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PHENOTYPIC EVALUATION OF FIFTEEN *GLYCINE MAX* (L.) MERRILL (VEGETABLE SOYBEAN) VARIETIES UNDER MINERAL AND BRIS SOILS OF MALAYSIA

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Abstract

Glycine max (L.) Merrill (vegetable soybean) is an important vegetable mainly among the Asian community. It is mainly consumed by human as a highly nutritious and savory snack. Instead of having a relatively higher protein and lower oil contents, it is also has a sweet and better tasting. Thus, this study aims to investigate the phenotypic characteristics of fifteen varieties of Glycine max (L.) Merrill developed by the Asian Vegetable Research and Development Center (AVRDC), Taiwan in order to select the potential varieties to be planted under Malaysian environments. The fifteen varieties were planted under mineral and bris soils at International Islamic University Malaysia (IIUM) Kuantan, Pahang. Eight phenotypic traits included the seed numbers per plant, the pod numbers per plant, the weight of fifteen seeds per plant, the days to emergence per plant, the days to flowering per plant, the plants height per plant, the pods width per plant and the pods length per plant were measured. Selection of potential varieties were mainly done by determining the yielding characteristics. Among these eight morpho-agronomic characteristics, the seed numbers per plant is the main yield determinant while, the other characteristics would be useful for future breeding programs. From the observation, Variety 4 (AGS429) obtained the highest seed numbers per plant (81 seeds) under mineral soil and Variety 1 (AGS 190) produced the highest seed numbers per plant (91 seeds) under bris soil, thus having the promising higher yielding ability to be selected as a potential vegetable soybean varieties to be planted under Malaysian conditions.

Keywords: Glycine max (L.) Merrill, phenotypic evaluation, yield and yield components, mineral and bris soils

1.0 INTRODUCTION

Soybean is rich in nutrient contents and it is valuable to human health. Apart from composing of 40% protein, 35% carbohydrate, 20% oil and 5% ash (vitamins and minerals) on a dry-weight basis, soybean comprises as much as 3 mg/g dry weight of isoflavone content, allowing it to acquire functional food status [1, 2]. The well-publicized beneficial effects of soybean on diet and health, enable it to create market potential worldwide. In Asia, especially China, Japan, Taiwan and Korea, *Glycine max* (L.) Merrill (vegetable soybean) is an important vegetable [3]. It is a specialty soybean grown as an edible version because it has better tasting. It is harvested as a vegetable when the seeds are immature. While the conventional grain soybean will be turned into oil or animal feed, vegetable soybean is consumed by human mainly as a snack. Immature green soybean pods are soft in texture and can be cooked just like lima beans, sweet peas or chickpeas while its green seeds can be boiled in salt water, added to soup and stews or roasted like peanut seeds [2, 4]. However, its consumption is not popular in Malaysia. It is only available at the Japanese concept restaurants. This is mainly because it is an imported food, and thus more expensive. In Malaysia, *Glycine max* (L.) Merrill has the opportunity to be a great crop. The high protein and low oil contents of vegetable soybean make it attractive particularly to the health conscious people. Thus, this study was conducted in order to introduce a new highly nutritive snack in the diet of Malaysian consumers and new high value vegetable types in this country.

2.0 EXPERIMENTAL

Fifteen *Glycine max* (L.) Merrill varieties (V1: AGS190, V2: AGS292, V3: AGS346, V4: AGS429, V5: AGS430, V6: AGS432, V7: AGS440, V8: AGS461, V9: AGS464, V10: AGS465, V11: AGS466, V12: AGS469, V13: AGS470, V14: AGS471 and V15: AGS472) that were developed at AVRDC, Taiwan were introduced to Malaysia for varietal evaluation. The study was conducted from November 2014 until January 2015 at IIUM Kuantan, Pahang. Climatic conditions of the study site were determined based on weather data recorded by Malaysian Meteorological Department.

One seed was directly grown in poly bags containing mineral or bris soils. Dried cow dung at the ratio of 1:3 was incorporated with the bris soil as a soil amendment to increase its fertility. The vegetable soybean varieties were planted in a Randomized Complete Block Design (RCBD) with three replications. NPK Blue Fertilizer at the rate of 300kg/ha was applied three times (first, second and third months) during the crop cycle.

