as heavy rainfall. Therefore, it is desirable to improve new varieties with high adaptability to such unfavorable environmental conditions. Thirty-seven yardlong bean and cowpea accessions were tested in the field in Songkhla province in 2002 (Sarutayophat, 2007). Based on the field tests, VU162 was the best among the southern accessions and was expected to be the most suitable female parent. It exhibited vigorous indeterminate growth with relatively high pod yield and high consuming qualities. VU189 was the elite line from China, with determinate growth and a vigorous peduncle that produced consecutive well-developed pods with high consuming qualities. VU171 (known as Green Arrow 692) was one of the most popular among Thai farmers; it was indeterminate, produced high pod yield and had the highest consuming qualities immature pod. Based on the field tests and genetic relatedness realized by RAPD markers (Sarutayophat, 2007), VU189 and VU171 were expected to be the most suitable male parents. Two crosses of yardlong bean (VU 162 × VU 189 and VU 162 × VU 171) were made. The F_1 plants from each cross were allowed to self-pollinate to produce F_2 seeds. The F_2 populations of the two crosses, cross 4501 (VU162 × VU189) and cross 4502 (VU162 × VU171), were used as segregated material by two selection methods, PS and SSD. The procedure used for each method is illustrated in Figure 1. In the pedigree method, 15 desirable individuals among 800 F_2 plants of each population were selected based on visual criteria and the F_3 seeds were collected separately. Fifteen F_3 progenies were planted in separate rows. Fifteen desirable F_3 plants were selected between and within rows and the F_4 seeds from each F_3 plant were collected separately.

In the SSD procedure, one seed from all 800 F_2 plants was individually harvested from each population. A separate reserve single seed of F_3 was harvested for four sets, with one for the yield test and the other three for unexpected failures during the selection procedure. Then 800 F_3 seeds were planted, with 15 desirable F_3 plants selected based on visual criteria and all F_4 seeds from each F_3 plant were collected separately. A total of 30 F_4 lines, made up of 15 from each of the two selection methods, were grown for yield, which was tested separately in each population with parents and two check cultivars (selected-PSU and VU135). During 2004, yield trails were conducted at the Songkhla Field Crop Research Station, Songkhla province. A randomized complete block design (RCBD) with three replications was used. Narrow sense heritability was estimated by the regression analysis of F_4 progenies on the F_3 parental plants. Correlation coefficients between yield and yield components were estimated among the 30 F_4 progenies of each population.

RESULTS AND DISCUSSION

Pod yield and yield components of F_4 progenies from SSD and PS methods

Mean pod yield of the F_4 progenies derived by SSD and PS was not significantly different in both populations (Table 1). In the 4501 population (VU 162 × VU 189), the SSD progenies produced a non-significantly higher pod yield than the PS progenies (328.8 and 298.0 g/plant, respectively), while the SSD and PS progenies from the 4502 population (VU 162 × VU 171) produced almost the same yield (366.3 and 368.3 g/plant, respectively). In the 4501 population, the best SSD progeny produced a non-significantly

