Effect of Sowing Rate and Row Spacing in Seed Production of *Poa pratensis* L.

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ABSTRACT

Seed production of perennial grasses is favoured by low plant densities, but competition from weeds might disturb this relationship. This research was conducted to determine appropriate sowing rates and row spacings in seed production of one arctic (Lavang) and one temperate (Leikra) cultivar of *Poa pratensis* L. Field experiments with sowing rates of 2.5, 5.0 and 10.0 kg ha^{-1} and row spacings of 16.5 and 33.0 cm were established at Landvik Research Station (SE Norway, 58°N) in May/ June 1988 and 1989. In 1988, rapid field emergence caused intense tiller competition, and in the following ley years seed yields increased with lower sowing rates in both cultivars and with wider row spacing in cv. Lavang. In 1989 both cultivars established slowly, and seed yields in ley year 1 were lower and had a greater weed contamination at 2.5 kg ha^{-1} than at higher sowing rates. While unaffected by sowing rate, the average seed yield in cv. Lavang was significantly higher at the 33.0 than at the 16.5 cm row spacing (737 vs. 625 kg ha^{-1}). Conversely, the average seed yield in cv. Leikra was unaffected by row spacing, but significantly lower at the 10.0 kg ha^{-1} sowing rate than at the 5.0 and 2.5 kg ha^{-1} sowing rates (321, 369 and 395 kg ha^{-1}, respectively). The relationship between tillering in the sowing year and subsequent seed production is discussed.

***Additional index words:* *Alopecurus geniculatus* L., panicle number, plant density, *Poa annua* L., seed yields, tiller competition**

INTRODUCTION

In Norway, *Poa pratensis* L. is used both for turf and forage production. While nearly all seed for recreational use is imported, there is a small domestic production of seed for pastures. Two Norwegian cultivars have been bred for this purpose.

The cultivar Lavang is an exceptionally winter–hardy ecotype adapted for forage production in arctic grasslands (67–71°N). Because of its extreme photoperiodic requirements, seed production of this cultivar, as of its predecessor, cv. Holt, is practically impossible in the seed producing areas of Denmark, The Netherlands and the Pacific Northwest of the United States. Even in southeast Norway (58–62°N), seed yields are often poor, showing great year to year variation.

The second cultivar, Leikra, is mainly used for permanent pastures in the mountain region of south central Norway. It has a somewhat unclear background, probably being a hybrid between native Norwegian material and introduced plants of *Poa ampla* L. from California. It is light green, tall growing and gives high yields of dry matter. Due to low panicle densities and susceptibility to lodging, seed yields of this cultivar have also been low, but unlike the north–Norwegian cultivar, seed production seems to be promoted at low latitudes (Nordestgaard, 1983a).

As for other grass species, seed production in *Poa pratensis* L. is generally favoured by low plant densities. On average for the two first ley years, Nordestgaard and Larsen (1974) found that a reduction in sowing rate from 15 to 5 kg ha^{-1} increased seed yield from 1200 to 1450 kg ha^{-1}, panicle number from 2584 to 2756 m^{-2} and the calculated seed number per panicle from 153 to 179. Meijer (1984) reported a significant drop in seed yield and panicle number in ley year 1 as sowing rate was raised from 12 to 24 kg ha^{-1}; in these trials seed yields were unaffected by sowing rates in the range 3–12 kg ha^{-1}. In Finnish experiments, higher seed yields were obtained in plots sown at 4 kg ha^{-1} than in plots sown at 8 kg ha^{-1} (Kansanen, Saari and Laitinen, 1982).

In addition to low sowing rate, wide row spacing is a well–known method of controlling plant density in grass seed production. In tall forage grasses, row spacings of 30 cm or greater are more conducive to seed yield in *Bromus inermis* Leyss., *Dactylis glomerata* L., *Festuca arundinacea* L. and *Phleum pratense* L. (Austenson and Peabody, 1964; Buller, Bubar, Fortmann and Carnahan, 1955; Canode, 1968; Fulkerson, 1959; Fulkerson and Tossell, 1961; Young, 1991). Similar enhancement by wide row spacing was not achieved in the ornamental grasses *Festuca rubra* L. and *Agrostis capillaris* L. (Austenson and Peabody, 1964; Canode, 1968). Although *Poa pratensis* L. is generally characterized by a more vigorous rhizome production than these species, Rampton, Jackson and Lee (1971) reported substantially higher seed yields at 30 than at 76 cm row spacing even in ley year 3 and 4, and Canode (1968) found 90 cm to be inferior to 30 and 60 cm row spacings. Canode and Law (1975) stated that increased row spacings could not prevent the reduction in seed yield commonly associated with ageing stands.

