

# A Study of Seed Production in Phalaris (*Phalaris aquatica* L.)

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## ABSTRACT

Apex growth and development, the contribution of different sized tillers, and the effects of row spacings on seed yield were investigated in phalaris (*Phalaris aquatica* L.) cv. Grasslands Maru. Shoots were sampled at weekly intervals from mid winter to monitor apex growth and development in relation to seed yield. Phalaris reached the double ridge stage of reproductive development by late July, and a height of about 70 mm above soil level by the third week of September. This was followed by rapid stem elongation, with panicle emergence in mid November. Of tillers tagged at floret initiation in September, the largest tillers (>4-6 mm in diameter) had 97% survival, while medium (>2-4 mm) and small tillers (2 mm and less) had 78% and 15% survival respectively. The largest tillers produced the longest panicles (130 mm) having 197 seeds per panicle whereas medium and small tillers produced panicles averaging 99 mm and 67 mm in length with 177 and 97 seeds per panicle respectively. Seed yield was significantly greater from 45 and 60 cm row spacings (683 and 635 kg ha<sup>-1</sup> respectively), than from 15 and 30 cm row spacings (428 and 520 kg ha<sup>-1</sup> respectively). While the number of panicles m<sup>-2</sup> increased as row spacing decreased, panicle size and the number of seeds per panicle decreased, thus lowering seed yield.

*Additional index words:* apex, grazing, *Phalaris aquatica*, row spacing, seed yield, tiller population, tiller size, yield components.

## INTRODUCTION

Maximising seed production in phalaris (*Phalaris aquatica* L.) requires a sound knowledge of agronomic requirements. While floral initiation and morphological development of the growing point have been described for some temperate grasses (Evans, 1940; Langer, 1972), no such information is available for phalaris. Such information is important in New Zealand where livestock grazing and seed production are often integrated.

A number of studies on tiller survival in perennial ryegrass (*Lolium perenne* L.) (Langer, 1956; Langer and Lambert, 1959; Wilson, 1959; Hill and Watkin, 1975) have shown that tillers formed early in late summer and autumn have the highest seed production capacity. Seed yield decreases progressively with later dates of tiller origin. The smallest tillers become most vulnerable when the plant undergoes stress, and as a result, death of these tillers occurs before those originating earlier (Ong, 1978). Similar studies in timothy (*Phleum pratense* L.) and cocksfoot (*Dactylis glomerata* L.) (Langer, 1956; Ryle, 1964) have shown that the late-formed tillers produce less seed as they produce fewer primary branches and spikelets respectively. The contribution made by tillers of different sizes towards seed yield of phalaris is unknown.

Previous row spacing studies with herbage grasses have shown that large differences can occur in the seed yield of the same species depending on the inherent potential of the cultivar and on the cultural conditions imposed (Lewis, 1968; Acikgoz and Karagoz, 1989). The effect of row spacing on seed yield in phalaris has not been reported. The studies reported here therefore examined apex development, tiller size and survival and the effects of row spacing on seed yield and its components in phalaris cv. Grasslands Maru.

## MATERIALS AND METHODS

### Experimental design and management

The experiments were carried out on a Wakanui silt loam soil (after a white clover seed crop) on the Lincoln University farm (43°S) in the 1990/91 season using phalaris (*Phalaris aquatica* L. cv. Grasslands Maru). The design was a factorial randomised complete block with six replications. Plot size was 10 x 2.5 m. Treatments were four row spacings (15 cm, 30 cm, 45 cm and 60 cm) with a seed rate equivalent to 8 kg ha<sup>-1</sup> (when calculated for the 15 cm row spacing), to measure the effects of row spacing on seed yield and yield components. For the measurement of apex growth and development, and tiller survival, plots were sown using a 45 cm row spacing with a seed rate equivalent to 4 kg ha<sup>-1</sup> (when calculated for the 15 cm row spacing).

All plots were drilled with an 'Oyjord' cone seeder on 6 December, 1989 and rolled two days later. Salvo (ai = 107 g l<sup>-1</sup> MCPA, 210 g l<sup>-1</sup> mecoprop, 233 g l<sup>-1</sup> dichlorprop and 17 g l<sup>-1</sup> dicamba, as the dimethyl amine salt in the form of a soluble concentrate) at 4 l ha<sup>-1</sup> and dicamba (ai = 200 g l<sup>-1</sup> dicamba as dimethyl amine salt in the form of a soluble concentrate) at 550 ml ha<sup>-1</sup> were applied on 20 January 1990 to control broadleaf weeds. The first irrigation of 30 mm was applied three weeks after sowing, and this was followed by a further 30 mm two weeks later. The need for further irrigations was monitored using a time delayed refractometer and a further 30 mm was applied in both September and October. A soil test indicated that 20 kg N ha<sup>-1</sup> was required to bring the soil nitrogen level to the 130 kg ha<sup>-1</sup> required for maximum seed production as suggested by Hampton (1985) and Rolston *et al.* (1985). Nitrolime (calcium ammonium nitrate, 28 % N) was applied in August to correct this deficit.

