

ADAPTABILITY OF SOYBEAN CULTIVARS IN THE AGRO-ECOLOGICAL REGIONS OF SRI LANKA

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ABSTRACT

Seed yields of fifteen promising soybean (*Glycine max* (L) Merr.) cultivars tested in 26 common trials under the International Soybean (INTSOY) programme were analysed for genotype $\times$ environment interaction effects by the method of Finlay and Wilkinson (1963) to identify their adaptability ranges. The 26 trials involved seven sites spread over 4 agro-ecological regions and five different seasons.

The cultivar Hardee excelled all other cultivars in yield in the overall performance and in most of the regional and seasonal performances, but in all instances it was of below average stability. Its specific adaptability is in the calcic red latosols in the dry zone and in the yala season of the mid country wet zone.

Davis and Pbl are adaptable in the maha and yala seasons respectively in general, and in particular in the dry zone. Although Davis was the second highest yielder in general performance it showed mostly below average stability. Pbl was unique in maintaining stable high yields in the general, seasonal and dry zone regional performances, except in the mid country wet zone where it showed below average stability.

Bossier was the most promising cultivar in the southern dry zone. In the mid country wet zone SJ2 had an advantage over Hardee because of its above average stability with comparable yield levels, but Hardee is specifically suitable for the yala season in this region.

INTRODUCTION

Soybean is unique in its high nutritive value, wide utility and versatility for human and animal nutrition, and lends itself for the production of a variety of industrial products. It is believed that soybean was first introduced to Sri-Lanka in the 17th century. Farmers in the Nuwara-Eliya District are maintaining an old introduction which is adaptable to suit their cultivation conditions. This is now referred to as "Nuwara Eliya Local". A limited number of cultivars was introduced in 1947 and these were tested for yield in Sri-Lanka. These tests did not show much promise compared to the other pulses.

With the initiation of a programme to introduce and improve agro industrial crops at the Research Station, Maha Illuppallama in 1966, several soybean cultivars were introduced and the promising ones were released to interested farmers (Fernando and Fernando 1967). Subsequently under the International Soybean Programme (INTSOY), uniform yield trials of promising soybean introductions were conducted in Sri-Lanka from 1973 in several locations and seasons. The diverse agro-ecological regions of Sri-Lanka often require specific cultivars to obtain high grain yields. Using special statistical techniques adaptation response of individual genotypes to the range of environments could be identified.

Joint linear regression of genotypic performance in each environment on a suitable index of that environment was proposed (Yates and Cochran, 1938; Finlay & Wilkinson, 1963; Perkins & Jinks, 1968; Freeman, 1973). The mean yield of all genotypes has commonly been used as the biological index of environment.

In order to identify the adaptability range of the promising soybean cultivars, analyses were carried out using the method of Finlay & Wilkinson (1963). The demarcation of different agro-ecological regions of Sri-Lanka by Panabokke & Kanangara, 1975, by considering the diversity of land forms and soils, climate and altitude, has considerably assisted in grouping the locations to determine the adaptive responses of the soybean cultivars on a regional basis.

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MATERIALS AND METHODS

Seed yields from uniform trials where fifteen promising soybean cultivars were tested in 26 common trials were taken from INTSOY reports (Whigham 1975, 1976, Whigham and Judy 1978, and Judy and Whigham 1978). The locations and regions were as follows :

Dry Zone (a) D.L1 region — Maha-Illuppallama, Angunukolapallessa.

(b) D.L3 region — Thinnaveli, Kilinochchi, Vannathavillu.

Intermediate Zone (a) IL2 region — Alutharama

Wet Zone (a) WM2 region — Gannoruwa

The seasons of tests were yala '74, '75, '76 and maha 74/75 and 75/76.

The cultivars tested are given in Tables I to III.

To determine the adaptability and yielding stability of the varieties tested, analyses were carried out using the method of Finlay and Wilkinson (1963). In this method the performance of individual genotypes is regressed against the site mean yields which give a biological measure of the environment in relation to the character in question divorced from any consideration of the alteration between the sites in specific environmental variable such as rainfall, temperature, soil fertility etc.

The trials, 26 in number, were analysed together to determine general adaptability, and separately for the different zones, regions and seasons to determine specific adaptability.

