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EFFECT OF CLONAL SELECTION AND PLANTED CLOVE WEIGHT ON YIELD OF GARLIC

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ABSTRACT

Four clones were selected over three years from 200 bulbs of above-average size out of a commercial crop of Marlborough White garlic. In 1985/86 these clones, each planted at five clove weights were compared with the recently introduced cultivar Printanor planted at four clove weights, at a population of 200,000 plants/ha. Three of the Marlborough White clones produced 31-40% more than the fourth clone, but Printanor outyielded the best of these by 40%. When the weight of the planted cloves of the Marlborough clones was increased from 1.8 g to 4.5 g the mean yield increased linearly from 7.0 t/ha to 10.8 t/ha. A similar linear trend occurred in Printanor, which increased in yield from 11.2 t/ha for cloves of 2.4 g to 16.0 t/ha for cloves of 6.4 g. In the clones of Marlborough White the contribution of bulbs over 50 mm diameter to yield increased when larger cloves were planted. In Printanor more bulbs over 60 mm diameter were obtained from larger cloves. In 1986/87 the highest and lowest yielding Marlborough White clones and Printanor were again compared, each at two clove weights, and results confirmed earlier findings. Yields of 17.4 t/ha were obtained from Printanor which outyielded the highest clone of Marlborough White by 90%. The causes of differences between clones and the advantages of clonal selection, grading of cloves before planting and adjusting plant populations in accordance with clove size are discussed.

Additional Key Words: Allium sativum, *cultivars, Marlborough White, Printanor, bulb diameter.*

INTRODUCTION

Garlic (*Allium sativum* L.) is a sterile species considered to be descended from *A. longicuspis* Regel, which is endemic to Central Asia (Vvedensky, 1944). Archaeological records indicate that garlic has been cultivated for more than 5000 years. Despite its sterility garlic is an extremely diverse species. A collection of 559 cultivars was reported to be held at the National Bureau of Plant Genetic Resources, New Delhi (Astley *et al.*, 1982).

A mature garlic bulb consists of a number of axillary buds or cloves attached to a basal plate and covered with the shrivelled basal portions of the leaves. In some cultivars the plant produces an inflorescence with bulbils amongst its withered flower buds. Cloves are commonly planted to establish a garlic crop but in some cultivars bulbils can also be used.

Marlborough White is the main commercial cultivar grown in New Zealand. Presumably it was derived from the cultivar Californian Late, an introduction from North America, but it is not known to what extent it has diverged during its period of cultivation in New Zealand.

Marlborough White has been a popular cultivar, because of its good keeping quality. However, it produces relatively small bulbs with large numbers of cloves of varying size.

In 1982/83 a project was begun at Crop Research Division, DSIR, Lincoln to investigate whether bulb size and hence bulb yield of Marlborough White could be increased by clonal selection. To make the comparison between clones valid, the weight of planted cloves had to be taken into consideration. At Levin a highly significant increase in yield had been obtained when the weight of the planted cloves of an unspecified line of garlic was increased from 1.0-1.9 g to 2.0-2.9 g (Minard, 1978).

In New Zealand all garlic plants in the field tested by Mohamed and Young (1981) were infected with a virus they described and named garlic yellow streak virus (GYSV). In France Delecolle and Lot (1981) identified a similar, and possibly identical virus, as a strain of onion yellow dwarf virus (OYDV), although it was non-pathogenic to onions (B. Delecolle pers. comm.). Printanor developed at INRA, Montfavet, France is a new cultivar of garlic that is relatively free from OYDV (B. Delecolle pers. comm.). To avoid confusion with OYDV in onions the name GYSV is preferred in New Zealand (B.R. Young pers. comm.). In 1983 Printanor was introduced to New Zealand and multiplied at Lincoln by Crop Research Division, DSIR (Lammerink, 1987). The bulbs of Printanor consisted of cloves that were generally larger than those of Marlborough White. From 1985 Printanor was included in field trials for comparison with selected clones of Marlborough White.

MATERIALS AND METHODS

The project was conducted over five years at Crop Research Division, DSIR, Lincoln on a Templeton silt loam out of wheat.

1982/83. 200 bulbs of above average size were selected out of a commercial crop of Marlborough White and planted as single clones in unreplicated plots.

1982/83. The 42 highest (HY) and the seven lowest yielding (LY) clones were compared in a 7 x 7 lattice design trial with one LY clone per block.

1984/85. Out of the 42 HY clones of the previous trial, six high yielding, two medium yielding and the lowest yielding clone, the latter at two mean clove weights, were compared in a randomised block trial.

In both trials the average weight of the planted cloves was recorded for each plot. Covariance analysis was used to adjust harvest yields for the weights of the planted cloves.

