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Asparagus growth physiology

A report prepared for the
New Zealand Asparagus Council

D R Wilson, S M Sinton & C E Wright
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New Zealand Institute for Crop & Food Research Limited
Private Bag 4704, Christchurch, New Zealand

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1 EXECUTIVE SUMMARY

Asparagus has a complicated annual growth cycle. The goal of our research is to provide a sound basis for good crop management decisions through improved understanding of the cycle. This report presents results from two aspects of the project:

- Influence of spear harvest management on the growth and yield of asparagus.
- Comparative performance of male and female plants.

In the first part, we present results from a field experiment in which the annual growth cycle was changed by varying the time of fern growth and spear harvest during the season. Four treatments were applied to an established crop:

- Undisturbed annual cycle - no spear or fern harvest.
- Spring spear harvest, then fern growth.
- Extended spring spear harvest, about a month longer than usual, then fern growth.
- Autumn spear harvest, spring and summer fern growth.

The treatments had large effects on both above- and below-ground growth of the crop. We will measure their ultimate effects by taking a standard spear harvest of about 75 days from all plots in spring 1997. Key results from 1996-97 were:

- Spear yield was highest from the extended spring harvest, but recharge of the root system by late autumn was poor. This will probably cause a low spear yield next season.
- As in the results we reported in 1995-96, the normal spring harvest achieved the best balance of a good spear yield and a fully recharged root system at the end of the season.
- Spear yield was not limited by availability of buds. About 50 buds per crown were available but no more than 20 spears per crown were produced.

- The crop's dry matter balance was dominated by fern and root weight. These were much greater than spear weight.

- At full recharge, 50-60% of root weight was storage carbohydrate (CHO). The amount of stored CHO fluctuated by as much as 6 t/ha during the season. Initial fern growth caused the main depletion of CHO from root reserves. These were recharged after the fern was established.

The results confirm last year's finding that the common management aim of stimulating vigorous fern growth is not desirable. Although fern growth and yield were relatively low in the normal spring harvest treatment, this had no adverse effect on root system performance.

In the second part, we present results from a project in which we measured the yields separately of male and female plants in a mixed population of Jersey Giant Syn 4. We also determined how the growth of their root systems differed during the crop's annual cycle.

The ratio of male:female plants in the population was 57:43. Male plants were substantially superior in all respects, so the advantage of using an all-male population, is clear. In the mixed population, males produced an 80% higher total spear yield per plant, and contributed 70% of the yield per unit area. If all plants in the population had been males, yield per unit area would have been about 20% greater than that of the mixed population. The spear yield difference between males and females was associated with large below-ground differences. Male root systems were much larger, accumulated more storage CHO, and had more buds and storage roots than females.

2 INTRODUCTION

Asparagus has a complicated annual growth cycle. Spear production is the result of a complex sequence of physiological processes. Events during fern growth, when spear yield potential is established by the formation of new buds and accumulation of reserves in the storage root system, are related very indirectly to spear production during the following season. This makes it difficult to understand the effects of weather and crop management on spear yield.

The goal of our research is to provide a sound basis for good crop management decisions through improved understanding of the growth cycle. To achieve this, we are using two complementary approaches: development of a model of the growth physiology of asparagus, and field experiments to provide information for developing and testing the model.

In 1996-97 we continued our long-term project to achieve this goal. In this report we present results on two aspects of the project:

- Influence of spear harvest management on the growth and yield of asparagus.
- Comparative performance of male and female plants.

In both cases the results highlight some interesting features of the crop's growth and have important practical implications for crop management.

3 INFLUENCE OF SPEAR HARVEST MANAGEMENT ON GROWTH AND YIELD OF ASPARAGUS

3.1 Introduction

Spear growth depends on the availability of resources in the root system during harvest. Two measures of resource availability are numbers of buds and storage roots, and the amount of stored soluble carbohydrate. Both fluctuate during sequences of fern and spear growth in the crop's annual cycle. The aim of crop management is to balance accumulation and depletion of resources so that (a) spear yield is maximised, (b) excessive fern growth is avoided, (c) the root system is fully recharged at the end of each season, and (d) long-term crop performance is ensured by maintaining or increasing the size of the root system.

For the second year, in 1996-97, we studied resource accumulation and depletion by excavating whole root systems at regular intervals during an annual growth cycle. Treatments were imposed that changed the annual cycle by varying sequences of fern growth and spear harvest.

3.2 Methods

Measurements were made in a Jersey Giant Syn 4 crop established in October 1993 by planting crowns that had been graded for uniformity. Rows were 1.5 m apart with 0.3 m spacing between plants within rows. For three years the crop was managed using standard practices for the establishment phase. There were no spear harvests.

From September 1996 to May 1997, there were four spear harvest and fern management treatments:

- NH: No spear harvest, uninterrupted fern growth all season.
- SPR: Usual spring harvest (20 September to 4 December, 75 days), then fern growth.
- XSPR: Extended spring harvest (20 September to 7 January, 109 days), then fern growth.

- AUT: Spring-summer fern growth, then a summer-autumn harvest (10 January to 24 March, 73 days).

There were three replicates of each treatment. The harvested area in each plot was 30 m^2 (10 m by two rows). During harvest periods, spears were harvested every second day and divided into marketable and reject grades. Four plants per plot were harvested destructively on six occasions during the season. The yield of ferns was measured when they were present. Root systems were excavated, the numbers of buds and roots were counted, and the weight and carbohydrate (CHO) content of the roots were measured.

3.3 Results

Spear yield differed among the three treatments in which spears were harvested (Fig. 1). Yield was highest from the extended spring harvest and lowest from the autumn harvest. The proportion of marketable spears was similar for all treatments.

The ***number of spears produced per crown*** also differed among the treatments (Fig. 2). More spears were produced in the extended spring harvest (about 19 per crown) while about 12 per crown were produced in the other two treatments.