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## Sampling and measurements

### Apex growth

At weekly intervals starting from the third week of July, the largest shoots from a randomly selected 0.5 metre length of row were dug out and dissected. These shoots were chosen as those being most likely to (a) become reproductive (b) be killed by grazing and (c) make a major contribution to seed yield (Langer, 1972).

The position of the shoot apex in relation to the soil surface is a reliable guide as to whether grazing will remove the apex. Apex height was defined as the length between the uppermost root on the tiller to the tip of the developing inflorescence, whereas apex length was the distance between the node of the lower most side-branch (collar) to the tip of the inflorescence. Two months after sampling started, the most advanced shoots had their uppermost roots protruding from nodes 10-20 mm above the soil surface. For this reason, from 17 September all later measurements for shoot height were taken from ground level to the tip of the inflorescence. Measurement of reproductive apex length remained the same.

Measurements of apex height and apex length continued until the inflorescences of early formed tillers were fully emerged from the flag leaf sheath.

### Tiller survival

Three different sizes of tillers were labelled in all six replicates in September. Tiller sizes were grouped as large, medium or small by measuring the diameter of the stem at the base of the uppermost fully expanded leaf. Large tillers were defined as having a stem diameter of >4 to 6 mm, medium tillers >2 to 4 mm, and small tillers were 2 mm and less in diameter. Tillers of different sizes were marked using colour coded wires.

All wires were recovered at maturity and panicles from each recovered tiller harvested and bagged separately. Percent tiller survival was determined by the number of tillers recovered at harvest. All recovered panicles were air dried and hand threshed and cleaned; seeds were separated to measure seed number and seed weight.

### Row spacing

Seed yield and yield component measurements were taken from all four row spacings; 15 cm, 30 cm, 45 cm and 60 cm. Tiller population was determined by destructive sampling of all tillers in a 0.25 metre length of row selected at random from all four row spacings at the late vegetative stage (May), early reproductive stage (panicle initiation, June) anthesis (November) and maturity (January). All tillers in the sampling area were dug out so that the underground shoots could be counted. At maturity total shoot numbers above ground were counted.

Seed was harvested at 40% seed moisture by cutting all the seed heads from within a 0.5 m<sup>2</sup> quadrant in each plot. Seed heads with straw attached were placed into calico bags to minimise seed losses. All the panicles obtained were counted, then air dried to 14% seed moisture content. Panicle size was measured from 20 randomly selected seedheads and the number of side-branches counted. Using the weight of seeds obtained from 20 panicles, the number of seeds per side-branch and panicle was calculated. Thousand seed weight (TSW) was also

determined from the seeds from these 20 panicles.

The air dried seedheads from the plots were hand threshed and seeds separated and cleaned using an air-screen 'Westrup' seed cleaner, before weighing to determine seed yield.

## RESULTS

### Apex growth

Apex height increased slowly from July to the third week of September when it had reached 74 mm (Fig 1). The average increase per day was 0.95 mm. The most rapid increase in apex height (25.6 mm per day) occurred from the end of September to the third week of November, at which time it was 1708 mm from the soil surface. No further increases in apex height were recorded.

Apex length followed a similar trend to apex height (Fig. 1). An average increase of 0.08 mm per day was obtained from July to the third week of September, when apex length was 5.7 mm. The largest increase in apex length occurred between the end of September and second week of November, when apices grew at 3.4 mm per day until reaching a length of 104 mm. Growth rate declined from this point but apex length continued to increase into December.