Varietal characteristics of fifteen varieties were recorded including the color of flower, seed coat, pod and pubescence and the shape of leaflet and seed. In addition, eight morpho-agronomic traits were measured during harvesting: (i) the seed numbers per plant (total number of marketable seeds available in all pods for each plant), (ii) the pod numbers per plant (total number of marketable pods presented for each plant), (iii) the weight of fifteen seeds per plant (the weight of randomly selected fifteen marketable seeds for each plant), (iv) the days to emergence per plant (day of sowing to the day each seed emerged from the soil), (v) the days to flowering per plant (day of sowing to the day each plant initiated first flower), (vi) the plants height per plant (height of the main stem for each plant from the ground level to the top of the main stem at the time of harvesting), (vii) the pods width per plant (width of randomly chosen five 2-seeded pods for each plant) and (viii) the pods length per plant (length of randomly chosen five 2-seeded pods for each plant). Harvesting started when the plants reached R6 developmental stage where the plants were ninety days old, the pods were green and the beans have just began to touch each other in the pod [4]. However, this stage was determined by using a combination of the published day information [4] and visual examination of pods.

The morpho-agronomic data except for the seed numbers per plant were statistically analyzed using IBM SPSS Statistics 20 Software. Univariate General Linear Model (GLM) was performed to determine the interaction of replications under RCBD towards each data per soil type and One-way Analysis of Variance (ANOVA) was performed to compare means of varieties for each data per soil type. Means were compared by the Duncan's Multiple Range Test at the probability of $P<0.05$. The mean of the seed numbers per plant was determined by adding all marketable seeds from all harvested plants and then averaged.

3.0 RESULTS AND DISCUSSION

3.1 Climatic Condition

The study was conducted during the North-East Monsoon. On December 2014, Kuantan received heavy rainfall almost every day. However, on November 2014 (beginning of North-East Monsoon) and January 2015 (final phase of North-East Monsoon), Kuantan received both sunlight and rainfall. Based on the records of Principal Meteorological Stations in Peninsular Malaysia, the highest total rainfall volume was recorded at Kuantan Meteorological Station (1806.0 mm) in December 2014 [5].

3.2 Varietal Characteristics

The physical characteristics of fifteen *Glycine max* (L.) Merrill varieties were presented in Table 1. The bilateral symmetry flowers of V1, V2 and V4 were purple in color while the others were white. The seed coats color varied between varieties which were yellow (V1, V2 and V8), light green (V3, V4, V5, V6, V7, V12, V14 and V15), brown (V9, V10 and V13) and black (V11). All harvested pods of fifteen varieties had green color with different pubescence color whereby V7 and V11 were tawny, V9, V10 and V13 were light tawny and the others were white. The trifoliate leaves of all varieties had intermediate-shaped leaflets and their seeds were spherical. Immature green vegetable soybean seeds of V8, V9, V10, V11, V12, V13, V14 and V15 had basmati flavor while the others did not.

Table 1 Varietal characteristics of fifteen *Glycine max* (L.) Merrill varieties

Variety	Color				Shape		Special attribute
	Flower	Seed coat	Pod	Pubescence	Leaflet	Seed	
V1	Purple	Yellow	Green	White	Intermediate	Spherical	-
V2	Purple	Yellow	Green	White	Intermediate	Spherical	-
V3	White	Light green	Green	White	Intermediate	Spherical	-
V4	Purple	Light green	Green	White	Intermediate	Spherical	-
V5	White	Light green	Green	White	Intermediate	Spherical	-
V6	White	Light green	Green	White	Intermediate	Spherical	-
V7	White	Light green	Green	Tawny	Intermediate	Spherical	-
V8	White	Yellow	Green	White	Intermediate	Spherical	Basmati flavor
V9	White	Brown	Green	Light tawny	Intermediate	Spherical	Basmati flavor
V10	White	Brown	Green	Light tawny	Intermediate	Spherical	Basmati flavor
V11	White	Black	Green	Tawny	Intermediate	Spherical	Basmati flavor
V12	White	Light green	Green	White	Intermediate	Spherical	Basmati flavor
V13	White	Brown	Green	Light tawny	Intermediate	Spherical	Basmati flavor
V14	White	Light green	Green	White	Intermediate	Spherical	Basmati flavor
V15	White	Light green	Green	White	Intermediate	Spherical	Basmati flavor