1985/86. From the previous trial the three highest yielding clones and the lowest yielding clone were compared along with Printanor in a split-plot trial in which clove weight grades were sub-treatments. The grade for clove weight were: 1.7-2.0 g, 2.1-2.5 g, 2.7-3.2 g, 3.4-4.0 g and 4.2-4.8 g for the Marlborough White clones and 2.0-2.8 g, 3.0-3.8 g, 5.0-5.8 g and 6.0-6.8 g for Printanor.

Table 1. Yield of nine clones of garlic selected from the cultivar Marlborough White in 1984/85. Yield is adjusted to the overall mean planted clove weight in the final column.

Clone	Harvested yield (t/ha)	Clove weight (g)	Adjusted yield (t/ha)
MW 52	16.8	4.1	16.1
MW 16	16.1	3.7	16.1
MW 61	15.9	3.8	15.6
MW 71	15.7	3.7	15.6
MW 36	15.8	3.8	15.5
MW 53	15.6	3.7	15.5
MW 73	14.1	3.2	14.8
MW 26	15.1	3.9	14.6
MW 75 L†	12.3	4.2	11.5
MW 75 S†	10.1	2.3	12.3
LSD 5%	0.86	0.14	2.11 ††

† L = large cloves; S = small cloves
†† Average value; range: 0.84-4.77

1986/87. One high-yielding and one low-yielding clone of Marlborough White, each at clove grades of 1-2 g and 3-4 g, and Printanor at clove grades of 2-3 g and 5-7 g were compared in another split plot trial. Additional treatments were included in this trial but they will be reported elsewhere.

The trials were planted between late May and the middle of June each year. In all four trials plots consisted of single rows, 4.5 m long and 0.5 m apart. Plants were spaced at 0.1 m intervals along the row giving a population of 200,000 plants per ha. There were four replications. Reverted superphosphate at 500 kg/ha, urea at 200 kg/ha and the herbicide trifluralin (40% a.i.) at 2 l/ha were incorporated in the soil three weeks before planting. The plots were hand hoed twice to control weeds. In 1983/84, 1985/86 and 1986/87 the trials were irrigated once using sprinklers. The 1984/85 trial was irrigated twice.

Plants were lifted during the 2nd to 4th week of January when the foliage was turning yellow and starting to lodge. After drying for 3 to 10 days in the field the plants were stored for 3 to 4 weeks before the bulbs were topped, tailed and weighed.

In 1985/86 and 1986/87 side cloves were removed and bulbs were sorted into four grades: under 40 mm, 40-50 mm, 50-60 mm and over 60 mm diameter. In 1985/86 side cloves were included with the bulbs under 40 mm in diameter, but they were weighed separately in 1986/87. Analysis of variance was carried out on total yield of bulbs in all trials, and in the last three trials on yield of bulbs of diameters greater than 40 mm, 50 mm and 60 mm. For each class yield was calculated as a percentage of the total yield and data were angularly transformed before analysis of variance. Data were back transformed before presentation.

RESULTS

1983/84

Differences amongst clones in the average weight of planted cloves were highly significant as were differences in the yield of bulbs harvested. The clove weights at planting ranged from 1.8 to 4.2 g with a mean of 3.0 g and the bulb yields from 6.9 to 14.6 t/ha with a mean of 11.3 t/ha. There was a linear relationship between planted clove weight and bulb yield with an estimated increase of 1.3 t/ha for each gram increase in clove weight ($P<0.001$). Clove weight at planting, as a covariate, explained 9% of the residual sum of squares. After adjustment to the overall mean clove weight, differences amongst clones remained highly significant. They varied from 7.2 to 8.4 t/ha for the LY clones and from 9.1 to 13.7 t/ha for the HY clones (Figure 1).

1984/85

There were again highly significant differences amongst clones in the weight of cloves planted and in the yield of bulbs harvested (Table 1). The effect of clove weight on yield was demonstrated in clone MW75. After adjustment to the mean overall clove weight of 3.6 g yield differences amongst clones were still highly significant and the results were consistent with those obtained in the previous season (Figure 2).

1985/86

The Marlborough White clones MW16, MW52 and MW61 produced, after averaging over all clove weight grades, 34% more total yield than MW75 (Table 2). The average yield of Printanor was 46% higher than the average of the three highest yielding clones of Marlborough White. In all four clones of Marlborough White and in Printanor there was a linear relationship ($P<0.001$) between clove weight and bulb yield. Bulb yields increased by 1.4 t/ha for the mean of the Marlborough White clones and by 1.2 t/ha for Printanor for each gram increase in clove weight. For the Marlborough White clones increasing the clove weight gave significantly higher percentages of total yield of bulbs over 50 mm diameter, reaching 60% for all clones at the highest clove weight. Very few bulbs were over 60 mm diameter for any of the MW clones and most of these were produced from the heavier cloves. The highest percentage by weight of bulbs over 60 mm diameter was 14 (s.e. 3.5), for MW52 from cloves over 4.2 g. In Printanor all clove weight grades produced at least 25% of total yield as bulbs over 60 mm diameter and more than 65% over 50 mm diameter. However the percentage of yield of bulbs over 40 mm diameter decreased linearly from 93 to 77 with increasing clove weights, due to an increase in double bulbs and side cloves.