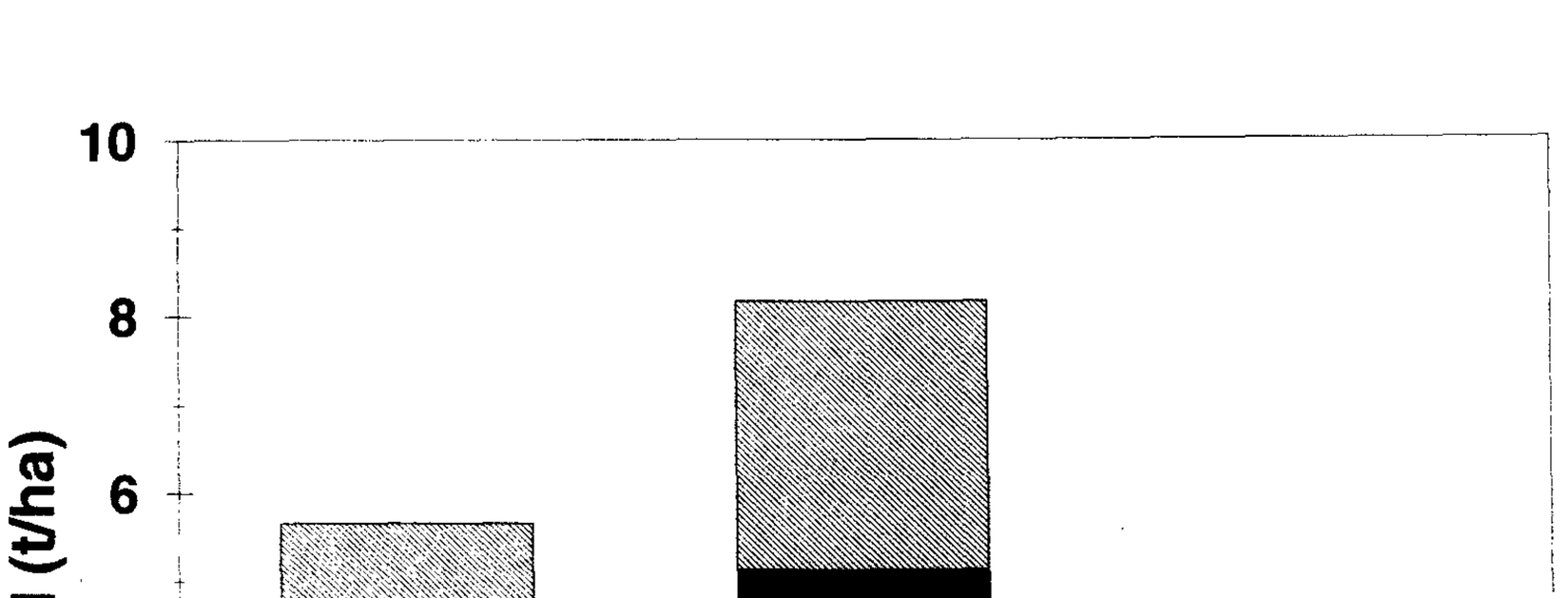

Figure 1: Marketable and reject spear yields in the three treatments with spear harvests.

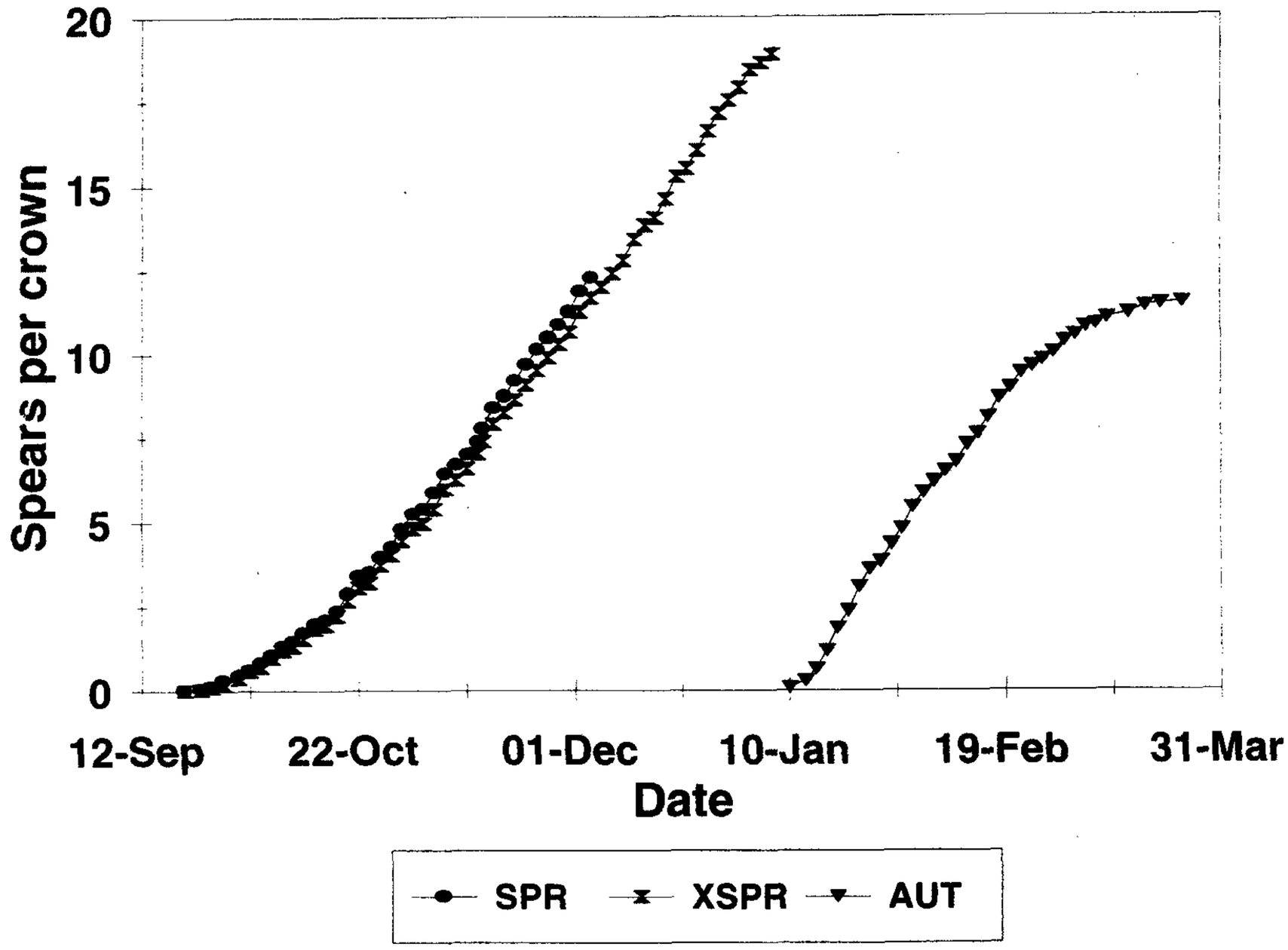

Figure 2: Number of spears produced per crown in the three treatments with spear harvests.

The treatments strongly affected the seasonal patterns of ***bud and storage root numbers per crown*** (Figs 3 and 4). The patterns were similar for buds and roots in each treatment. Numbers of buds and roots declined during spear harvests and fern growth periods, and then recovered once fern was established. Most new roots and buds were formed in summer and autumn. Recovery of numbers by late autumn was best following the usual spring harvest. There was no advantage from having no spear harvest, and allowing fern growth all season. There was no evidence that spear production was restricted by availability of buds. There were about 50 buds per crown at the start of the season, no more than 20 spears were produced per crown, and the number of unused buds per crown was never less than about 28.

The dry matter balance of the crop was dominated by the root system and fern growth. Maximum ***root dry weight*** was 12 t/ha, much greater than the maximum ***spear dry weight*** of 1 t/ha (Fig. 5). Root weight declined during spear harvests and, especially during fern growth periods, and then recovered once fern was established. Root recovery was best with either no spear harvest or following the usual spring harvest. Spear weight was highest from the extended spring harvest and lowest from the autumn harvest. ***Fern dry weight*** was much greater than spear weight but less than root weight (Fig. 6). There were large maximum fern weight differences among the treatments, with a range from 2 to 8 t/ha.

The ***soluble CHO content*** of the roots varied from 20% to 60% of root weight during the season (Fig. 7). The CHO content followed similar patterns to root weight—it declined during spear harvests and fern growth periods, and then recovered once fern was established. The ***amount of CHO*** in the root system was about 5 t/ha in all treatments at the start of the season. Subsequently, it ranged from about 1 to 8 t/ha as both the weight of roots and their CHO content changed during the season. It declined more during fern growth periods than during spear harvests. Recovery of stored CHO by late autumn was best with either no spear harvest or after the usual spring harvest. The amount of CHO was low at the end of the season following the extended spring and autumn harvests.

3.4 Conclusions

The treatments had large effects on both above- and below-ground growth of the crop. We will measure their ultimate effects by taking a standard spear harvest of about 75 days from all plots in spring 1997. The main conclusions from 1996-97 were:

- Spear yield was highest from the extended spring harvest, but recharge of the root system by late autumn was poor. This will probably cause a low spear yield next season.

- As in the results we reported in 1995-96, the normal spring harvest achieved the best balance of a good spear yield and a fully recharged root system at the end of the season.

- Spear yield was not limited by availability of buds. About 50 buds per crown were available but no more than 20 spears per crown were produced.

- The crop's dry matter balance was dominated by fern and root weight. These were much greater than spear weight.