RESULTS

General Performance

When the performances of the soybean cultivars from the twenty six trials conducted in the various locations and seasons were analysed together, all the individual regression coefficients were significant (Table 1). The cultivar Hardee excelled all other cultivars in seed yield, with below average stability. The other promising cultivars in the order of yield performances were Davis, Bossier, Pbl and Bragg. Of these cultivars except for Bossier which showed moderate stability, the others were of average stability. The cultivars SJ2, Improved Pelican and Hill showed above average stability, but only the former two cultivars gave above average yields.

Seasonal Performance in General

An analysis for seasonal performances with the same data, by separating the maha and yala seasons trials showed that all the regression coefficients were significant (Table 1 and Figure 1).

In the maha season Davis gave the highest yield followed by Hardee and Bossier. Davis and Hardee showed moderate stability, but Bossier was average. The next highest yielders in order were SJ2, Improved Pelican, and Williams which showed average stability and above average yields. Pbl which was fourth in the yielding order in the general analyses attained the eleventh place with below average yields in the maha season.

In the yala season Hardee gave the highest yields followed by Pbl, and Davis. The latter two cultivars showed average stability, but that of Hardee was below average in stability. Bossier, Bragg and Forrest gave similar yields with moderate stability and stability approaching unity for Bragg.

In general the seed yield increased from the maha to the yala season for the cultivars tested, but Davis, Bossier, SJ2, Improved Pelican, Jupiter and Hill showed little variation in yield between the seasons.

Performance in the Dry Zone

When the performance of soybean cultivars in the dry zone locations comprising of 16 trials was analysed jointly, the yielding order of the high yielding cultivars was the same as that observed for the combined analysis for all the zones (Table 2). In this analysis most of the high yielding cultivars were of average stability; but Hardee which gave the highest yield was of below average stability.

To determine the performance in the maha and yala seasons in the dry zone locations, analyses were carried out separately for the 8 trials in each seasons (Table 2 and Figure 2). In the maha season Davis gave the highest yields with stability tending to be of below average level, followed in order of yield performance by Hardee with stability tending to be of below average level, Bossier and Bragg with average stability. Williams, SJ2 and Improved Pelican came in the next high yielding group with above average yields. The cultivar Pbl ranks eighth in the yielding order with below average yields, but with average stability.

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Pb1 which gave below average yields in the maha season of the dry zone has outyielded all other cultivars tested in the yala season of that zone. The other cultivars in the yielding order were Hardee, Bossier and Davis. Of these cultivars Pb1 and Davis were of average stability, Bossier showed moderate stability and Hardee maintained its below average stability.

In the dry zone locations the seed yield of all cultivars increased from the maha to the yala season, except for Davis and Hill which showed less variation in yield between the seasons.

Performance in the Agro-ecological regions

(a) **DL1 Region. Locations: Maha-Illuppallama and Angunukolapalessa.** In the DL1 Region three maha and four yala trials were analysed jointly. In this analysis 13 out of 15 individual regression coefficients were significant, and those of Hardee and Improved Pelican were insignificant (Table 3 and Figure 3a). Davis excelled all other cultivars in seed yield, followed by Bossier and Bragg. These three high yielding cultivars had below average stability, but the next highest yielder Pb1 showed average stability. Improved Pelican and Hardee ranked 5th and 6th with above average yields, but their regression coefficients were insignificant. The most stable and the most reactive cultivars appeared to be Bonus and Hampton respectively, both with below average yields.

Two trials each for the maha and yala seasons were conducted at Maha-Illuppallama, which when analysed jointly showed significant regression coefficients for 11 cultivars. The order of yield performances of promising cultivars was Davis, Pb1, Bossier and Improved Pelican. Bossier was of average stability, where as Davis and Pb1 showed below average stability. The regression coefficient of Improved Pelican was insignificant. The most sensitive cultivar was Hampton.

Most of the cultivars tend to give higher yields at Angunukolapalleassa than at Maha-Illuppallama. At Maha-Illuppallama Davis and Pb1 showed promise with the former more adaptable for the maha season, and the latter for the yala season. Bossier and Davis showed promise at Angunukolapalleassa.

(b) **DL3 Region, Locations: Thinnaveli, Kilinochchi and Vannathavillu.** The trials conducted in the DL3 region include 5 in the maha and 4 in the yala seasons. In the combined analysis when all the 9 trials were taken, a

high degree of significance was observed for the regression coefficients of all the cultivars (Table 3). However in the seasonal analyses, 14 and 7 regression coefficients for the maha and yala season respectively, were significant.