The leaves of soybean had either broad, intermediate or narrow leaflets. Ratio of leaflet width to leaflet length determines the differences in phenotypic expression of leaflet types. A value of 0.47 and 0.65 were used as a border lines to distinguish between narrow and intermediate leaflets types and intermediate and broad leaflets types, respectively [6]. A single gene, *ln*, controls the inheritance of narrow leaflet phenotype [6]. The soybean plants with heterozygous condition (intermediate leaflet, *Ln*/*ln*) expressed superior performance for plant yield than plants with either broad (*Ln*/*Ln*) or narrow (*ln*/*ln*) leaflets. Intermediate leaflet plants produced more pod numbers than broad or narrow leaflets plants [6]. All varieties had intermediate-typed leaflets which width to length ratio of leaflets ranged from 0.49 – 0.65 and 0.51 – 0.65 for mineral and bris soils, respectively.

Special feature of some varieties is by having basmati flavor. It is one of the successful project done by AVRDC in improving the quality and marketability of vegetable soybean. Similar with grain soybean, vegetable soybean has a beany savor. A taste-test conducted in India concluded that South Asians generally dislike the beany taste of vegetable soybean. Since it is consumed freshly by consumers as opposed to being dried or used for oil, AVRDC strived to produce varieties with a basmati flavor (like the fragrant rice) to increase consumers acceptability and global marketability [7].

3.3 Morpho-agronomic Characteristics Evaluation

The phenotypic evaluation was done mainly on morpho-agronomic characteristics as they could help to identify the potential of some varieties for the production of vegetable in the diet of Malaysian consumers as well as to provide valuable varieties performances information for further improvement of vegetable soybean in Malaysia. The results from Univariate GLM analysis showed that replications under RCBD were not different from one another on all morpho-agronomic characteristics (there was no significant replications effect) for each soil type. Thus, the interaction of replications under RCBD towards each data was not discussed. The results of One-way ANOVA analysis showed that there were significant differences among varieties in morpho-agronomic data for each soil type ($P<0.05$). Means comparison of fifteen *Glycine max* (L.) Merrill varieties were presented in Table 2 and Table 3 for mineral and bris soils, respectively.

The results showed that seed numbers per plant ranged from 36.50 (V8) - 81.17 (V4) and 36.17 (V10) - 91.17 (V1) for mineral and bris soils, respectively. Pod numbers per plant ranged from 19.33 (V8) - 50.83 (V13) for mineral soil and 25.17 (V10) - 53.83 (V1) for bris soil. The fifteen random seeds weight per plant ranged from 8.70 (V1) - 15.99 (V7) g for mineral soil and 7.47 (V1) - 15.42 (V7) g for bris soil. The varieties emergence per plant were observed ranging from 2.33 (V15) - 4.33 (V6) days and 2.17 (V11) - 4.67 (V10) days for mineral and bris soils, respectively. The varieties flowering per plant ranged from 27.33 (V3) - 34.67 (V1) days for mineral soil and 28.50 (V2) - 37.83 (V1) days for bris soil. The plants height per plant were recorded to be in the range of 34.83 (V13) - 76.83 (V1) cm for mineral soil and 38.00 (V2) - 82.67 (V1) cm for bris soil. The pods width per plant for mineral and bris soils ranged from 1.40 (V15) - 1.59 (V10) cm and 1.39 (V4) – 1.56 (V6) cm, respectively. The pods length per plant for mineral soil were 5.03 (V13) - 6.50 (V8) cm and for bris soil were 5.29 (V13) - 6.58 (V8) cm.

