Paper 10

SELECTION INDICES FOR YIELD ESTIMATION IN GRAIN LEGUME PLOTS

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ABSTRACT

Selection for yield in early generations may improve breeding efficiency but restricted seed supplies obtained from single plants and short rows prevent the sowing of plots of sufficient size for accurate yield estimation. Selection based on characters correlated with yield but with less variability and higher heritability than yield in small plots are discussed. Harvest index and a geometric yield index were measured with greater precision and had higher heritability than yield in hill and single-row plots in three experiments on mungbean and cowpea. The effectiveness of these characters as estimators of yield varied between experiments.

KEYWORDS

Harvest index, geometric yield index, mungbean, *Vigna radiata,* cowpea, *Vigna unguiculata,* heritability, genetic correlation, hill plots, row plots.

INTRODUCTION

Selection for yield is frequently delayed until seed supplies are adequate to sow large plots, and until selection for other characters has reduced the number of lines to be tested. This may not be the most efficient procedure.

Several studies in cereals (Baker and Leisle, 1970; Frey, 1965; Jellum *et al.,* 1963; Ross and Miller, 1955) and soybean (Buzzell and Buttery, 1984; Garland and Fehr, 1981; Torrie, 1962) have examined the possibility of selecting for yield in small plots, particularly in hill plots. Hill plots were always more variable than larger plots but in some instances correlations between yield in hill plots and larger plots were sufficiently high for hill plots to be considered a useful medium for yield selection.

The value of hill plots would be enhanced if they could be used for selection of characters correlated with yield but less variable than yield. Harvest index (Donald, 1962) and the geometric yield efficiency index (Imrie and Butler, 1983) have both been found to have low variability within genotypes. However, the use of harvest index as a selection criterion has given variable results (Buzzell and Buttery, 1977; Syme, 1972) and geometric index has not been tested.

In this paper I examine the use of harvest index (HI), and the geometric yield efficiency index (GI) as selection criteria in small plots for yield improvement in grain legumes.

MATERIALS AND METHODS

Three experiments were conducted. The first included 12 varieties of cowpea *(Vigna unguiculata)* which were grown at Dalby, Queensland, (lat. 27° 16'S, long. 151° 09'E) during the 1984 summer. The second and third experiments each contained 10 varieties of mungbean *(Vigna radiata)* and were grown at Dalby and Lawes (lat. 27° 34'S, long. 152° 20'E) respectively in 1985.

Each experiment comprised three adjacent sub-experiments, differing in plot size. The first had plots six rows wide and 6 m long with 0.5 m between rows. The harvested area of cowpeas was four rows x 4 m, and of mungbeans was four rows x 5 m. The second sub-experiment had single-row plots 6 m long with 1 m between rows. Harvested length was 3 m for cowpeas, and 5 m for mungbeans. The third sub-experiment contained hill plots sown on a 1 m x 1 m grid. Cowpea hills had five plants and mungbean hills had six plants. Each sub-experiment was sown in a randomised block design with four replicates.

All plants were harvested by cutting at ground level. Any remaining leaves were removed, and the plants were dried before being weighed to record plant yield. The number of pods from hill and single-row plots were counted. Material was threshed in a resilient tapered thresher and seed yields were recorded. Harvest index (HI) was calculated as seed yield/plant yield. Geometric index (GI) was $(a.b)^{0.5}$ where a was seed yield per unit forage yield (plant yield minus seed yield), and b was seed yield per pod.

Analyses of variance were calculated for each sub-experiment and broad sense heritability (h^2) estimates calculated from variance components (Kempthorne, 1957). Genetic correlations (r_g) were calculated (Kempthorne, 1957) with yield from large plots, and yield, HI, and GI from single-row and hill plots as covariates. The effectiveness of hill and short-row plots for estimation of true yield (as measured in large plots) was taken as the ratio $(h_a.r_g)/h_b$ where h_a is the square root of heritability in small plots, h_b the square root of heritability in large plots, and r_g

the genetic correlation between small and large plots (Falconer, 1952). Rank correlations (Daniel, 1978) were calculated to compare the ranking of lines in large and small plots.

RESULTS AND DISCUSSION

A harvested plot area of 8 to 10 m^2 was chosen to provide an estimate of the true yield of the varieties grown. Past experience and published information (Monzon *et al.*, 1975) indicated that plots smaller than this are more variable, while larger plots do not provide increased precision.

The coefficient of variation (CV) (standard error/mean) was used as a measure of precision in these experiments. The large plot experiments had coefficients of variation for yield of 10.5, 9.3 and 17.5% for Dalby 1984, Lawes 1985 and Dalby 1985 respectively. The higher than normal figure for Dalby 1985 was attributed to uneven germination, and accidental flooding of part of the trial site.

Hill plots were more variable than single-row plots

Table 1. Coefficient of variation (CV) and broad sense heritability (h^2) of seed yield (SY), harvest index (HI), and geometric index (GI) measured in hill and single-row plots. The genetic correlation (r_g), effectiveness score ($h_a.r_g/h_b$), and rank correlation (r_s) are measured relative to seed yield in large plots.

