Tropical Grasslands (2001) Volume 35, 26–33

Seed yield and its components of *Brachiaria decumbens* cv. Basilisk, *Digitaria milanjiana* cv. Jarra and *Andropogon gayanus* cv. Kent in north-east Thailand under different rates of nitrogen application

N.R. GOBIUS[1], C. PHAIKAEW[2], P. PHOLSEN[3], O. RODCHOMPOO[1] AND W. SUSENA[1]
[1]*Chiang Yeun Animal Nutrition Research Station, Mahasarakham*
[2]*Division of Animal Nutrition, Department of Livestock Development, Phyathai Rd, Bangkok*
[3]*Khon Kaen Animal Nutrition Research Centre, Khon Kaen, Thailand*

Abstract

In a study of seed yields of pasture grasses in Thailand, pure seed yields of *Brachiaria decumbens* cv. Basilisk, *Andropogon gayanus* cv. Kent and *Digitaria milanjiana* cv. Jarra in one season were 81–123 kg/ha, 326–569 kg/ha and 48–97 kg/ha, respectively. Corresponding thousand-seed weights were 4.68, 3.35 and 0.42 g. Germination rates were 36, 73 and 17% at 4–6 months post harvest. In Thailand, low plant density and seeds per inflorescence, not moisture availability, are likely to be the most important factors causing low seed yields of *B. decumbens*. Seed production and quality of *A. gayanus* were exceptionally high, while seed yields of *D. milanjiana* were similar to reported values. The nylon gauze seed collection bags facilitated full seed retrieval. Nitrogen application increased seed yield and inflorescence density but produced significant lodging in all species at 200 kg/ha N on this sandy loam. However, it did not affect seed weight, purity, germination or viability of any of these species. Seed yields of *B. decumbens* in Thailand are characteristically low and present results indicate that low plant density and few seeds per inflorescence are contributing factors. The reasons for this are unknown. Gamba grass (*Andropogon gayanus*), with its drought-resistant characteristics, high dry matter production, high seed production and quality and low nitrogen requirement for seed production is a useful addition to pasture options for north-east Thailand.

Introduction

Livestock numbers in north-east Thailand have been increasing rapidly over the last decade, as a direct result of government promotion. This has resulted in an increasing demand for pasture. A seasonal 6-month dry season, poor soils and lack of available drought-tolerant species restrict pasture productivity. For the past 20 years, ruzi grass (*Brachiaria ruziziensis*) has been the dominant sown pasture species, primarily due to its ease of seed production.

Signal grass (*Brachiaria decumbens*) has long been acknowledged as being a pasture species suitable for NE Thailand. It is drought-tolerant and carries its production into the dry season much better than ruzi grass. To date, its use in Thailand has been limited by very poor seed yields. Erratic rainfall at the start of the wet season, especially during seed set, may be the cause.

Gamba (*Andropogon gayanus* cv. Kent) and Jarra (*Digitaria milanjiana* cv. Jarra) are relatively recent pasture introductions to Thailand and research is required to improve knowledge and management of their seed production in local environmental conditions.

Gamba persists in dry conditions on infertile soils and is well suited to low input systems of agriculture. It is a tall, perennial tussock grass growing in nearly all tropical and subtropical savannas of sub Saharan Africa, in areas with a long dry season (Whyte *et al.* 1959).

Jarra may be a useful adjunct to grasses currently used in Thailand. Observations indicate that it responds to the first rains more quickly

---

Correspondence: N.R. Gobius, Australian Tropical Dairy Institute, DPI, Mutdapilly Research Station, MS 825, Peak Crossing, Qld 4306, Australia. E-mail: gobiusn@dpi.qld.gov.au

than ruzi. Its climatic range is from semi-arid (450 mm annual rainfall) to wet equatorial (1700 mm rainfall) regions and it commonly grows in grasslands in moderate rainfall areas, on sandy loams. Jarra was endorsed for release in Australia in August 1991 and registered in January 1993 (Hall *et al*. 1993).