Low sowing rates and wide row spacings generally create open stands with more need for weed control in the sowing year and in ley year 1. Of special concern in Norwegian seed production are *Poa annua* L. and *Alopecurus geniculatus* L.; every year these weeds cause the rejection of 20–50 % of all *Poa pratensis* L. seed crops.

The objective of the present research was to investigate the effects of sowing rate and row spacing on seed yields and related characters in two very different Norwegian cultivars of *Poa pratensis* L.

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MATERIALS AND METHODS

Experimental fields were established without a cover crop at Landvik Research Station (58°N, 0–15 m a.s.l.) on 19 May 1988 and 8 May 1989. Except for the 1988 planting of cv. Leikra, which occurred on a sandy loam (57 % sand, 34 % silt, 9 % clay), all plantings were situated on silt loams (29–33 % sand, 54–60 % silt, 13–16 % clay).

In 1989, field emergence of cv. Leikra was very slow, and, as an insurance, one additional field was drilled on a similar soil on 2 June. During June and July emergence was good in both fields and it was decided to keep both for the determination of seed yield and other parameters. The fields of cv. Leikra sown on 8 May and 2 June 1989 were designated A and B, respectively.

The experimental plan included two factors which were completely randomized into each of three blocks (replicates):

Factor 1	**Factor 2**
Sowing rates	Row spacing
1. 2.5 kg ha^{-1}	X. 16.5 cm
2. 5.0 kg ha^{-1}	Y. 33.0 cm
3. 10.0 kg ha^{-1}	

The plots were drilled with a tractor mounted Øyjord drill with interchangeable distributor heads and disc coulters set at 0.5 cm sowing depth (Aamlid, 1993). The gross plots were 9 m long and 1.8 m wide. Alley widths between plots were 30 cm, and the harvested area was 7.6 x 1.5 m.

The sandy soil selected for cv. Leikra in 1988 was practically free of grass weeds, and no special measure was therefore taken against *Poa annua* L. and *Alopecurus geniculatus* L. In the other fields, the 33.0 cm row spacing was combined with carbon banding (Lee, 1973) and the application of simazine, 750 g a.i. ha^{-1}, just after sowing. Broadleaved weeds were always controlled by application of bromfenoxim (1500g a.i.ha^{-1}) 3–4 weeks after sowing.

Both in the planting year and in subsequent ley years fields were fertilised with $Ca(NO_3)_2$ at a rate of 50 kg N ha^{-1} in September. In the beginning of April, NPK fertiliser was applied at rates of 30 kg N ha^{-1} in the first ley year and 50 kg N ha^{-1} in the second and third ley years.

The fields were not defoliated in the year of establishment. In the ley years, stubble was cut to 5 cm and removed before the application of nitrogen in September.

With the exception of field B of cv. Leikra established in 1989, vegetative tiller number was counted on small plots (20 x 33cm) during the late autumn/winter after sowing (1 November in 1988, but 1 February for the crops sown in 1989). Immediately before harvest in ley year 1, panicles were cut (1 cm below the lowest branch in the inflorescence), counted and weighed (unthreshed) from the same miniplots (Aamlid, 1993). In older leys and in all ley years of field B of cv. Leikra, panicle numbers were derived from *in situ* countings within 60 x 60 cm portable frames, and the seed numbers per panicle were calculated from seed yield and the other yield components. Percent lodging was always determined just before harvest.

At 30–35 % seed moisture content, seed was headed directly with a Nurserymaster field plot combine. The straw was weighed and usually rethreshed after approximately one week's curing. After seed drying and cleaning, one sample from each treatment in each field (common for three replicates) was analysed for purity and contamination by *Poa annua* L. and *Alopecurus geniculatus* L. at The Norwegian State Seed Testing Station. Since cv. Leikra was sown in a practically clean soil in 1988, the determination of weed content was omitted for this particular field. Analyses for thousand seed weight and germination were performed in the seed laboratory at Landvik Research Station in accordance with internationally agreed rules (ISTA, 1985). Thousand seed weight, weed contamination and germination data presented in this report are weighed means for the first and second harvests.

