Effects of time of final closing cut on seed yield and seed quality of *Paspalum atratum* in Thailand

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Abstract

The effects of time of final closing cut on seed production of *Paspalum atratum* were examined in 1999–2000 from 2 experiments conducted in Lampang province, northern Thailand. The results showed that the time of final closing cut had a significant effect on seed yields of *P. atratum* in both years.

In Experiment 1, where plots were cut at 30-day intervals, plots closed in mid-June produced the highest seed yield of 1333 kg/ha, followed by plots closed in mid-May and mid-April. Plots closed in mid-July produced about one-third the seed yield of plots closed in mid-June, and plots closed in mid-August produced no seed. Severe lodging at seed harvest occurred in plots closed in mid-April, mid-May and mid-June, resulting in a decrease in seed yield.

Experiment 2 was conducted to determine more accurately the most suitable date of final closing cut by comparing cutting at 15-d intervals during the critical period from June 1 to August 1. Seed yields were consistently high at over 1489 kg/ha from plots closed between June 1 and July 1, and yields then dropped in plots cut on July 15 to one-fifth the seed from plots cut on July 1. Plots closed on August 1 produced no seed.

There were small differences in seed quality attributes among plots from both experiments, which produced good seed quality, averaging 88% seed germination, 3.01 g thousand-seed weight and 81% seed purity. From the results in both experiments, it was confirmed that final closing cut date of *P. atratum* should not be delayed later than July 1.

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Introduction

Among tropical seed-producing grass species, *Paspalum atratum* seeds prolifically in both tropical and subtropical countries (Kretschmer *et al*. 1994; Phaikaew 1997; Phaikaew and Hare 1998; Hare *et al*. 2001a) and recently has been introduced into Thailand, where it is called Ubon paspalum (Hare *et al*. 1999a). Seed production of this grass in Thailand has now started on many Forage Stations of Thai Department of Livestock Development and with contracted farmers. More than 38 t of *P. atratum* seed was harvested in 2000 and again in 2001. Although the demand for seed is increasing each year in south-east Asia, there appear to be limited locations suitable for seed production (Phaikaew *et al*. 1997).

Our previous studies showed that this tall bunch grass had a tendency to lodge, which often caused a severe drop in seed yield (Phaikaew *et al*. 2001a; 2001b). There was an urgent need to develop methods to obtain consistently high yields of good quality seed and to prevent lodging. Many studies on the management of tropical grass seed crops have revealed the advantage of imposing a final closing cut at an appropriate time, by solving non-synchronisation of flowering and preventing lodging (Loch 1983; Andrade and Thomas 1984; Humphreys and Riveros 1986; Phaikaew *et al*. 1990; Phaikaew and Pholsen 1993; Ayala 1994; Kalmbacher *et al*. 1995; Hare *et al*. 1999b; Loch *et al*. 1999). We examined the effect of time of final closing cut on seed production of *P. atratum* in second-year swards in 2 experiments. In the first experiment,

30-day cutting intervals were examined on an infertile soil in Lampang province, northern Thailand in 1999–2000. A second experiment examined closer 15-day intervals of final closing cut at the same site to determine more accurately the most suitable dates for final closing cut on *P. atratum* for seed production in northern Thailand.

Materials and methods

Site, experimental design and plant cultivation

Two experiments were conducted in 1999–2000 at Lampang Animal Nutrition Research Center, northern Thailand (18.3°N, 99°E; 320 m asl). Mean temperature, sunshine hours and annual rainfall were recorded on the station. The soil is classified as Renu soil series (Rn), which consists of a sandy loam over a sandy clay. It is a deep, poorly drained, infertile, acid (pH 5.4, in water) soil with a low concentration of soil nutrients [1.51% organic matter; 63 ppm available P (Bray II extraction method); 99 ppm K].

Experiment 1 — Date of final closing cut at 30-day intervals. This experiment was conducted over 2 seasons in 1999–2000, and compared 5 final closing-cut dates (April 15, May 15, June 15, July 15, August 15).

Experiment 2 — Date of final closing cut at 15-day intervals. An additional experiment in 1999 examined 5 final closing cut dates (June 1, June 16, July 1, July 16, August 1).