- At full recharge, 50-60% of root weight was storage CHO. The amount of CHO varied by as much as 6 t/ha during the season. Initial fern growth caused the main depletion of CHO from root reserves. These were recharged after the fern was established.

The results confirm our finding last year that the common management aim of stimulating vigorous fern growth is not desirable. Although fern growth and yield were relatively low in the normal spring harvest treatment, this had no adverse effect on root system performance.

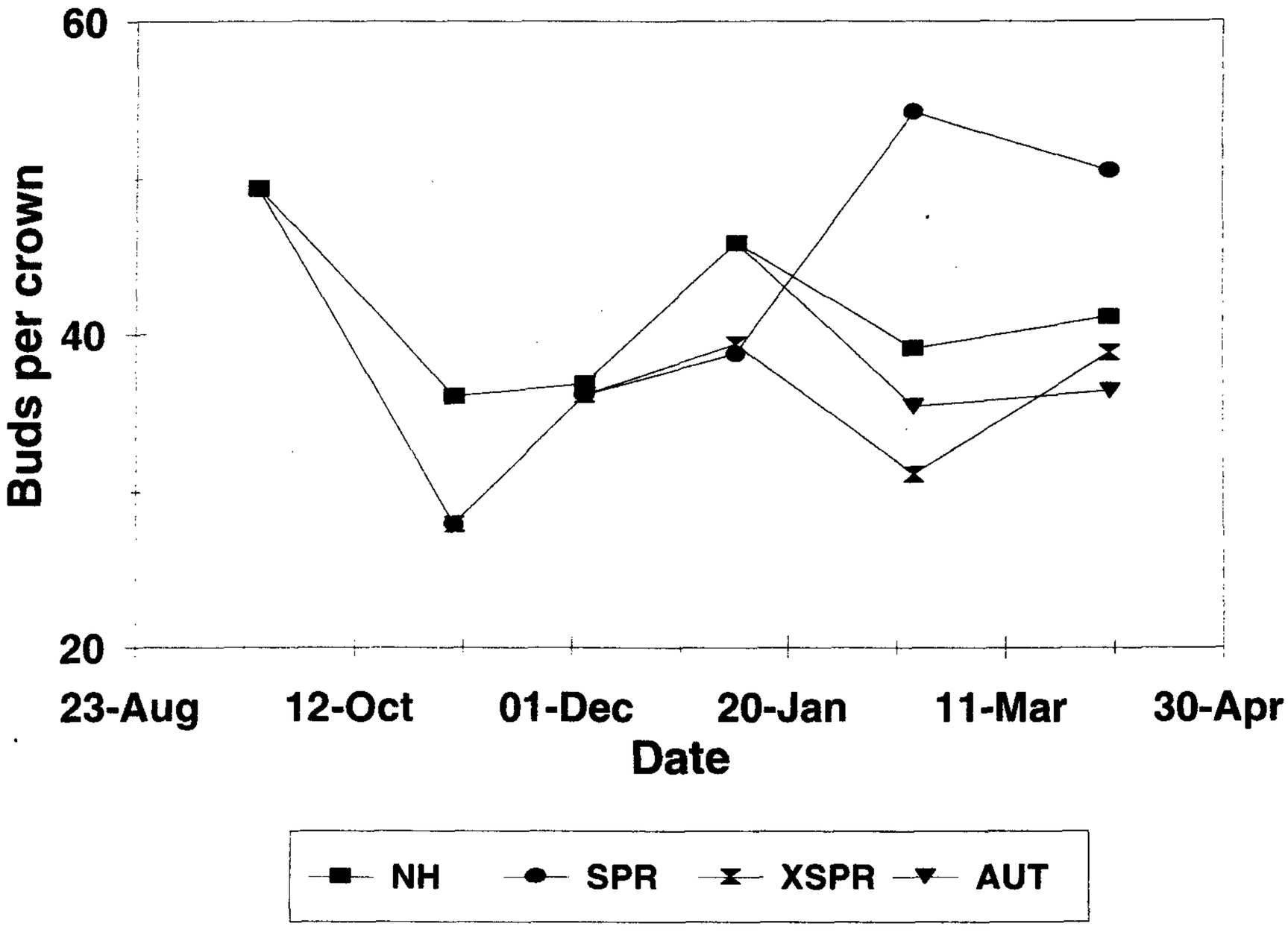

Figure 3: Seasonal patterns of numbers of buds per crown in the four treatments.

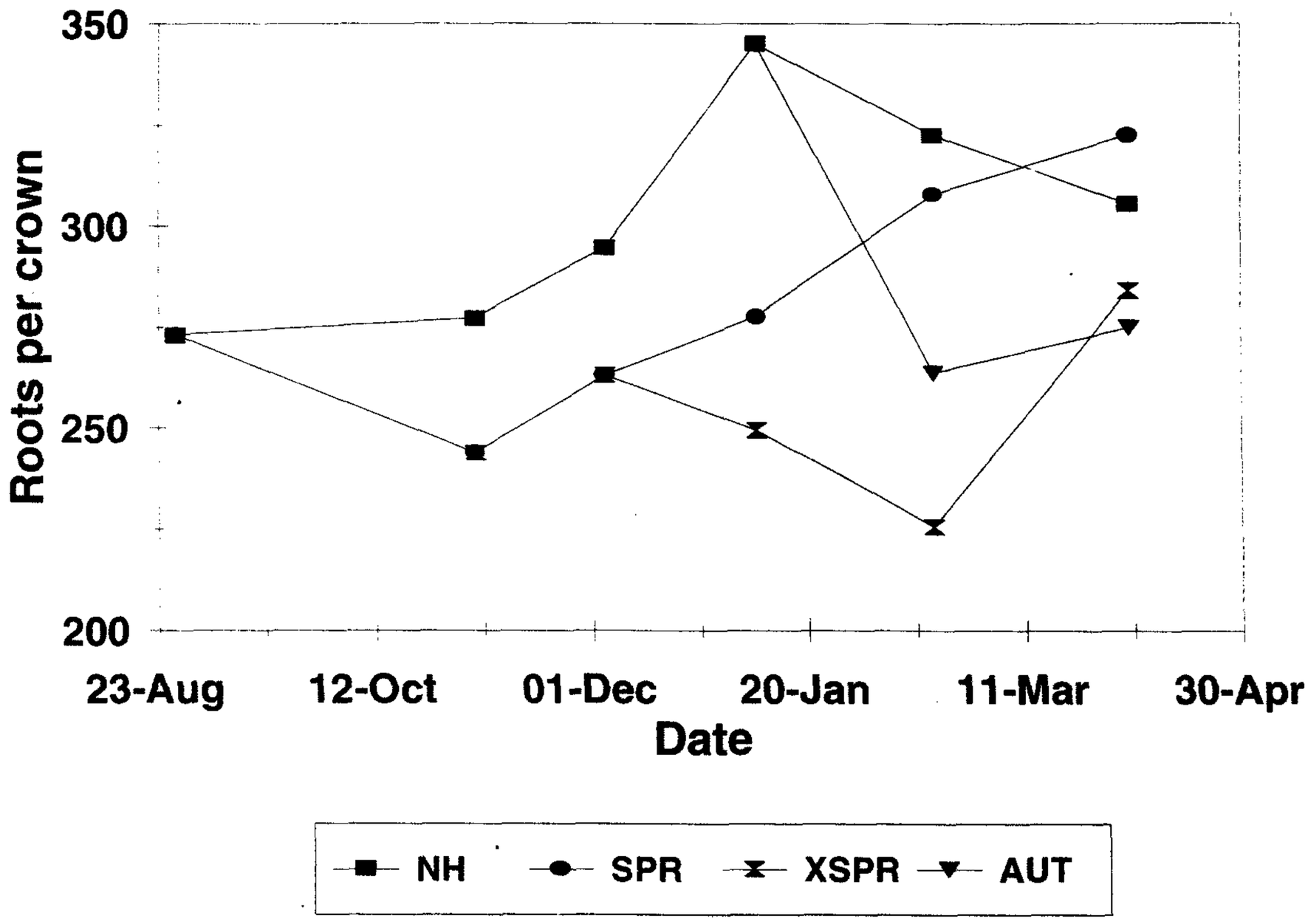

Figure 4: Seasonal patterns of numbers of storage roots per crown in the four treatments.