Statistical analyses

With the exception of seed quality data where no replicates existed, separate analyses of variance were performed for each harvest (i.e. each ley year in each field). In addition, one overall analysis of variance was conducted for each of the two cultivars, regarding harvests as replicates. Significance levels $P<0.05$, $P<0.01$ and $P<0.001$ are indicated by *, ** and ***, respectively, and for some non–significant tendencies, probability values are given. Least significant differences at the 5 % probability level were used to separate sowing rate means. Relationships between vegetative tiller number in late autumn/winter and seed yield in the first ley year were tested separately for each row spacing by simple linear regression.

RESULTS

Meteorological data

The growing season 1988 was characterized by a warm and dry June, and unusually high rainfall during July and August (Table 1). In 1989 temperatures were normal during the growing season, but June, July and September had rather low rainfall. For the three fields sown in 1989, the scarce rainfall in June and July was compensated by a total of 60 mm irrigation water. The seed crops were not irrigated during the harvest years.

The winters of 1988–89 and 1989–90 were both exceptionally mild. The ground was not permanently frozen, and precipitation came as rain rather than snow.

Table 1. Average monthly temperature and total monthly rainfall in 1988, 1989 and 1990 as well as average values (1961–90) for Landvik Research Station.

	Temperature, °C				Rainfall, mm			
	1988	1989	1990	Average (1961–90)	1988	1989	1990	Average (1961–90)
Jan	1.9	5.3	3.2	–1.6	339	50	229	113
Feb	0.8	4.1	5.0	–1.9	162	115	226	73
Mar	–0.1	4.3	5.5	1.0	149	126	62	85
Apr	3.7	5.4	6.9	5.1	71	100	66	58
May	11.3	11.0	11.9	10.4	28	25	37	82
Jun	16.8	14.1	14.1	14.7	15	30	109	71
Jul	15.5	16.7	16.2	16.2	305	11	92	92
Aug	14.9	14.5	15.7	15.4	190	97	143	113
Sep	12.7	11.9	10.6	11.8	154	49	184	136
Oct	7.0	8.1	8.1	7.9	168	151	138	162
Nov	2.1	4.3	2.0	3.2	51	127	77	143
Dec	1.3	0.4	1.4	0.2	128	132	119	102
Year	7.3	8.3	8.4	6.9	1760	1013	1482	1230

Establishment

In 1988, cv. Lavang germinated fast and uniformly and had a large tiller population by 1 November, regardless of sowing rate (Table 2). In 1989–90 the highest sowing rate created a tiller number on 1 February similar to that produced three months earlier by the lowest sowing rate in 1988. Stands sown at 2.5 kg ha^{-1} in 1989 were thin and severely infested by weeds.

The average tiller number in cv. Leikra was approximately 50 % lower than in cv. Lavang. Sowing rate had a significant effect on tiller number only in 1989–90.

While row spacing had no influence on tiller number in 1988, cv. Leikra tillered more profusely when sown at narrow row spacing in 1989. A similar tendency was recorded in cv. Lavang.

Seed yield

Increasing sowing rates reduced seed yields in ley year 1 and 2 for cv. Lavang sown in 1988, but 2.5 kg ha^{-1} was inferior to higher sowing rates in ley year 1 of the 1989–sown crop (Table 3). The wide row spacing stimulated seed yields in ley year 1 in both fields. The average seed yield in cv. Lavang was not affected by sowing rate, but it was higher at the 33.0 than at the 16.5 cm row spacing.

While the 2.5 kg ha^{-1} sowing rate produced the highest seed yields in ley year 1 and 2 for cv. Leikra sown in 1988, 5.0 kg ha^{-1} was superior to the other rates in ley year 1 of field A sown in 1989 (Table 4). Older leys of cv. Leikra established in 1989 tended to be stimulated by the lowest sowing rate. Significant effects of wide row spacing were recorded only in field A sown in 1989, but the wider row spacing tended to be advantageous also in ley year 3 of the second crop established in 1989. As an average for all harvests, seed yield in cv. Leikra was not influenced by row spacing, but it was significantly lower at the 10.0 than at the 5.0 and 2.5 kg ha^{-1} sowing rates.

Table 2. Effect of sowing rate and row spacing on tiller number m^{-2} in two cultivars in late autumn/ winter[1] after sowing. Data are means of two row spacings and three sowing rates, respectively.

