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BETWEEN PLANT VARIATION OF ASPARAGUS CULTIVARS

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ABSTRACT

1200 plants, from 30 lines in a cultivar evaluation trial were harvested individually for 40 days in 1983. Between plant variances were calculated for total spear numbers and total yield. Variances were highly correlated with means, even after square root transformation. Coefficients of variation were used to compare individuals within each cultivar, and cultivars grouped according to their breeding system. Coefficient of variation for both characters measured were high.

An increase in uniformity between individual plants was detected with advancement in breeding method.

The implications for asparagus breeding programmes are discussed.

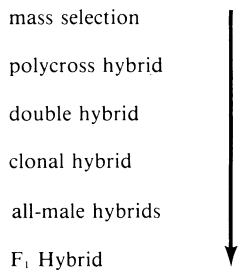
KEYWORDS

Asparagus officinalis L., variance, coefficient of variation, breeding method.

INTRODUCTION

Asparagus breeding has intensified in the last 40 years, with substantial gains in yield and quality. Many of the older cultivars, such as Mary Washington and Early of Argenteuil, were developed and improved by mass selection. Recent cultivars have been derived from fewer parents, some of which have been inbred to some degree, these should be less variable that older cultivars. The development of *in vitro* techniques has permitted greater selection pressure on a smaller number of parents.

Five breeding methods were represented in the trial and provided a worthwhile opportunity to measure the effectivenss of each method. In theory the relationship between the breeding systems can be represented thus:



The variability between individuals within cultivars should reflect the cultivar uniformity achieved by different breeding methods. The information gained would be useful in indicating future paths for asparagus breeding.

The breeding methods referred to are:

- Mass selection — seed is taken from a large number of individuals selected phenotypically from within a population or from the whole population after some form of selection pressure has been imposed, e.g. the population is long-lived or has produced high yields.
- Polycross — equal numbers of selected male and females plants are relocated into a seed block. The new population is of the some constitution as the original population but with an improvement in the character(s) selected for. In effect the parents are also selected for general combining ability.
- Double hybrid — four parents are involved. After testing, two good pair cross combinations are selected, designated AB and CD. The A and C females can only produce a few thousand seeds per year if used in pair crosses, so combinations of A X D and C X B are made and the resulting seed grown. The male plants from the A X D cross are discarded and the female plants from the C X B cross are discarded. The remaining plants from both crosses are set into a seed block. The resulting seed has a combination ADCB.

- Clonal hybrid — as for a double hybrid. After testing, the pair crosses AB and CD have been found as good combinations. *In vitro* cloning (hence clonal hybrid) of the parents A, B, C and D enables thousands of plants of each to be produced. The original combinations, AB and CD can now be produced on a large scale by setting two seed blocks in isolation from each other and other asparagus.
- All-male hybrids — female asparagus plants are designated XX; males XY; "supermales" YY. Combinations of female XX and "supermale" YY produces a population of 100% male plants, XY.

  Supermales can be obtained via hermaphrodite plants, XY, (these have subgenes enabling the development of the female part of the flower) which self-fertilise to produce a ratio of 1YY : 2XY : 1XX, or via anther culture produce a homozygous supermale. Thus a supermale can be one or more generations inbred or fully homozygous.

  Once suitable pair combinations have been found the parents are cloned *in vitro* as for clonal hybrids, or the female parent may be from an inbred line. If this method is used then the supermale is still cloned *in vitro*.
- F_1 Hybrid — A cross between two inbred lines. For a "true" F_1 hybrid the inbred lines are homozygous or almost so. In the case of asparagus, inbreds can be produced by generations of sib-mating, via hermaphrodites and hence self-fertilisation, or via production of haploids in anther culture and hence homozygous diploids.

MATERIALS AND METHODS

The study was conducted on one replication of a national cultivar series trial established at Lincoln, Canterbury, New Zealand in 1981. The trial consisted of 30 entries — 25 new cultivars, with Rutgers Beacon and four lots of Mary Washington 500W (MW500W) each from a different seed source, as controls. The classification of cultivars by breeding method is given in Table 1.

Plants were raised in a seed bed at Levin (North Island, New Zealand) and transplanted as one year old crowns. Rows were 1.5 metres apart and plants 0.45 m apart within rows. Each plot was one row containing 40 plants. The plants were three years old at the time of this experiment. It was the first time they had been harvested.

