Method and time of establishing *Paspalum atratum* seed crops in Thailand

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Abstract

Seed crops of *Paspalum atratum* cv. Ubon established by sowing seed produced no seed at all in the first year of establishment in Thailand. By comparison, seed crops planted with tillers at the beginning of the wet season in May produced 132 kg/ha seed 5 months after planting in one trial and 330 kg/ha seed in a second trial. In the second trial, delay in planting tillers until June and July severely reduced seed yields from a high of 330 kg/ha when planted in early May to a low of 25 kg/ha when planted in mid-July. Inflorescences/m^2 and seeds/inflorescence had the greatest effect on seed yield.

Twenty village farmers in a small, seed production project successfully harvested 1834 and 2207 kg of Ubon paspalum seed in 1998 and 1999, respectively. The method of hand knocking mature seed from seed heads into bags every day enabled farmers to harvest mean seed yields of 632 and 651 kg/ha in 1998 and 1999, respectively. This harvesting method, combined with slow drying in the shade and thorough cleaning, produced seed of a very high quality with a thousand-seed weight of 3.1 g, a seed purity of more than 99% and a germination of 81% in 1998-harvested seed and 91% in 1999-harvested seed after 5 months post-harvest storage.

Introduction

Paspalum atratum cv. Ubon is increasingly being used by dairy farmers in Thailand for growing on wet, waterlogged acid soils which were formerly rice paddy fields (Hare *et al*. 1999a; 1999b). A key attribute to its success and subsequent adoption by farmers is that Ubon paspalum seed is readily available as it is relatively easy to harvest compared with other tropical grasses in Thailand (Hare *et al*. 1999c).

Preliminary seed studies in Thailand found that seed yields of Ubon paspalum were affected by harvesting method and closing date (Hare *et al*. 1999c). Hand-knocking mature Ubon paspalum seed from seed heads into bags every day produced twice the amount obtained by threshing or sweating seed heads. Cutting seed crops late in the wet season, August and September in Thailand, produced little or no seed.

Successful forage seed production in Thailand has hinged on village farmers hand-harvesting seed of ruzi grass (*Brachiaria ruziziensis*) and Verano stylo (*Stylosanthes hamata*) (Hare 1993; Hare and Phaikaew 1999). In 1996, when we realised that there would be a future demand for Ubon paspalum seed, we contracted one village farmer to grow seed for us. We chose a farmer who had grown previous ruzi grass and Verano stylo seed crops for the Department of Livestock Development. In late May 1996, we gave the farmer rooted tillers of Ubon paspalum dug from mature plants which she hand planted in a 50 × 50 cm grid in a 1400 m^2 field. In September 1996, she harvested 47.5 kg of seed, equivalent to 340 kg/ha.

Neighbouring farmers in the same village saw her success and observed that seed production of Ubon paspalum appeared to be easier than that of ruzi grass and Verano stylo which they had grown for several years. In March 1997, we contracted 20 farmers, including the first farmer, to grow Ubon paspalum seed. Each farmer received 300 g of seed in March 1997 and they were instructed to plant the seed in a nursery and transplant strong plants to their fields in May–June. Each farmer was contracted to grow a field not exceeding 1600 m^2.

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Some farmers delayed transplanting the tillers until July as they wanted the soil to be very moist at the time of transplanting. They had frequently sown ruzi grass seed in June–July and harvested good seed crops in November. The result was that the fields planted in May and June averaged seed yields of 315 kg/ha and 65 kg/ha, respectively, whereas fields planted in July produced no seed. In a neigbouring province, the Department of Livestock Development also contracted farmers to grow Ubon paspalum seed. These farmers sowed their fields with seed in June (the traditional time for sowing ruzi grass seed crops in their village) and no seed heads were produced in the first year.

With this information, we established field experiments to determine: (a) which planting methods would give the best seed yields of Ubon paspalum; and (b) the most suitable time to establish seed crops. In addition, data were gathered from the village farmer seed project.