	1988 sowing		1989 sowing	
	Lavang	Leikra	Lavang	Leikra
Sowing rate kg ha^{-1}				
2.5	7009	2804	3886	2666
5.0	7494	2849	6055	3763
10.0	8258	3331	7042	4048
Sign.	ns	ns(P = 0.08)	**	***
LSD P<0.05	-	-	1827	380
Row spacing, cm				
16.5	7615	3095	6330	3941
33.0	7560	2894	4991	3044
Sign.	ns	ns	ns(P = 0.07)	***
LSD P<0.05	-	-	-	310

[1] *Actual assessment dates were 1 November 1988 for the 1988 sowing and 1 February 1990 for the 1989 sowing*

Table 3. Seed yield (kg ha^{-1}, 100% purity, 14% seed moisture content) of cv. Lavang in ley year 1, 2 and 3 in two experimental fields as affected by sowing rate and row spacing. Data are means of two row spacings and three sowing rates, respectively.

	1988 sowing Ley year			1989 sowing Ley year		Mean
	1	2	3	1	2	
Sowing rate kg ha^{-1}						
2.5	1557	510	275	535	525	680
5.0	1508	460	268	738	607	716
10.0	1346	367	207	713	595	646
Sign.	*	***	ns(P = 0.18)	**	ns	ns
LSD P<0.05	148	50	-	113	-	-
Row spacing, cm						
16.5	1351	432	241	557	543	625
33.0	1590	459	260	767	609	737
Sign.	***	ns	ns	***	ns(P = 0.13)	**
LSD P<0.05	121	-	-	92	-	73

No significant interaction between sowing rate and row spacing for seed yield was detected. There were, nevertheless, tendencies towards a lower optimum sowing rate at the 33.0 than at the 16.5 cm row spacing in both cultivars (data not shown).

Relationship between tiller number in late autumn/winter and seed yield

In 1988–89, no significant relationship was observed between tiller number on 1 November and seed yield in July. In 1989–90, the regressions were significant for plots sown at both row spacings in cv. Lavang (Fig. 1), and for plots sown at 16.5 cm in cv. Leikra (Fig. 2) In the former cultivar, increasing tiller numbers advanced seed yields more strongly at the wider row spacing.

Table 4. Seed yield (kg ha^{-1}, 100% purity, 14% seed moisture content) of cv. Leikra in ley year 1, 2 and 3 in two experimental fields as affected by sowing rate and row spacing. Data are means of two row spacings and three sowing rates, respectively.

	1988 sowing Ley year			1st 1989 sowing Ley year			2nd 1989 sowing Ley year			Mean
	1	2	3	1	2	3	1	2	3	
Sowing rate kg ha^{-1}										
2.5	696	400	195	349	663	194	465	432	164	395
5.0	500	290	163	513	742	160	424	384	142	369
10.0	378	193	155	397	718	143	425	373	107	321
Sign.	**	***	ns	**	ns	*	ns	ns(P=0.08)	ns(P=0.07)	**
LSD P<0.05	137	64	–	70	–	41	–	–	–	45
Row spacing, cm										
16.5	530	283	173	378	681	147	440	396	120	350
33.0	519	306	169	461	734	184	436	397	155	373
Sign.	ns	ns	ns	**	ns(P=0.13)	*	ns	ns	ns(P=0.08)	ns
LSD P<0.05	–	–	–	57	–	33	–	–	–	–

Panicle number

As compared with lower sowing rates, 10.0 kg ha^{-1} reduced the panicle number in ley year 3 in cv. Lavang established in 1988. The opposite tendency appeared in ley year 1 in the field established in 1989, but the overall effect of sowing rate on panicle number was not significant (data not shown). The average panicle number in cv. Lavang was 1625 m^{-2}.

When established in 1988, cv. Leikra produced significantly more panicles in ley year 1 and 2 in plots sown at 2.5 kg ha^{-1} than in plots sown at higher rates. In both fields sown in 1989, there were tendencies that the highest sowing rate gave the highest panicle number in the first year, but this shifted in favour of lower sowing rates as stands became older (data not shown). The overall effect of sowing rate on panicle number was not significant in cv. Leikra, the average density being 747 panicles m^{-2}.

Increasing the row spacing from 16.5 to 33.0 cm resulted in more panicles in ley year 1 in both fields of cv. Lavang (Table 5), but had no effect on panicle number in cv. Leikra (data not shown).