An interesting observation arising out of this analysis is that Hardee remained as the highest yielder with significant regression coefficients in the seasonal and combined analysis in this agro-ecological region. It showed average yielding stability in the maha season, but was highly reactive in the yala season and in the combined analysis.

Davis and Bossier attained the second and third places in the combined analysis in the maha season with yield stability tending to be of below average level. In the yala season Pbl, Forrest, and Clark63 gave high yields next to Hardee, only the regression coefficient for Clark63 was significant, but showing below average stability.

In this region the seed yield of all cultivars increased from the maha to the yala season, except for Improved Pelican which showed a reverse trend. In general Hardee, Davis and Pbl showed promise in this region (Figure 4).

(c) **IL2 Region, Location: Alutharama.** At Alutharama two maha and three yala trials were conducted. Since the number of trials in the major seasons was less, the analysis was only carried out combining the trials in both seasons as 5 trials.

In this analysis only the regression coefficients for Davis, Bossier, Improved Pelican and Hill are significant (Table 3 and Figure 3b). Davis recorded the highest yield, but with below average stability. The second highest yielder was Hardee, but its regression coefficient was insignificant. Bossier came third in yield, and it was highly reactive to changes from one environment to the other.

Unlike in other locations where there is a general tendency for the yala yields to be higher than the maha, a reverse trend for the yields at Alutharama was noticed. However Bonus and Tracy showed yield increase from maha to yala season.

(d) **WM2 Region. Location: Gannoruwa.** The two maha trials, and three yala trials of Gannoruwa were analysed jointly. Twelve regression coefficients were significant (Table 3). Hardee outyielded all other varieties

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and showed below average stability (Figure 3c). The other promising cultivars in order of yield performance were SJ2, Improved Pelican and Davis. Of these cultivars SJ2 and Davis showed above average stability, and Improved Pelican show below average stability.

SJ2 was the most stable cultivar in the high yielding group, and has an advantage over Hardee because of its comparable yield performance. Considering the seasonal performances Hardee gave the highest yield followed by Improved Pelican and SJ2 in the yala season. In the maha season SJ2 outyielded all other cultivars. The ranking of the other promising cultivars was Davis, Forrest, Improved Pelican and Hardee. All the cultivars showed without any exception increases in yield from the maha to the yala season.

DISCUSSION

The trial locations cover the dry, intermediate and wet zones, but more specifically fall under four agro-ecological regions in the Island. Since the dry zone area is large, the test locations were more in the dry zone than in the other two zones. Further the test locations in the dry zone come under two different agro-ecological regions. Thus it is justifiable to have more test locations in the dry zone area than in the other two zones.

The yield ranges of the soybean cultivars and their regression coefficients for the agro-ecological regions where the trials were carried out are given in Figure 4. Among these agro-ecological regions the DL3 region gave high yields and wider yield differences. The yield ranges of these cultivars in the DL1 region are comparable to that of the IL2 region. In the WM2 region some of the cultivars fall in the yield range of DL1 and IL2, whereas the others surpass this range, thus giving a wider difference in cultivar yielding ability.

Of the cultivars tested in the twenty six environments, Hardee outyielded all other cultivars in the overall performance in general, and in the dry zone. It has also given the highest yields for the yala season in general, and in the DL3 and WM2 regions. In all these instances it showed mostly below average stability and appeared to be the least stable cultivar in most of the analyses. This below average response of Hardee suggests that it might be a high yielding cultivar under certain circumstances, and this appears to be

in the DL3 region and specially in the calcic red latosol area of the dry zone, where in fact very high yields were obtained. This cultivar had also performed well in the WM2 region, outyielding all other cultivars tested and showed below average stability. It is specifically adapted to the yala season in the WM2 region. Its yield levels were lower at WM2 than at DL3 region.

Hardee attained the second place in yield performance in the maha season in general, and in both the seasonal performance in the dry zone and in the IL2 region. In contrast it moved down to the 6th place in the yielding order in the DL1 region.

The other promising cultivars in the high yielding group were Davis and Bossier. Although Davis came second in the yielding order in general performance, it outyielded all other cultivars tested in the maha season both in the general and dry zone performances, and in the DL1 and IL2 regions. In all these instances it was of below average stability. It also became the second highest yielder in the DL3 region and in the general dry zone performance where its stability was approaching unity. It gave the highest yield at Maha-Illuppallama in the DL1 region, Kilinochchi in the DL3 region, and Alutharama in the IL2 region. In the general and dry zone performances, it showed promise in the maha rather than the yala season. In fact it gave the highest yields in the maha season.

