Effects of plant population on pyrethrins yield of pyrethrum, (*Tanacetum cinerariifolium)* in Tasmania

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ABSTRACT

Previous studies have examined the influence of density on pyrethrins yield but none have been conducted as sown trials, in cool temperate environments, and over a wide range of plant densities. Furthermore, the influence of plant density on components of yield has not been intensively investigated. To address this, a density trial was undertaken. This work identified that maximum yield was achieved in the first season at between 16 and 39 plants/m^2 and at or above 16 plants/m^2 in the second season. Yield was a function of flower head (capitulum) yield rather than change in percentage of pyrethrins in the flowers. Higher flower yield was associated with higher above ground dry matter production. Flowering tillers/$m^{2\ was}$ the yield component that increased with plant density. Yield components decreasing with density included, number of flowering tillers/plant, flowers (capitula)/tiller and dry weight/flower.

Key words

Yield, pyrethrins, plant population, sowing, *Tanacetum cinerariifolium,* pyrethrum.

Introduction

Since 1997, pyrethrum crops in Tasmania have been established by sowing into prepared soils. Choice of plant density is no longer limited by the costs associated with planting splits or seedling plugs.

Past density studies conducted on pyrethrum have investigated plant populations in the range two to nine plants/m^2. Yield increases were reported for plantings at the highest density, but the advantages were not considered economic due to the high cost of manual crop establishment (5, 6). More recently, Parlevliet et *al*. (7) investigated the influence of a similar range of plant densities on pyrethrins yield and reported optimum yield at 5.5 plants/m^2. The only yield parameter that varied greatly with plant density was flower weight per hectare, which was due to production of a greater numbers of flowers (capitula). No significant differences in the concentrations of pyrethrins were observed for the different density treatments. Further work (9) reported an optimum plant density of 4.4 plants/m^2 and attributed the high yield to an increase in the number of flowers per plant and dry matter production efficiency.

All of the past research investigating optimum plant density in pyrethrum has been conducted on a narrow range of plant densities and on highland crops where flowering occurs in a number of flushes through the year. There are no reports investigating the influence of very high plant density on yield. Nor were there any studies where trials were conducted in temperate environments, which promote a single annual flowering. The current work investigates opportunities for increasing yield of pyrethrins through optimising plant density in Tasmania. The results from the study have significant commercial cropping implications.

Methods

The trial was located at Forthside Vegetable Research Station (FVRS) (41?10'S, 146?40'E) in northern Tasmania. Two weeks prior to sowing, the ground was worked with a power rotary hoe. Basal fertiliser (N:P:K) was applied with a drill (14:16:11 750 kg/ha). Sowing was conducted on 5/10/95 using a tractor mounted Ojoid trial drill. Seed was provided by British Oxygen Company (BOC) was Pyper 3A95F and was reported to have a germination capacity of above 80%. Details of densities and row spacings are presented in Table 1.

High sowing rates (8.0 kg/ha) were used to ensure nominal treatment densities were achieved. Thinning of plants to required densities was conducted two months following sowing. Thinning was undertaken firstly to achieve the correct density and secondly, to obtain regular spacing between the remaining plants within the rows. A randomised complete block design trial with six blocks was used**.** From each of the six replicates, either a number of plants were harvested in low density treatments (4, 6, 12, 12 plants in treatments A, B, C, D respectively) or a set area was harvested of one square metre in the higher density treatments. In the low-density treatments, where individual plants were found to be missing or dead, a replacement plant was harvested and the area of harvest and calculation of plant density adjusted accordingly. Data were analysed using Systat 5.2.1™ software. Analysis of total pyrethrins (1) was conducted on the stored samples after the second harvest. Storage of dried pyrethrum flowers even at room temperature does not result in decreased pyrethrins (4).

Table 1. Block density trial plant arrangement details.