A significant interaction between sowing rate and row spacing was recorded in ley year 2 in cv. Leikra established in 1988. In this case, increasing sowing rate led to a stronger reduction in panicle formation in fields sown at the 33.0 than at the 16.5 cm row spacing (data not shown). However, this tendency was not confirmed by the overall analyses in either cultivar.

Table 5. Panicle number (m^{-2}) in cv. Lavang in ley year 1, 2 and 3 in two experimental fields as affected by row spacing. Data are means of three sowing rates.

Sowing year	Ley year	Row spacing, cm 16.5	33.0	Sign.	LSD P<0.05
1988	1	2710	3288	*	498
	2	1331	1396	ns	
	3	816	722	ns	
1989	1	1579	2161	*	567
	2	1026	1218	ns	
Mean		1493	1757	*	239

Inflorescence weight / seed number per panicle (calculated)

In ley year 2 for cv. Lavang established in 1988, the calculated seed number per panicle decreased from 135 at 2.5 kg ha^{-1} to 111 and 105 at sowing rates of 5.0 and 10.0 kg ha^{-1}, respectively. While this was the only significant effect of sowing rate on inflorescence weight or the calculated seed number per panicle, the wider row spacing consistently produced heavier inflorescences in the first year's stands of cv. Lavang (77mg at 33.0 cm cf. 67 mg at 16.5 cm, $P<0.01$).

The calculated seed number per panicle in cv. Leikra was generally 30–50 % higher than in cv. Lavang. In field A sown in 1989, the weight per unthreshed panicle in ley year 1 decreased significantly from 180 mg at a sowing rate of 2.5 kg ha^{-1} to 140 mg at sowing rates of 5.0 and 10.0 kg ha^{-1}. In the corresponding field established in 1988, inflorescence weights were 127, 130 and 108 mg at sowing rates of 2.5, 5.0 and 10.0 kg ha^{-1}, respectively. While the overall analysis verified the negative effect of increasing sowing rate on the calculated seed number per panicle in cv. Leikra, row spacing had no impact on either this character or inflorescence weight.

Thousand seed weight

Thousand seed weight was never significantly affected by sowing rate or row spacing. On average for all harvests and ley years, thousand seed weight at 14 % seed moisture content was 306 mg in cv. Lavang and 272 mg in cv. Leikra.

Straw yield

Straw yield was not significantly influenced by sowing rate or row spacing. The average straw yield was 3850 kg ha^{-1} in cv. Lavang and 5800 kg ha^{-1} in cv. Leikra.

Lodging

In cv. Lavang, lodging occurred only in ley year 1 on the field established in 1988. When evaluated just before harvest, percent lodging was 48 on plots sown at the 33.0 cm row spacing and 12 on plots sown at the 16.5 cm row spacing.

On average for nine harvests, percent lodging in Leikra was 43. Sowing rate or row spacing had no impact on this figure.

Weed contamination

In both cultivars, increasing sowing rates clearly diminished the contamination of *Poa annua* L. and *Alopecurus geniculatus* L. in precleaned seed (Table 6). This effect was most evident in cv. Lavang established in 1989, where the total contamination decreased from 17.4 % (w/w) at the 2.5 kg ha^{-1} sowing rate to 9.1 % at 5.0 kg ha^{-1} and only 2.9 % at 10.0 kg ha^{-1}.

Double row spacing reduced the weed problem in ley year 1 in both fields of cv. Lavang but only in one field of cv. Leikra. While in cv. Lavang established in 1988 the weed contamination diminished from ley year 1 to ley year 2 in plots sown at the 16.5 cm row spacing, the opposite tendency was recorded at the 33.0 cm row spacing (data not shown). As an average for all harvests, the effect of row spacing on weed contamination was not significant in either cultivar.

Table 6. **Percentage by weight of *Poa annua* L. and *Alopecurus geniculatus* L. in seed lots of cv. Lavang and cv. Leikra as affected by sowing rate and row spacing. Data are means of five harvests in cv. Lavang and six harvests in cv. Leikra.**

	Cultivar	
	Lavang	**Leikra**
Sowing rate, kg ha^{-1}		
2.5	5.7	1.0
5.0	3.1	0.6
10.0	1.5	0.5
Sign.	*	*
LSD P<0.05	3.1	0.4
Row spacing, cm		
16.5	4.1	0.8
33.0	2.8	0.7
Sign.	ns	ns

Germination

Percent germination was not significantly affected by sowing rate or row spacing. The average values were 90% for cv. Lavang and 83% for cv. Leika.

