Agronomic influences on the yield of Echinacea and Valerian in Canterbury

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Abstract

Two agronomic trials, one on Echinacea or purple coneflower (*Echinacea purpurea* (L.) Moench) and the other on valerian (*Valeriana officinalis* L.), were sampled on five occasions over three years. Treatments in both trials were no irrigation or a low level of irrigation, and low or high fertiliser, and, in the Echinacea trial only, high and low plant density. Echinacea root yields increased over the three years of the study from 0.5 t/ha of dried root in the first year, to 1.9 t/ha in the second and 4.0 t/ha in the third. Top dry yields increased from 7.1 t/ha in the first year to 8.5 t/ha in the second and 13 t/ha in the third. Increasing plant population from 11 to 22 plants/m^2 increased yields by 64% in the first year, 40% in the second and 19% in the third, but irrigation and the high rate of fertiliser had little effect on yields. Valerian root yields averaged 1.4 t/ha in the first year, 2.9 t/ha in the second and 3.8 t/ha in the third. In the second and third years, irrigation increased root yield by an average of 45% and top yields by up to 42%. The effect of the higher rate of fertiliser was less consistent but increased winter root yields by up to 50%.

Additional key words: *leaf area, irrigation, fertiliser, plant density*

Introduction

Echinacea and Valerian are grown extensively overseas for the natural health market (Parmenter *et al.*, 1992). *Echinacea purpurea* (L.) Moench, also known as purple coneflower, is a perennial herb indigenous to North America and was widely used by native North Americans as a cure-all for everything from venereal disease to snakebite (Hobbs, 1994). It is currently in demand in Europe, especially Germany, and in North America as an immunostimulant, antibiotic and wound healer. It is uncertain which chemicals are the active ingredients responsible for these properties (Brown, 1997), but these chemicals are present in the tops, and in greater concentrations, in the roots. *Echinacea purpurea* is currently being grown commercially in New Zealand and the dried tops and roots are being exported to the United States.

Valerian (*Valeriana officinalis* (L.)) is a perennial herb from Europe and North America, and extracts from the roots have sedative and anti-spasmodic effects, although again there is uncertainty as to which chemicals are responsible (Hobbs, 1989). It is widely used in Europe, especially in Germany, but current prices make it uneconomic to grow in New Zealand.

Both plants have been successfully in trials at various sites in New Zealand (Parmenter *et al.*, 1992), but little is known of their agronomic requirements. In order to answer some of the agronomic questions, two trials were carried out at Lincoln over three years, one with Echinacea, the other with Valerian. The Echinacea trial included and investigation of the effects of plant density, irrigation and fertiliser, and the Valerian trial, irrigation and fertiliser.

Methods

Both trials were carried out on a Templeton Silt Loam at Crop & Food Research's Lincoln Farm.
The soil fertility status in the top 30 cm over the site before planting, determined by AgResearch Quick Tests (Cornforth and Sinclair, 1984) was: pH 5.7; Ca 10; K 15; P 21; Mg 16; S 17 and NO_3 19.

Seedlings were raised in trays by a commercial enterprise. The Echinacea was planted out by hand on 14 December 1993, and the Valerian on 13 January 1994, in 6 rows 30 cm apart in a prepared seed bed. Both species were at the 3 to 4 leaf stage at planting. Main plots were 9 m long by 1.5 m wide.

In the Echinacea trial, irrigation treatments were no irrigation or irrigation, using a 'T tape' trickle irrigation system, at a soil moisture of 10% (equivalent to approximately nil available soil moisture); plant population treatments were 11 plants/m^2 (30 cm within the row x 30 cm row spacing) or 22 plants/m^2 (15 cm within the row x 30 cm row spacing); and fertiliser treatments were Low (75 kg N, 50 kg P, 50 kg K and 40 kg S per ha applied as Cropmaster 15 after planting) or High (150 kg N, 100 kg P, 100 kg K and 80 kg S per ha applied as Cropmaster 15 after planting followed by 90 kg N/ha applied as either Cropmaster 15 or urea each winter and after the summer harvest in 1994). The trial was a standard split split plot design with the irrigation treatment applied to the main plots, plant density to the subplots and fertiliser to sub-subplots. There were 4 replicates.

The irrigation and fertiliser treatments in the Valerian trial were the same as in the Echinacea trial, and in the first two years, the trial was run as a split plot design with the irrigation treatment applied to main plots and fertiliser to subplots.

The plots were hand weeded. Glyphosate was sprayed over the dormant plants in August 1994. Rovral was sprayed on two occasions in December 1994 to control *Rhizoctonia*.

Both trials were sampled five times, in May 1994, December 1994, July 1995, January 1996 and July 1996. At each harvest, except for Valerian in January 1996, a quadrat containing two plants from each of the middle four rows (equivalent to 0.72 m^2 for the Valerian and low density Echinacea, and 0.36 m^2 for the high density Echinacea) was harvested from each plot. For the Valerian harvest in January 1996, shortage of plants restricted sampling to four plants (0.36 m^2).

