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AGRONOMIC FACTORS AFFECTING THE YIELD OF CROPS OF EVENING PRIMROSE (OENOTHERA SPP.)

Fieldsend, A.

Department of Land Use, University of Debrecen, Böszörményi út 138., H-4032 Debrecen, Hungary. E-mail fieldsend@helios.date.hu

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Abstract. Seed yields of spring-sown crops of evening primrose cv. Rigel grown in the Canterbury Plain area of the South Island of New Zealand in 1997-98 ranged from 1.85 t ha^{-1} to 0.27 t ha^{-1}. This paper presents agronomic data for each crop and discusses the possible agronomic and environmental causes of the differences in seed yield.

INTRODUCTION

Evening primrose (*Oenothera* spp.) has been successfully commercialised as a crop in north and central Europe, North America and Australasia. Its seed oil contains γ-linolenic acid (GLA) which has valuable nutritional and pharmaceutical properties (Horrobin, 1990). Evening primrose may be either overwintered or spring sown (Fieldsend & Morison, 2000).

Scotia Pharmaceuticals Ltd, a UK-based company, regularly placed contracts for evening primrose seed production throughout the 1980s and 1990s. Its growers were provided with improved cultivars and with agronomic expertise. Even so, yields from individual crops within a given year and region often differed widely. This paper discusses the possible reasons for some of these differences amongst crops harvested in New Zealand in 1998.

MATERIALS AND METHOD

In mid-March 1998 the author visited spring-sown evening primrose cv. Rigel crops being grown on contract to Scotia Pharmaceuticals in the Canterbury Plain area of the South Island of New Zealand. With the aid of a questionnaire each grower was asked a standard set of questions. After harvest, the yield of cleaned seed from each crop was recorded. The data were then analysed in an attempt to identify the major factors determining the yield of crops.

RESULTS AND DISCUSSIONS

605.7 ha of crops were drilled, of which 434.0 ha were harvested. Harvested yields ranged from 1.85 t ha^{-1} to 0.27 t ha^{-1}. Crops have been divided into five groups, as listed in Table 1. Each group, except the 0.5-1.0 t ha^{-1} category, is reviewed below. For the 0.5-1.0 t ha^{-1} category, only crops giving results substantially different to those expected are considered.

The highest yielding crops. Eight crops yielded over 1.3 t ha^{-1}. The data in Table 2 indicate some common factors. (See appendix for details of abbreviations). All were assessed as being high yielding. All received numerous rounds of irrigation, (almost) all had very low weed levels. Plant populations tended to be high but crops had generally fully bolted (i.e. stem extension had occurred). All crops were of uniform growth stage and all except crops 51 and 60 were in the same locality.

Table 1. Spring-sown evening primrose crops, New Zealand, 1998 harvest.

Seed yield t ha^{-1}	Crop area drilled (ha)	Crop area harvested (ha)	% total crop area	% harvested crop area
More than 1.3	79.0	77.0	13.0	17.7
1.0 - 1.3	30.8	30.8	5.1	7.1
0.5 - 1.0	207.9	198.9	34.3	45.8
Less than 0.5	136.3	127.3	22.5	29.3
Failed crops	151.7		25.0	

Other factors were less consistent. Four crops were grown by grower 6, an experienced grower, but grower 14 was a first-time grower. Most crops followed cereals or grass and almost all received post-emergence herbicide. However, all soil types are represented in the list (including Lismore), as are different drilling methods and types of irrigator, and (relatively) high *Botrytis* levels seemed not to be a problem. A range of drilling dates are represented, including some particularly late dates. It would have been helpful to have had dates of emergence to hand as well, as drilling and emergence dates are not necessarily closely correlated. The better than expected performance of crop 51 is of note.

Table 2. Data from spring-sown evening primrose crops yielding more than 1.3 t seed ha^{-1}.

Crop no.	Grow-er i.d.	Soil type	Previous crop	Date of drilling dd.mm	Drilling rate kg ha^{-1}	Meth-od of drilling	Plant population m^{-2}	Fertiliser kg ha^{-1} seedbed	post-em	Weeds present	Weed score 0-5
32	6	H	serradella	26.09	2.0	b	100	s sup	125 u	7,8	1
65	22	T	wheat	02.09	2.5	d	120-130	0	185 u	5	1
60	16	M	cocksfoot	03.10	3.0-3.5	d	200-250	150 c15	230 am s	3	1
07	14	L	wheat	08.09	3.0	b	80-100	125 c15	125 u	3,4	1
51	18	Ta	grass	23.10	1.0-2.5	b	100-200	55 c20	0	5,8	3
33	6	C	spinach	09.10	2.0	b	80-100	s sup	125 u	7	1
34	6	H	wheat	20.09	2.0	b	100	s sup	125 u	7,8	1
35	6	H	wheat	16.10	2.0	b	100	s sup	125 u	7,8	1