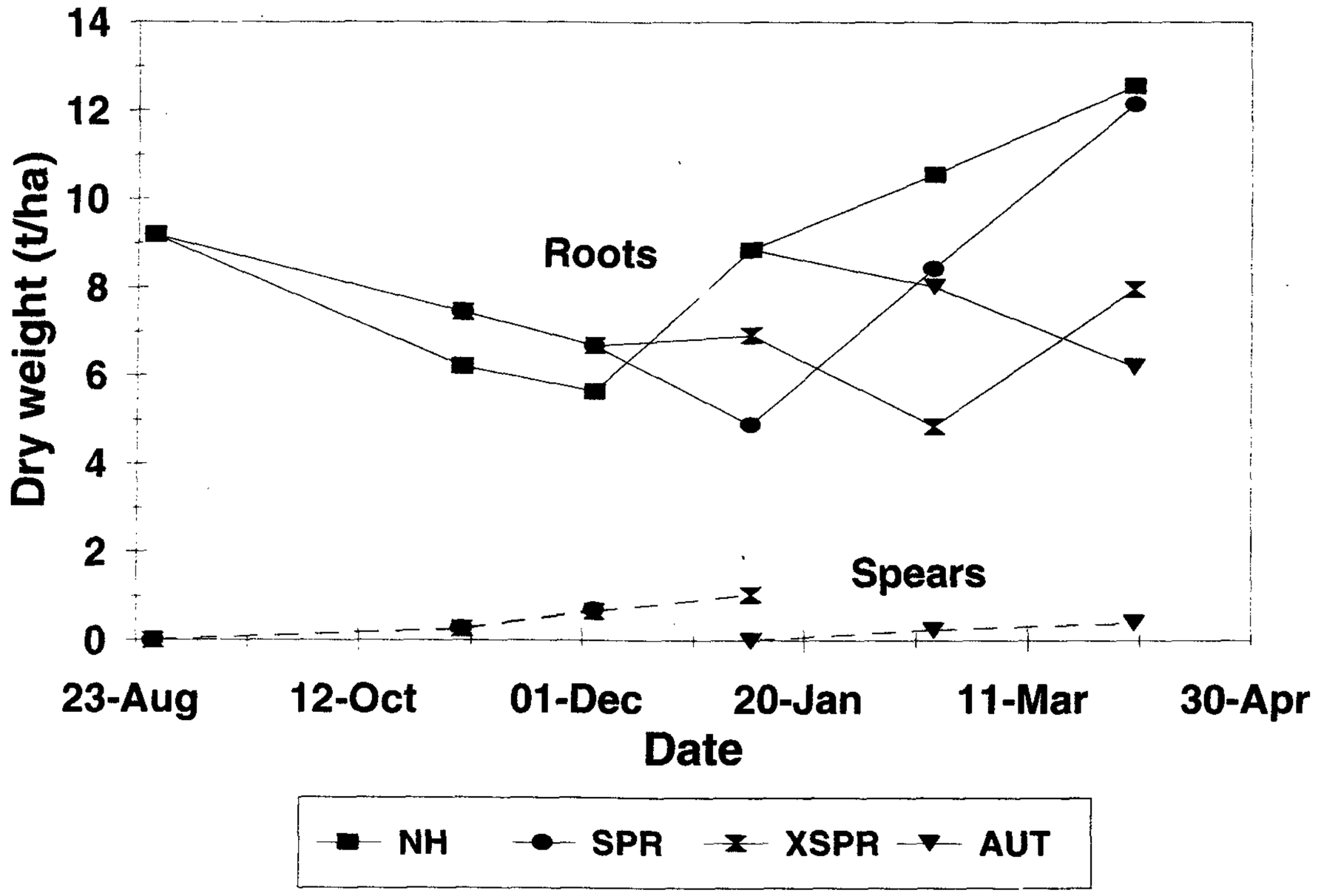

Figure 5: Seasonal patterns of root and spear dry weight in the four treatments.

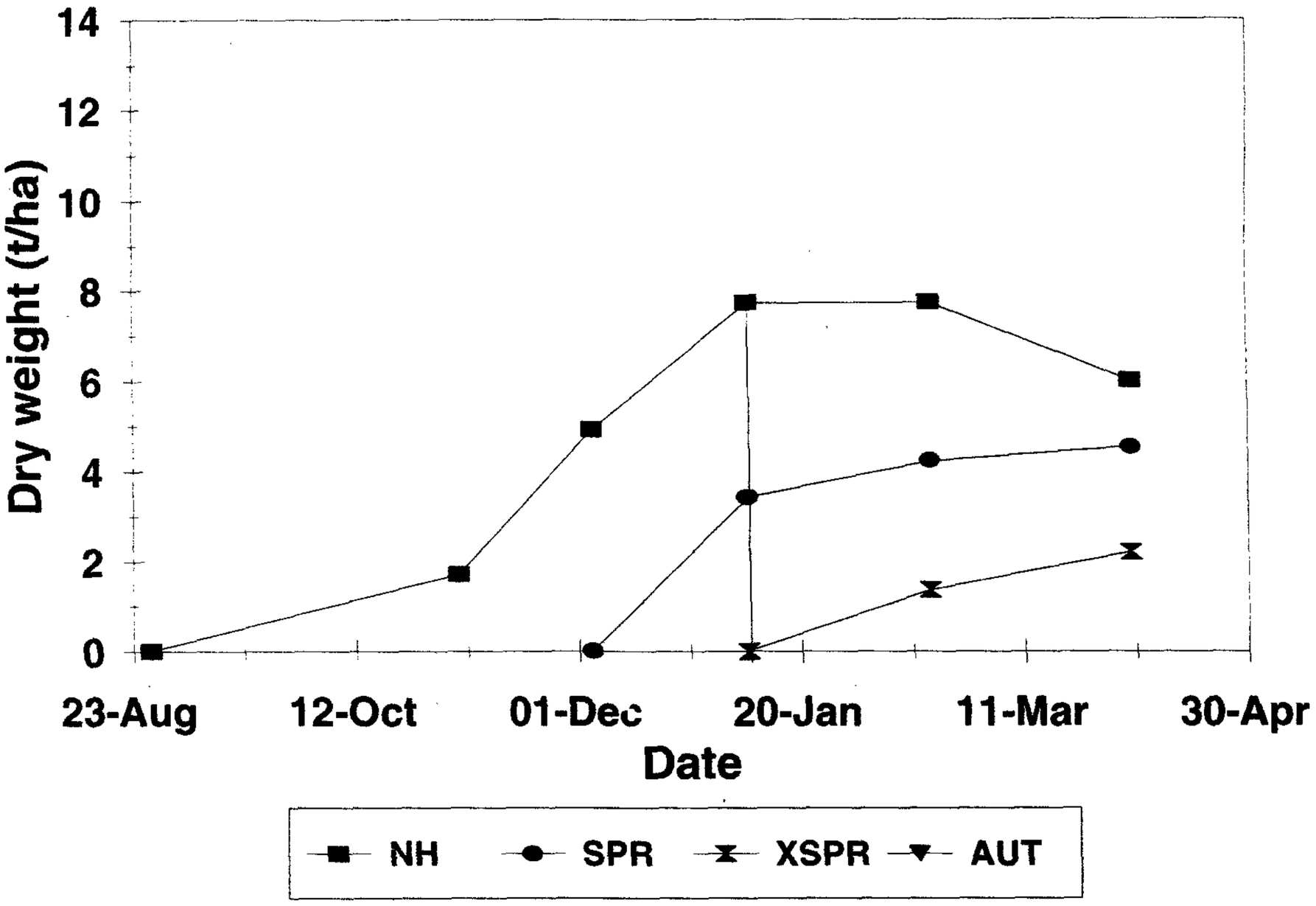

Figure 6: Seasonal patterns of fern dry weight in the four treatments.