In the May 1994, December 1994, and January 1996 harvests, top and root fresh weights were determined, and leaf area of one of the plants was taken for leaf area determinations. Dry weights were determined by drying in a forced draft oven at 35°C until no further loss in weight occurred (around 72 hours). In the July 1995 and July 1996 harvests, the tops had died down before harvest, and so only roots were sampled.

The data were analyzed using the Genstat statistical package (Genstat 5 Committee, 1993). Yields per unit area were calculated from the area sampled, whereas yields per plant were calculated for the actual number of plants harvested.

Results

Echinacea

The Glyphosate spray caused up to 5% mortality in some plots. Up to 5% of plants died from *Botrytis* and *Rhizoctonia* infections. This resulted in an overall reduction in plant numbers of 10%, but there was no consistent treatment effect.

Roots: Root dry weights at the highest population were over 2 t/ha after the first 7 months, and over 4 t/ha after 17 months (Table 1), but by the final harvest, root dry weight did not differ with population. There appeared to be a decline from the summer to the winter harvest in the second and third years.

About 100 mm of irrigation was applied each year to the irrigated treatments. This had no significant effect on root dry weights. The different fertiliser regimes also had little or no effect on root dry weights (data not presented).

Tops: The agronomic treatments had no effect on LAI in the first year (Table 2) but top dry weights were higher at the higher density. Subsequently, the higher plant density increased both LAI and top dry weight, and the higher fertiliser regime increased top dry weight.

In the summer of the second year, LAI was higher with irrigation, especially at the high plant density and under the higher fertiliser regime. Top dry weights increased significantly only under irrigation at the higher plant population. In the summer of the third year, irrigation had no effect on top yield, but increased LAI under the higher fertiliser regime.

Table 1. Effect of plant population on Echinacea root dry weights (kg/ha) and root weights per plant (g/plant).

	May 94		Dec 94		July 95		Jan 96		July 96	
	kg/ha	g/plant	kg/ha	g/plant	kg/ha	g/plant	kg/ha	g/plant	kg/ha	g/plant
Density										
11	572	5.2	1650	15.3	1464	13.3	3931	39.2	3267	34.2
22	940	4.2	2328	10.7	2024	9.4	4929	22.0	3681	17.7
Significance	***	*	***	**	**	***	**	***	ns	***
LSD (P<0.05)	140	0.71	310	2.07	366	1.72	619	6.22	-	4.0

ns, not significant; *, P<0.05; **, P<0.01; ***, P<0.001

Table 2. Echinacea leaf area index (LAI) and top dry weight.

	May 94			Dec 94			Jan 96		
		Top dry wt.			Top dry wt.			Top dry wt.	
Treatments	LAI	(kg/ha)	(g/plant)	LAI	(kg/ha)	(g/plant)	LAI	(kg/ha)	(g/plant)
Irrigation (I)									
Nil	2.31	6980	39.8	2.22	7425	49.8	2.29	12829	86.1
Irrigated	2.52	7329	42.5	4.38	9596	62.9	3.48	13719	92.3
Significance	ns	ns	ns	**	*	*	ns	ns	ns
LSD (P<0.05)	-	-	-	0.92	1573	12.72	-	-	-
Density (D)									
11	2.08	5869	48.1	2.80	7404	68.5	2.41	11213	112.1
22	2.74	8439	34.2	3.80	9618	44.2	3.36	14794	66.3
Significance	ns	***	***	***	***	***	*	*	**
LSD (P<0.05)	-	801	4.67	0.56	719	7.96	0.72	2857	20.60
Fertiliser (F)									
75	2.45	7351	42.1	3.36	8288	54.5	2.61	12044	84.4
100	2.37	6957	40.2	4.14	8734	58.1	3.16	13964	94.0
Significance	ns	ns	ns	***	ns	ns	*	*	ns
LSD (P<0.05)	-	-	-	0.31	-	-	0.50	1467	-
Significant interactions (P<0.05)	-	-	-	I x D, I x F	I x D	-	I x F	-	-

ns, not significant; *, P<0.05; **, P<0.01; ***, P<0.001

Valerian

Valerian plants were much more variable in size than the Echinacea, and at some harvests results were very variable (Tables 3 and 4). There was also some rotting of older roots in the second and third years.

Roots: Root yields were about 1.3 t/ha at the end of the first year, and had risen to 4 t/ha for irrigated plants with the higher fertiliser regime and 2 t/ha for other treatments in the second year, with a further 0.5 t/ha increase in the third year (Table 3). Irrigation had no effect in the first year, when the plants did not flower, but generally gave significantly higher root yields in subsequent harvests. The higher fertiliser regime significantly improved yield in the second and third winters.