Successful seed production could provide the basis for greatly increased pasture production. With knowledge of seed-production requirements, potential seed producers can decide whether such an enterprise would be technically and economically viable.

Nitrogen fertiliser is required for grass seed crops (Humphreys and Riveros 1986). Three trials were designed to determine the components of seed yield and quality of signal, Jarra and gamba grasses in north-east Thailand, and the effects of nitrogen fertiliser application.

Materials and methods

Research was conducted over one year at the Department of Livestock Development's Chiang Yeun Animal Nutrition Station, Mahasarakham, in north-east Thailand (16.5° N, 103° E). Average rainfall is 1075 mm per annum. The soil is classified into the Khorat soil series and is characterised by a sandy loam over a clay loam. Organic matter concentration is 0.57%, available phosphorus (P) 9 ppm and available potassium (K) 35 ppm, with a pH range of 4.6–5.8.

Three separate experiments were conducted on 3 swards established in 1993, using a randomised complete block design (RCBD) with 3 nitrogen treatments and 4 replications (Table 1). Plot size was 4 × 3 m. The experimental period was May 1995–April 1996. Management details for all experiments are given in Table 1. One seed crop was harvested from each experiment — the signal and Jarra grass in mid-summer 1995, and the gamba grass in autumn 1995.

Data collection and seed harvesting

Before the start of the wet season in 1995, all plots were burnt and the excess material removed. Gamba was subjected to a closing cut in August 1995, when plots were cut back to 25 cm and all trash was removed. All recordings were taken from the central 3 × 2 m of each plot. Initial flowering (anthesis) date was recorded for each plot. Ripening seedheads were tied together into manageable bunches and, when the seed was almost ripe, nylon gauze bags were tied over the bunches and remained for the duration of the harvest. Bags facilitate the collection of all seed produced. Inflorescence density was calculated from the total number of inflorescences in the 6 m^2 harvest area. At seed harvest, two 1 m^2 quadrat cuts were taken for estimation of tiller numbers and (except gamba) total dry matter production. Tiller fertility is expressed as the percentage of inflorescences over the total number of tillers. Plant height was measured immediately before seed harvest. First harvest date and succeeding retrieval dates were recorded (Table 1). Plots were harvested individually. Harvest took place after seed started to drop, and when seed was easily displaced from racemes by light brushing. Seed was allowed to collect in the gauze bags until weather permitted the collection of dry seed. Ripe seed was threshed off the inflorescences by lightly rubbing or tapping the gauze bag. At the final retrieval, seed heads were cut, heaped in the shade and allowed to sweat for 5 days, after which any remaining seed was collected. Seed was air-dried, in the shade, over several days and weight was then adjusted to a moisture percentage nearest to the mean of all samples. Seed quality tests were conducted for each species as prescribed in the I.S.T.A. Rules for Seed Testing (ISTA 1985).

Statistical analysis

Response variables for each experiment were analysed by analysis of variance and LSD tests. All data were analysed using the Genstat® for Windows™ Statistical Programme.

*Experiment 1. Seed production components of signal grass (*Brachiaria decumbens *cv. Basilisk) under different nitrogen levels*

Signal grass was irrigated to minimise the chance that lack of water would limit the production of viable seed. Height was measured before first harvest, but with the nylon seed collection bag on. Total seed, cleaned seed and thousand-seed weight (TSW) were recorded (adjusted to 11% moisture concentration). Random subsamples (10 g) were analysed for purity. Signal grass seed was analysed for quality by a viability test at 2, 4 and 6 months, and a germination test at 6 months post harvest. Seed germination tests were conducted over 28 days at room temperature, with

Table 1. Management details.