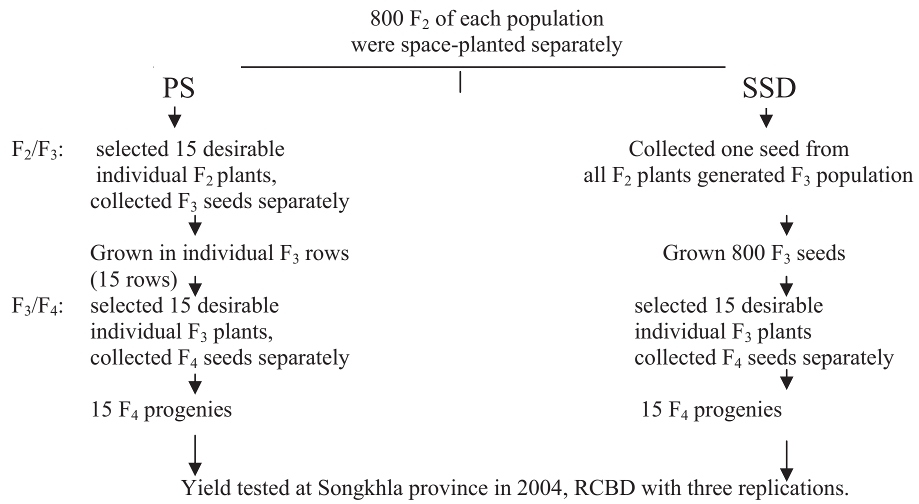

Figure 1 Diagrammatic illustration of PS and SSD for each yardlong bean population.

higher pod yield than the best PS progeny (470.30 and 354.20 g/plant, respectively) (Table 2). Table 3 shows that the best PS progeny in the 4502 population produced a slightly higher pod yield than the SSD (503.53 and 445.03 g/plant, respectively). However, in both populations there was no significant difference in pod yield between the SSD and PS methods. The pod yield and number of selected lines from the F_4 progenies in both populations are presented in Figure 2. The

Table 1 Mean pod yield and yield components of F_4 progenies derived by SSD and PS from two yardlong bean populations.

Population	Selection method	Pod yield (g/plant)	No.of pods/ plant	Pod wt. (g./pod)	No. of inflorescences/plant	Pod diameter (cm)	Pod length (cm)
4501	SSD	328.8	20.7 a	16.1 ab	15.7 a	0.75 bc	44.4 c
	PS	298.0	17.4 b	17.1 ab	14.8 a	0.75 bc	46.3 bc
	Mean parent	262.3	17.7 b	13.7 b	12.2 b	0.72 d	43.7 c
	National check	278.2	14.6 c	18.8 a	14.8 a	0.79 a	50.0 ab
	Local check	299.0	15.3 c	19.5 a	12.2 b	0.77 ab	50.9 a
	F. test	ns	**	*	*	**	*
	C.V. (%)	12.6	6.1	11.2	9.1	1.6	4.6
4502	Mean (SSD)	366.3	18.1 ab	20.1	15.1	0.77	48.8
	Mean (PS)	368.3	18.9 a	19.1	15.1	0.76	48.9
	Mean parent	260.0	12.5 c	20.9	13.6	0.74	47.0
	National check	278.2	14.6 bc	18.8	14.8	0.79	49.4
	Local check	299.0	15.3 abc	19.5	12.2	0.77	50.9
	F. test	ns	*	ns	ns	ns	ns
	C.V. (%)	15.4	13.1	10.0	10.0	2.4	3.6

Note: Means within the same column followed by different letter(s) indicates significant differences between treatments by Duncan's multiple range test (DMRT).

ns = non significant difference.

* = significant at p<0.05.

** = significant at p<0.01.

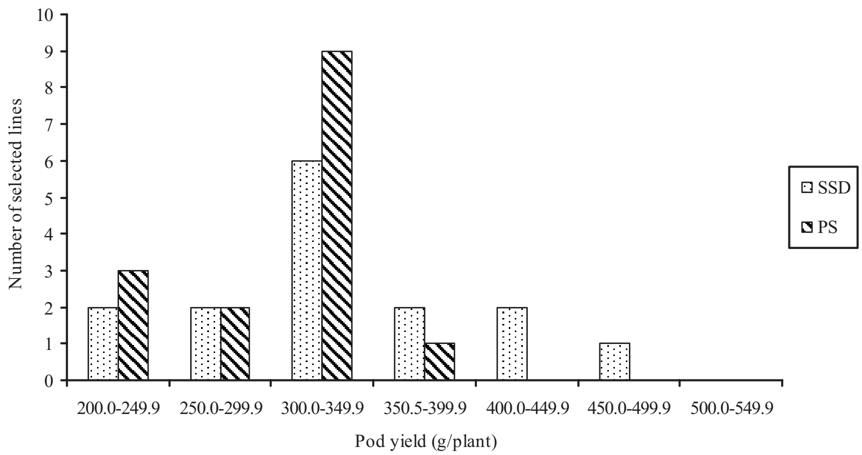

Figure 2 Pod yield (g/plant) of F_4 progenies derived by PS and SSD from the 4501 population.