Materials and methods

Field experiments

The field experiments were conducted in Ubon Ratchathani province, Thailand (15°N, 104°E), on the Ubon Ratchathani University farm at 2 sites in a 2 ha paddock. Rainfall was recorded 1 km from the trial paddock (Table 1). The soil and site history have previously been described by Hare *et al*. (1999c).

Trial 1. Method of sowing

A trial commenced in May 1998 to study methods of establishing Ubon paspalum seed crops in a field planted with tillers in July 1996 with 50 × 50 cm grid spacings. This field produced no seed in 1996 but produced seed in 1997.

The trial was a randomised complete block design of 5 replications and 4 treatments:

1. Second-year plants established in 1996 (T1).
2. First-year plants sown by seed in 1998 at 12 kg/ha (T2).
3. First-year plants established in 1998 from tillers dug from second-year mature plants (T3).
4. First-year plants established in 1998 from seedlings grown in plastic bags (T4).

Plots for T2, T3 and T4 were cultivated within the 2-year-old field and all existing Ubon paspalum plants were removed. T1 plants were left intact but were cut at 5 cm above ground level on May 20, 1998, when the other treatments were planted. Seed in T2 was sown in rows 50 cm apart and lightly covered with soil. Tillers in T3 were divided from freshly dug plants and planted in a 50 × 50 cm spaced grid. Seedlings in T4 were established in a nursery from seed in March 1998 and had well developed roots when planted in a similar grid pattern on May 20. Plants in T3 and T4 were trimmed to 5 cm above ground at planting and all plots were cut to a similar height of 5 cm on July 1, 1998 to prevent lodging at seed harvest. Plots measured 5 × 6 m.

Fertiliser was applied at planting (40 kg N, 50 kg K, 20 kg S and 20 kg P/ha), on July 1 after cutting (20 kg N, 25 kg K, 10 kg S and 10 kg P/ha), on August 3 (25 kg/ha N) and on August 19, 1998 (20 kg/ha N).

On September 19, 1998, all inflorescences in eight 5 m rows in each plot were counted and then tied into 'living sheaves' (Kowithayakorn and Phaikaew 1993). Twenty inflorescences from each plot were taken from just outside this area for reproductive analysis. All racemes were counted on each inflorescence and spikelets per raceme were counted from 3 racemes per inflorescence, taken from the top, middle and bottom of each inflorescence. Seed harvesting commenced on September 24 with daily knocking of seed from the 'living sheaves' into buckets. On October 9, all 'living sheaves' were cut, sweated in a shed for 3 days and then threshed. The seed was dried slowly in doors on newspaper and then cleaned through hand screens and a Dakota seed blower. Following cleaning, seed yields and thousand-seed weights (TSW) were corrected to 12% seed moisture content (SMC). Seeds per inflorescence were calculated by dividing seed yield/inflorescence (seed yield/m^2 ÷ inflorescences/m^2) by the weight of 1 seed (TSW/1000).

After harvest, the stubble was cut to ground level and the plots were left to grow for another seed harvest. In May 1999, the plots were cut close to ground level and fertilised with a compound fertiliser (NPK 15:15:15) at 156 kg/ha. The compound fertiliser was used because it was easily available. The same amount of fertiliser was applied again on June 18 and August 13, 1999. All plots were trimmed to 30 cm above ground level on June 13 and again to 50 cm above ground level on August 13, 1999 to prevent lodging. This last anti-lodging cut was 6 weeks

later than in the previous year because the plants in all treatments grew more vigorously in 1999. These heights were well above the height of the reproductive apices in the plants (Kalmbacher *et al*. 1995).