Table 2 Means comparison of fifteen *Glycine max* (L.) Merrill varieties under mineral soil

Variety	Seed numbers (means)	Pod numbers (means)	Fifteen seeds weight (g)	Days to emergence (days)	Days to flowering (days)	Plants height (cm)	Pods width (cm)	Pods length (cm)
V1	78.50	40.67 ^{bc}	8.70 ^{f}	2.83 ^{abcd}	34.67 ^{i}	76.83 ^{a}	1.42 ^{dc}	5.16 ^{h}
V2	37.50	22.50 ^{gh}	12.59 ^{d}	3.00 ^{abcd}	28.50 ^{abc}	39.17 ^{c}	1.45 ^{c}	5.44 ^{g}
V3	52.17	30.83 ^{def}	12.68 ^{d}	2.50 ^{ab}	27.33 ^{a}	52.83 ^{b}	1.52 ^{b}	6.08 ^{d}
V4	81.17	45.00 ^{ab}	10.08 ^{e}	4.00 ^{ef}	34.33 ^{hi}	73.83 ^{a}	1.42 ^{dc}	5.60 ^{fg}
V5	59.50	33.33 ^{de}	13.14 ^{d}	2.83 ^{abcd}	28.33 ^{abc}	49.17 ^{b}	1.49 ^{b}	5.84 ^{e}
V6	39.00	24.17 ^{fgh}	15.65 ^{ab}	4.33 ^{f}	28.67 ^{abc}	52.00 ^{b}	1.53 ^{b}	5.82 ^{e}
V7	37.33	23.67 ^{fgh}	15.99 ^{a}	3.33 ^{bcde}	27.83 ^{ab}	49.33 ^{b}	1.51 ^{b}	5.66 ^{ef}
V8	36.50	19.33 ^{h}	13.24 ^{d}	3.50 ^{cdef}	30.00 ^{cde}	47.67 ^{b}	1.53 ^{b}	6.50 ^{a}
V9	42.83	25.50 ^{efgh}	13.03 ^{d}	3.50 ^{cdef}	29.50 ^{bcd}	47.50 ^{b}	1.45 ^{c}	5.47 ^{fg}
V10	54.17	34.50 ^{cd}	12.54 ^{d}	3.67 ^{def}	29.83 ^{cd}	51.17 ^{b}	1.59 ^{a}	5.48 ^{fg}
V11	38.00	21.83 ^{gh}	15.13 ^{abc}	2.83 ^{abcd}	31.50 ^{efg}	50.83 ^{b}	1.50 ^{b}	6.29 ^{bc}
V12	53.17	28.83 ^{defg}	12.72 ^{d}	3.50 ^{cdef}	31.67 ^{fg}	50.00 ^{b}	1.49 ^{b}	6.14 ^{cd}
V13	59.50	50.83 ^{a}	10.30 ^{e}	3.50 ^{cdef}	33.00 ^{gh}	34.83 ^{c}	1.42 ^{dc}	5.03 ^{h}
V14	44.17	29.17 ^{defg}	14.97 ^{bc}	2.67 ^{abc}	30.83 ^{def}	46.50 ^{b}	1.58 ^{a}	6.34 ^{ab}
V15	47.67	27.50 ^{defg}	14.45 ^{c}	2.33 ^{a}	28.50 ^{abc}	53.83 ^{b}	1.40 ^{d}	5.58 ^{fg}

$^{a, b, c, d}$ and other values containing the same superscript are not significant (*P*<0.05).

Table 3 Means comparison of fifteen *Glycine max* (L.) Merrill varieties under bris soil