Harvesting of the 1200 plants began on 24th September 1983 and the last plants were harvested on 16th November 1983. Each plot was harvested for approximately 40 days,

Table 1. Spear numbers and yields of the asparagus cultivars used in the experiment.

Breeding method	Cultivar	Total spear number/plant		Total yield (gms)/plant	
		Range	Mean	Range	Mean
Mass selected	MW500w (Yates)	1-21	4.5	30-525	117.2
	MW500w (Yates)	1-10	3.9	25-370	113.7
	MW500w (Lincoln)	1-15	5.0	20-465	129.8
	MW500w (Baines)	1-24	5.4	25-515	133.0
	Spaganiva	1-31	8.9	25-580	242.8
Polycross	Rutgers Beacon	1-11	3.0	10-225	89.3
Double hybrid	Diane	2-22	5.7	20-485	200.8
	Larac	1-17	6.9	25-775	275.5
	Minerve	1-22	7.4	25-400	240.2
	Junon	1-18	6.6	50-815	280.5
Clonal hybrid	Limbras 10	2-21	8.8	55-645	270.5
	Limbras 18	1-27	7.5	35-455	205.4
	Limbras 22	1-30	8.5	10-710	241.0
	Limbras 26	1-14	5.8	30-480	205.0
	Mira	1-34	12.2	75-1575	554.9
	Aneto	1-31	9.5	25-805	357.1
	Bruneto	2-16	7.7	25-975	398.0
	Cito	3-24	11.3	75-750	383.3
	Desto	1-21	8.3	75-635	331.7
	UC157	1-15	6.0	40-630	233.4
All-male	Sieg	1-17	6.9	20-715	243.9
	Rekord	1-11	5.4	40-435	170.9
	Lucullus	1-16	5.3	5-560	150.2
	Lucullus Early Hybrid	1-15	5.8	40-420	178.4
	Jersey Giant	1-12	6.0	25-600	261.1
	Md10 x 22-8	1-14	5.4	25-375	191.1
F_1 hybrid	Schwetzinger-Meisterschuss	1-8	2.1	40-230	71.0

at two day intervals. At each harvest, number and weight of spears from each plant was recorded. Spears were graded into two categories — saleable or reject. At the end of the season, results for each plant were amalgamated and total spear numbers and total yields (saleable + reject) were calculated.

RESULTS

Of the cultivars in this study only five produce spears of consistent enough quality to consider recommending them to New Zealand growers. Generally, quality was extremely poor, reflecting the fact that most were bred for white asparagus production.

The range, mean total spear numbers and mean total yield for each cultivar were calculated. These are set out in Table 1.

Histogram plots of total spear numbers and total yields for each cultivar revealed that all showed a right skewed population distribution.

An analysis of variance was performed on total yield and total spear numbers, and cultivar variances for both calculated. Graphs revealed a high correlation between the variance of individuals and cultivar means. To try and remove this correlation, total yields and total spear numbers were transformed using $\sqrt{(\text{data} + 0.5)}$ and another analysis of variance was performed. Transformation failed to remove the correlation between mean and variance. The relationship, after transformation, between variance and total spear numbers is shown in Fig. 1 and variance and total yield in Fig. 2. As the relationship between mean and variance wasn't altered by transformation variance could not be used as a measure of uniformity. Therefore coefficient of variation has been used.

Coefficients of variation for each cultivar are set out in Table 2.

In order to compare the uniformity of breeding methods, cultivars were grouped according to system and the coefficient of variation for each group was calculated. These are set out in Table 3. It should be noted that three of the original 30 cultivars weren't included in the grouped analysis, Arlette because only 20 plants were measured and two others because the breeding method was not known.

DISCUSSION

In this study it was proposed to use variance as a measure of the uniformity of cultivars and breeding systems. Variance is a classical measure of uniformity but is affected by outliers in a population. In the population studied, because of the number of outliers and the high correlation of mean and variance, variance could not be used as a method of comparison. For this reason,