On September 20, 1999, all inflorescences in four 1 m rows in each plot were counted and 20 inflorescences from each plot were taken from just outside this area for reproductive analysis as detailed above. All inflorescences in eight 5 m rows were tied into 'living sheaves' and daily seed knocking commenced on September 24, 1999. All seed in 1999 was harvested by knocking and no seed was collected by cutting or threshing. The seed was dried and cleaned as in 1998 and seed yields and TSW were corrected to 12% SMC. Seeds/inflorescence were calculated as above.

Trial 2. Time of planting

This trial in 1999 studied the effect of planting date on Ubon paspalum seed production. The trial was adjacent to Trial 1 and was a randomised complete block design replicated 5 times with 6 planting date treatments, 2 weeks apart (May 7, May 21, June 4, June 18, July 2 and July 15, 1999). The field was cultivated in early May and, on the day of each planting, the plots to be planted were hand-cultivated again. On the day of each planting, mature plants were dug from an adjacent 2-year-old field and divided into single rooted tillers. These tillers were trimmed to a 10 cm height and hand-planted in a 50×50 cm spaced grid. Plots measured 4×5 m.

The plots that had been planted were fertilised with a compound fertiliser (NPK 15:15:15) at 156 kg/ha on June 18 and July 2 and all plots were fertilised at the same rate on August 13, 1999. The first 2 sowing date treatments only were trimmed back to 50 cm above ground level on August 13, 1999 to prevent lodging.

On September 23, 1999, all inflorescences in four 1 m rows in each plot were counted and 20 inflorescences from each plot were taken from just outside this area for reproductive analysis as detailed above. All inflorescences in six 4 m rows in each plot were tied into 'living sheaves' and daily seed knocking commenced on September 27, 1999 and continued in some plots until October 22, 1999. The seed was dried and cleaned as described previously and seed yields and TSW were corrected to 12% SMC. Seeds/inflorescence were calculated as above.

Data from all trials were analysed using the IRRISTAT program from IRRI.

Village farmer seed project

In March 1997, 20 village farmers signed contracts to produce Ubon paspalum seed. Each farmer was contracted to grow an area up to 1600 m^2 and the contract price was 100 baht/kg (43 baht/$US; Feb. 2001) for clean seed with a TSW above 2.5 g. All farmers were experienced in growing ruzi grass seed on their land. At the time of contract signing, each farmer received 300 g of seed. This seed was planted into nurseries in late March and seedlings were transplanted into the field from May onwards. Six farmers planted in May, 7 in June and 7 in July. All farmers hand-planted the seedlings in 50×50 cm grids.

Towards the end of September, 20 inflorescences were taken from each field for reproductive analysis. Inflorescences were then tied into 'living sheaves' and the seed knocked into large seed-net receptacles (Kowithayakorn and Phaikaew 1993). The seed was dried slowly on mats in the shade and then cleaned by winnowing on cane trays. This field-dressed seed was purchased in October 1997 and re-cleaned through a seed cleaner, mainly to get rid of dust, anthers and some small seed. We wanted all seed to be of a constant purity. The field-dressed seed was very clean and only about 2–3% reduction in weight resulted. Seed moisture content of the machine-dressed seed averaged 12% and seed yields and TSW were calculated from the machine-dressed seed.

During the dry season, November 1997 to April 1998, the fields were grazed and some were burnt in March 1998. All burnt fields recovered quickly. All fields were cut to 20–30 cm above ground level in early July to prevent lodging. Farmers applied fertiliser in June and early August. Harvesting commenced in late September 1998, with seed being knocked daily from 'living sheaves'. The seed was dried in the shade and the field-dressed seed purchased in late October 1998 and re-cleaned to remove dust, anthers and small seed. Seed yields and TSW were corrected to 12% SMC.

The fields were grazed over the dry season and some were burnt in March 1999. In May 1999, 3 farmers planted new fields with tillers but the other 17 farmers used their existing fields to produce a third seed harvest in October 1999. All

third-year fields were cut back in July 1999 to prevent lodging and fertiliser applied after cutting. Seed was dried and cleaned as in previous years. Seed yields and TSW were calculated on machine-dressed seed and corrected to 12% seed moisture.