Activity	Timing and fertiliser levels		
	Experiment 1 Signal	Experiment 2 Jarra	Experiment 3 Gamba
Sowing of pasture	Wet season 1993	Wet season 1993	Wet season 1993
Cleaning cut/Burn	Cut Apr 11, 1995 Re-cut and burnt May 15, 1995	Cut May 11, 1995	Burnt March 13, 1995 Cut May 11, 1995 Cut Aug 15, 1995
Basal fertiliser applied	Wet season 1993 Wet season 1994 30 kg/ha P 50 kg/ha K 20 kg/ha S May 17, 1995	Wet season 1993 Wet season 1994 30 kg/ha P 50 kg/ha K 20 kg/ha S May 17, 1995	Wet season 1993 Wet season 1994 30 kg/ha P 50 kg/ha K 20 kg/ha S 90 kg/ha N May 17, 1995
Fertiliser applied at August closing cut			10 kg/ha P 50 kg/ha K Aug 15, 1995
Treatment fertiliser applied	Treatment 1: 50 kg/ha N (N_{50}) Treatment 2: 100 kg/ha N (N_{100}) Treatment 3: 200 kg/ha N (N_{200}) May 17, 1995	Treatment 1: 50 kg/ha N (N_{50}) Treatment 2: 100 kg/ha N (N_{100}) Treatment 3: 200 kg/ha N (N_{200}) May 17, 1995	Treatment 1: 50 kg/ha N (N_{50}) Treatment 2: 100 kg/ha N (N_{100}) Treatment 3: 200 kg/ha N (N_{200}) Aug 15, 1995
Irrigation applied	May 17, 1995 and when required during the month of May	None	None
Growth recorded	Aug 1995	Jul 1995	Dec 1995
Seed harvested	Aug 7, 1995 Aug 11, 1995 Aug 18, 1995 Aug 23, 1995 Aug 28, 1995	Jul 25, 1995 Aug 2, 1995 Aug 7, 1995	Dec 11, 1995 Dec 16, 1995
Seed quality testing	Oct 1995 Dec 1995 Feb 1996	Oct 1995 Dec 1995 Feb 1996	Apr 1996

pads kept moist. Tetrazolium chloride 0.5% (w/v) tests were conducted to determine viability of seed that failed to germinate. Caryopses were dissected out, allowed to steep in water over night and then stained in tetrazolium solution in the dark for 4 hours. The number of pure seeds per inflorescence was calculated using inflorescence density, thousand-seed weight and pure seed yield.

*Experiment 2. Seed production components of Jarra grass (*Digitaria milanjiana *cv. Jarra) under different nitrogen levels*

Plant height, with gauze seed collection bags in place on the seedheads, was measured just prior to initial seed collection. Total seed, cleaned seed and TSW were recorded (adjusted to 12% moisture). Random subsamples of about 100 spikelets were drawn from each sample and separated into spikelets with and without caryopsis. Both fractions were weighed and relative weights of each were used to calculate pure seed yields. Seed quality was measured by germination and viability tests at 2 and 4 months post harvest. Seed was incubated at 35°C for 28 d with the pads kept moist. To determine viability, seeds that failed to germinate after 28 d were dissected and stained in the dark, in a solution of 0.1% (w/v) tetrazolium chloride at 35°C, over a period of 12 h. The number of pure seeds per inflorescence was calculated.

*Experiment 3. Seed production components of gamba grass (*Andropogon gayanus *cv. Kent) under different nitrogen levels*

A basal amount of N fertiliser was applied after the cleaning cut to provide for the large amount of DM produced in the first 3 months of the wet season. Plant height was recorded before the first seed retrieval date. Total seed, cleaned seed and TSW were recorded (adjusted to 10% moisture). ‘Pure seed’ was defined as ‘equivalent to any seed-like structure with or without an enclosed caryopsis’ (Harrison 1987). Germination tests (over 14 days) were conducted on the seed 4 months post harvest. KNO_3 (0.2%) was applied to attempt to break dormancy. The number of pure seeds per inflorescence was calculated.

Results

Rainfall and temperature

Rainfall in 1995 was above average with 1303 mm being recorded (Figure 1). July is normally a relatively dry month but in 1995 was very wet. Temperatures were not recorded at the site but average monthly temperatures for Khon Kaen (25 km east) are provided.