Both trials were arranged in a randomised complete block design with 5 treatments and 4 replications. The field was established in 1998 by transplanting seedlings of *Paspalum atratum* at a spacing of 1 m × 1 m, and the same field was used for both trials. Plot size was 4 m × 5 m and the cutting height was 10 cm above ground level. On March 15, 1999, the field was given a conditioning cut, the cut herbage was removed and fertiliser was applied at the rate of 125 kg/ha N, 125 kg/ha P and 125 kg/ha K. Additional fertiliser of 125 kg/ha N as urea was applied again before flowering in August 1999. In the second year of the experiment (2000), all plots were given a conditioning cut again in March 2000 and were cut subsequently according to the different dates of closing-cut treatments. The cut forage was removed and weighed and then oven-dried (72°C for 48 h) to determine forage dry matter (DM) yield at each defoliation. Fertiliser was applied in March and August 2000 in the same form and amount as in 1999.

Seed harvesting

For both experiments, all seed heads within each plot were harvested each year over the period of seed maturity (late September–mid-October). One week prior to first seed collection for all treatments, groups of adjacent seed heads were tied into bundles as "living sheaves". Seed heads were then covered with nylon net bags with an outlet to collect seed and seed was collected twice at 5-day intervals (the "Cover" method of Phaikeaw *et al.* 2001a). Tiller number (TN), inflorescence number (IN) per plant and plant height were recorded on 6 randomly selected plants in each plot at harvest. In Experiment 1, raceme number per inflorescence and spikelet number per raceme were recorded from 20 inflorescences in each plot. In 2000, the percentage of grass bunches which had lodged was measured in each plot 1 week before seed harvest. After seed harvest, the grass was cut at 10 cm above ground level, the cut forage was removed, and forage DM yield at seed harvest was determined each year.

Seed processing, seed quality testing and statistical analysis

Seed from both experiments was air-dried for 3–4 days in a seed shed before cleaning. Seed moisture content (SMC), thousand-seed weight (TSW), seed purity (SP) and seed germination (SG) followed the same procedures as in Phaikaew *et al.* (2001a). The percentage of effective tillers (PET), spikelet number/inflorescence (SN/I), spikelet number/m^2 (SN), pure seed yield (PSY) and pure germinated seed yield (PGSY) were obtained by calculation.

Data from both experiments were statistically analysed by analysis of variance procedures for a randomised complete block design, using the IRRISTAT program from IRRI. The mean differences between treatments were tested for significance by least significant difference procedures.

Results

Weather conditions.

Monthly rainfall and monthly mean air temperatures at Lampang in 1999–2000 along with

the medium-term mean rainfall are shown in Figure 1. Temperatures were similar in both years and annual rainfall in 1999 and 2000 (1268 and 1289 mm, respectively) were above the average of 1110 mm at the Lampang site. Rainfall was evenly distributed during the growing season in the first year, while the rainy season in 2000 started later than in the first year (May *vs* April). Heavy rainfall in September 1999, and August and September 2000 caused severe lodging of plants at seed harvest, especially in plots closed in mid-April, mid-May and mid-June.

Experiment 1 — Date of final closing cut at 30-d intervals

Flowering and seed-harvesting times. With the delay in closing cut, both flowering and seed-harvesting times were delayed in each year, the delay being largest in plots cut in mid-July (Table 1). With the latest closing cut in mid-August, no flowers or seed were produced in either year. The daylength at the time of first flowering for each treatment decreased from 12.4 h (April closing) to 12.0 h (July closing). The differences in the dates of first flowering between successive closing cut treatments were 7–8 d which contrasts with the 30-d intervals between closing-cut dates. Delaying the time of closing cut also delayed the start of seed harvesting from late September to early October.

Table 1. Effect of date of closing cut on date and daylength at first flowering and period of seed harvesting of *Paspalum atratum* (Experiment 1).

Date of closting cut[1]	Date of first flowering	Average daylength (h)[2] at first flowering	Seed-harvesting period
Year 1999			
Apr 15	Aut 29	12.4	Sep 25–Oct 8
May 15	Sep 6	12.3	Sep 28–Oct 10
Jun 15	Sep 12	12.2	Oct 2–13
Jul 15	Sep 20	12.0	Oct 9–20
Aug 15	—	—	—
Year 2000			
Apr 15	Sep 1	12.4	Sep 28–Oct 11
May 15	Sep 7	12.3	Sep 30–Oct 12
Jun 15	Sep 11	12.2	Oct 3–15
Jul 15	Sep 23	12.0	Oct 10–21
Aug 15	—	—	—

[1] Conditioning cuts were imposed uniformly on March 15, 1999 and 2000.
[2] Daylength data (1999–2000) were derived from AGROMET, Thai Department of Meteorology.