Results

Rainfall

Rainfall in 1997 was above average with waterlogging occurring in Trial 1 from July until the beginning of October (Table 1). Rainfall in 1998 and 1999 was below average, with the trial sites waterlogged only in September of each year. During the 3-year study period, an average rainfall of 330 mm fell during the September–October flowering and seed-harvesting period at the trial sites.

Table 1. Rainfall (mm) at Ubon Ratchathani University during the study and the medium-term mean.

	Rainfall (mm)			
Month	Average[1]	1997	1998	1999
Jan	1	3	0	1
Feb	11	2	44	3
Mar	29	71	0	92
Apr	80	52	60	92
May	223	150	294	235
Jun	258	352	183	221
Jul	240	399	168	291
Aug	228	324	193	96
Sep	296	239	208	256
Oct	98	107	85	95
Nov	34	0	106	0
Dec	5	0	0	0
Total	1503	1699	1341	1382

[1]8-year average, 1993–1999.

Trial 1. Method of sowing

Method of sowing affected seed yields in the first year of establishment (Table 2a). Plots sown with seed produced no inflorescences at all. Second-year plants (T1) produced more seed than first-year plants (T3, T4) because they produced twice the number of inflorescences per m^2 ($P < 0.05$). However, there were large variations in seed yields between these plots due to foraging birds, resulting in no significant differences in seed yield. Treatments had no effect on TSW, which averaged 3 g.

Plots sown with seed produced some seed in the second year but yields were lower than from other plots as very few inflorescences were produced (Table 2b). Overall, yields were considerably less than in the previous year as foraging birds reduced seed yields in many plots There were more inflorescences and spikelets but fewer racemes and seeds/inflorescence than in the previous year.

Trial 2. Time of planting

Planting date significantly ($P < 0.05$) affected Ubon paspalum seed yields in the first year (Table 3). Planting tillers in May produced the highest seed yields, 3–4 times those from plantings in June and more than 10 times the yields from plantings in mid-July. The number of inflorescences was significantly reduced by planting in June and July. However, the number of racemes/inflorescence and spikelets/raceme plus TSW were not significantly ($P > 0.05$) affected by planting date. Planting in early May produced significantly ($P < 0.05$) more seeds/inflorescence than later plantings.

Table 2. Effect of method of sowing on Ubon paspalum seed production.

Treatment	Seed yield (kg/ha)	TSW (g)	Inflorescences /m^2	Racemes /inflorescence	Spikelets /raceme	Seeds /inflorescence
(a) 1998						
T1 2nd year plants	171 a[1]	3.00 a	38 a	8 b	107 b	154 a
T2 Seed sown, 1st year	—	—	—	—	—	
T3 Tillers planted, 1st year	132 a	3.09 a	17 b	10 a	126 a	234 a
T4 Plastic bag seedlings, 1st year	91 a	2.88 a	16 b	8 b	107 b	197 a
(b) 1999						
T1 3rd year plants	44 ab	3.13 a	50 bc	6 0 ab	114 a	26 a
T2 Seed sown, 2nd year	13 b	3.06 a	15 c	5.7 b	131 a	40 a
T3 Tillers planted, 2nd year	85 a	2.98 a	123 a	6.5 a	122 a	24 a
T4 Plastic bag seedlings, 2nd year	56 ab	3.11 a	78 b	6.6 a	126 a	18 a

[1]Within columns and years, means followed by a common letter are not significantly different at P = 0.05 by Duncan's Multiple Range Test.

Table 3. Effect of date of planting on Ubon paspalum seed production in the first year.