DISCUSSION

Germination of *Poa pratensis* L. is generally slow and highly dependent on seedbed conditions. According to Nordestgaard (1983b), more than 30 % emergence can not be expected under practical field conditions, even at the most favourable sowing depth (0.5 cm). In the present experiments, field emergence of both cultivars was much faster and more uniform in 1988 than in 1989. This can be attributed to higher temperatures during the first four weeks after sowing: 13.7°C in 1988 versus 10.6°C in 1989 (cv. Lavang and field A of cv. Leikra). Provided moisture is not limiting, soil temperature is the single most decisive factor for germination of *Poa pratensis* L. (Arntzen and Aamlid, 1992).

In 1988, sowing rate or row spacing had no significant impact on tiller number when counted on 1 November (Table 2). Similar results were obtained in Dutch experiments, but in that case, countings in August and September showed the main flush of tillering to occur earlier at high than at low sowing rate (Meijer, 1984). It seems fair to postulate that in the present experiments competition for space, light and nutrients also started sooner and was more fierce at the high sowing rate. One factor intensifying competition for nutrients might have been the exceptionally high rainfall during July– September 1988 (Table 1), which probably caused leaching, especially from the light soil where cv. Leikra was established.

In the present experiments, no assessment of tiller size or weight was made in connection with the tiller counts. However, it seems very likely that the average tiller size on 1 November 1988 was stimulated by low sowing rates (cv. Lavang and cv. Leikra) and by wide row spacing (cv. Lavang only). In American experiments, 70% of the tillers with a base diameter of 2.0 mm in late November produced panicles the following season; the corresponding percentages for tillers with base diameters 1.5 and 1.0 mm were only 23 and 1, respectively (Canode and Law, 1979). These data might indicate the existence of a juvenile stage in smooth meadow grass, even though the physiological understanding of this phenomenon is still incomplete. However, the present data support Meijer's (1984) findings that even tillers emerging late in autumn or early winter may produce panicles as long as tiller competition is not too severe.

In southern Norway, the growing season is usually terminated by killing frosts or snowfall in November. The mild winters during the present experiments (Table 1) probably led to tiller emergence well beyond 1 November, which was chosen as the counting date in 1988. Phytotron experiments have shown short daylengths, such as occur during winter, to be more promotive to tillering in cv. Leikra than in cv. Lavang (Aamlid, 1992).

Unlike 1988–89, three out of four regressions between tiller number in winter and seed yield in July were significant in the 1989–90 experiments (Fig. 1). In this year, poor and late field emergence obviously resulted in underoptimal tiller development at the lowest sowing rate, and this effect was aggravated through competition from grass weeds. Doubling the sowing rate to 5.0 kg ha^{-1} clearly enhanced tillering and thus seed yield in both cultivars, but a further increase to 10.0 kg ha^{-1} produced no further increase (cv. Lavang, Table 3) or even a reduction (cv. Leikra, Table 4) in seed yields due to tiller competition as in the previous year.

Seed production experiments with different row spacings often imply certain experimental dilemmas. The best way of establishing such experiments is probably to sow the rows perpendicular to plot length, but this is laborious and unpractical if small plots are used. In the present experiments a drill with 9 or 5 coulters (giving 16.5 and 33.0 cm row spacing, respectively) was used along the plots, the distance between the outermost rows always being 132 cm. Ideally, the harvested width of such plots should have been adjusted for row spacing, but in the present case, all plots were harvested with a combine 150 cm wide, and the same factor was used to convert plot yields to hectare yields for both row spacings. Most likely, this methodology positively biased the wider row spacing in the first ley year, but had the opposite effect in older leys where the interrow area is usually most productive. On average for three ley years, the effects of row spacings given in Tables 3 and 4 are presumably representative for practical conditions.