Variety	Seed numbers (means)	Pod numbers (means)	Fifteen seeds weight (g)	Days to emergence (days)	Days to flowering (days)	Plants height (cm)	Pods width (cm)	Pods length (cm)
V1	91.17	53.83 ^{a}	7.47 ^{f}	2.50 ^{ab}	37.83 ^{e}	82.67 ^{a}	1.43 ^{ef}	5.42 ^{hi}
V2	41.50	25.67 ^{e}	12.44 ^{d}	3.33 ^{bcd}	28.50 ^{a}	38.00 ^{e}	1.40 ^{f}	5.77 ^{ef}
V3	68.33	40.67 ^{bc}	11.91 ^{d}	3.33 ^{bcd}	28.83 ^{ab}	61.83 ^{de}	1.51 ^{bc}	6.13 ^{c}
V4	77.83	44.33 ^{ab}	10.04 ^{e}	4.33 ^{ef}	35.17 ^{d}	61.50 ^{b}	1.39 ^{f}	5.40 ^{hi}
V5	52.33	37.17 ^{bcde}	12.12 ^{d}	3.83 ^{def}	30.17 ^{abc}	47.67 ^{cde}	1.49 ^{cd}	6.04 ^{cd}
V6	62.17	30.50 ^{cde}	15.20 ^{ab}	4.00 ^{def}	29.67 ^{abc}	56.50 ^{cde}	1.56 ^{a}	6.16 ^{c}
V7	42.50	26.33 ^{e}	15.42 ^{a}	3.17 ^{bcd}	28.50 ^{a}	46.83 ^{e}	1.53 ^{ab}	5.64 ^{fg}
V8	56.33	28.83 ^{cde}	11.56 ^{d}	4.33 ^{ef}	30.83 ^{abc}	55.00 ^{cde}	1.52 ^{abc}	6.58 ^{a}
V9	48.00	27.50 ^{de}	12.23 ^{d}	3.50 ^{cde}	31.33 ^{bc}	45.50 ^{cd}	1.49 ^{cd}	5.66 ^{fg}
V10	36.17	25.17 ^{e}	12.23 ^{d}	4.67 ^{f}	32.33 ^{c}	45.50 ^{c}	1.54 ^{ab}	5.57 ^{gh}
V11	61.83	31.67 ^{cd}	14.95 ^{ab}	2.17 ^{a}	30.33 ^{abc}	50.83 ^{cde}	1.52 ^{abc}	6.40 ^{b}
V12	69.17	39.83 ^{bcde}	11.57 ^{d}	3.50 ^{cde}	31.67 ^{c}	56.17 ^{c}	1.49 ^{cd}	6.23 ^{bc}
V13	60.50	45.50 ^{ab}	10.06 ^{e}	3.50 ^{cde}	31.33 ^{bc}	60.67 ^{cd}	1.45 ^{de}	5.29 ^{i}
V14	50.00	35.00 ^{bcde}	13.91 ^{c}	2.50 ^{ab}	31.67 ^{c}	47.17 ^{c}	1.54 ^{ab}	6.18 ^{ab}
V15	57.17	34.50 ^{bcde}	14.29 ^{bc}	2.83 ^{abc}	28.50 ^{a}	57.50 ^{e}	1.49 ^{cd}	5.88 ^{cde}

$^{a, b, c, d}$ and other values containing the same superscript are not significant (*P*<0.05).

Selection of several potential vegetable soybean varieties to be planted in Malaysia is a crucial effort since it is a foundation before the varieties can be commercialized and further developmental programs can be initiated. Several characteristics of soybean variety need to be considered prior to selection, including yield (high yield and yielding stability), disease and pest resistances, maturity group, quality traits and plant height and lodging. Among these, yield is the most important characteristic in selecting potential varieties [8]. Soybean yield is divided into several components such as seed numbers per plant, pod numbers per plant, node numbers per plant, pod numbers per node, seed numbers per pod and seeds weight [9]. However, seed numbers per plant is the main yield determinant [9, 10]. From the observation, V4 (81.17), V1 (78.50) and V5 and V13 (59.50) had the highest seed numbers per plant in mineral soil and V1 (91.17), V4 (77.83) and V12 (69.17) in bris soil.

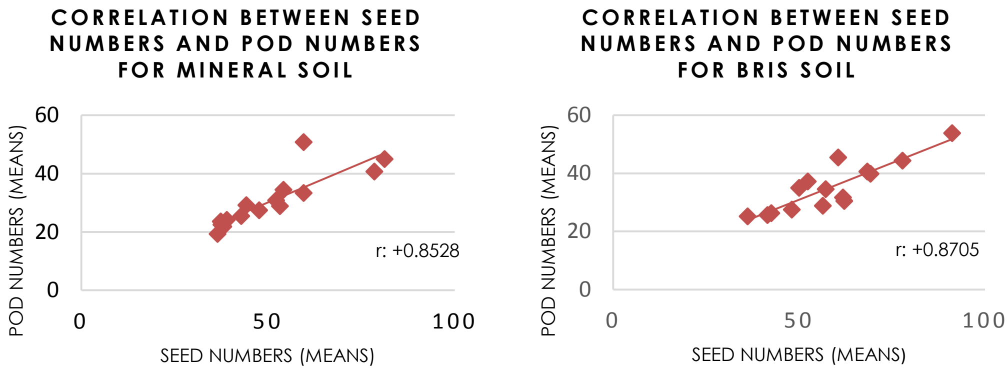

Figure 1 Positive correlation between seed numbers and pod numbers for mineral and bris soils