Seed yield and yield components. The date of final closing cut showed a significant effect on seed yield and its components in both years of the experiment (Table 2). The highest seed yield was obtained from plots closed in mid-June which averaged 1333 kg/ha over 2 years, followed by the mid-May and mid-April closing cuts. Plots closed in mid-July produced only about 38% as much seed as plots closed in mid-June. Mean seed yield in the first year exceeded that in the second year (1067 *vs* 861 kg/ha).

Table 2. Effect of date of closing cut on seed yield and its components of *Paspalum atratum* (Experiment 1).

Date of closing cut	Seed yield	Tillers	Inflorescences	Effective tillers	Racemes/ Inflores.	Spikelets/ Raceme	Spikelets/ Inflores.	Spikelets
	(kg/ha)	(no/m^2)	(no/m^2)	(%)	(no)	(no)	(no)	(no/m^2)
Year 1999								
Apr 15	1011 b[1]	134 ab	45 c	34 b	11.5 ab	136 a	744 a	33 943 b
May 15	1299 a	155 a	57 b	37 b	11.3 ab	136 a	751 a	42 372 a
Jun 15	1380 a	150 a	77 a	52 a	10.8 b	130 a	612 a	46 636 a
Jul 15	579 c	136 ab	47 c	35 b	12.2 a	127 a	423 b	19 392 c
Aug 15	—	120 b	—	—	—	—	—	—
Mean	1067	139	56	39	11	133	630	35 586
CV (%)	11.5	18.9	10.6	12.4	5.7	5.1	14.4	12.8
Year 2000								
Apr 15	745 c	79 c	44 b	56 a	11.3 a	190 a	560 b	24 449 c
May 15	986 b	108 b	68 a	63 a	10.6 a	167 b	486 c	32 937 b
Jun 15	1286 a	102 b	64 a	63 a	11.6 a	141 c	667 a	42 634 a
Jul 15	426 d	142 a	40 b	28 b	10.9 a	99 d	357 d	13 941 d
Aug 15	—	110 b	—	—	—	—	—	—
Mean	861	108	54	53	11	149	518	28 490
CV (%)	15.8	11.0	13.8	11.0	7.4	7.3	8.7	15.6

[1] Within columns each year, means followed by different letters differ significantly ($P < 0.05$).