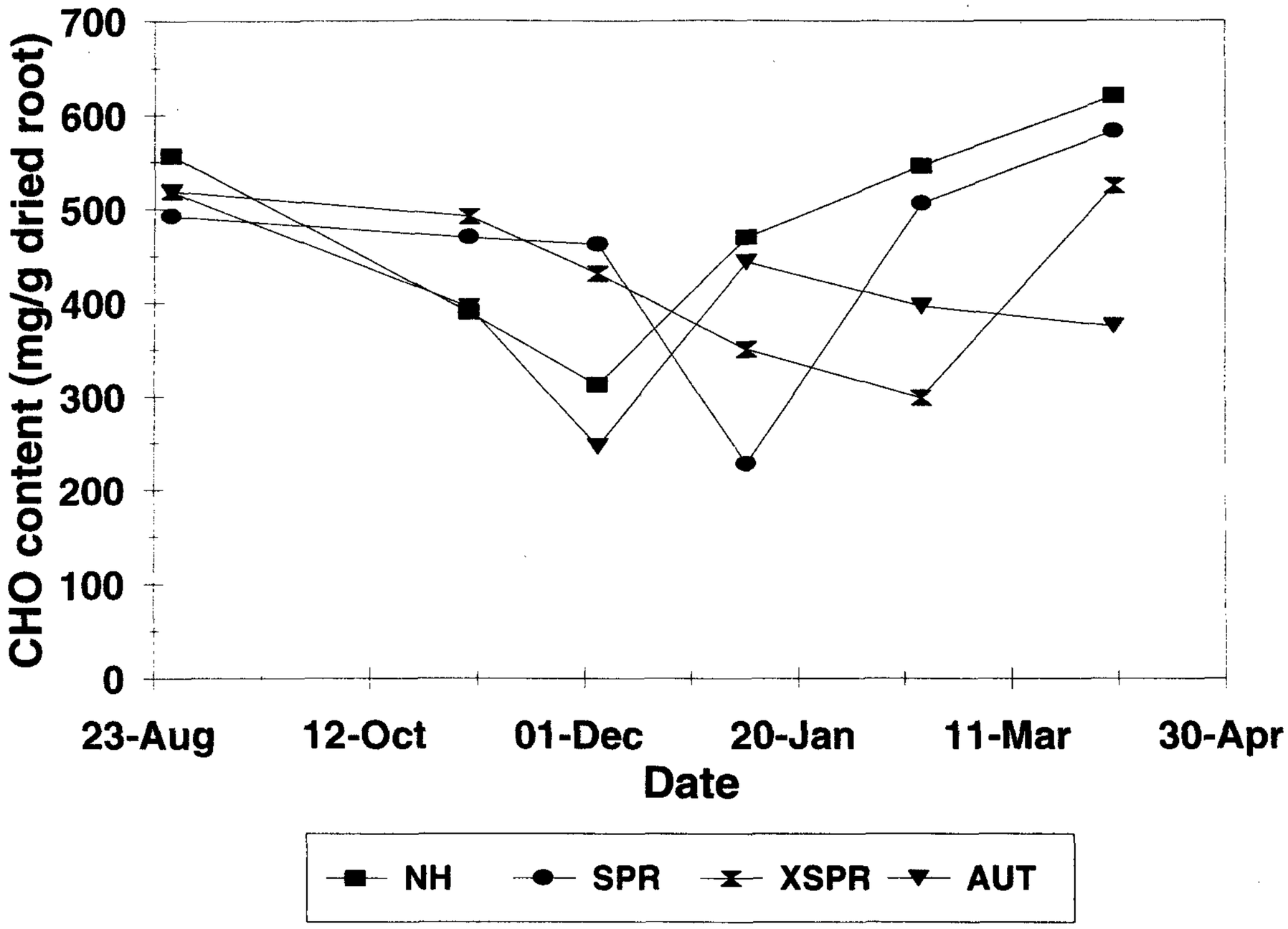

Figure 7: Seasonal patterns of soluble CHO content of the roots in the four treatments.

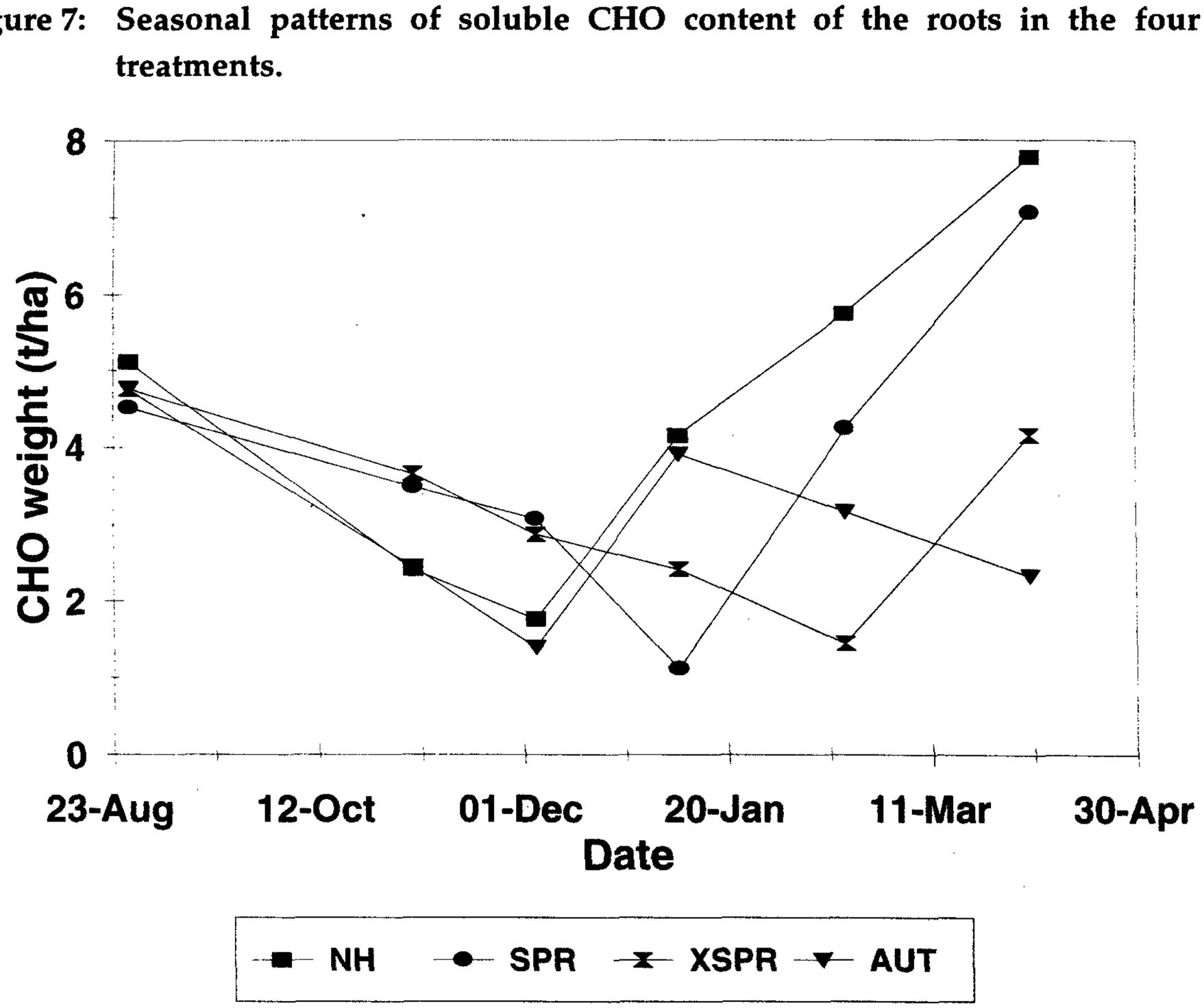

Figure 8: Seasonal patterns of the amount of CHO in the root system in the four treatments.