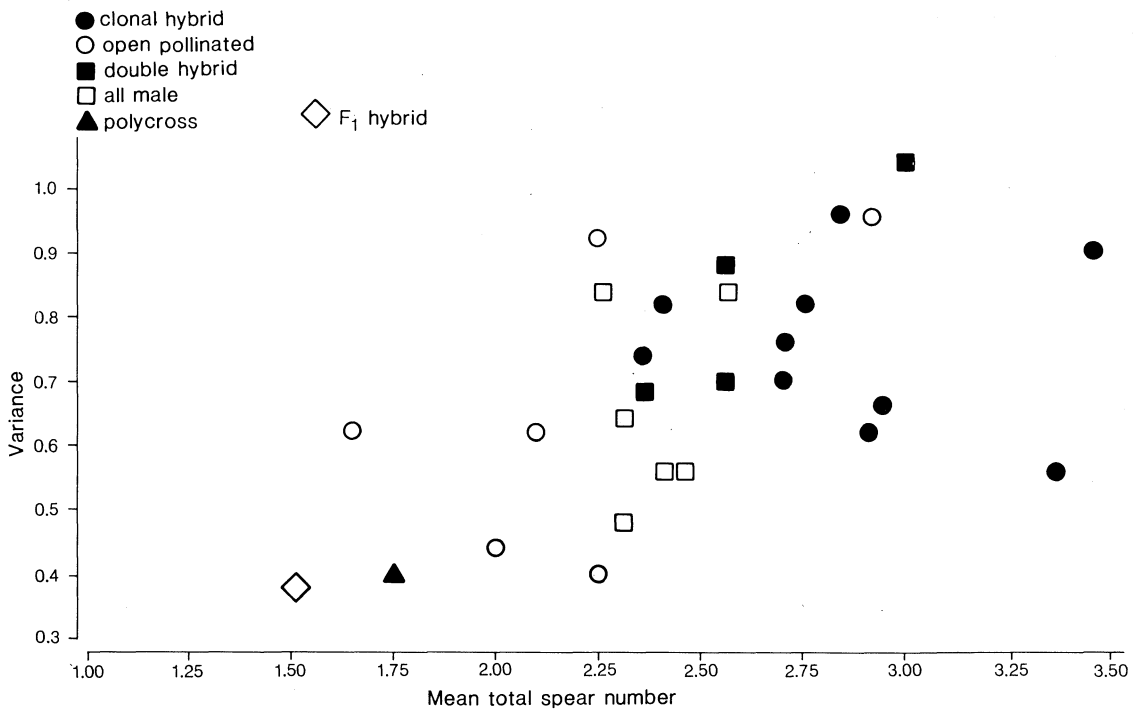


Figure 1. Plot of variance against mean total spear number for each cultivar, after transformation.