Bossier was the second highest yielder in the DL1 region, but maintains the third position in the dry zone seasonal performance, and in the DL3 and IL2 regions. It was of moderate to average stability in these situations. It gave only average yield with average stability in the WM2 region. It was the most promising cultivar in the southern DL1 region.

Of the other cultivars Pb1 was unique in maintaining stable high yields in the general, seasonal and dry zone regional performances, but in the WM2 region it showed below average stability. It outyielded all other cultivars in the yala season of the dry zone with appreciable stability indicating its seasonal adaptability, and at Vannathavillu in the DL3 region. It gave the second highest yield at maha Illuppallama, and in the general yala performance. The cultivar Bragg also gave stable high yields in most of the analyses, except in the DL1 region where it showed below average stability.

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The cultivars SJ2 and Improved Pelican gave high yields in the WM2 region, occupying the second and third positions. Of these SJ2 was of above average stability. SJ2 has an advantage over Hardee in the WM2 region because of its above average stability with comparable yield levels, but Hardee is specifically suitable for the yala season in the WM2 region.

From the performance of soybean cultivars in the twenty six trials, covering the various locations, regions and seasons it could be inferred that Hardee is more adaptable in the DL3 region, and more specifically in the calcic red latosol area. It has also showed specific adaptability in the yala season of the WM2 region.

Davis and Pb1 are adaptable in the maha and yala seasons respectively in general and in particular in the dry zone. Davis has also showed promise in the DL1 and IL2 locations. However Bossier showed promise in the southern dry zone. Improved Pelican also showed promise in the yala season of the DL1 region. SJ2 has general adaptability in the WM2 region.

At present Pb1 has been accepted by the cultivators in the north central DL1 region where large scale soybean cultivation has been undertaken. Bossier is the next popular variety in the dry zone.

It was observed by Hearth (1974) that in Sri Lanka high elevation locations gave high protein values and low values for oil, and vice versa for the low-elevation locations. Gannoruwa in the WM2 region comes in the first category where the most promising and stable cultivar SJ2 recorded very high values for protein compared to most of the other cultivars.

Although Hardee gave outstanding yield performances, its seed viability reduces rapidly compared to other cultivars, and as a result of this it is not popular. Transference of the high seed viability of "Nuwara Eliya Local" to the genetic background of Hardee should yield promising genotypes for the DL3 and WM2 regions.

It is interesting to note that in the ISVEX programme in the tropical and sub-tropical countries, the Sri Lanka locations Thinnavelly and Kilinochchi gave high potential yields for Hardee, Davis, Pb1, SJ2,

Bossier, Bonus, Bragg, Clark⁶³, Forrest, Hampton, Improved Pelican, Jupiter, and Williams. Another location comparable to these was Maracay in Venezuela. (Shanmugasundaram 1976).

Soyabean cultivation for grain production is on the increase since 1979 (Table 4) and it is picking up momentum from 1980. Promising cultivars have to be used to step up production.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. C. R. Panabokke, and Dr. G. W. E. Fernando, former Directors of Agriculture, and Dr. Carl N. Hittle, (INTSOY) for permitting this study, and Dr. S. D. I. E. Gunawardene, Director of Agriculture and Dr. H. M. E. Herath, Deputy Director of Agriculture (Research) for their encouragement.

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Table 1. Mean seed yields (t/ha) and regression coefficients for 15 soybean cultivars

Cultivars	General and seasonal performances					
	General performance		Seasonal performance		yala season	
	Combined seasons		maha season		(14 trials)	
	(25 trials)		(12 trials)			
	Mean yield	coefficient	Mean yield	coefficient	Mean yield	coefficient
1. Hardee	2.76	1.21†	2.68	1.14†	2.83	1.27†
2. Davis	2.71	1.07†	2.73	1.16‡	2.69	0.99†
3. Bossier	2.61	1.11†	2.63	1.09†	2.59	1.15†
4. Pb1	2.50	1.08†	2.22	1.06†	2.73	1.07†
5. Bragg	2.47	1.03†	2.33	1.01†	2.59	1.04†
6. SJ2	2.46	0.85†	2.45	0.95†	2.46	0.76†
7. Forrest	2.45	1.02†	2.29	0.92	2.59	1.11†
8. Williams	2.44	1.05†	2.40	0.94	2.47	1.16‡
9. Imp. pelican	2.43	0.83†	2.41	1.10†	2.45	0.59†
10. Jupiter	2.32	0.96†	2.34	1.07†	2.30	0.88†
11. Hampton	2.31	1.06†	2.24	0.99†	2.38	1.13†
12. Clark.63	2.30	1.13†	2.18	1.01†	2.40	1.23†
13. Hill	2.13	0.76†	2.12	0.86†	2.06	0.65†
14. Bonus	2.10	0.88†	1.94	0.91†	2.24	0.85†
15. Tracy	2.06	0.94	1.90	0.78	2.20	1.08