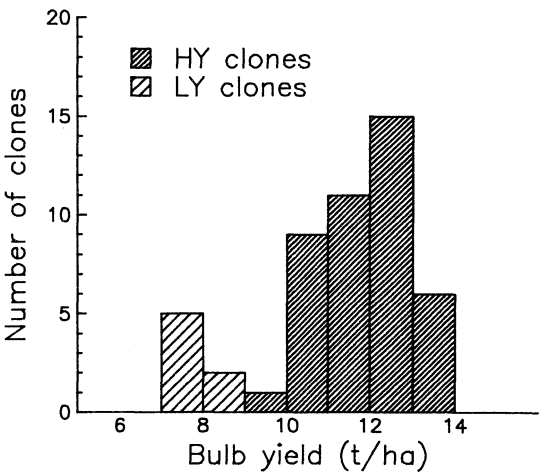

Figure 1: Yield of 49 clones of Marlborough White garlic in 1983/84, adjusted to the mean clove weight of 3.0

Table 2. Yield of four clones of garlic selected from Marlborough White and of Printanor and means at several planted clove weights in 1985/86.

	Yield (t/ha)			
	Total	Bulb diameter (mm)		
		>40	>50	>60
Clone/cultivar				
Mean over clone weights				
MW52	9.8	7.7	4.8	0.7
MW16	9.2	8.0	4.7	0.1
MW61	9.2	7.3	4.3	0.4
MW75	7.0	6.0	3.1	0.2
Printanor	13.7	11.2	9.8	4.5
LSD 5%				
between MW clones	0.91	0.83	1.33	0.41
Printanor vs MW clones	0.75	0.75	1.09	0.64
Clove weight (g)				
Mean over all MW clones				
1.7 – 2.0	7.0	5.9	2.0	0.0
2.1 – 2.5	7.8	6.7	3.6	0.2
2.7 – 3.2	8.6	7.0	3.9	0.2
3.4 – 4.0	9.8	7.8	5.3	0.6
4.2 – 4.8	10.8	8.5	6.4	0.7
SEM	0.11	0.14	0.28	0.10
Increase/g clove				
wt increase	1.4	1.0	1.6	0.3
SE	0.05	0.06	0.13	0.05
Clove weight (g)				
Printanor				
2.0 – 2.8	11.2	10.3	9.2	2.8
3.0 – 3.8	12.5	10.4	9.2	4.2
5.0 – 5.8	15.0	11.8	10.5	5.6
6.0 – 6.8	16.0	12.3	10.4	5.5
SEM	0.33	0.34	0.41	0.42
Increase/g clove				
wt increase	1.2	0.5	0.4	0.7
SE	0.10	0.11	0.13	0.13

1986/87

Differences amongst MW52, MW75 and Printanor were again highly significant for both large and small cloves (Table 3). MW52 produced 35% more than MW75 and Printanor produced 90% more than MW52. Differences in yield between clove sizes were also highly significant for both clones of Marlborough White and for Printanor. For each gram that planted clove weight increased total yield increased by 1.2 t/ha for the mean of the Marlborough White clones and by 1.3 t/ha for Printanor. The biggest increase again occurred in the over 50 mm grade of the MW clones and in the over 60 mm grade of Printanor.

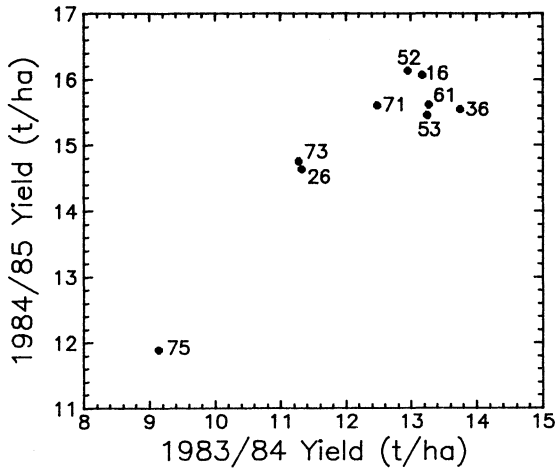

Figure 2: Yield (t/ha) of nine selected clones of Marlborough White garlic in 1983/84 and 1984/85, each adjusted to the mean clove weight planted that year.