Treatment/ Planting date	Seed yield (kg/ha)	TSW (g)	Inflorescences /m^2	Racemes /inflorescence	Spikelets /raceme	Seeds /inflorescence
T1 May 7	331 a[1]	3.22 a	148 ab	9.7 ab	133 a	73 a
T2 May 21	274 a	3.23 a	162 a	10.9 a	133 a	47 b
T3 June 4	115 b	3.15 a	100 bc	10.6 ab	155 a	39 b
T4 June 18	69 b	3.24 a	42 d	10.1 ab	157 a	51 b
T5 July 2	70 b	3.30 a	72 cd	9.7 ab	155 a	31 b
T6 July 16	25 b	3.02 a	28 d	9.4 b	133 a	30 b

[1]Within columns, means followed by a common letter are not significantly different at P = 0.05 by Duncan's Multiple Range Test.

Village farmer seed project

Delay in planting time severely reduced village seed yields in the first year of production (Table 4). The 6 farmers who planted in May 1997 harvested a mean machine-dressed seed yield of 315 kg/ha in October 1997. June plantings produced only 65 kg/ha of machine-dressed seed and July plantings produced no seed at all as these fields did not flower. May-planted fields averaged 32 inflorescences/m^2, 12.3 racemes/inflorescence, 149 spikelets/raceme and 336 seeds/inflorescence compared with June-planted fields which averaged 18 inflorescences/m^2, 11.8 racemes/inflorescence, 147 spikelets/raceme and 138 seeds/inflorescence (Table 5).

The mean seed yields of the 20 fields in 1998 and 1999 were 632 and 651 kg/ha, respectively (Table 4), with an average seed purity for both years of 99.6% and a TSW of 3.1 g. After 5-months post-harvest storage at ambient temperatures in hessian bags, germination rates for seed harvested in 1998 and 1999 were 81 and 91%, respectively.

Table 4. Ubon paspalum village farmer seed yields.

Farm	Planting time in 1997	1997	1998 (kg/ha)	1999
1	May	161	625	581
2	May	577	530	566
3	May	405	495	994
4	May	313	825	765
5	May	165	781	626
6	May	266	644	288
7	June	75	842	611
8	June	70	807	611
9	June	70	529	828
10	June	9	802	981
11	June	51	557	639
12	June	98	578	581
13	June	80	472	640
14	July	—	413	642
15	July	—	409	378
16	July	—	649	828
17	July	—	894	640
18	July	—	611	640
19	July	—	559	544
20	July	—	622	634
Mean		180	632	651

Table 5. Seed yield components of farmer seed fields in the establishment year (1997).

Farm	Planting time in 1997	Inflorescences /m^2	Racemes/ inflorescence	Spikelets/ raceme	TSW (g)	Seeds/ inflorescence
1	May	27	11.9	132.9	3.15	189
2	May	78	13.8	160.0	3.36	220
3	May	23	12.7	146.4	3.28	537
4	May	34	12.7	149.2	3.49	263
5	May	18	12.2	147.0	3.03	303
6	May	16	10.8	159.5	3.28	506
7	June	18	10.8	146.9	2.77	150
8	June	10	11.5	166.3	3.38	207
9	June	35	10.2	144.4	3.24	212
10	June	21	12.0	131.1	3.35	13
11	June	14	12.5	139.8	3.12	115
12	June	21	12.4	160.9	3.39	137
13	June	20	11.4	142.1	2.90	138

Discussion

The method of establishment of Ubon paspalum is extremely critical for first-year seed production. In our studies, seed crops established by sowing seed produced no inflorescences in the first year. In Florida, Kalmbacher *et al*. (1997) also found that little flowering and seed set can be expected in the year of sowing *P. atratum*. We have also found that, in pastures sown by seed, no seed heads emerge until the second year after establishment. This is a bonus in grazed pastures, as the leafy, stem-free swards in the first year are generally of a higher nutritional quality than second year and older pastures which produce seed heads in September–October (M. Hare, unpublished data).