In all tables *, †, ‡ significant at P = 0.05, 0.01 and 0.001 respectively.

Table 2. Mean seed yields (t/ha) and regression coefficients for soybean cultivars

Performance in the dry zone DL1 and DL3 agro-ecological regions

Cultivars	Combined seasons		Maha season		Yala season	
	16 trials		8 trials		8 trials	
	Mean yield	coefficient	Mean yield	coefficient	Mean yield	coefficient
1. Hardee	3.01	1.22†	2.95	1.12†	3.08	1.34†
2. Davis	2.99	1.07†	2.97	1.16†	3.01	1.00†
3. Bossier	2.93	1.09†	2.83	1.08†	3.02	1.11†
4. Pb1	2.82	1.04†	2.50	1.01†	3.13	1.02†
5. Bragg	2.81	1.03†	2.63	0.96†	2.99	1.09†
6. SJ2	2.62	0.85†	2.57	1.01†	2.68	0.71†
7. Forrest	2.71	1.03†	2.45	0.94†	2.96	1.09†
8. Williams	2.74	1.05†	2.62	0.93†	2.87	1.18†
9. Imp. pelican	2.60	0.82†	2.57	1.13†	2.64	0.51†
10. Jupiter	2.53	0.94†	2.45	1.10†	2.60	0.77†
11. Hampton	2.55	1.11†	2.43	1.01†	2.67	1.22†
12. Clark.63	2.62	1.13†	2.42	1.00†	2.83	1.26†
13. Hill	2.29	0.74†	2.31	0.87†	2.28	0.63
14. Bonus	2.25	0.94†	2.10	0.94†	2.39	0.93†
15. Tracy	2.36	0.95†	2.16	0.74†	2.56	1.14†
Means	2.66		2.53		2.78	

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Table 3. Mean seed yields (t/ha) and regression coefficients for soybean cultivars

Performance in the agro-ecological regions								
<i>Cultivars</i>	<i>DL1 (7 trials)</i>		<i>DL3 (9 trials)</i>		<i>IL2 (5 trials)</i>		<i>WM2 (5 trials)</i>	
	<i>Mean yield</i>	<i>coeffi- cient</i>	<i>Mean yield</i>	<i>coeffi- cient</i>	<i>Mean yield</i>	<i>coeffi- cient</i>	<i>Mean yield</i>	<i>coeffi- cient</i>
1. Hardee	1.94	0.82	3.84	1.22†	2.13	1.56	2.58	1.54*
2. Davis	2.16	1.20†	3.63	1.10†	2.16	1.27†	2.36	0.90†
3. Bossier	2.09	1.15†	3.56	1.15†	2.06	2.27†	2.17	0.98†
4. Pbl	2.00	1.08†	3.46	1.05†	1.88	1.10	2.09	1.77†
5. Bragg	2.04	1.30†	3.41	1.05†	1.93	0.03	1.92	0.86*
6. SJ2	1.82	0.66*	3.24	0.80†	1.84	1.43	2.56	0.74*
7. Forrest	1.83	1.24†	3.39	0.96†	1.80	0.87	2.29	0.98
8. Williams	1.92	1.04†	3.48	1.01†	1.75	0.85	2.15	0.65
9. Imp. pelican	1.95	0.72	3.11	0.85	1.90	1.46†	2.42	1.12†
10. Jupiter	1.89	1.35†	3.02	0.98†	1.71	2.42	2.26	1.38
11. Hampton	1.71	1.39†	3.20	1.14†	1.82	0.32	2.06	0.70*
12. Clark .63	1.68	0.81†	3.35	1.18†	1.64	0.62	1.93	0.88†
13. Hill	1.55	0.81*	2.86	0.61*	1.56	0.65*	2.16	1.09*
14. Bonus	1.61	0.60†	2.77	1.09†	1.68	0.14	2.00	0.68*
15. Tracy	1.45	0.96†	3.01	0.82†	1.52	0.17	1.64	0.74*

Table 4. Area under soybean production (ha)

<i>Year</i>	<i>'78 / '79</i>	<i>'79 / '80</i>	<i>'80 / '81</i>	<i>'81 / '82</i>	<i>'82 / '83</i>
Maha	862	913	1102	6077	10326
Yala	359	179	1111	—	5808
Total	1221	1092	2213	6077	16134

Figure 1.