Crop no.	No. times irrigated	Max. freqncy days	Type of irri-gator	Bolt-ing %	*Botrytis* 0-5	Crop height cm	Growth stage 5,xx	Stage uniform. 1-5	Crop score 1-5	Harv. area ha	Est. yield t ha^{-1}	Seed yield t ha^{-1}
32	10-14	5-6	l	100	1		70	5	5	9.0	1.5	1.31
65	10-14	14	l	99	2		85	5	5	12.0	1.4	1.33
60	12-14	7	g	80	2	75-85	60-70	5	4	10.0	1.1	1.36
07	14		fs	98	1		80	5	5	10.0	1.4	1.39
51	7-9		r	75-100	2	80-95	25-90	4	4	9.0	1.2	1.47
33	10-14	5-6	l	100	0		60	5	5	10.0	1.5	1.53
34	10-14	5-6	l	100	1		70	5	5	11.0	1.5	1.71
35	10-14	5-6	l	100	1		70	5	5	6.0	1.5	1.85

"Near misses". Four crops yielded between 1.0 and 1.3 t ha^{-1}. Plant populations tended to be below 100 plants m^{-2} but almost all plants had bolted, despite fewer applications of irrigation than in the highest yielding crops. Incidence of weeds was slightly higher but this may partly be a reflection of a thinner crop canopy. Growth stage uniformity was less than in the best crops.

Table 3. Data from spring-sown evening primrose crops yielding between 1.0 and 1.3 t seed ha^{-1}.

Crop no.	Grow -er i.d.	Soil type	Previous crop	Date of drilling dd.mm	Drilling rate kg ha^{-1}	Meth- od of drilling	Plant population m^{-2}	Fertiliser kg ha^{-1} seedbed	post-em	Weeds present	Weed score 0-5
27	20	L	wheat	29.08	3.0	b	40-100	140 c15	140 u	8	2
17	9	W	?	17.09	2.0	r	40-100	180 s sup	?	5,6,8	2
49	15	T	kale seed	22.09	2.5	b	60-85	250 s sup	195 u	1,6-8	2
55	1	T	pasture	10.10	3.0	b	60-100	supph	100 u	8,9	2

Crop no.	No. times irrigated	Max. freqncy days	Type of irri- gator	Bolt- ing %	*Botrytis* 0-5	Crop height cm	Growth stage 5,xx	Stage uniform. 1-5	Crop score 1-5	Harv. area ha	Est. yield t ha^{-1}	Seed yield t ha^{-1}
27	8	12-14	b	90	0		70-90	3	4	6.8	0.95	1.02
17	2-4		?	100	0	85-95	60	4	4	10.0	1.0	1.02
49	10+		l	90	3	75-100	50-95	3	4	4.0	1.1	1.14
55	6		r	100	3		65	4	4	10.0	1.1	1.20

Surprises. Several crops appeared likely to achieve seed yields of 1 t ha^{-1} but failed to do so (Table 4). Most appeared to be well grown in most significant respects (i.e. plant population, weed control, frequency of irrigation, level of bolting and stage uniformity were good). It would be helpful to know why these failed to yield as well as expected. Some thoughts are as follows:

Table 4. Data from some crops spring-sown evening primrose crops yielding between 0.5 and 1.0 t seed ha^{-1}.

Crop no.	Grow -er i.d.	Soil type	Previous crop	Date of drilling dd.mm	Drilling rate kg ha^{-1}	Meth- od of drilling	Plant population m^{-2}	Fertiliser kg ha^{-1} seedbed	post-em	Weeds present	Weed score 0-5
67	17	H	ryecorn	16.10	1.8	r	40	0	0	3,6,8,15	3
14	5	L	pasture	02.09	3.0	b	100-150	s sup	0	3,8	1
38	10	W	wheat	19.09	3.0	b	80-120	400 s sup	100 u	0	0
58	16	M	cocksfoot	26.09	3.0-3.5	d	60-130	150 c15	230 am s	0	0
66	6	C	serradella	16.10	2.0	b	80-100	s sup	125 u	6,7,8	1
41	4	C	onions	20.09	3.0	b	?	?	260 u	8	1

Crop no.	No. times irrigated	Max. freqncy days	Type of irri- gator	Bolt- ing %	*Botrytis* 0-5	Crop height cm	Growth stage 5,xx	Stage uniform. 1-5	Crop score 1-5	Harv. area ha	Est. yield t ha^{-1}	Seed yield t ha^{-1}
67	10		r	95	0	80-90	40-90	3	4	4.0	1.0	0.58
14	9-10		t	50	0		90	4	4	8.0	1.0	0.67
38	7	14	r	100	1	85-115	70	5	5	16.0	1.35	0.76
58	12-14	7	l	100	1	80-90	60-80	5	5	7.0	1.2	0.83
66	10-14	5-6	l	100	0		60	5	5	6.0	1.2	0.91
41	8	7	?	99	1		80	?	3	11.0	0.8	0.99

- The plant population of crop 67 was low and the crop received no nitrogen fertiliser, but the visual yield assessment should have allowed for this. Nightshade was present in the crop and this may have caused seed cleaning losses.
- Crop 14 was early maturing, and the slightly high population grown on a Lismore soil (described as “a thin covering of dust over stone”) with no post-emergence fertiliser may be the combined cause of the low bolting. Although the crop looked complete, uniform and weed-free, 65% contamination with the old cultivar Peter and competition caused by the non-bolters for water and nutrients may have depressed yield.