### Tiller survival

At harvest, 97% of the large, 78% of the medium and 15% of the small tillers were recovered (Table 1). The remainder had died between the time of labelling on 11

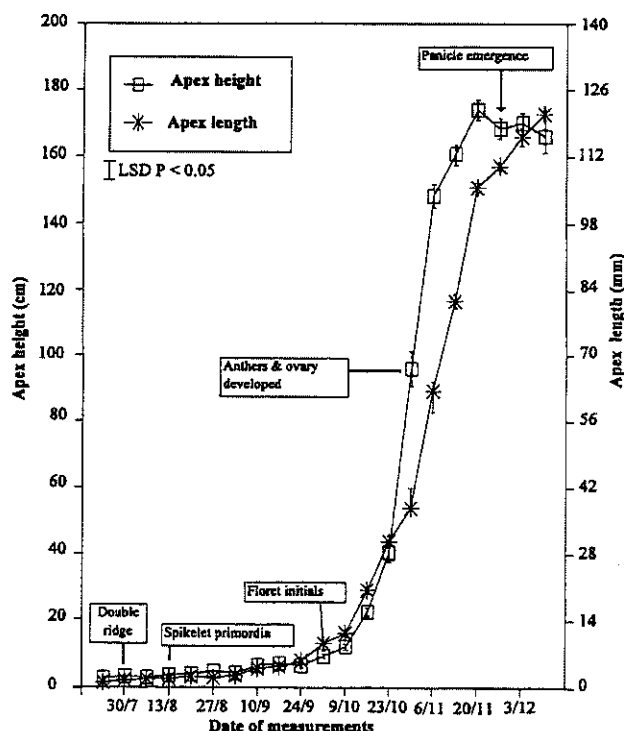


Fig. 1: Changes in apex height and length throughout the growing season in phalaris cv. Grasslands Maru

**Table 1. Effects of tiller size on tiller survival and yield components of phalaris cv. Grasslands Maru.**

	Tiller Sizes			LSD P<0.05
	Large (>4-6 mm)	Medium (>2-4 mm)	Small (2 mm & less)	
Survival (%)	97	78	15	12
Panicle length (mm)	130	99	67	11
Seeds/panicle (No)	197	177	97	4
Wt. of seeds/panicle (g)	0.30	0.26	0.13	0.16
TSW (g)	1.54	1.46	1.31	0.07

September, 1990 and harvest on 11 January, 1991. All the tillers recovered were fertile.

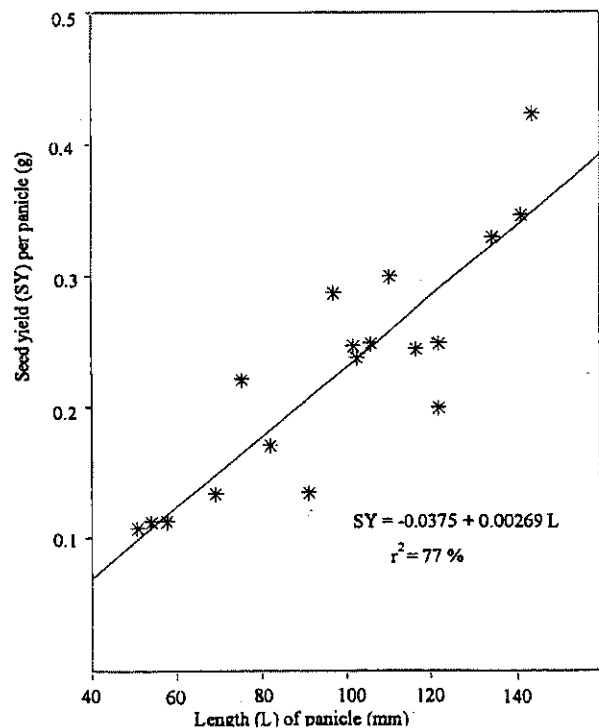
The largest tillers produced significantly longer panicles and more seeds per panicle than the others. The panicles produced by large tillers were 32% and 93% longer than the panicles produced by medium and small tillers respectively, while they produced 11% and 103% more seeds per panicle than the medium and small tillers respectively. A similar relationship existed between the total weight of seeds per panicle, where the seed yield of large panicles was 15% and 131% more than the yield produced by the medium and small tillers respectively. Thousand seed weight increased significantly as tiller size increased.

There was a direct linear relationship between the weight of seed per panicle and panicle length (Fig. 2). The relationship was: seed yield per panicle (SY) = -0.0375 + 0.00269 panicle length (L).

#### Row spacing

At the late vegetative stage the largest number of tillers was produced at the 15 cm row spacing whereas tiller numbers did not differ for row spacings of 30 cm, 45 cm and 60 cm, producing 38%, 46% and 60% fewer tillers respectively at this stage (Table 2). The 15 cm row spacing maintained the greatest number of tillers until harvest. At harvest the 30 cm, 45 cm and 60 cm row spacings had 32%, 36% and 50% fewer tillers than the 15 cm row spacing (Table 2).