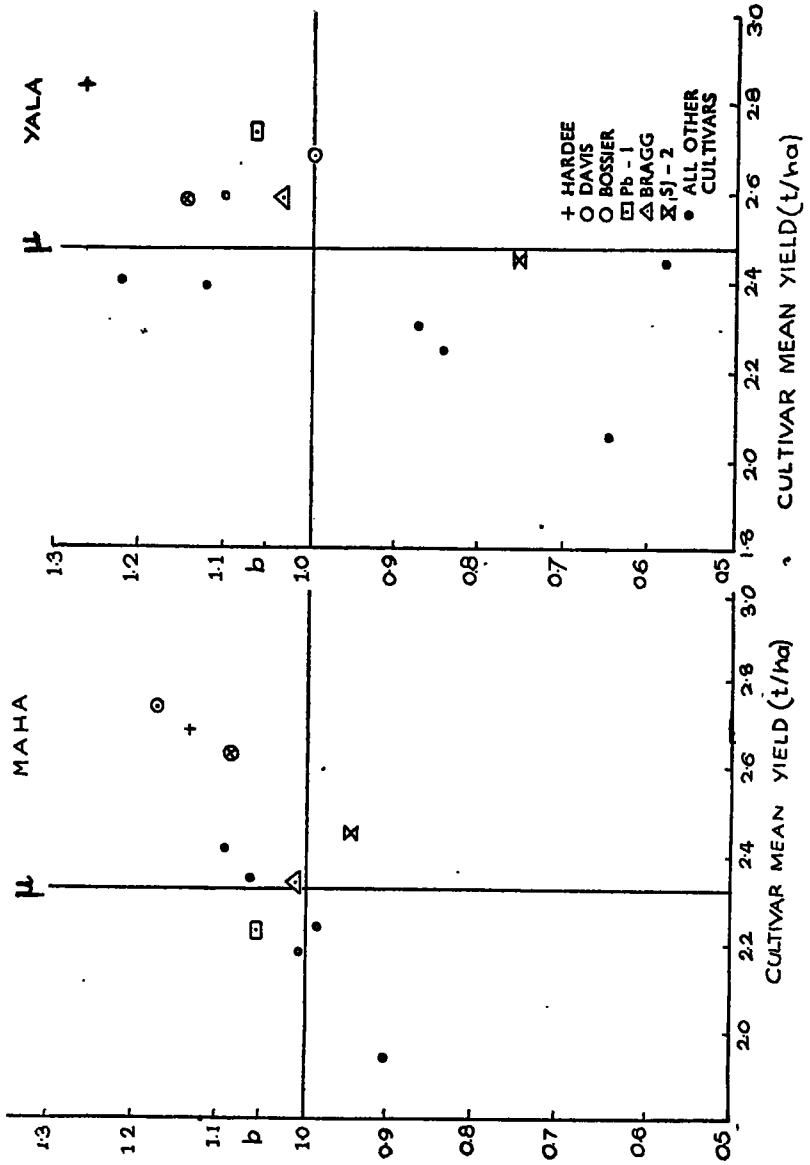


Figure 2.