This behaviour sets Ubon paspalum apart from other tropical grasses used for seed production in Thailand. Seed crops of ruzi grass, *Panicum maximum*, *Paspalum plicatulum*, *Brachiaria decumbens*, *Setaria sphacelata* and *Andropogon gayanus* can all flower and produce seed in the first year following seed sowing. It seems that Ubon paspalum may have to pass through a juvenile phase during which plants have to be exposed to long days before they can respond to a flowering stimulus. Currently, we are conducting experiments in growth chambers to confirm whether or not a juvenile phase exists in Ubon paspalum.

Even in the second year after establishment, Ubon paspalum plants sown from seed produced very low yields compared with yields from spaced plants grown from tillers or seedlings. This may reflect strong inter-plant competition in the seed-sown treatments. Plant numbers in these treatments were high and plants were sparsely tillered and less robust than spaced plants. The seed sowing rate of 12 kg/ha was probably too high for seed production. Recent evidence has found that seed production of Ubon paspalum is higher in fields with distances of 50–100 cm between spaced plants (C. Phaikaew, personal communication).

Our research has shown that planting tillers or seedlings is the best method of establishing Ubon paspalum seed crops in Thailand but the time of planting must be early in the wet season for productive seed yields. Planting tillers in June–July (the traditional period for planting grass seed crops in Thailand) produces considerably less seed than planting in May. This behaviour again suggests that Ubon paspalum plants may require longer exposure to long days before they will flower profusely. Both late wet season planting and cutting (Hare *et al*. 1999c) will reduce potential seed yields.

The village farmer seed project demonstrated that village farmers can hand-harvest high seed yields. Many farmers achieved a gross income of over 60 000 baht/ha (equivalent to US$1395/ha). Ubon paspalum is now a new addition to the range of tropical grass and legume species village farmers can successfully hand-harvest for seed in Thailand (Hare 1993; Phaikaew and Hare 1998; Hare and Phaikaew 1999). However, seed production of Ubon paspalum is not without its difficulties. Heavy thunderstorms frequently occur during the September–October flowering and harvest period causing seed to shed, while foraging birds may dramatically reduce seed yields. Farmers have set up nets to capture the birds for sale or installed bird-scaring devices such as scarecrows and tins filled with stones. Some farmers sleep in their fields in order to chase away birds which forage in the early morning.

In order to enhance seed quality, we have emphasised drying the seed in the shade in order to prevent rapid moisture loss which produces non-viable shrivelled seed. Seed purity of the machine-dressed seed produced by farmers in 1998 and 1999 was excellent and satisfactory germination rates were obtained after 5 months storage in hessian bags at ambient temperatures to break embryo dormancy (Hare *et al*. 1999c). The method of hand-knocking mature seed from seed heads and then slow drying in the shade produces seed of high viability.

Site appears to have a significant impact on Ubon paspalum seed production. The university site where Ubon paspalum has been successfully grown for forage (Hare *et al*. 1999a; 1999b) has consistently produced lower seed yields in these and previous trials (Hare *et al*. 1999c) than yields harvested by farmers and at the Yasothon Animal Nutrition station, 70 km north of Ubon Ratchathani University (Phaikaew *et al*. 2001). By employing the method of knocking seed from seed heads, the highest seed yields at the university site, from the Yasothon station and from farmer fields have been 331, 622 and 994 kg/ha seed, respectively. The Yasothon station produced 1108 kg/ha seed when seed heads were covered with nylon net bags (Phaikaew *et al*. 2001). Drainage may play an important role. Both the

university and the Yasothon sites are usually waterlogged during flowering and seed harvest, whereas farmer sites remain free-draining throughout the wet season. Soils at all sites are acid and low in organic matter, nitrogen, potassium and phosphorus. Trees appear to be the only other main physical difference between the sites. The university site has several large trees adjacent to the trials whereas the other two sites have no trees in the immediate vicinity of the seed fields. These trees may have produced some shading effect and also sheltered flocks of birds which foraged on the seed in the early morning. More studies are needed to examine the influence of trees and shading on Ubon paspalum seed production.