4 COMPARATIVE PERFORMANCE OF MALE AND FEMALE PLANTS

4.1 Introduction

Male asparagus plants usually produce larger spear yields than females. This difference between the sexes largely explains the superior performance of all-male hybrid cultivars. In cultivars that consist of mixed-sex populations there is considerable plant-to-plant variability of performance, with the males contributing proportionately more to yield than the females.

We quantified the difference by identifying male and female plants in a mixed population and measuring their yields separately. We also determined how the growth of their root systems differed during the crop's annual cycle.

4.2 Methods

Measurements were made in the same crop as described in the previous section. At the start it was expected to be an all-male hybrid, but the number of seed-bearing plants during fern growth showed that it was severely contaminated. During fern growth in autumn 1996, the sex of every plant was determined and the area was mapped so that each plant could be identified during the following season.

The treatments and measurement procedures during the 1996-97 season were the same as those described in the previous section except that, during harvest periods, spears from male and female plants were harvested separately. Also, when plants were harvested destructively on six occasions during the season, two male and two female plants were harvested separately.

4.3 Results

The ratio of male:female plants averaged 57:43.

In all harvest treatments, ***spear weight per plant*** was significantly higher for males (Table 1). The marketable weight difference between male and female plants varied from 37% when yield was high in the extended spring harvest to 67% when yield was low in the autumn harvest. Males had a much higher reject yield than females but,

because total yield averaged almost 80% higher for males than for females, the reject proportion of total yield was only slightly higher for males.

Spear yield per unit area, calculated with the area split according to the proportion of each sex in each plot, was also significantly higher for males in all treatments (Table 2). In all cases, males contributed about 70% of the yield per unit area (marketable, reject and total) in the mixed population. Part of the difference resulted from the larger number of males than females and part resulted from the higher yield per male plant. The difference between males and females was separated into these two components and, in all cases, most of it was attributable to superior male plant performance (Table 2).

The yield per plant results were used to estimate a ***hypothetical spear yield per unit area***, assuming that all plants in the population were either male or female. This procedure made the untested assumption that plants in each single-sex population would, on average, perform the same as those in the mixed-sex population. The results showed that, potentially, the spear yield per unit area (marketable and total) was about 20% greater if all plants were males (Table 3). Conversely, yield was about 20-30% lower if all plants were females. The latter may be an over-estimate because females would produce no berries in the absence of males, and it could be that use of resources in berry production contributes to the lower yield of females. In that case, the assumption of performance being the same as in a mixed-sex population would not be valid.

The spear yield differences were associated with large below-ground differences in all treatments. Results for the normal spring spear harvest treatment are presented in Figs. 9 to 12. The effects of the other treatments on below-ground growth during the crop's annual cycle are presented in the previous section.

Biomass of the storage root system was almost twice as large for males during most of the seasonal growth cycle (Fig. 9). Biomass decreased during spear and fern growth, then recovered once the fern was established. Recovery was better by males than females. The ***CHO content of the root system*** followed a similar pattern to biomass during the year. It ranged from about 200 mg/g when the roots were depleted at the end of fern extension to about 530 mg/g when the roots were fully recharged at the end of the season. The content was usually about 5% higher for males and females, but the difference was not statistically significant. The ***amount of soluble CHO in the roots***, which is a measure of resource availability for spear production, was about twice as large for males as for females during most of the season and also followed a similar pattern to biomass (Fig. 10). Bud and storage root numbers per crown, another two characteristics of resource availability, were both lower for females than males throughout the season (Figs. 11 and 12).

4.4 Conclusions

Male plants were substantially superior in all respects, so the advantage of using an all-male population is clear. In the mixed population, males produced an 80% higher total spear yield per plant, and contributed 70% of the yield per unit area. If all plants in the population had been males, yield per unit area would have been about 20% greater than that of the mixed population.

The spear yield difference between males and females was associated with large below-ground differences. Male root systems were much larger, accumulated more storage CHO, and had more buds and storage roots than females.

Table 1: Mean spear weight per plant for male and female plants in the three spear harvest treatments.

		Spear yield (g/plant)			
Harvest	Sex	Marketable	Reject	Total	% reject spears
Spring	Male	213	121	334	36
	Female	142	57	199	29
	% difference	50	112	68	
Extended spring	Male	274	207	481	43
	Female	200	70	270	26
	% difference	37	196	78	
Autumn	Male	100	80	180	44
	Female	60	39	99	40
	% difference	67	105	84	
LSD (P>0.05), Harvest		23	41	56	
LSD (P>0.05), Sex		33	24	55	
CV (%)		17.2	21.9	18.3	

Table 2: Mean spear yield per unit area from male and female plants and the percentage of total yield from the male plants in the three spear harvest treatments. The yield difference between males and females is separated into the two components attributable to higher male plant number and superior male plant performance.

		Spear yield (kg/ha)		
Harvest	Sex	Marketable	Reject	Total
Spring	Male	2550	1450	4000
	Female	1190	460	1650
	% male	68	76	71
	% difference	114	215	142
	- number	51	65	55
	- performance	63	150	87
Extended spring	Male	3070	2340	5410
	Female	2040	720	2760
	% male	60	76	66
	% difference	50	225	96
	- number	12	20	14
	- performance	38	205	82
Autumn	Male	1370	1100	2470
	Female	530	340	870
	% male	72	76	74
	% difference	158	223	184
	- number	73	87	79
	- performance	85	136	105
LSD (P>0.05), Harvest		230	440	520
LSD (P>0.05), Sex		540	340	860
CV (%)		26.4	27.7	26.0

Table 3: Spear yield per unit area calculated assuming that all plants in the population were either male or female in the three spear harvest treatments. The mixed population values are the totals of the measured male and female yields from Table 2.