results from the present study found that selecting lines from early generations for pod yield was ineffective in yardlong bean, as has been previously reported in wheat (De Pauw and Shebeski, 1973; Inagaki *et al*., 1998), barley (Hanson *et al*., 1979), mungbean (Gill *et al*., 1995), linseed (Salas and Friedt, 1995) and rice (Nagai, 1962). In the 4501 population, the best progenies

Table 2 Mean of pod yield and five yield components of F_4 yardlong bean progenies derived by PS and SSD from the 4501 population.

Progeny/selection method	Pod yield (g/plant)	No. of pods/ plant	Pod wt. (g./pod)	No. of inflor-escences/plant	Pod diameter (cm)	Pod length (cm)
1 Best (SSD)	470.30 a	27.93 a	17.20 ab	17.40	0.77	47.60
2 Best (PS)	354.20 ab	23.97 ab	17.80 ab	17.50	0.77	49.87
3 Mean 3top (SSD)	430.47 ab	26.20 a	17.50 ab	17.10	0.77	47.37
4 Mean 3top (PS)	341.77 bc	20.82 abc	18.30 ab	16.40	0.76	49.57
5 Mean all 15 F_4 (SSD)	328.77 bc	20.67 abc	16.10 b	15.70	0.75	44.37
6 Mean all 15 F_4 (PS)	297.93 c	17.43 bc	17.10 ab	14.83	0.75	46.27
7 Mean parents	262.27 c	17.73 bc	13.70 b	12.23	0.72	43.67
8 National check	278.20 c	14.60 c	18.80 ab	14.77	0.79	49.43
9 Local check	299.03 c	15.30 c	19.50 a	12.20	0.77	50.86
F-test	*	**	*	ns	ns	ns
C.V. (%)	14.6	21.3	9.4	9.3	1.6	4.9

Note: Means within the same column followed by different letter(s) indicate significant differences between treatments by DMRT.
ns = non-significant difference.
* = significant at p< 0.05.
** = significant at p< 0.01.

Table 3 Mean pod yield and five yield components of F_4 yardlong bean progenies derived by PS and SSD from the 4502 population.

Progenies/selection method	Pod yield (g/plant)	No. of pods/ plant	Pod wt. (g./pod)	No. of inflor-escences/plant	Pod diameter (cm)	Pod length (cm)
1 Best (SSD)	445.03 ab	22.63 bc	19.7	16.80	0.80	52.50
2 Best (PS)	503.53 a	28.10 a	18.0	16.53	0.78	52.70
3 Mean 3top (SSD)	442.10 ab	21.50 bc	20.5	16.43	0.78	52.20
4 Mean 3top (PS)	447.33 ab	23.73 b	19.4	16.43	0.77	52.10
5 Mean all 15 F_4 (SSD)	366.30 bc	18.13 d	20.1	15.10	0.77	48.76
6 Mean all 15 F_4 (PS)	368.33 bc	18.87 cd	19.1	15.07	0.76	48.90
7 Mean parents	259.95 d	12.47 e	20.9	13.60	0.74	47.03
8 National check	278.20 cd	14.60 de	18.8	14.77	0.79	49.43
9 Local check	299.03 cd	15.30 de	19.5	12.20	0.77	50.86
F-test	*	*	Ns	ns	ns	ns
C.V. (%)	15.5	13.4	7.0	13.5	2.6	6.2

Note: Means within the same column followed by different letter(s) indicate significant differences between treatments by DMRT.
ns = non-significant difference.
* = significant at p< 0.05.
** = significant at p< 0.01.

from the two selection methods and the three top progenies from SSD of the 4501 population produced significantly ($p<0.05$) higher pod yields than the mean parental and two check cultivars (Table 2). Whereas in the 4502 population, the best and the three top progenies of both selection methods produced significantly ($p<0.05$) higher pod yields than the mean parental and two check cultivars (Table 3).