The critical potential seed yield components appear to be the number of inflorescences/m^2 and the number of seeds per inflorescence. Many plots in the university trials had more inflorescences/m^2 than those produced in the farmers' fields, but overall, the university inflorescences produced far fewer seeds/inflorescence leading to lower seed yields than those produced by farmers. This indicates that it may be better to have a smaller number of big heads than a larger number of small heads. Furthermore, fields which produced high seed yields generally had 10 or more racemes per inflorescence. More detailed studies need to be conducted into seed yield components of Ubon paspalum.

For high seed yields, Ubon paspalum seed crops should be hand-planted with tillers or seedlings early in the wet season. Sowing seed crops by seed or planting tillers late in the wet season will result in low seed yields or no seed at all in the first year of production.

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References

HARE, M.D. (1993) Development of tropical pasture seed production in Northeast Thailand — two decades of progress. *Journal of Applied Seed Production*, **11**, 93–96.

HARE, M.D. and PHAIKAEW, C. (1999) Forage seed production in Northeast Thailand: A case history. In: Loch, D.S. and Ferguson, J.E. (eds) *Forage Seed Production Volume 2: Tropical and Subtropical Species*. pp. 435–443. (CAB International: UK).

HARE, M.D., THUMMASAENG, K., SURIYAJANTRATONG, W., WONGPICHET, K., SAENGKHUM, M., TATSAPONG, P., KAEWKUNYA, C. and BOONCHARERN, P. (1999a) Pasture grass and legume evaluation on seasonally waterlogged and seasonally dry soils in north-east Thailand. *Tropical Grasslands*, **33**, 65–74.

HARE, M.D., BOONCHARERN, P., TATSAPONG, P., WONGPICHET, K., KAEWKUNYA, C. and THUMMASAENG, K. (1999b) Performance of para grass (*Brachiaria mutica*) and Ubon paspalum (*Paspalum atratum*) on seasonally wet soils in Thailand. *Tropical Grasslands*, **33**, 75–81.

HARE, M.D., WONGPICHET, K,. TATSAPONG, P., NARKSOMBAT, S. and SAENGKHAM, M. (1999c) Method of seed harvest, closing date and height of closing cut affect seed yield and seed yield components in *Paspalum atratum* in Thailand. *Tropical Grasslands*, **33**, 82–90.

KALMBACHER, R.S., MARTIN, F.G. and KRETSCHMER, A.E. (1995) Effect of rest period length prior to atra paspalum seed harvest. *Soil and Crop Science Society of Florida Proceedings*, **54**, 1–5.

KALMBACHER, R.S., BROWN, W.F., COLVIN, D.L., DUNAVIN, L.S., KRETSCHMER, A.E.Jr, MARTIN, F.G., MULLAHEY, J.J. and RECHCIGL, J.E. (1997) 'Suerte' atra paspalum. Its management and utilization. *University of Florida, Agricultural Experimental Station. Circular S-397*.

KOWITHAYAKORN, L. and PHAIKAEW, C. (1993) Harvesting and processing techniques of tropical grass and legume seeds for small farmers. *Proceedings of the XVII International Grassland Congress*. pp. 1809–1813.

PHAIKAEW, C. and HARE, M.D. (1998) Thailand's experiences with forage seed supply. In: Horne, P.M., Phaikaew, C. and Stur, W.W. (eds) *Forage Seed Supply Systems — Proceedings of a workshop held at Tha Pra, Thailand on 31 October and 1 November 1996*. pp. 7–14. *CIAT Working Document No. 175, Los Banos, Philippines*.

PHAIKAEW, C., PHOLSEN, P., TUDSRI, S., TSUZUKI, E., NUMAGUCHI, H. and ISHII, Y. (2001) Maximising seed yield and seed quality of *Paspalum atratum* through choice of harvest method. *Tropical Grasslands*, **35**, 11–18.

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