Seed yields did not differ between the 15 and 30 cm, or the 45 and 60 cm row spacings. The yield at the

**Fig. 2. Relationship between seed yield per panicle and panicle length for phalaris cv. Grasslands Maru.****Table 2. Effects of row spacing on number of tillers m<sup>-2</sup> at different stages of growth of phalaris cv. Grasslands Maru.**

Row spacing (cm)	Stages of crop growth			
	Late vegetative	Panicle initiation	Anthesis	Harvest
15	3440	2000	1150	920
30	2140	1580	700	620
45	1860	1350	660	590
60	1380	1070	610	430
LSD (P<0.05)	523	268	144	62

**Table 3. Effects of row spacing on seed yield and yield components of phalaris cv. Grasslands Maru.**

Row spacing (cm)	Seed yield (kg ha <sup>-1</sup> )	No. of panicles (m <sup>-2</sup> )	Length of panicle (mm)	No. of seeds per panicle	Side-branches per panicle	Seeds per side-branch	TSW (g)
15	428	372	82	78	18.6	4.2	1.47
30	520	324	96	108	20.4	5.3	1.48
45	683	322	109	142	21.2	6.8	1.50
60	635	283	114	150	21.7	6.9	1.50
LSD (P<0.05)	105	50	3.4	25	0.48	1.2	0.05

**Table 4. Correlation coefficients between seed yield and yield components in phalaris cv. Grasslands Maru.**

	Seeds m <sup>-2</sup>	Seeds panicle <sup>-1</sup>	Seeds side-branch <sup>-1</sup>	Panicles m <sup>-2</sup>	Side-branch panicle <sup>-1</sup>	TSW (g)	Panicle length (mm)
Seeds panicle <sup>-1</sup>	0.601*						
Seeds side-branch <sup>-1</sup>	0.682**	0.917**					
Panicles m <sup>-2</sup>	0.004	-0.688**	-0.659**				
Side-branch panicle <sup>-1</sup>	0.528**	0.496*	0.452*	-0.410*			
TSW (g)	0.436*	0.395	0.519**	-0.275	0.186		
Panicle length(mm)	0.595**	0.714**	0.716**	-0.567**	0.833**	0.316	
Seed yield	0.993**	0.614**	0.704**	-0.026	0.515*	0.536**	0.595**

higher two row spacings was significantly greater than that at the lower two row spacings (Table 3). Panicle number did not differ among the 15, 30 and 45 cm row spacings, but was significantly reduced at the 60 cm row spacing. Panicle length, the number of side branches per panicle and the number of seeds per panicle increased as row spacing increased, with the exception that the 45 and 60 cm row spacings did not differ for seeds per panicle (Table 3). The number of seeds per side-branch did not differ between the 15 and 30 cm, or the 45 and 60 cm row spacings. The number of seeds per side-branch at the higher two row spacings was significantly greater than that at the lower two row spacings. There was no difference in thousand seed weight among the four row spacings. (Table 3).

Simple linear correlation between seed yield and its components revealed that the number of seeds per unit area was the main determining factor for seed yield. The number of seeds per side-branch and thus the number of seeds per panicle were the major seed yield components which determined the number of seeds per unit area, and thus seed yield (Table 4).

## DISCUSSION

Maru phalaris is a selection from lines originating in Mediterranean regions (Rumball, 1980). Mediterranean populations of phalaris require 6-8 weeks of vernalization

at temperatures of below 10°C (Ketellapper, 1960), as do many other populations of phalaris (Ketellapper, 1960; Cooper and McWilliam, 1965). The temperatures experienced during the month of July 1990 at Lincoln were below 10°C (long time mean = 7.9°C) and daylength was 9.2 hours. Therefore, floral initiation would be expected to occur in July in cv. Grasslands Maru, similar to other Mediterranean populations.

Higher temperatures and longer days are prerequisites for floral initiation and further development in most temperate grasses (Bean, 1980). In the present study, double-ridge structures were present during the third week of July, indicating that floral initiation had taken place before this period. However, rapid increase in apex height and length did not take place until the third week of September. Temperatures greater than about 10°C and day lengths of more than 10 hours seem to be associated with rapid increase of apex length and apex height, similar to that reported in other Mediterranean strains of phalaris (Cooper and McWilliam, 1965).

Although the double-ridge stage in cv. Grasslands Maru was attained by the end of July, this study suggests that phalaris seed crops may be grazed with little risk of apex damage in winter. Grazing should be stopped by late September as the risk of adversely affecting seed yields through apex damage or the removal of fertile tillers increases rapidly from late September.