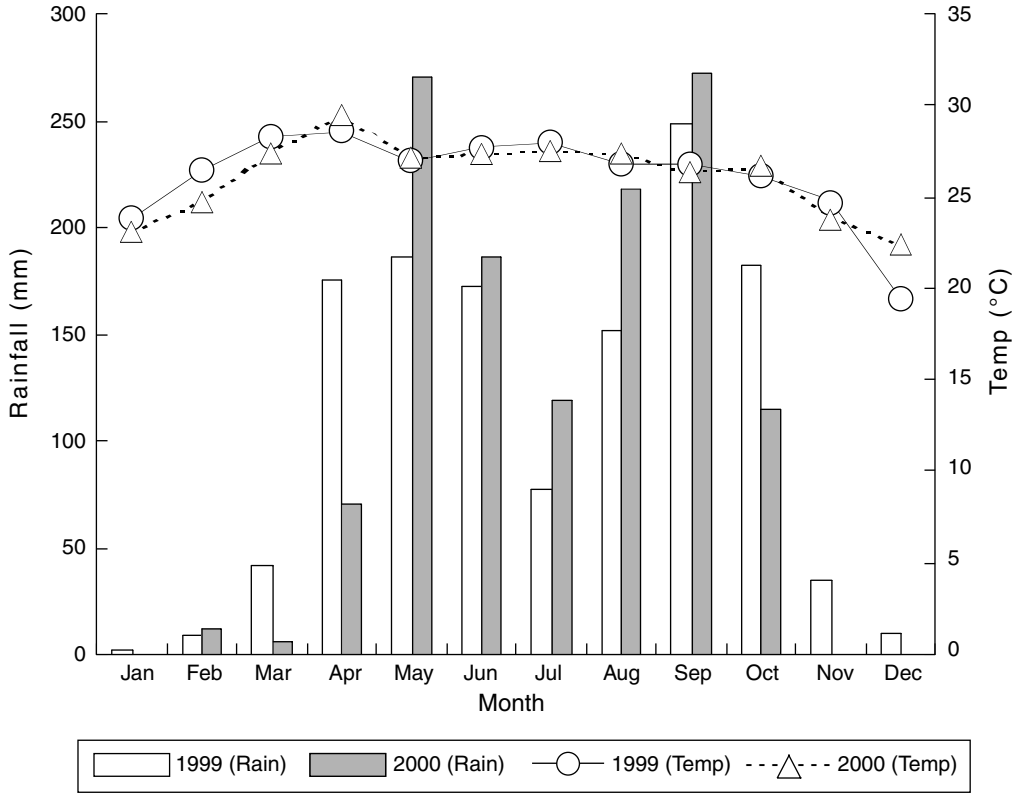

Figure 1. Monthly rainfall and mean monthly temperature (Temp) at Lampang site in 1999 and 2000. (Experiments 1 and 2).

Table 3. Effect of date of closing cut on seed quality of *Paspalum atratum* (Experiment 1).

Date of final closing cut	1000-seed weight	Seed purity	Seed germination	Pure seed yield	Pure germinated seed yield
	(g)	(%)	(%)	(kg/ha)	(kg/ha)
Year 1999					
Apr 15	2.98 a[1]	80 a	91 a	810 b	735b
May 15	3.08 a	85 a	89 b	1096 a	976a
Jun 15	2.96 a	85 a	87 b	1177 a	1024 a
Jul 15	2.98 a	83 a	86 b	483 c	414 c
Aug 15	—	—	—	—	—
Mean	3.00	83	88	890	787
CV (%)	4.6	3.6	2.7	10.8	11.1
Year 2000					
Apr 15	3.04 a	68 c	91 a	506 bc	458 bc
May 15	2.99 a	67 c	90 a	661 b	598 b
Jun 15	3.02 a	79 b	90 a	1020 a	914 a
Jul 15	3.10 a	87 a	81 b	367 c	295 c
Aug 15	—	—	—	—	—
Mean	3.03	75	88	639	567
CV (%)	1.8	6.3	2.2	19.1	20.7

[1] Within columns each year, means followed by different letters differ significantly ($P < 0.05$).

Seed quality. Overall seed quality of *P. atratum* was good with high seed germination (81–91%) and high thousand-seed weight (2.96–3.08 g), with medium seed purity (67–87%) (Table 3). Closing cut had no effect on the TSW in both years, and seed purity in the first year. Early closing cuts in the second year had lower seed purity but germination % was generally higher with earlier closing cuts. The responses in pure seed yield and pure germinated seed yield to the timing of closing cut were quite similar to that in seed yield in both years.

Herbage DM yield, plant height and lodging percentage. Delaying the date of closing cut significantly reduced plant height of *P. atratum* at seed harvest. Herbage DM yield at seed harvest was reduced by delayed closing cuts in the first year but only with the August cut in the second year (Table 4). Herbage DM yield when the closing cut was applied increased progressively with the delay in closing-cut time. Closing plots in mid-April and mid-May produced severe lodging of plants at seed harvest (96–98%).

Table 4. Effect of date of closing cut on forage DM yield, height and lodging of *Paspalum atratum* at harvest (Experiment 1).

Date of closing cut	DM yield at seed harvest[1]	Plant height	DM yield at closing cut	Lodging
	(kg/ha)	(cm)	(kg/ha)	(%)
Year 1999				
Apr 15	20 149 a[2]	232 a	_	—
May 15	19 259 a	244 a	—	—
Jun 15	17 090 b	238 a	—	—
Jul 15	16 691 b	216 b	—	—
Aug 15	7 568 c	127 c	—	—
Mean	16 159	211	—	—
CV (%)	8.1	4.8	—	—
Year 2000				
Apr 15	11 569 a	274 a	2 636 d	98
May 15	14 695 a	289 a	4 427 cd	96
Jun 15	12 809 a	272 a	6 297 cd	71
Jul 15	12 425 a	244 b	12 994 b	0
Aug 15	8 294 b	161 c	17 096 a	0
Mean	11 959	248	8 690	53
CV (%)	16.0	5.3	20.5	—

[1] Herbage cut after seed harvest on October 30, 1999 and October 27, 2000.
[2] Within columns each year, means followed by different letters differ significantly ($P < 0.05$).