Code	Density (plants/m^2)	Between row spacing (B) (mm)	Plants per linear metre	Within row spacing (A) (mm)	Rectangularity (B) : (A)
A	2	300	0.6	1666	0.18:1
B	4	300	1.2	833	0.36:1
C	8	300	2.4	416	0.72:1
D	16	300	4.8	208	1.44:1
E	24	150	3.6	277	0.54:1
F	32	150	4.8	208	0.72:1
G	64	150	9.6	104	1.44:1
H	100	150	15	67	2.24:1

Results and Discussion

In highland tropical regions where the crop flowers in a number of flushes through the year, dry flower yields of 1 000 kg/ha are considered to be high (11). More recently, field trials in Kenya reported dry flower yields of 1 766 kg/ha (12). In Australia, efforts at Black Mountain, Australian Capital Territory, in 1931 resulted in flower dry matter yields from 1 200 to 1 400 kg/ha (3).

In 1992, the average flower yield of Tasmanian crops was nearly 1700 kg/ha (5). In Tasmania during the early 1990s, plants were established at approximately 5/m^2 and the highest commercial yields of achenes rarely exceeded 2 000 kg/ha. As achenes make up approximately 80% of the weight of the flower, this was equivalent to whole flower yields of 2 500 kg/ha. In a trial on the northern coast of Tasmania, achene yields of 2 400 kg/ha (3 000 kg/ha whole flowers) were reported (9). That yield was from a second season crop established from splits. In the current trial, first and second season flower yields were 3 491 kg/ha and 2 745 kg/ha respectively at 4 plants/m^2. These results are significantly higher for first flower yield and comparable to yields (second season) reported for a trial established from splits reported (9).

Flower dry weights increased to an optimum well beyond the maximum plant densities evaluated in any of the previously reported work. In the first season, dry flower yields increased from 3 491 to 4 807 kg/ha in the 4 to 16 plants/m^2, a 38% increase in yield. The greatest increase occurred between 8 and 16 plants/m^2. Similar results were obtained in the second harvest with yields increasing from 2 745 to 4 589 kg/ha from 4 to 16 plants/m^2, a 67% increase in yield. In the second season a greater increase was observed from 4 to 8 plants/m^2 than from 8 to 16 plants/m^2. The increase in flower yield with density followed an increase in aboveground dry matter production.

Yields generated (Figure 1) of over 100 kg/ha are unprecedented in pyrethrum agronomy literature. The highest recorded pyrethrins yield is 48 kg/ha for a Tasmanian trial (9) and the highest trial yields in Africa do not exceed 25 kg/ha (2).

With increasing density and higher flower yields, pyrethrins concentration remained constant. Pyrethrins yield was therefore directly related to flower yield. In the first season, mean pyrethrins concentration was 2.36% while the second season pyrethrins concentration was 2.28%. Pyrethrins concentration appears to be a plant characteristic that varies little under different plant densities (2), under plants generating significantly different dry flower yields due to plant immaturity (8), and from first to subsequent flowering seasons (8).

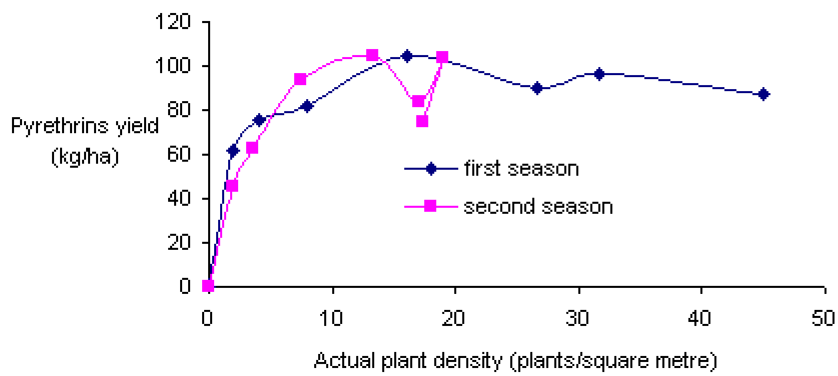

Figure 1. Pyrethrins yield in first and second harvest.