Harvest		Spear yield (kg/ha) Marketable	Reject	Total
Spring	Male	4440	2510	6950
	Female	2940	1170	4110
	Mixed	3740	1910	5650
	% increase if all male	19	31	23
	% decrease if all female	21	39	27
Extended spring	Male	5820	4420	10240
	Female	4290	1510	5800
	Mixed	5110	3060	8170
	% increase if all male	14	44	25
	% decrease if all female	16	51	29
Autumn	Male	2260	1810	4070
	Female	1360	880	2240
	Mixed	1900	1450	3350
	% increase if all male	19	25	21
	% decrease if all female	28	39	33

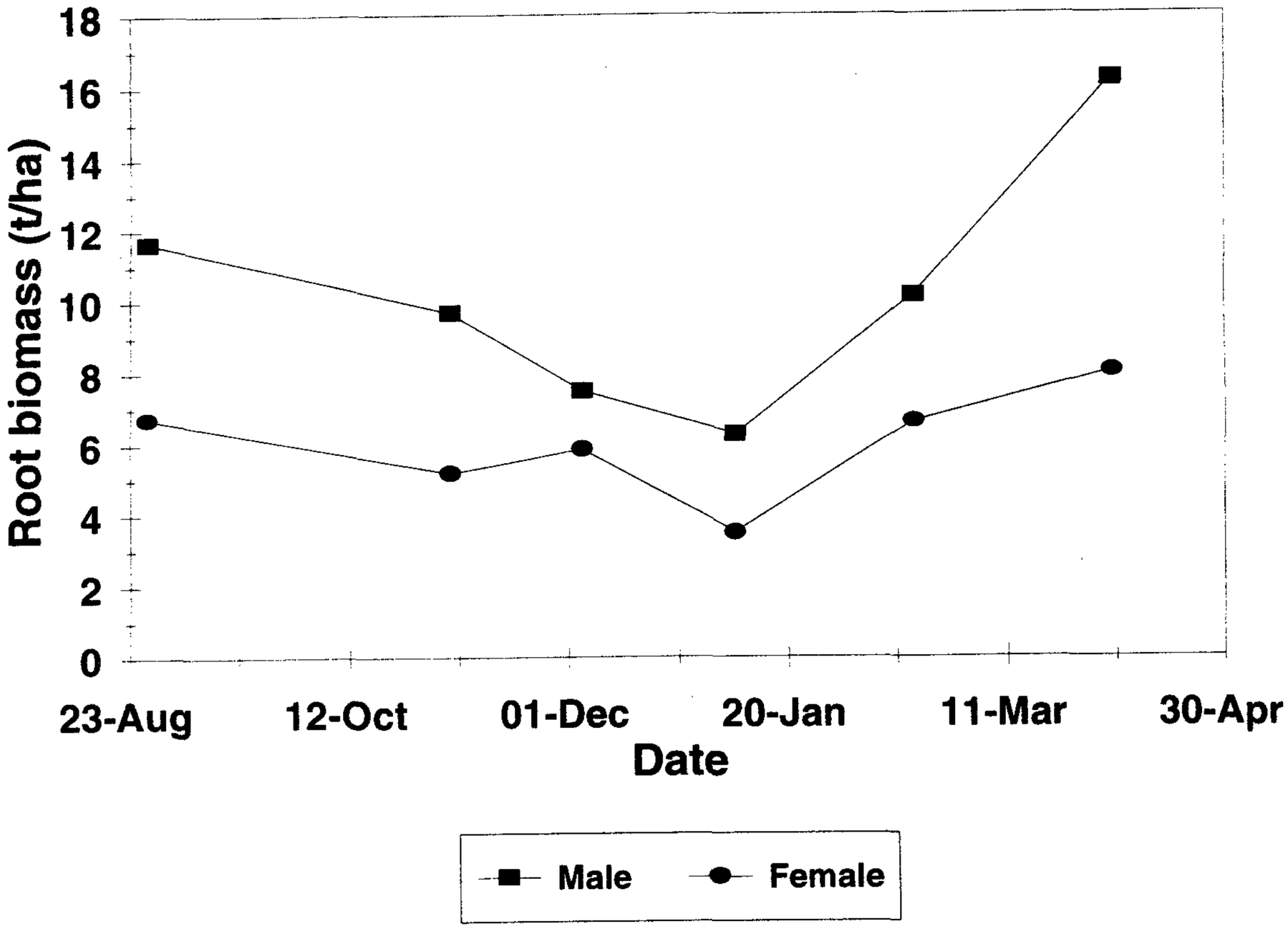

Figure 9: Patterns of storage root biomass of male and female plants in the spring

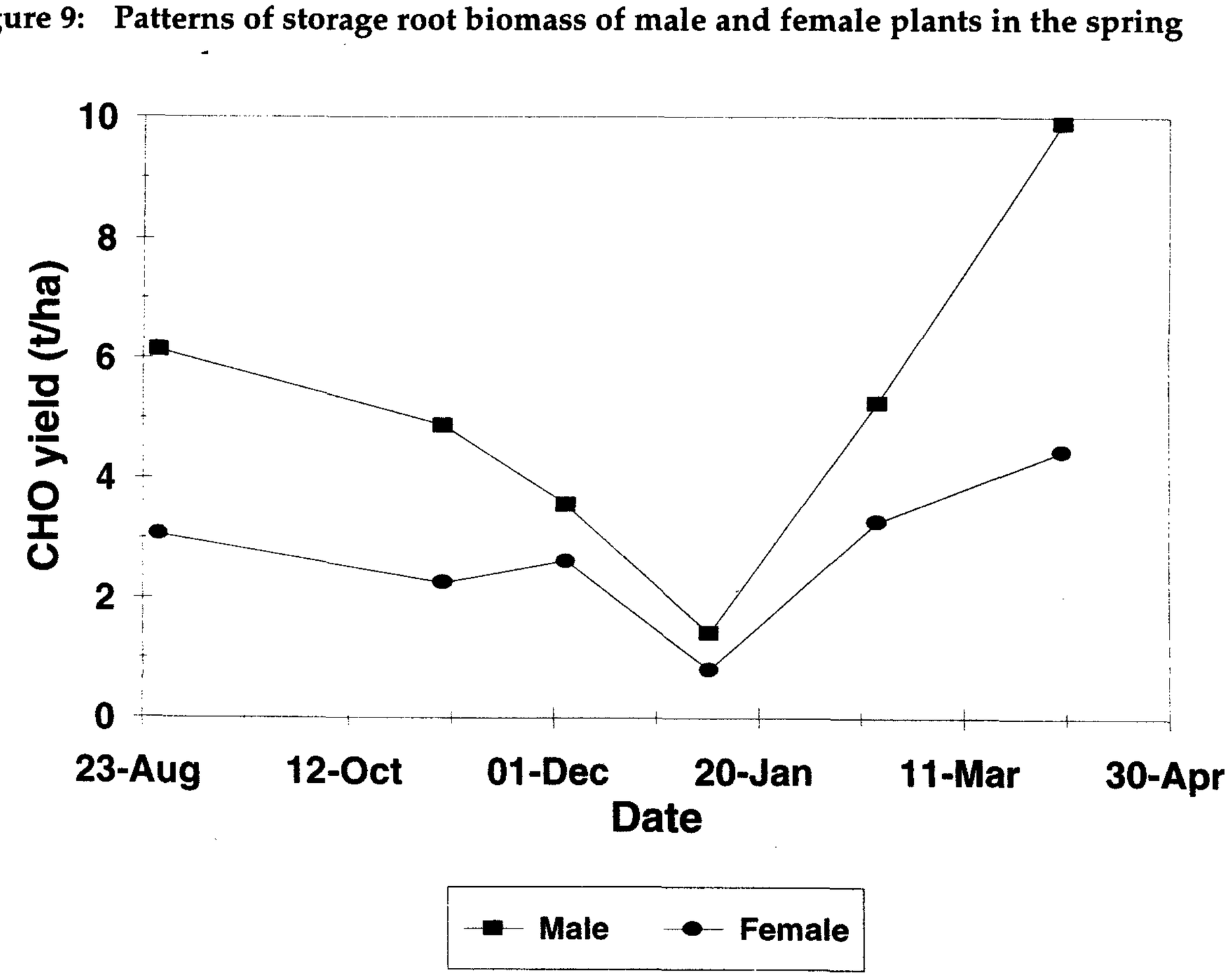

Figure 10: Amounts of soluble CHO in the storage root systems of male and female plants during the season in the spring spear harvest treatment.