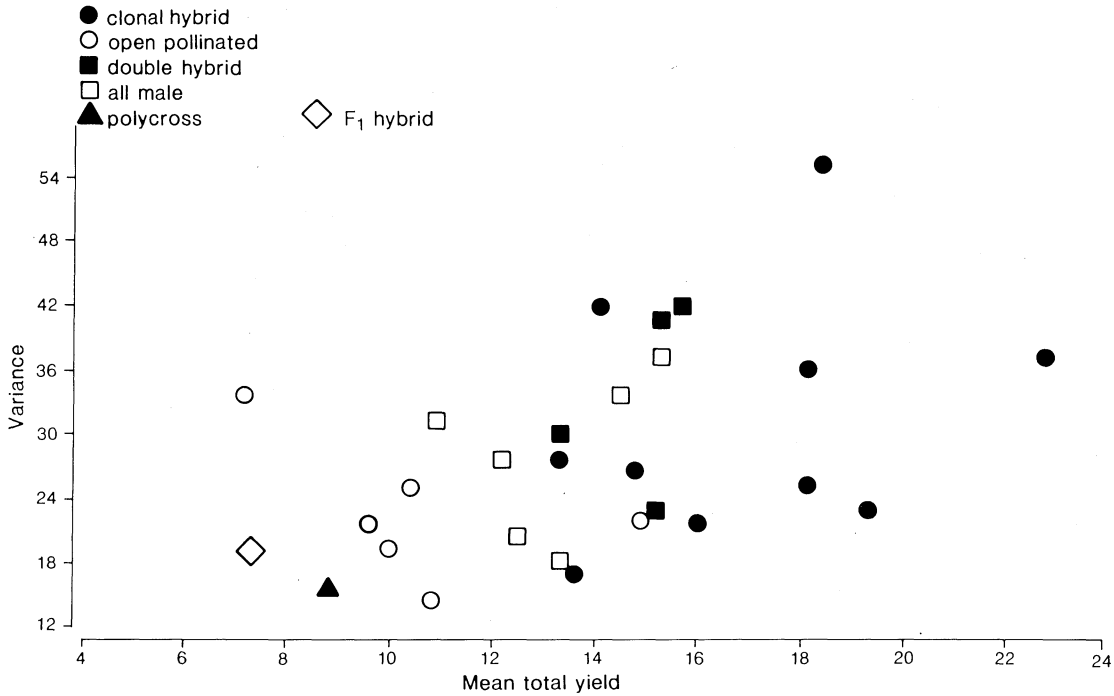


Figure 2. Plot of variance against mean total yield for each cultivar, after transformation.

coefficient of variation has been used. As coefficient of variation is the ratio of the standard deviation of the sample to the sample mean, it is less dependent on the size of the sample mean. Others (Bannerot, *et al.*, 1969; Corriols-Thevenin, 1979) have also used coefficients of variation as a measure of uniformity in asparagus trials.

Coefficients of variation were very high for both spear numbers and total yield. High correlations of variation between individuals for a number of characters in asparagus have also been reported by Bannerot, *et al.* (1969). Relative differences between plants for a number of characteristics related to yield have been found to remain the same over a number of years, even though yield increases (Bannerot *et al.*, 1969, Moon 1976). Thus, even though this study was conducted during the first harvest season on three year old plants, the same results could be expected if the study had been conducted on mature plots.

The number of plants of each cultivar measured was relatively small, but when cultivars are grouped according to breeding system, reasonable size populations result and this gives a way of comparing breeding systems.

Generally in this study as the breeding system becomes more advanced (reduction in the number of parents, or use of inbred parents), uniformity between individuals increases (Table 3). The grouped cultivar coefficients of variation show that there has been significant improvement in uniformity for both spear numbers and total yield except for the F1 hybrid cultivar. Clonal hybrids are the most uniform of the five breeding systems.

Although Schwetzainger Meisterschuss has been designated a F_1 hybrid by the breeder, the parents are inbred to only approximately 70% homozygosity (H.D. Greiner, pers. comm.). The use of parents with this degree of inbreeding appears to give no advantage in uniformity.

In theory, all-male hybrids should be more uniform than clonal hybrids as the male parent is inbred to some degree. In three of the all-male hybrids, Seig, Rekord and Luccullus Early Hybrid, the female parent is from an inbred line, (inbred to 70% homozygosity H.D. Greiner, pers. comm.) developed using sister-brother mating. These three cultivars are more uniform than the all-male clonal hybrid Luccullus. They are less uniform than Jersey Giant and Md10 x 22-8, both of which have the same supermale parent.

Mean yield of male plants is higher than yield of female plants in the same population (Bannerot *et al.*, 1969, Moon 1976). Hence the interest in all-male cultivars. These have been predicted to yield more than dioecious cultivars because the females, and thus a considerable portion of the lower yielders, have been removed from the population.

As a group, all-male cultivars in this study have not yielded as much as clonal or double hybrids. This probably reflects that breeders have imposed a lower selection pressure on supermales, in order to release these initial all-

Table 2. Coefficients of variation of cultivars for total spear numbers and total yield.

	Coefficients of variation	
	Total spear number	Total yield
Mass selected		
MW500w (Yates)	81.7	83.1
MW500w (Yates)	66.5	72.0
MW500w (Lincoln)	64.4	84.2
MW500w (Baines)	100.7	90.0
Spaganiva	74.8	60.8
Polycross		
Rutgers Beacon	86.9	82.7
Double hybrid		
Diane	70.4	74.7
Larac	67.1	67.6
Minerve	70.4	58.9
Junon	61.8	65.4
Clonal hybrid		
Limbras 10	57.8	50.6
Limbras 18	64.3	54.4
Limbras 22	65.9	62.8
Limbras 26	67.2	63.3
Mira	58.3	52.2
Aneto	65.2	59.9
Bruneto	57.7	60.8
Cito	41.9	39.4
Desto	55.9	52.3
UC157	72.3	71.3
All-male hybrid		
Sieg	63.1	62.7
Rekord	64.9	69.4
Lucullus	78.6	80.5
Lucullus early hybrid	63.8	61.7
Jersey Giant	54.7	56.3
Md10 x 22-8	59.5	53.9
F_1 hybrid		
Schwetzinger-Meisterschuss	92.9	93.9

Table 3. Mean coefficients of variation for cultivars grouped according to breeding system.