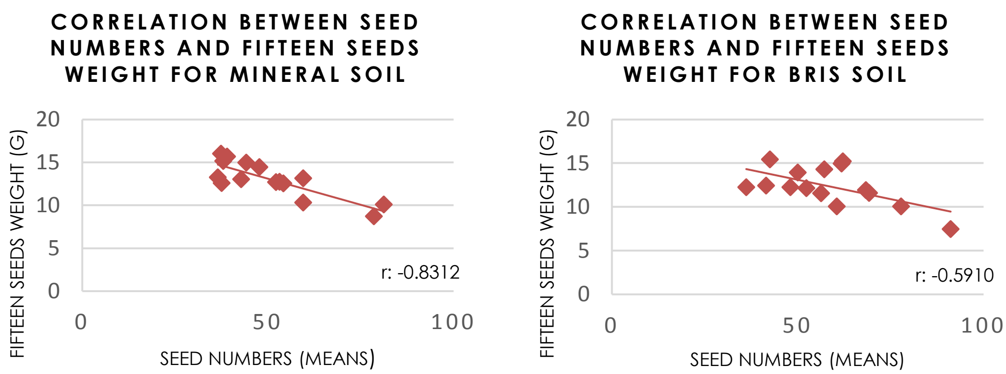

Figure 2 Negative correlation between seed numbers and fifteen seeds weight for mineral and bris soils

There is a close relationship between seed numbers and pod numbers with soybean yield [11, 12]. The seed numbers and pod numbers in soybean are determined from beginning of flowering, and extend to pod formation until seed-filling begins. Thus, the post-flowering period is regarded as the crucial period for yield determination [11]. The results showed that V13 (50.83), V4 (45.00) and V1 (40.67) have the highest pod numbers per plant in mineral soil and V1 (53.83), V13 (45.50) and V4 (44.33) in bris soil. The correlation graphs between seed numbers and pod numbers of *Glycine max* (L.) Merrill grown on mineral and bris soils were shown in Figure 1. The correlation coefficient, *r* of both graphs showed a strong uphill linear relationship (+0.70) [13], which were +0.8528 for mineral soil and +0.8705 for bris soil. From the results of seed numbers and pod numbers, V1, V4 and V13 dominated the position as the best varieties for both mineral and bris soils. Under bris soil condition, V12 (69.17) had higher seed numbers compared to V13 (60.50) even though V13 (45.50) has higher pod numbers than V12 (39.83). This circumstance occurred probably during seed-filling period where environmental stress caused reduction on one of the yield components which is seed numbers per pod thus lowering seed numbers per plant even though pod numbers per plant are high.

However, based on the results, there were inverse relationship between seed numbers with fifteen seeds weight. The correlation graphs between seed numbers and fifteen seeds weight for vegetable soybean grown on mineral and bris soils were shown in Figure 2. The correlation coefficient, *r* of the graphs showed a strong downhill linear relationship (-0.70) for mineral soil while a moderate downhill linear relationships (-0.50) for bris soil [13], which were -0.8312 for mineral soil and -0.5910 for bris soil. If the plants have fewer pod numbers, they are able to maximize their nutrient and water intake resulting in much greater pods weight [14]. Since pod numbers were positively correlated with seed numbers, the negative correlation between seed numbers and fifteen seeds weight was probably due to lower nutrient and water intake for higher seed numbers varieties and vice versa.

4.0 CONCLUSION

Based on the results, V4 and V1 produced higher yielding ability in terms of seed numbers in mineral and bris soils, respectively. However, the other varieties can also be taken into account to have a higher performance for plants yield since their leaflets type are in heterozygous condition. Among them, three varieties which were V1, V4 and V13 showed the greatest potential to be planted under Malaysian soils as well as its climatic conditions. Further study is needed to ensure the yield stability of the selected varieties across multiple locations and years in order to accurately indicate the variety performances and stability. Besides, study on other characteristics involved in variety selection which are disease and pest resistances, maturity group, quality traits and height and lodging are also crucial in order to select the best *Glycine max* (L.) Merrill variety for commercialization and future development projects in Malaysia.

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