The positive effect of double row spacing on seed yields of cv. Lavang and cv. Leikra (field A) in 1989–90 can partly be attributed to less competition from weeds because of the carbon banding (Lee 1973; Rolston & Hare 1986). In fields with a lower weed pressure, the 33.0 cm row spacing was advantageous to seed yields in cv. Lavang, but not in cv. Leikra. This can be explained by differences in growth behaviour between the two cultivars. While cv. Lavang has a vigorous rhizome system developing numerous tillers close to the mother plant, tillering in cv. Leikra is slow and mainly intravaginal during the sowing year (Aamlid, 1992). Consequently, cv. Lavang has a greater ability to expand by tillering out of the rows shortly after establishment, and it may fully utilize the improved light availability at the 33.0 cm row spacing during the critical stage of tiller elongation in spring. Contrary to this, aggregating a given amount of seed of cv. Leikra into fewer rows will lead to weak and etiolated tillers in autumn, and this may counteract any positive effect of wide row spacing on light availability. As stands become older, however, fewer, but longer rhizomes will fill the gap between rows in cv. Leikra, whereas rhizome formation and tillering in cv. Lavang often declines due to inadequate photoperiod and temperature at latitudes below 67 °N.

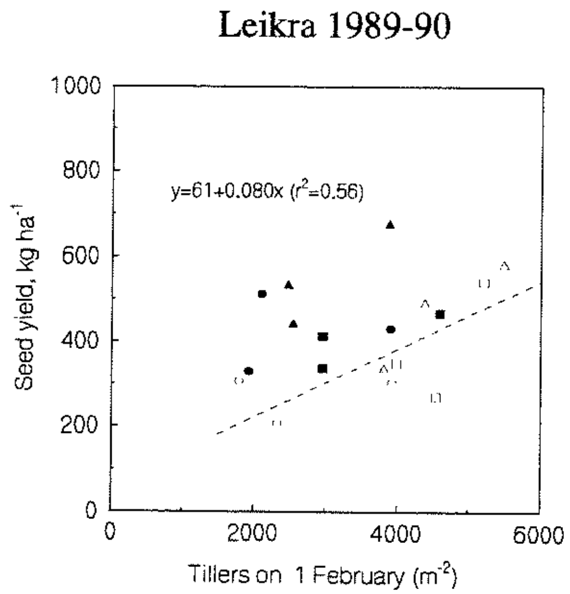

Figure 1. **Relationship between tiller number on 1 February and seed yield in July for cv. Lavang sown in 1989. Circles, triangles and squares denote sowing rates of 2.5, 5.0 and 10.0 kg ha^{-1}, respectively. Open symbols: 16.5 cm row spacing; filled symbols: 33.0 cm row spacing. Significant linear regressions for the two row spacings are indicated.**

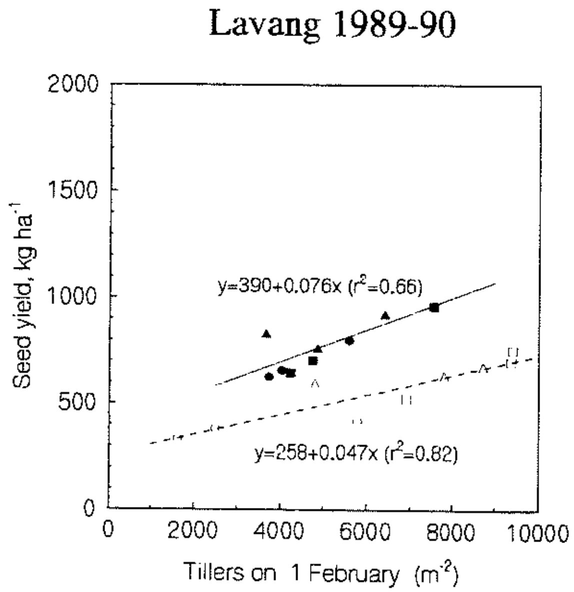

Figure 2. **Relationship between tiller number on 1 February and seed yield in July for cv. Leikra sown in 1989. Circles, triangles and squares denote sowing rates of 2.5, 5.0 and 10.0 kg ha^{-1}, respectively. Open symbols: 16.5 cm row spacing; filled symbols: 33.0 cm row spacing. The linear regression for the 16.5 cm row spacing is indicated.**

CONCLUSION

In Norwegian seed production of *Poa pratensis* L., sowing rates have to be adjusted for seedbed conditions, soil temperature and the contamination of *Poa annua* L. and *Alopecurus geniculatus* L. in the soil. Appropriate starting points for such adjustments are 6 kg ha^{-1} in cv. Lavang and 4 kg ha^{-1} in cv. Leikra. At low weed pressure, the 33.0 cm row spacing seems to be favourable for seed yields in cv. Lavang, but not in cv. Leikra.

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