Size of the tillers was the major factor determining seed yield per panicle. Although the time of tiller origin

was not measured in the present experiment, it was assumed that the largest tillers were those present before the onset of winter. Smaller tillers formed late in the season had a high mortality; 85% of the smallest tillers died, whereas 22% of the medium and only 3% of the large tillers died before harvest. Later formed tillers are dependent largely on the older tillers for assimilate supply and also are disadvantaged by shading created by the larger tillers (Colvill and Marshall, 1984). In other grass species the survival of tillers of different sizes seems to be directly related to the availability of assimilates (Colvill and Marshall, 1984; Lauer and Simmons, 1988) especially during floral initiation and stem elongation, as demand for assimilate becomes greater at this time due to inflorescence development. During these periods, the larger tillers dominate in the utilization of photo-assimilate, fail to partition nutrient to smaller tillers and in addition may create shading. Together, these effects result in increased death among smaller tillers.

In phalaris cv. Grasslands Maru, the largest inflorescences were produced by the largest tillers, presumably due to their long period of vegetative growth during which time more primordia would have accumulated. This normally results in the production of more lateral branches and thus more florets and seeds. The number of seeds per inflorescence was an important factor determining seed yield, as the largest tillers produced 11% and 103% more seeds than the medium and small tillers respectively.

It seems that the dominant effect of tiller size was on tiller survival and panicle size, both of which affected seed yield. This study has shown a very substantial influence of tiller size on seed yield. There is little doubt that seed stands need continuous sound management in autumn. The application of nitrogen in autumn may have a role. Early tiller formation and establishment is necessary to enhance the potential number of large fertile tillers, which contribute most towards the seed yield. In other grass species application of nitrogen in spring meets the requirement of these early formed fertile tillers and possibly their survival (Nordestgaard, 1981), production per tiller through reduced spikelet dieback (Kirby and Faris, 1970) and increased floret site utilization (Hampton and Hebblethwaite, 1985), and thus influences seed yield. There is obviously a need for more work in phalaris to determine management factors which can produce the optimum number of large tillers without producing an excessive panicle population to the detriment of seed yield per panicle and per unit area.

The number of fertile tillers is one of the important seed yield components (Hill and Watkin, 1975; Hampton, 1988) and tillers already in existence in winter are major contributors to fertile tiller numbers. This was clearly seen at the 15 cm row spacing, where the larger number of tillers present during the winter months resulted in more tillers becoming fertile than that at the wider spacings. However the largest number of seedheads does not necessarily result in maximum seed yield (Meijer, 1984; Colvill and Marshall, 1981), as individual plants, in higher plant populations, fail to produce to their maximum potential due to competition. These relationships were clearly demonstrated in this trial where although the 15 cm row spacing had the highest panicle number, panicle size and the number of seeds per panicle were low, and although

fewer panicles were produced in the 45 cm compared with the 15cm row spacing, an increase in seed yield of 60% was obtained.

The largest contribution towards seed yield was the number of seeds per panicle and number of panicles per unit area. Although the longest panicles with the most seeds were produced at the 60 cm row spacing, seed yield did not differ from the 45 cm row spacing because there was no difference in the number of seeds m<sup>2</sup> produced. This was probably due to the limited ability of shoots of phalaris to compensate for the lower shoot populations at the wider spacing. The number of seeds per panicle seems to be dependent on the number of side-branches per panicle and number of seeds per side-branch and these components are dependent on the length of the panicle.

The number and size of panicles produced at the 45 cm row spacing seemed to be optimum as although 13% fewer panicles were produced than at the 15 cm row spacing, this reduced number was compensated for by larger panicles which had 92% more seeds per panicle, resulting in a significantly greater seed yield.

The reduced number of side-branches produced at close row spacings was probably due to competition among the larger numbers of shoots, reducing the formation of nodes for side-branch formation as found in many perennial grasses (Hebblethwaite, 1985). Competition was probably also responsible for fewer seeds per side-branch and per panicle as reported in cocksfoot by Brown *et al.* (1983).

## CONCLUSION

Reproductive growth began in late July, but rapid elongation of the apex did not occur until two months later, suggesting that lax grazing could be practiced until late September. The largest winter tillers had the highest survival rate and produced the most seeds per panicle. Seed yield per unit area in phalaris was greater at 45 and 60 cm row spacings than at 15 and 30 cm row spacings.

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