Lodging

Applications of 200 kg/ha N caused severe lodging of all species during anthesis and seed maturation, which created moist conditions under the canopy. When nitrogen was applied at lower levels, lodging was not so evident. The weight of the nylon gauze bags used for seed collection exacerbated the lodging problem, but greatly simplified seed retrieval.

*Experiment 1. Seed production components of signal grass (*Brachiaria decumbens *cv. Basilisk)*

The experiment was to be irrigated until just before seed harvest; however, above average and regular rainfall during the experimental period meant that only intermittent irrigation throughout May was required.

Pure seed yield of *B. decumbens* ranged from 81–123 kg/ha, with a viability of 65–82% and a germination percentage of 33–37% (Table 2). Viability declined from 76% at 2 months to 68% at 6 months post harvest. Fungal attack was very noticeable during germination tests.

Most properties measured were not significantly affected by N application. The main response was an increase in pure seed yield with yield at 200 kg/ha N significantly higher ($P < 0.05$) than that at 50 kg/ha N. The effect of N application on pure seeds per inflorescence tended to be asymptotic.

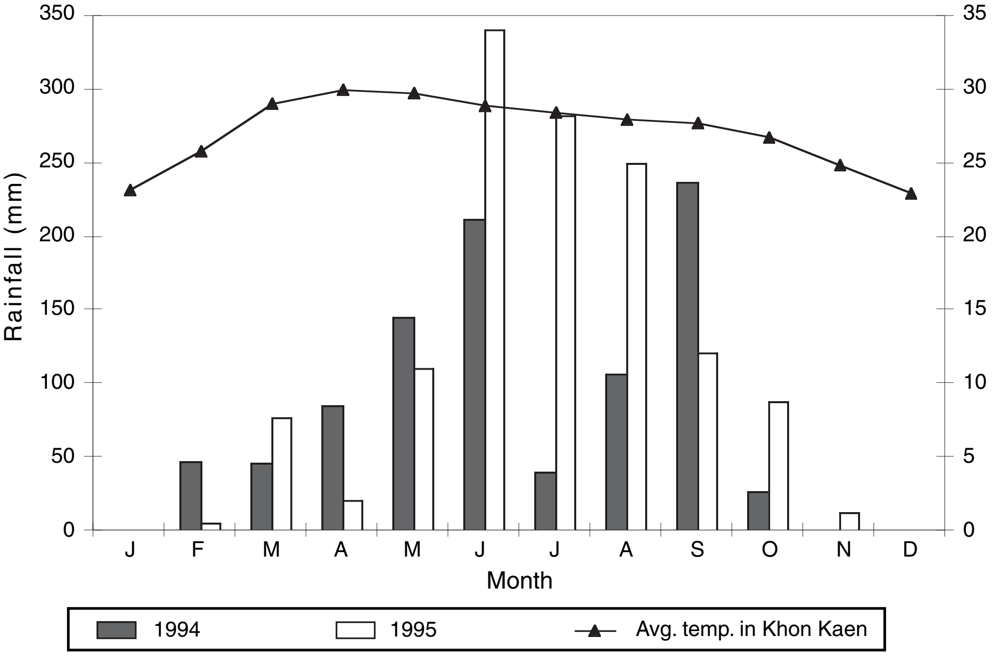

Figure 1. Monthly rainfall for 1994 and 1995 and mean long-term monthly temperatures (using daily average).

*Experiment 2. Seed production components of Jarra grass (*Digitaria milanjiana *cv. Jarra)*

Pure seed yield from *D. milanjiana* ranged from 48 kg/ha at 50 kg/ha N to 97 kg/ha at 200 kg/ha N ($P<0.05$) (Table 3). Viability ranged from 38–50% and germination increased from 6% at 2 months to 17% at 4 months post harvest.