Experiment 2 — Dates of final closing cut at 15-d intervals

The highest seed yields, which averaged about 1489 kg/ha, were obtained from plots closed on June 1, June 15 and July 1, while plots closed on July 15 produced less than one-fifth the yields of earlier closed plots. Plots closed on August 1 produced no seed at all, even though the plants continued good vegetative growth with more tillers than the earlier cuts (Table 5).

The seed yield components (inflorescence density, PET, spikelets/inflorescence and spikelets/m^2) were significantly higher in plots closed on June 1, June 15 and July 1 than those cut on July 15. Although plant height at seed harvest was directly related to the time since the closing cut was applied, herbage DM yield at seed harvest was not significantly affected by date of closing cut.

Seed quality was good, with high SG (81–93%), TSW (2.90–3.08 g) and seed purity (80–89%). Seed germination from plots cut on July 15 was 7–12 percentage units lower than for earlier closed plots.

Table 5. Effect of date of closing cut on (A) seed yield and its components and (B) seed quality of *Paspalum atratum* in 1999 (Experiment 2).

(A) Seed yield and its components

Date of closing cut	Seed yield	Tillers	Inflorescences	Effective tillers	Spikelets/ inflorescence	Spikelets	Plant height	Dry matter yield
	(kg/ha)	(no/m^2)	(no/m^2)	(%)	(no)	(no/m^2)	(cm)	(kg/ha)
Jun 1	1446 a[1]	103 b	58 b	57 ab	820 a	46 908 a	220 a	16 017
Jun 15	1556 a	114 b	74 a	67 a	730 a	53 540 a	207 ab	15 256
Jul 1	1467 a	101 b	68 ab	67 a	739 a	50 474 a	190 b	14 242
Jul 15	271 b	98 b	47 c	48 b	203 b	9 391 b	198 bc	16 239
Aug 1	—	139 a	—	—	—	—	182 c	16 293
Mean	1185	111	62	60	623	40 078	199	15 609
CV (%)	13.3	10.7	11.4	14.1	14.7	15.6	4.4	11.2

(B) Seed quality

Date of closing cut	1000-seed weight	Seed purity	Seed germination	Pure seed yield	Pure germinated seed yield
	(g)	(%)	(%)	(kg/ha)	(kg/ha)
Jun 1	3.08	85	88 a	1238 a	1088 a
Jun 15	2.92	80	90 a	1248 a	1120 a
Jul 1	2.94	82	93 a	1201 a	1123 a
Jul 15	2.90	89	81 b	241 b	193 b
Aug 1	—	—	—	—	—
Mean	2.99	84	88	982	881
CV (%)	5.3	5.1	4.7	13.9	14.9

[1] Within columns, means followed by different letters differ significantly ($P < 0.05$).

Discussion

The results from these experiments indicated that the time of final closing cut was critical for seed production of *P. atratum*, confirming the results of Hare *et al*. (1999b) from a different location in north-east Thailand and Kalmbacher *et al*. (1995; 1997) from Florida. In Experiment 1 under 30-d cutting intervals, plots closed in mid-June produced the highest seed yields, while plots closed in mid-July and mid-August produced only one-third the maximum and nil seed, respectively. Experiment 2 produced a similar result although the deadline for the final closing cut could be extended to July 1. Hare *et al*. (1999b) found no significant difference in seed yields between plots cut in either early June or early July though they recommended a cutting height of 20–40 cm above ground level for July closing cuts compared with cutting to ground level for June closing cuts.

The relationship between final closing-cut time and the relative pure seed yield is presented in Figure 2. If the final closing cut is delayed until after July 1, seed yield will decrease by 5% per day from the maximum. This rapid decrease in seed yield is mainly a result of the decrease in percentage of effective tillers (PET) and spikelet no/inflorescence. The poor seed yields from late season final closing cuts are due to the long-short day response of *Paspalum atratum* which is necessary to induce flowering (Hare *et al*. 2001b).

Sowing time is just as critical as final closing cut for seed production, with no seed being produced at all in the first year of establishment from seed crops sown from May onwards in north-east Thailand (Hare *et al*. 2001a). From our previous experiment on sowing time of *P. atratum* at the same site (Phaikaew *et al*. 2001b), we found that earlier sowing from mid-March to mid-May produced good seed yields in the establishment year, while seed yield decreased greatly with sowing in mid-June and no seed was produced from sowing in mid-July. This suggests clearly that *P. atratum* requires a long day period for the induction of flowering and seed set (Hare *et al*. 2001b).