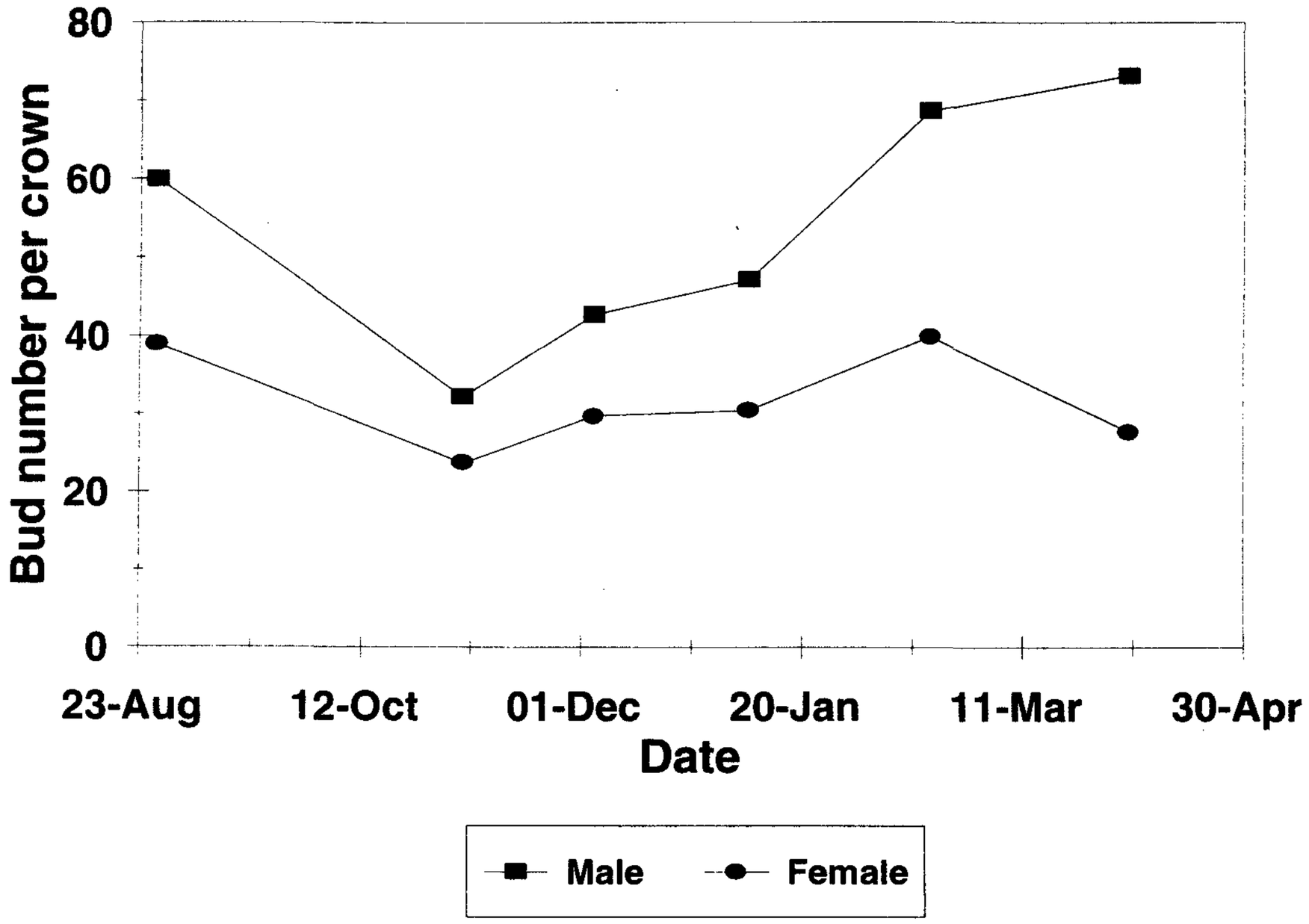

Figure 11: **Bud numbers per crown during the season for male and female plants in the spring spear harvest treatment.**

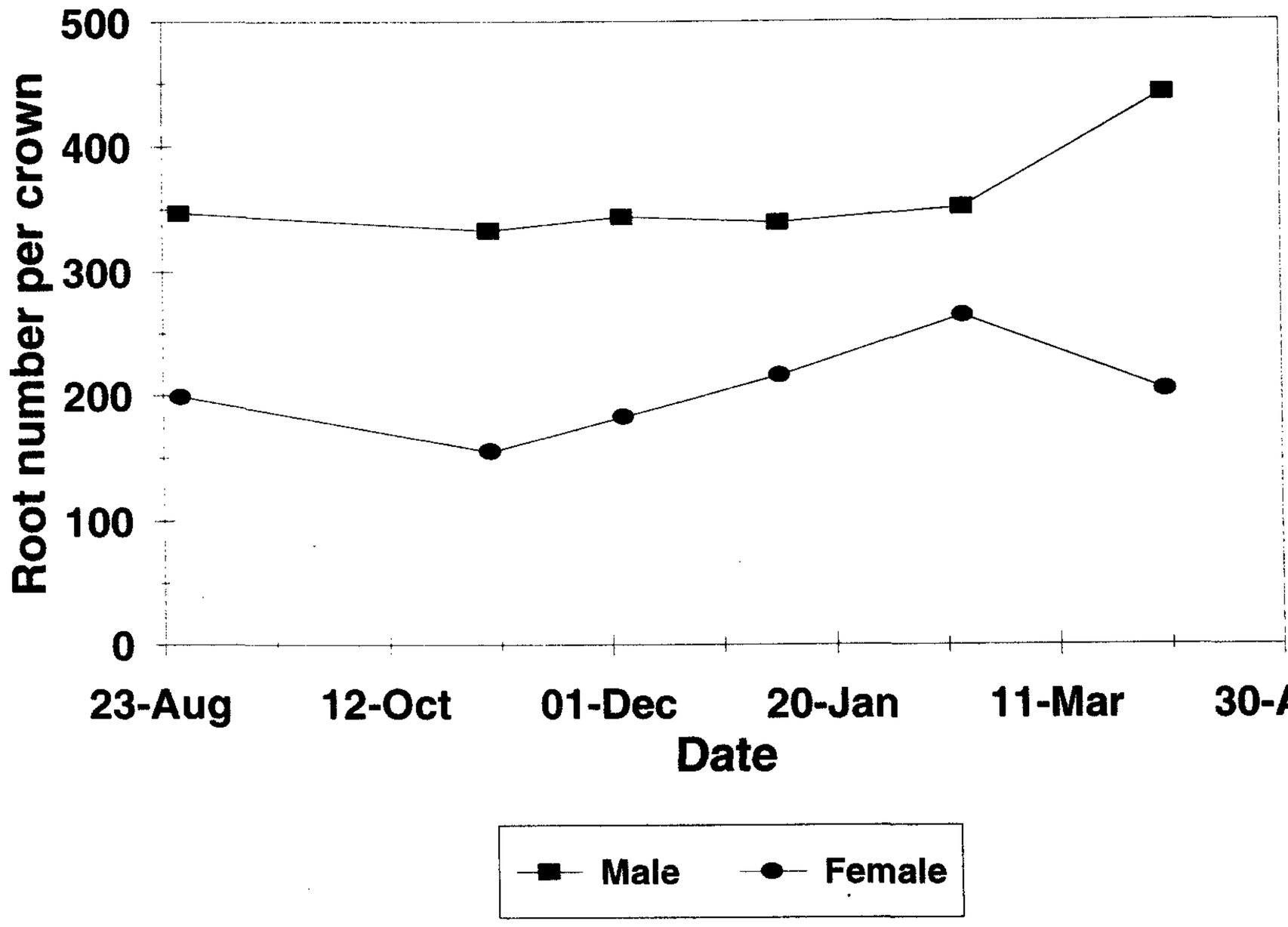

Figure 12: Numbers of storage roots per crown during the season for male and female plants in the spring spear harvest treatment.

5 ACKNOWLEDGEMENTS

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