Breeding system	Total spear number	Total yield
Mass selected	77.6	78.0
Polycross	86.9	82.7
Double hybrid	67.4	66.6
Clonal hybrid	60.6	56.7
All-male hybrid	64.1	64.0
F_1 hybrid	92.9	93.9

male cultivars. This is probably analagous to the Cost of Natural Selection discussed by Haldane (1957), in that it is difficult to select simultaneously for all desired qualities, particularly for long-generation plants such as asparagus.

Also, when a new character, such as resistance to disease or herbicide or a new quality character, is first incorporated into a cultivar, breeders and customers are often prepared to accept a lower standard for other characters, to obtain the novelty.

An alternative indication of variability, is the proportion of plants that make only a small contribution to the yield. Set out in Table 4 are the mean proportion of plants in each breeding system contributing 80% of the total yield. There are only small differences in the proportion of small or non-contributors between the breeding systems in this trial. Improved breeding method has not resulted in less non-contributors in a population.

Corriols-Thevenin (1979) has given coefficient of variation figures of 52.4% for 4 double hybrids, 47.8% for 5 clonal hybrids and 44% for an F_1 hybrid. These were measured on 60 plant populations in year 3 (presumably the first harvest season although this is not clear). These are lower than the figures measured in this study, probably because the spears were harvested as white asparagus, but show a similar trend.

Table 4. The proportion of plants contributng 80% of the total yield, for cultivars grouped according to breeding system.

Breeding system	Proportion of plants contributing 80% of total yield
Mass selected	57.0
Polycross	58.0
Double hybrid	57.0
Clonal hybrid	58.7
All-male hybrid	57.6
F_1 hybrid	58.0

An interesting point from Corriols-Thevenin's study is the relatively small reduction in coefficient of variation between the 5 clonal hybrids (heretozygous parents) and the F_1 hybrid, which is dioecious. This has one parent derived from a pure line created by intercrossing doubled haploids (found in polyembronic seeds), and the other parent a doubled haploid derived via anther culture, i.e. two homozygous parents. The figure given for the F_1 hybrid could be considered a reasonable measure of the environmental effects since there is only one genotype, and suggests that a considerable amount of the between plant variation measured in the present study and by Corriols-Thevenin, is due to the local environment. This is feasible given that asparagus is a perennial and subject to the vagaries of management and seasons. No estimates for the environmental effects on asparagus has yet been published, but a number of trials using tissue cultured clones have been initiated. These should provide estimates.

The results reported by Corriols-Thevenin have some implications for an asparagus breeding programme, as it appears very little gain in uniformity has resulted from expensive *in vitro* production of homozygous parents. Other benefits of the technique may outweigh this

disadvantage, certainly the quick and prolific production of supermales would be one.

From the lower yield of all-male hybrids in the present study, it would appear that large numbers of supermales of diverse origins are necessary to enable greater selection pressure on supermales, to produce all-male hybrids of the standard of dioecious clonal hybrids. While an improvement in uniformity has been achieved solely by improved breeding method, further improvement in uniformity may need greater selection pressure on parents.

The final point that can be made about this study, is that a considerable range of variation for characters other than yield was evident, enough to encourage further selection within the population. Since the environmental effect on asparagus yield appears to be quite large, this will affect selection procedure for yield. In practise this means that selection pressure for yield could be less intense, particularly if other desirable characters are present.

CONCLUSIONS

Considerable variation was evident in the two characters measured. The coefficients of variation between individuals were very high.

Differences in the uniformity of breeding systems were apparent. Generally, less parents resulted in greater uniformity. It is difficult to know if the reduced uniformity found within the all-male cultivars is real, or a result of the sample size.

Coefficients of variation reported elsewhere for an F_1 hybrid mean that careful consideration of this system should be made before expensive, *in vitro* homozygous parent production is initiated.

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SYMPOSIUM DISCUSSION

Mr T.P. Palmer, private breeder, N.Z.

If the environmental component of variation in single plants is so high is it in fact detrimental to engage in any selection rather than get into a progeny test programme?

Mr Nikoloff

If you start off with 2000 plants it's impossible to do a progeny test using all those parents. Most breeders would take the high yielding plants although they are interested in other traits.