The relationship between time of final closing cut in 1999 or sowing time in 1998 and relative seed yield are presented in Figure 3. The closing cut experiment in 1999 was on second-year swards, so data in Figure 3 illustrate the management for sowing time in the first year and closing cut in the second year to obtain maximum seed yields. There is a one-month difference in management with sowing time in May and cutting in June.

Lodging can occur in seed crops that are not defoliated in the wet season (Kalmbacher *et al*. 1997; Hare *et al*. 1999b). In our experiments, the lower seed yields in plots closed in mid-April and mid-May were caused by severe lodging at seed harvest with nearly 98% of tillers lodged. In order to minimise lodging, seed crops should be defoliated in June. This will have the added benefit of delaying crop flowering and shifting seed harvesting into the drier month of October away from the normally heavy September rainfall. Lodging also reduced the grass growth, resulting in lower forage DM yield at seed harvest. Forage remaining after seed harvest is usually very fibrous and low in crude protein concentration (Hare *et al*. 1999b) but this residue is still valued by village farmers as standing roughage that is grazed in the dry season by beef cattle and buffalo, when the supply of roughage is quite limited.

Forage DM yields doubled from about 6300 kg/ha when closed in mid-June to about 13 000 kg/ha when closed in mid-July but the one-month difference in closing reduced seed yields by 67% which is too much for seed growers to carry. While the price of fresh grass in the wet season is 0.7 baht/kg and the price as dry grass in the dry season after seed harvest is 1.0 baht/kg, the price of seed is 60 baht/kg. Village farmers need to calculate the sale prices of forage and seed cut both in mid-June and mid-July to determine the optimal cutting time. Calculations on data from our experiments indicate that combined sales of seed and forage from crops cut in mid-June and mid-July would be 82 850 baht/ha and 35 900 baht/ha, respectively. The optimal time of closing cut for *P. atratum* will make allowance for both forage and seed production. Applying the closing cut before July 1 will provide a relatively high forage yield together with high yield of good quality seed in October.

Because of the long period of flowering and rapid seed shedding, it is sometimes quite difficult to determine the optimal seed harvesting time for tropical pasture crops (Humphreys and Riveros 1986). Therefore, the more synchronised flowering from mid-June closing cuts compared with earlier closing makes harvesting easier for farmers. The seed-harvesting method used in these 2 experiments has proved to be the best seed-harvesting method in *P. atratum* (Phaikaew