Table 3. Yield of two clones of garlic selected from Marlborough White and of Printanor at two planted clove weights in 1986/87.

	Yield (t/ha)			
	Total	Bulb diameter (mm)		
		>40	>50	>60
Clone/cultivar				
MW52				
clove wt 1-2g	8.0	7.3	4.1	0.0
3-4g	10.2	9.4	8.4	2.2
MW75				
clove wt 1-2g	5.6	5.0	1.3	0.0
3-4g	8.0	7.1	4.5	0.8
Printanor				
clove wt 2-3g	15.1	14.7	14.6	11.1
5-7g	19.6	19.0	18.8	17.9
SEM †	0.46	0.48	0.57	0.94 ††

† for comparison of clove weights within each clone or cultivar; multiple by 1.14 for comparison of clones at a given clove weight.

†† for Printanor only; less than 0.5 for MW clones

DISCUSSION

Clonal selection. Yield was clearly improved by clonal selection. There was good agreement in the relative performance of selected clones over 4 years with MW52 yielding 42, 37, 40 and 35% more than MW75 (Figure 3). Naturally average bulb size was also increased and hence market acceptability and price

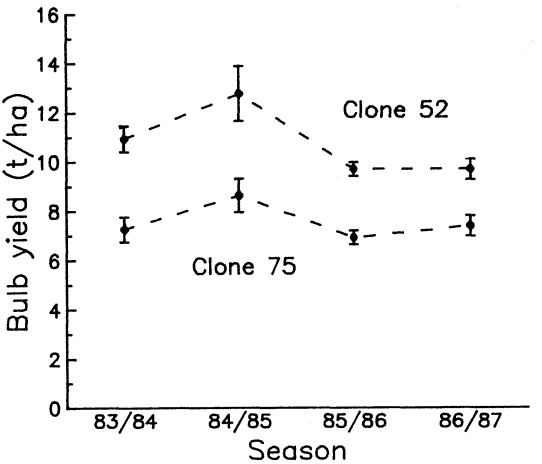

Figure 3: Yield (± SEM) (t/ha) of two selected clones of Marlborough White garlic over four seasons, adjusted to a mean weight of 3.0 g. In this figure the ungraded yields for the first 2 seasons have been reduced to allow for losses due to grading, using percentages obtained in the third season.

are likely to improve. No attempt was made to monitor environmental factors responsible for seasonal fluctuations. In the last two trials more rigorous handling during grading and better storage conditions increased dry matter content but decreased bulb weights so that total yields were lower. Printanor was included in these trials. It yielded considerably more and produced bigger bulbs than clones of Marlborough White.

Planted clove weight. In the first two years covariance analyses indicated a linear relationship between clove weight and yield for Marlborough White. This was confirmed in the last two years and a similar relationship was found for Printanor. The estimated yield increase per gram increase in clove weight were 1.4 and 1.2 t/ha for the mean of the Marlborough White clones and 1.2 and 1.3 t/ha for Printanor, all at a fixed population of 200,000 plants/ha. It is to be expected that with smaller cloves, yields can be increased by increasing the plant population but there will be a corresponding tendency for bulb size to decrease (Lamerink, unpub. data). Grading of cloves should give the following benefits.

1. Substantial increases in yield and bulb size if only large cloves are planted.
2. The ability to adjust plant spacing according to clove size.
3. Less competition amongst the smaller plants grown from smaller cloves than when grown in a mixed population.
4. Lower costs of grading harvested bulbs, because of greater uniformity in bulb size.

True progency testing is impossible in this sterile vegetatively propagated species, so it cannot be proven that clonal differences are of a genetic nature. All trials were inspected and found to be free of non-viral diseases. All Marlborough White garlic grown in New Zealand is heavily infected with viruses which are readily transmitted by aphids and thrips, In 1986/87 uniformly high levels of GYSV were found in five random bulbs from both MW52 and MW75 using the ELISA technique. Thus it is unlikely that the differences in yield between the clones of Marlborough White are due to differences in the incidence of disease.

In this project clones have been compared for bulb size and yield only. However there are indications that other characters such as size and number of cloves per bulb also vary in Marlborough White. Presumably the diversity in this cultivar is the result of somatic mutations which have occured during the period that it has been grown in New Zealand and perhaps before its introduction to New Zealand. If any mutations have been beneficial, selection could give improvements over the original cultivar. If mutations have been deleterious selection could return the cultivar to its original state. In either case clonal selection is essential for optimum performance.

Printanor. Presumably Printanor's superior bulb size and yield are primarily due to its relative freedom from virus. However, it is speculated that even with a level of virus infection similar to that of Marlborough White is could be more productive because of the clonal selection that went into its development and maintenance as a cultivar.

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