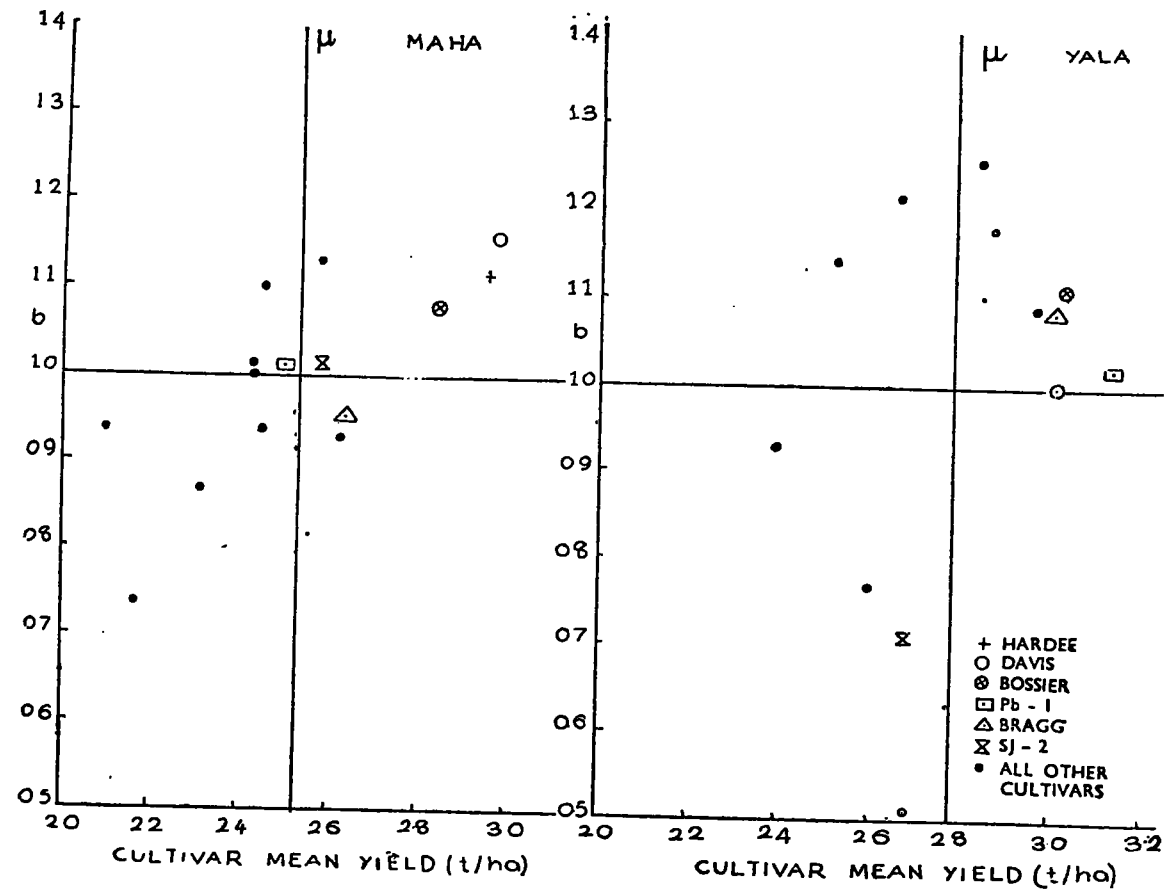
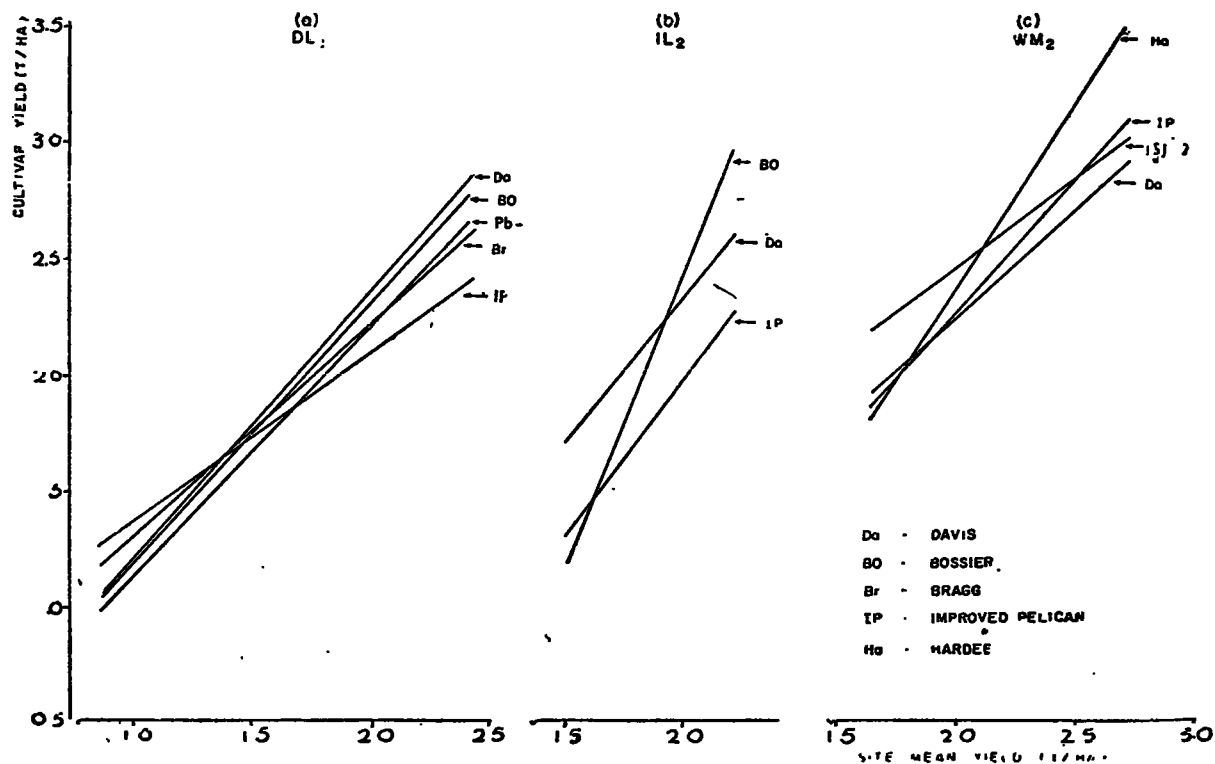