- Crop 38 looked excellent although its height was slightly variable due to irrigation overlap. It was subsequently reported that the crop had bolted less than was thought but the level of yield loss is still surprising.
- The reason for the low yield of crop 58 is not evident. It was one of three fields grown by grower 16, his crop number 60 produced 1.36 t seed ha^{-1}.
- 42% contamination with the obsolete cultivar 421 may be the reason why the yield of crop 66 was over-estimated.

Crop 41 gave an unexpectedly high yield. It was variable in height and may have looked poorer than it actually was.

The lowest yielding crops. In this group of crops plant populations were mostly low despite fairly high seeding rates but the proportion of bolted plants was generally poor, despite several rounds of irrigation (Table 5). Weed scores were average to poor. Grower 19 did not apply post-emergence fertiliser and had a very labour-intensive irrigation system. Most of the other crops in were grown on Lismore soil and presumably the amount of irrigation applied was insufficient. Crop 50 suffered from a very high plant population whilst crop 26 was drilled very late, the population was low and the crop was weedy. The poorer than expected performances of crops 40 and 21 are of note, both were weedy but the main weed species present are not usually considered to be major causes of cleaning losses; nonetheless the latter was cleaned four times to remove fat hen. Crop 06 also reputedly suffered from cleaning losses due to the need to remove sclerotia whilst crops 54A and 47 perhaps suffered cleaning losses through nightshade contamination.

Table 5. Data from spring-sown evening primrose crops yielding less than 0.5 t seed ha^{-1}.

Crop no.	Grow-er i.d.	Soil type	Previous crop	Date of drilling dd.mm	Drilling rate kg ha^{-1}	Meth-od of drilling	Plant population m^{-2}	Fertiliser kg ha^{-1} seedbed	post-em	Weeds present	Weed score 0-5
22	19	W	(wheat	30.09	4.0	b	40-80	c15	0	5,8,10	2
23	19	W	(or	30.09	4.0	b	40-80	c15	0	5,8,10	2
24	19	W	(barley	30.09	4.0	b	40-80	c15	0	5,8,10	2
40	13	L	wheat	08.09	3.0	b	40-60	yes	100 u	3,7,8	4
21	7	L	wheat	22.09	3.0	b	60-80	150 c15	100 u	2,3,5,7	4
50	8	T	wht/grass	08.09	2.5-3.0	d	200+	0	100 u	1,3,6,11	2
26	3	W	fog grass	30.08	2.2-2.5	b	20-30	200 c20	?	3,5,7-9	4
06	23	L	cocksfoot	16.09	3.0	b	60-80		110 u	1,2	2
54A		T	peas	02.10	2.5	d	30	0	75 u	3,6,8,10	2
47	11	C	ryecorn	16.09	2.0	r	45	250 c15	0	2,3,6,14	2
10	21	L	wheat	25.09	2.5-3.0	d	40-60	150 c15	100 u	3,7,8	4
11	21	L	barley	25.09	2.5-3.0	d	40-60	150 c15	100 u	3,7,8	4

Crop no.	No. times irrigated	Max. freqncy days	Type of irri-gator	Bolt-ing %	*Botrytis* 0-5	Crop height cm	Growth stage 5,xx	Stage uniform. 1-5	Crop score 1-5	Harv. area ha	Est. yield t ha^{-1}	Seed yield t ha^{-1}
22	5-6+		g	20	0	50-90	0-90	2	1	4.0	0.1	0.27
23	5-6+		g	20	0	50-90	0-90	2	1	4.0	0.1	0.27
24	5-6+		g	20	0	50-90	0-90	2	1	6.5	0.1	0.27
40	6-7		r	50+	1		55	4	3	8.0	0.7	0.27
21	9-10		r	50	1		70	4	3	14.0	0.55	0.29
50	7		li	5-10	2	60-100	30-100	1	2	12.0	0.3	0.29
26	6		r	10-90	0	45-100	0-50	3	3	10.8	0.3	0.29
06	6	7-10	r	60	2		1	4	4	14.0	1.0	0.43
54A	6		r	100	2	85-90	0-70	3	4	8.0	1.0	0.44
47	6-7		r	90	0	70-85	20-50	3	3	14.0	0.7	0.44
10	8-10	10	l	<50	0		70-80	3	2	8.0	0.4	0.45
11	8-10	10	l	<50	0		40-60	3	2	8.0	0.4	0.45

Failed crops. 103 ha of crops were lost through wind blow and 28 ha through poor crop emergence. Just two crops (20 ha) seem to have been lost directly as a result of poor husbandry practice. Crop 43 suffered severe competition from yarrow and did not bolt whilst crop 63 had a low plant population and did not bolt, probably because it was not irrigated.