Most parameters were not affected significantly by N application, although plant height was reduced at the highest level of N application ($P<0.05$) due to lodging. Inflorescence density was higher ($P<0.05$) at the intermediate and high levels of N application than at the low level.

*Experiment 3. Seed production components of gamba grass (*Andropogon gayanus *cv. Kent)*

Pure seed yields from gamba grass ranged from 326 kg/ha at the lowest level of N to 569 and 537 kg/ha at the intermediate and high levels of N, respectively ($P<0.05$) (Table 4). Germination at 4 months post harvest was 71–77%. Seed purity was high for all treatments, averaging 94%.

Nitrogen application affected inflorescence density with the intermediate and high N levels carrying a higher density of inflorescences than the low level of N ($P<0.05$).

Table 2. Seed yield and its components of *Brachiara decumbens* cv. Basilisk at different rates of N fertiliser.

Variable	Months post harvest	Nitrogen treatment (kg/ha)			LSD (P = 0.05)
		50	100	200	
Plant height (cm)		103	101	101	NS
Dry matter production (kg/ha)		10 231	9569	13 008	NS
Inflorescence emergence (days after closing cut)		52	52	52	NS
Tiller density (no/m^2)		268	243	305	NS
Fertile tillers (%)		55	45	57	NS
Inflorescence density (no/m^2)		144	107	168	23.8
Thousand-seed weight (g)		4.682	4.635	4.72	NS
Pure seeds per inflorescence		12	21	16	6
Purity (%)		33	39	32	NS
Viability (%)	2	75	81	73	NS
	4	76	82	73	NS
	6	70	68	65	NS
Germination (%)	6	33	37	37	NS
Pure seed yield (kg/ha)		81.4	100	122.6	26.7

Table 3. Seed yield and its components of *Digitaria milanjiana* cv. Jarra at different rates of N fertiliser.

Variable	Months post harvest	Nitrogen treatment (kg/ha)			LSD (P = 0.05)
		50	100	200	
Plant height (cm)		169	172	110	46
Dry matter production (kg/ha)		7240	8469	9730	NS
Inflorescence emergence (days after closing cut)		31	27	28	NS
Tiller density (no/m^2)		431	471	478	NS
Fertile tillers (%)		32	38	40	NS
Inflorescence density (no/m^2)		139	177	189	35.7
Thousand-seed weight (g)		0.416	0.431	0.420	NS
Pure seeds per inflorescence		82	74	124	NS
Purity (%)		32	30	36	NS
Viability (%)	2	38	40	41	NS
	4	50	46	40	NS
Germination (%)	2	5	5	7	NS
	4	17	16	18	NS
Pure seed yield (kg/ha)		47.6	55.9	96.6	26.9

Discussion

Irrigation

Average monthly rainfall for July in NE Thailand is normally relatively low. This month corresponds with inflorescence emergence and seed set of signal grass, and adequate moisture at this stage is critical for crop maturation. Tiller survival is dependent on adequate moisture and nutrition. In this study, moisture conditions were excellent at this stage. In addition, waterlogging, to which signal grass is especially susceptible (Hopkinson and English 1982), was never a problem on the sandy loam soil.

Much higher seed yields of signal grass are achieved in Australia (Hopkinson and English 1982; Stur and Humphreys 1985) than those obtained in this trial. C. Phaikaew (unpublished data) achieved similar signal grass seed yields of 60–90 kg/ha without irrigation. We conclude that moisture was not a constraining factor on signal grass seed production in our study. Since production in Australia reaches much higher levels, something other than water must have limited seed production in this trial.

Seed yield

We achieved the highest signal grass seed yield of 122.6 kg/ha at 200 kg/ha N. Seed yields can vary from 33 kg/ha per crop (Humphreys and Riveros 1986) to 750 kg/ha per crop in north Queensland though recovered yields may only be as much as 500 kg/ha (Hopkinson and English 1982). Recovering fallen seed increased seed yields from a standing seed yield of 100 kg/ha to a recovered seed yield of 300kg/ha (70% purity) in a single controlled crop (Hopkinson and English 1982).