Figure 3. Regression lines showing yield performances of promising soybean cultivars in the DL₁, IL₂ and WM₂ regions of Sri Lanka.



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Figure 4. Regression lines showing yield performances of promising soybean cultivars in the DL3 region of Sri-Lanka.

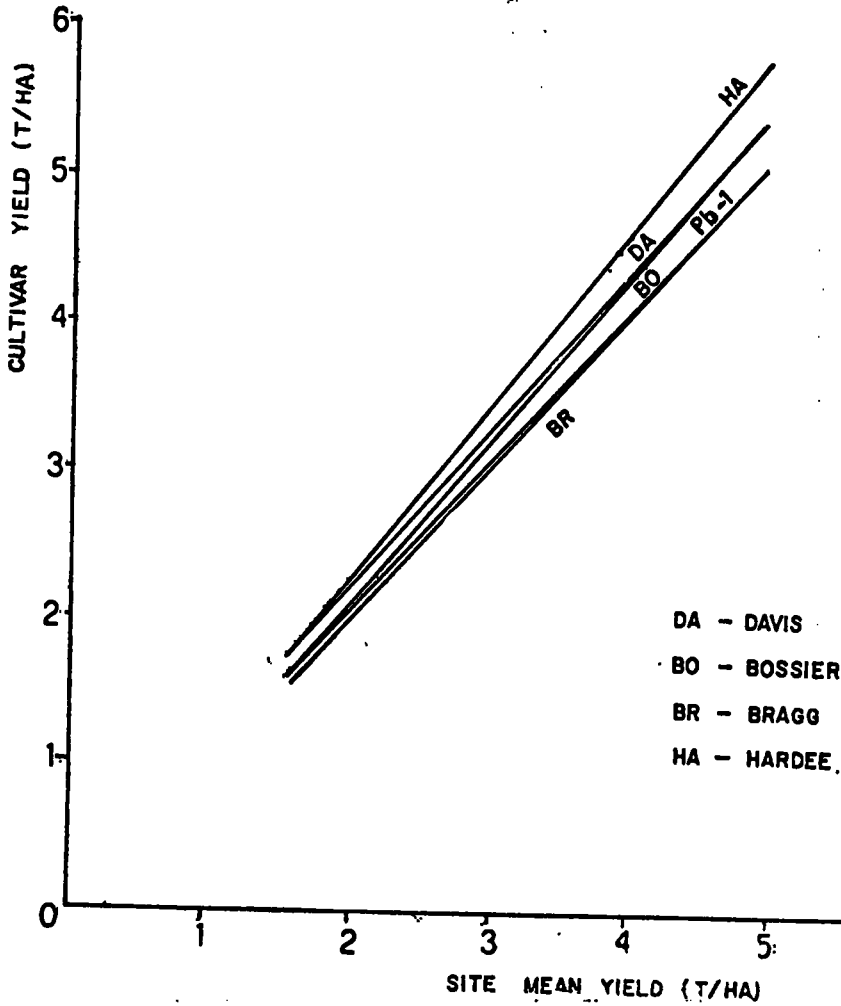


Figure 5. Regional adaptation of soybean cultivars in Sri Lanka