Location and plot type	Character	CV	h^2	r_g	$h_a.r_g/h_b$	r_s
Dalby 1984						
Single row	SY	20.7	0.63	0.99**	0.91	0.82**
	HI	9.4	0.67	0.79**	0.75	0.85**
	GI	14.9	0.65	0.75**	0.70	0.92**
Hill plot	SY	23.7	0.25	0.76**	0.44	0.04
	HI	9.1	0.54	0.25	0.21	0.64*
	GI	20.0	0.19	0.72*	0.36	0.70*
Lawes 1985						
Single row	SY	14.2	0.54	0.37	0.30	0.44
	HI	9.3	0.56	0.78**	0.65	0.76**
	GI	11.8	0.64	0.86**	0.77	0.69*
Hill plot	SY	16.1	0.47	0.33	0.25	0.36
	HI	11.8	0.35	0.99**	0.66	0.76**
	GI	12.5	0.62	0.80**	0.70	0.58*
Dalby 1985						
Single row	SY	13.6	0.64	0.88**	1.23	0.76**
	HI	4.5	0.85	0.79**	1.27	0.70*
Hill plot	SY	18.2	0.39	1.16[1]**	1.09	0.35
	HI	8.6	0.58	0.93**	1.23	0.76**

[1] Assumed to be 1.00

* Significant at $P = 0.05$, ** Significant at $P = 0.01$.

(Table 1) which agrees with published information in cereals (Frey, 1965) and soybeans (Torrie, 1962). The CV of HI was always more precise than the CV of GI. Both indices had lower coefficients of variation than yield in all trials.

Broad sense heritability estimates also provide a guide to the relative precision of the different plot sizes since heritability provides an estimate of genetic variation relative to total variation. The heritability of yield was higher in large plots (average 0.63) and single-row plots (0.60) than in hill plots (0.37). Hill plots also had lower heritabilities than single-row plots for HI and GI (Table 1).

There were no consistent patterns in the genetic correlations between SY, HI and GI measured in small plots and seed yield in large plots (Table 1). Correlations ranged from $r_g = 0.25$ to $r_g = 1.00$ and averaged 0.76. This result differs from that of Buzzell and Buttery (1977) who found HI to be negatively associated with yield in soybeans.

Genetic correlations were considered in association with heritability to obtain an index of effectiveness of small plots as estimators of yield. Single-row plots had an advantage over hill plots and averaged 0.72, whereas hill plots averaged 0.62. This result is consistent with that of Buzzell and Buttery (1984) who found hill plots to be 43-95% as effective as row plots.

CONCLUSIONS

It was concluded that hill plots were not as effective as single-row plots for the estimation of yield. Neither hill plots nor row plots were as precise or as effective as large plots.

The question of whether HI or GI might be preferable to yield as a selection criterion in small plots was not clearly resolved. In the 1984 cowpea experiment yield was more effective than the indices as an estimator of true yield, but in the 1985 mungbean experiments HI and GI were both more effective than yield. One other indicator of the value of the indices relative to yield was the rank correlation coefficient (Table 1). In four of the six estimates, rank correlations (r_s) of indices were statistically significant while r_s of yield was non significant. This observation, combined with the greater precision of estimation of the indices, suggests that the use of indices for yield selection in small plots is preferred to selection for yield *per se*.

There was no consistent difference between HI and GI except in the precision of measurement as indicated by the coefficient of variation. HI would therefore be preferred to GI as an index of yield in grain legumes.

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SYMPOSIUM DISCUSSION

Dr E. Walsh, University College, Dublin

What correlation would exist between your yield performance in 8 by 10 m rows and actual field plots.

Imrie

The 8 by 10 m size was selected by previous workers who found that was adequate to get a good estimate of crop yield in a field situation. Once you get below that size you start running into variability problems.

Walsh

What level of replication did you use in your row plots?

Imrie

Four reps in March and six reps of each of the small reps.

Dr H.S. Easton, Grasslands Division, DSIR

Did you have some particular reason for looking at harvest index as a correlating character?

Imrie

I had two reasons. One is that it's been promoted in some circles as a good selection criteria to use either in place of or in addition to yield, and the other reason was that there are a few sets of published results on the use of harvest index and they have been conflicting. In my own case in legumes our general experience has been that the earlier maturing the material is, the higher the harvest index. In practice I use a combination of harvest index and yield as a basis for selection.

Dr W. Jermyn, Crop Research Division, DSIR

Have you given any thought to using harvest index at a time of maximum dry matter or maximum forage before you get leaf senescence. I understand that the relationship of canopy development or sink would perhaps be closer to final yield than the scheme of harvest index that you are measuring.

Imrie

Physiology experiments have been done by others in our lab. The figures show there is a little bit of variation between genotype in the relationship between their measurements and my measurement which is stems and inflorescences at full maturity. That is a source of error in the estimate of harvest index but I do not think it has been more than about 5-10% variation.