For yield components, significant differences were found in almost all characters in the 4501 population, notably the number of pods/plant, pod weight, pod length, pod diameter and the number of inflorescence/plant. The F_4 progenies from the SSD method had a higher number of pods/plant than from the PS method, while only the number of pods/plant between PS, SSD and mean parents were significantly different (Table 1). There was limited segegration among the 4502 progenies, because the male and female parents of the 4502 progenies were similar in almost all characteristics. The best SSD progeny also produced a non-significantly higher number of pods/plant than the best PS (27.93 and 23.97 pods/plant, respectively) (Table 2), while the best PS progeny in the 4502 population produced significantly ($p<0.05$) higher pods/plant than the best SSD (28.10 and 22.63 pods/plant, respectively) (Table 3). The mean number of inflorescence/plant, pod diameter and pod length of F_4 progenies of both methods, mean parents and check cultivars were non-significantly different in both populations (Tables 2, 3). The results were similar to those previously reported in cowpea (Padi and Ehlers, 2008), where the selection for yield components in an early generation was ineffective. Inca and Inca-LD are two yardlong bean cultivars created through SSD (Ponce and Casanova, 1999). Gill *et al.* (1995) reported that the SSD method for mungbean was preferable to PS and BM because of the shorter time required and the greater cost effectiveness in handling segregation of generations. The same recommendation and reasons were given for wheat by Oeveren (1992). In contrast, PS was found to be superior to SSD for seed size of greengram (*Vigna radiata* L.) (Dahiya and Singh, 1986). Several cultivars of cowpea, a very closely related subspecies of yardlong bean, have previously been derived by the PS method, such as Mouride, Melakk and Ein El Gazal (Singh *et al.*, 2003). The success of PS is based on the number of plants to be selected for segregation and the traits of interest should be highly heritable and predominantly controlled by an additive gene.

Heritability

Heritability for selected traits was quite low. For example, pod yield in the 4501 and 4502 populations was 4.62 and 2.96%, respectively (Table 4). The same findings were reported by Santhadphanich (1987), who found that heritability

Table 4 Heritability (h^2) in the narrow sense for pod yield and five yield components in two yardlong bean populations.

Traits	Heritability (%)	
	4501 population	4502 population
Regression of F_4 progenies on F_3 parents		
Pod yield	4.62	2.96
Pod weight	18.48	7.88
No. of pod/plant	18.43	12.93
No. of inflorescences/plant	0.13	1.47
Pod diameter	38.21	0.06
Pod length	39.13	0.01

in the broad sense for pod yield varied from 4.03 to 25.30%. Low estimated heritability may be due to a relatively low genetic diversity among cultivated yardlong beans. In contrast, Pornsuriya (1994) estimated the heritability from three yardlong bean populations and reported a highest narrow sense heritability for pod yield of 66%. Heritability was quite high in his study because his estimation used the variance, so environmental interactions were confounded with the genetic variance. Table 4 shows that the heritability of pod diameter and pod length of the 4501 and 4502 populations were very different (38.21 and 39.13% in 4501and 0.06 and 0.01% in the 4502 population). The pod characteristics of the parents of the 4502 population were quite similar, while those of the 4501 population were different (Sarutayophat, 2007). It has been reported that pedigree was the most effective selection method when heritability was high (75%) or moderate (50%). With heritability around 10%, SSD without prior selection would be the preferred method (Tigchelaar and Casali, 1976).