Note (1) Differences between some treatments are significant, $P = 0.04$, LSD = 25.2 kg/ha.. (2) Differences between some treatments are significant, $P < 0.001$, LSD = 25 kg/ha. Variability in yields among the four highest density treatments was due to variable populations resulting from self- thinning.

Data from the first season indicate that significant reductions in plant population, due to self-thinning, occurred only in the two highest density treatments (Figure 2). Plant populations remaining in the self-thinned treatments indicate that maximum plant densities sustainable up to the first harvest were 35 to 40 plants/m^2. Evidence indicates that maximum first year dry matter production was achieved without any self-thinning at plant densities above 16 and below 39 plants/m^2.

Plant density was evaluated again in the second flower harvest (Figure 2). Although population had decreased in all treatments, competition could not be held responsible for plant losses in any densities below 16 plants/m^2. A decrease in plant population after the first harvest to levels that would not allow maximum dry matter production to be achieved in the shorter second season was held responsible for lower second harvest yields. Plant populations in self-thinned plots at the time of the second harvest were variable, with populations ranging from 8 to 28 plants/m^2.

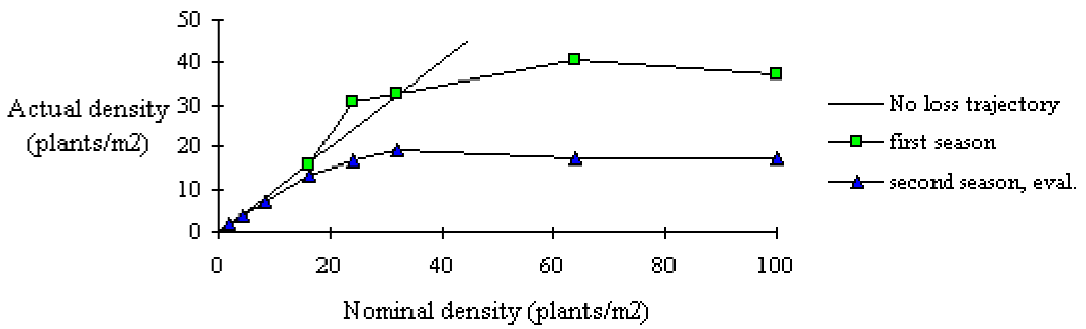

Figure 2. Actual density vs nominal density in the block trial, first and second season.

Note (1) First season treatment densities were calculated from the mean of all samples (18) taken in that harvest. CV's for the 16 to 100 plants/square metre treatments 20.1%, 18.3%, 29.3%, and 30.7% respectively. (2) Second season CV's for six replicates of treatments 2 to 100 plants/square metre to H respectively were 0%, 17.8%, 6.2%, 11.4%, 40.6%, 30.2%, 24.9%, and 37.7%.

With increasing density, the number of tillers produced per plant decreased significantly. Variation in plant tiller numbers appears to be a major mechanism by which plants respond to competition. Substantial increases in tillers/m^2 were observed up to densities of 16-20 plants/m^2 and this increase was totally responsible for the increasing yields. Flowers/tiller decreased significantly in the density range of 2 to 8 plants/m^2 but did not vary significantly from 8 plants/m^2 to the highest densities evaluated. Therefore, at densities below 8 plants/m^2, increasing flowers/tiller is a means by which the plant regulates its productivity. Mean dry weight/flower was found to vary only at the lowest density examined. Flowers from the 2 plants/m^2 were significantly heavier all other density treatments and this effect was not due to any difference in flower maturity. Plant density had no significant influence on either mean flower maturity or uniformity of flower maturity.

In other producing regions, and until recently in Tasmania, density of planting pyrethrum was largely determined by the high cost of plant material or the significant labour involved in crop establishment. The recent Tasmanian advance of crop establishment by sowing means that high establishment costs are avoided and optimal plant density could be selected. The current work demonstrates that appreciable increases in yield are achievable if plant densities are increased from the current standard of 4 to 16 plants/m^2. Densities higher than this, but below 40 plants/m^2, will avoid self thinning and are recommended for maximum first season yields.

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