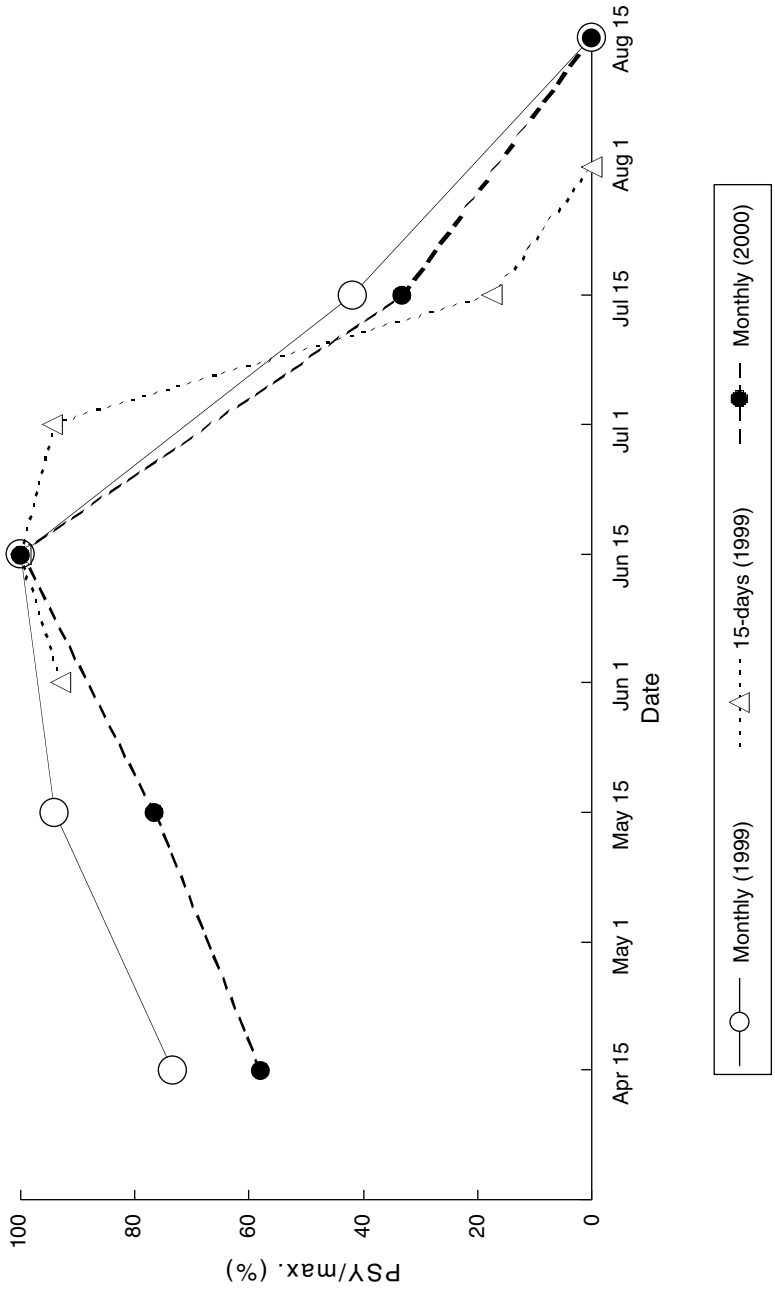

Figure 2. Relationship between the time of closing cut and pure seed yield measured as a percentage of the maximum yield for that year (PSY/maximum).

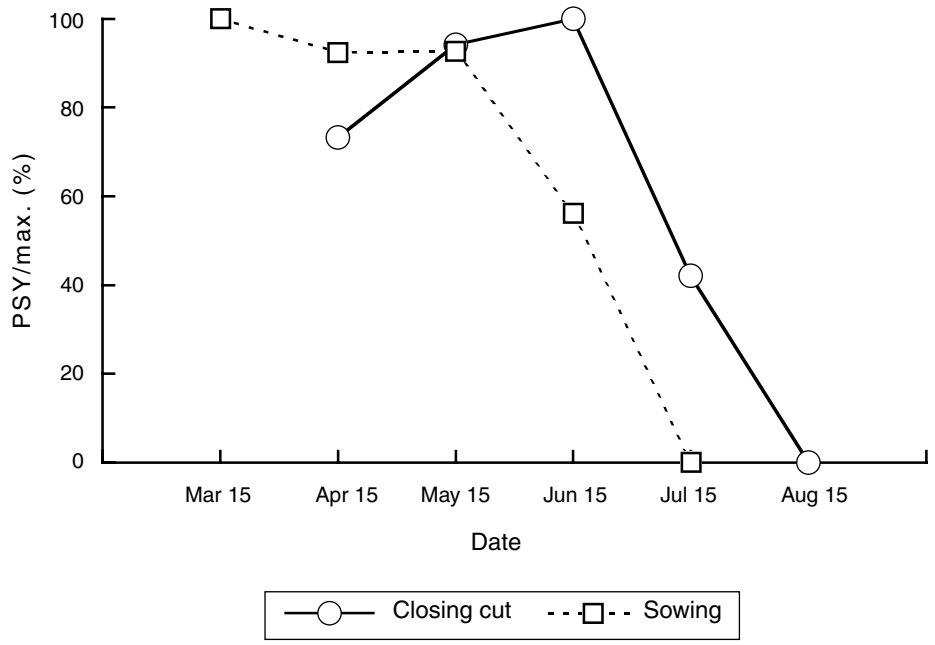

Figure 3. Relationships between the time of closing cut or sowing date and pure seed yield measured as a percentage of the maximum yield for that year (PSY/maximum).

et al. 2001a), as it allows the collection of mature, high quality seed and high seed yields. However, the most popular method with farmers is the daily knocking of seed heads (Hare and Phaikaew 1999; Hare *et al*. 2001a), even though seed yields are usually less than half those produced by the nylon-bag technique.

For high seed yields, *P. atratum* seed crops should be cut back before the beginning of July to minimise lodging during flowering and to produce good quality forage for sale at the final closing cut. Late season cutting will result in little or no seed at harvest and the quality of forage at cutting is generally inferior to that from crops cut earlier.

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