General comments. The key requirements for a yield of 1.3 t ha^{-1} or more appear to be a fully-bolted population of approximately 100 plants m^{-2} and very good weed control. There is some evidence that the application of post-emergence fertiliser may be of benefit. It is not possible to say to what extent the application of irrigation contributed to increasing yield over and above ensuring adequate bolting. Final crop yield does not appear to be greatly influenced by date of drilling or, in 1997-98, incidence of *Botrytis*.

A strategy of growing 100 seed-producing plants m^{-2} depends upon their access to sufficient soil moisture. Weeds and non-bolted plants will use some of this moisture. Thus, on the poorer soil types or where adequate irrigation cannot be guaranteed, a sensible strategy may be to aim for, say, 50-80 plants m^{-2}, so that 100% bolting can be achieved, with a view to producing up to 1 t ha^{-1} seed. Extra attention to weed control may be necessary.

There are several instances where less-than-expected yields may be a consequence of cleaning losses caused by weed contamination, particularly nightshade. More hand rogueing of weeds may be economically viable. For example, crop 9751 was hand rogued for nightshade at a cost of NZD 175 ha^{-1}. If a crop yielding 1 t ha^{-1} suffered 15% cleaning losses, the value of the lost seed would be NZD (150 $\times$ 3.5), i.e. NZD 525 ha^{-1}. A better understanding of the mechanics and control of sclerotia contamination might also be beneficial.

CONCLUSIONS

The experience of 1997-98, which was a very dry year, seems to indicate that there is merit in selecting a target reproductive plant population in line with what can be supported by the anticipated available soil moisture and to minimise competition for this moisture from non-bolted plants and weeds. As plant populations fall significantly below 100 plants m^{-2} the yield potential of the crops appears to decline. However, the financial break-even point for evening primrose production will vary from farm to farm. The best-equipped farms should expect to aim for 1.3 t ha^{-1} or more whereas those located on, for example, Lismore soil may well consider a substantially lower yield target to be realistic. In some instances as little as 0.5 t ha^{-1} might be acceptable. The effect on yield of applied nitrogen, particularly post-emergence, under New Zealand conditions, seems to merit further investigation.

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APPENDIX

Explanations for the abbreviations used in Tables 2-5 are as follows:

Soil type	C	Chertsey silt loam	T	Templeton sand
	H	Hatfield silt loam	Ta	Tamuka clay loam
	L	Lismore silt loam	W	Wakanui silt loam
	M	Mayfield silt loam		
Drilling method	b	broadcast	r	crop drilled in rows
Plant population	From post-emergence counts			
Fertiliser	am s	ammonium sulphate (21% N, 24% S)	c15	Crop 15 (15:10:10:7)
	DAP	diammonium phosphate	c20	Crop 20 (20:10:10:7)
	s sup	sulphur super (0:8:0:20)	u	urea (46% N)
	supph	superphosphate		
Weeds present	1 rape	*Brassica* spp.	9 mayweed	*Matricaria* spp.
	2 fat hen	*Chenopodium album*	10 wild oats	*Avena* spp.
	3 clover	*Trifolium* spp.	11 hedge mustard	*Sysimbrium officinale*
	4 wheat	*Triticum aestivum*	12 gorse	*Ulex* sp.
	5 grass		13 field madder	*Sherardia arvensis*
	6 nightshade	*Solanum nigrum*	14 beans	*Vicia* spp
	7 yarrow	*Archillea millefolium*	15 potatoes	*Solanum tuberosum*
	8 thistle	*Cirsium*. & *Sonchus* spp.		
Weed score	0 = no weeds; 5 = very weedy			
Irrigation	'Number of times' may or may not include applications to achieve crop establishment (normally 2-3).			
Type of irrigator	b	borderdyke	l	fixed boom linear
	g	raingun	li	lateral irrigator
	r	rotorainer	sr	side roll irrigator
	fs	fixed boom with sprinklers		
Level of *Botrytis*	0 = no disease; 5 = severe disease			
Crop growth stage	Measured according to the method developed by Simpson (1994).			
Growth stage uni.	1 = poor crop uniformity; 5 = good			
Crop score	1 = poor overall appearance; 5 = good			
Estimated yield	Seed yield estimated by the author during his visit.			