Correlation coefficient

The highest positive correlation was found between pod number per plant and pod yield in both the 4501 and 4502 populations, with correlation coefficients (r) of 0.7540 and 0.9229, respectively, which were both highly significant at p< 0.01 (Table 5). In the 4501 population, pod weight was significantly positively correlated to pod diameter with a correlation coefficient of 0.5211, significant at p< 0.01. Based on the low heritability for yield, a number of breeders have used other traits that are related to yield and express high heritability for indirect selection (Singh *et al.*, 2003). The results from the current study showed that pod number/plant had a highly significant positive correlation with pod yield in both populations; however, pod number/plant has low heritability (18.48% in the 4501 population and 12.93% in the 4502 population). The low heritability found in the current study confirmed low genetic diversity among cultivated yardlong beans. A higher estimation of heritability was found in other characters, such as pod length and

Table 5 Correlation coefficients among pod yield and yield components of F_4 progenies of 4501 and 4502 populations.

Population	Traits	Pod weight g./pod)	No. of inflor-escences/ plant	No. of pods/plant	Pod diameter	Pod length	Pod yield
4501	Pod weight	1.0000	0.0389	-0.4839	0.5211*	0.3546	0.1913
	No. inflorescences/plant		1.0000	0.3727	-0.0453	-0.0306	0.4438
	No. podss/plant			1.0000	-0.3645	-0.02334	0.7540**
	Pod diameter				1.0000	0.2681	0.0961
	Pod length					1.0000	0.0301
4502	Pod weight	1.0000	0.0368	-0.2563	0.3529	0.1628	0.1247
	No. inflorescences/plant		1.0000	0.1959	0.0353	-0.3118	0.1914
	No. pods/plant			1.0000	0.2114	0.2874	0.9229**
	Pod diameter				1.0000	0.3405	0.3626
	Pod length					1.0000	0.3488

* = significant at p<0.05.
** = significant at p< 0.01.

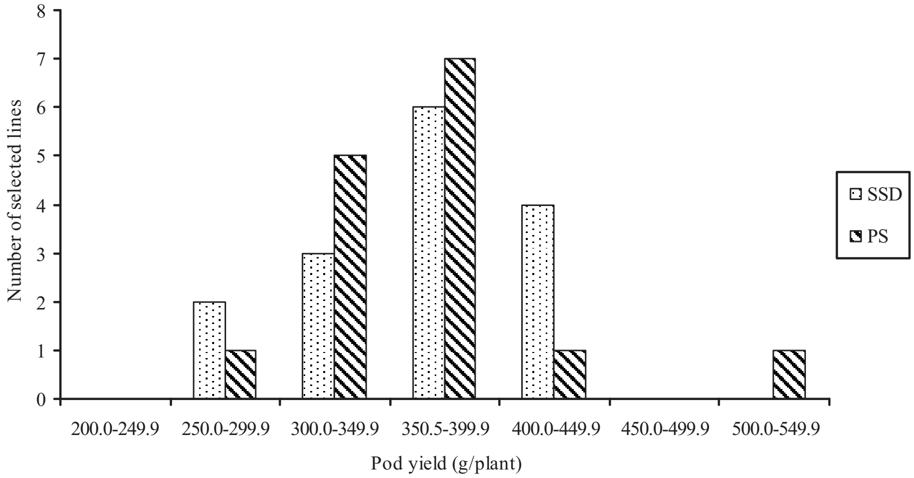

Figure 3 Pod yield (g/plant) of F_4 progenies derived by PS and SSD from the 4502 population.

pod diameter in the 4501 population. In faba bean, Sinhu *et al*. (1986) reported that the efficiency of selection had been improved by up to 30% by some combinations of characters. In order to obtain a good choice of characters for indirect selection, the correlation and path coefficient must be analyzed (Ranalli and Cubero, 1997).

CONCLUSION

Comparative efficiency between selection methods has been studied in various species. However, to date, this has not been studied in yardlong bean. The current study found that for the PS and SSD selection methods, pod yield and yield components in two yardlong bean populations were not significantly different. Heritability in the narrow sense for pod yield in the 4501 and 4502 populations was low with a value of 4.62 and 2.96%, respectively, which explained why selection for yield improvement had been ineffective. However, the best, and the three top F_4 progenies of both populations derived by PS and SSD produced higher pod yields than the mean parent and check cultivars.

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