Tops: Irrigation had significantly increased LAI and top yields in the second summer, and LAI in the third summer (Table 4), but the higher rate of fertiliser increased LAI and top yield in the third year only.

Discussion

The irrigation was insufficient to greatly increase soil moisture contents above wilting point in the 0-15 cm zone in the Echinacea trial. Greater responses to irrigation may have possible in Echinacea if more water had been applied, although, in perennial species, the greatest response is usually to the first application of water (Hayman and McBride, 1984). However, the deep rooted Echinacea has evolved in dry open microclimates, with fluctuating rainfall, on the Great Plains of North America, and is a drought avoider, minimizing water loss and maximizing water uptake (Chapman and Auge, 1994). At times the non irrigated treatment in this trial had gravimetric soil water contents of under 5%, well below the accepted wilting point level of 9-10% for this soil type. The fact that this plant is susceptible to *Botrytis* and *Rhizoctonia* infections suggests that there could be considerably higher mortality under wetter or more humid conditions.

In contrast to Echinacea, Valerian did respond to the amount of irrigation water applied and also to fertiliser.

Table 3. Valerian root dry weights (kg/ha) and root dry weight per plant (g/plant).

	May 94		Dec 94		July 95		Jan 96		May 96	
	kg/ha	g/plant	kg/ha	g/plant	kg/ha	g/plant	kg/ha	g/plant	kg/ha	g/plant
Irrigation (I)										
Nil	1340	12.1	2767	27.6	2074	18.7	3555	43.4	2597	24.8
Irrigated	1404	12.6	3879	37.2	3015	27.2	4657	51.4	4332	48.4
Significance	ns	ns	**	ns	*	*	ns	ns	***	*
LSD (P<0.05)	-	-	460	-	651	5.87	-	-	40	11.49
Fertiliser (F)										
75	1389	12.5	3455	34.2	2020	18.2	4164	46.5	3012	29.9
150	1355	12.2	3191	30.6	3069	27.6	4049	48.4	3917	43.3
Significance	ns	ns	ns	ns	*	*	ns	ns	*	*
LSD (P<0.05)	-	-	-	-	1035	9.33	-	-	774	7.39
Significant interactions (P<0.05)	-	-	-	-	I x F	-	-	-	-	-

ns, not significant; *, P<0.05; **, P<0.01; ***, P<0.001

Table 4. Valerian leaf area index and top dry weight (kg/ha).

	May 94		Dec 94		Jan 96	
Treatment	LAI	Top dwt	LAI	Top dwt	LAI	Top dwt
Irrigation (I)						
Nil	1.05	917	2.93	8487	0.89	5604
Irrigated	1.01	917	4.33	11526	1.72	7971
Significance	ns	ns	*	*	**	ns
L.S.D. (P<0.05)	-	-	1.26	2062	0.35	-
Fertiliser (F)						
75	1.02	934	3.47	9700	1.24	5236
100	1.04	901	3.79	10314	1.37	8339
Significance	ns	ns	ns	ns	*	*
L.S.D. (P<0.05)	-	-	-	-	0.57	2843
Significant interactions (P<0.05)	-	-	-	-	-	-

ns, not significant; *, P<0.05; **, P<0.01

From his literature review, Hobbs (1989) concluded that adequate moisture and fertiliser is necessary for high yields of valerian, and can also influence active ingredient levels.

Echinacea root yield increases of 2 t/ha occurred between the first and second and the second and third years. Echinacea is currently being grown for both tops and roots, the tops being harvested at full flower for the first two or three years and then the roots harvested. How much effect harvesting the tops has on root yields is not known, but will be the subject of future research.

In Valerian, the biggest increase in yield was in irrigated crops between the May and December 1994 harvests, and the overall increases after that were much smaller. In this crop, many plants in both irrigated and non irrigated plots suffered from rotting in the older central parts of the roots, associated with the dying down of the old flowering stems, in the second and third growth years, indicating that this plant behaves more like a biennial than a perennial.

Parmenter and Littlejohn (1997) reported that Echinacea would produce higher yields when densities were increased to around 20 plants/m^2. Echinacea roots and rhizomes were not differentiated in this study, but Parmenter and Littlejohn (1997) found that the ratio of root to rhizome increased as plant density increased. This is assumed to lower the concentration of alkylamides, one of the active ingredients in the below ground parts (Perry *et al.*, 1997), so the optimum density of Echinacea for maximizing yields of active ingredients still has to be determined.

In these trials, there was considerable variation between plants, which showed through in the large LSDs in the results. In Valerian in particular, this led to up to a six fold difference in yield between adjacent plants. Valerian is noted for being a very variable species (Hobbs, 1989). This trial was very restricted by the number of transplants available. Now that these crops can be successfully drilled (Martin and Deo, unpublished), detailed trials along the lines of Jamieson *et al.* (1995) could be set up to define the irrigation, density and nutrient responses of these two crops.

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