We hypothesise that, as thousand-seed weight was similar to that reported in the literature (Humphreys and Riveros 1986), the lower seed yields at our site are a result of lower inflorescence density, and lower tiller fertility and density. Stur and Humphreys (1985) reported a hand-harvested cleaned seed yield of 537 kg/ha from an inflorescence density of 1040/m^2. Our highest yield was 122 kg/ha from an inflorescence density of 168/m^2. We also had a tiller fertility of approximately 50%, compared with 80% in the other studies. Our results indicate that each inflorescence yielded 0.0726 g of seed compared with 0.0516 g of seed in the Stur and Humphreys (1985) experiment. Due to competition, a correlation normally exists between inflorescences/ha and seed yield/inflorescence. As inflorescence density increases, nutrients become more limiting. This effect can also be seen in many crops where, in the first year, inflorescence density is low and inflorescences are large, while in the second year a massive increase in the number of smaller inflorescences can be seen, with less branching.

Shoot density, which determines the number of sites available for inflorescence occupation, is positively associated with sowing rate, soil fertility and moisture supply, and is modified by cutting or grazing practice (Humphreys and Riveros 1986). Shoot survival is dependent on adequate nutrition and moisture. As moisture and N, P, K and S nutrition were adequate, the low tiller and inflorescence density and consequent low seed yield for signal grass, may be due to low plant numbers from the outset, and/or the effects of the cut and burn at crop closure. Boron responses have been widely recorded on similar soils in north-east Thailand and boron is known to be very important

Table 4. Seed yield and its components of *Andropogon gayanus* cv. Kent at different rates of N fertiliser.

Variable	Months post harvest	Nitrogen treatment (kg/ha)			LSD (P = 0.05)
		50	100	200	
Plant height (cm)		275	278	283	NS
Inflorescence emergence (days after closing cut)		82	81	81	NS
Tiller density (no/m^2)		140	150	125	NS
Fertile tillers (%)		32	43	54	NS
Inflorescence density (no/m^2)		44	63	66	7.5
Thousand-seed weight (g)		3.392	3.448	3.204	NS
Pure seeds per inflorescence		223	265	247	NS
Purity (%)		93	96	94	NS
Germination (%)	4	71	77	71	NS
Pure seed yield (kg/ha)		326	569	537	163

for pollen tube germination. However, a boron-application experiment with signal grass showed no benefits in terms of seed production (S. Udchachon, personal communication).

Two hypotheses regarding the inability of signal grass to produce satisfactory yields of seed in Thailand should be investigated (J. Hopkinson, personal communication). Firstly, signal grass will not produce well on sandy soils in Australia which may be because sandy soils do not provide the sustained release of nitrogen required for seed production. Seed production on a heavier soil may be worth investigating. Secondly, it is recognised that signal grass suffers from high temperatures more than some other *Brachiarias i.e. B. humidicola*. Growing signal grass for seed production at a higher elevation, rather than on the hot north-eastern plains, may improve seed production.

Generally gamba is said to be a good seed producer and may produce up to 350 kg/ha pure seed (Schultze-Kraft 1992). In Australia, yields of 15–120 kg/ha have been recorded on moderate sized areas from one mechanical harvest at the end of the wet season. These low yields are probably caused by the crops being grown under dryland conditions and hence a marked effect of reduced rainfall during seed filling (Harrison 1987). Haggar (1966) increased seed yields of *A. gayanus* with N treatment, although maximum, hand-harvested and unthreshed, seed yield was only 88 kg/ha when approximately 230 kg/ha N and 34 kg/ha P were applied. The increased seed yield was attributed to increased inflorescence density as well as larger inflorescences. The maximum pure seed yield achieved in our experiment compares very favourably with both of these figures. Our seed was hand-harvested (with the use of nylon gauze collection bags) and manual harvests are said to produce up to 100% more than mechanical harvests. As with Haggar's experiments (1966), nitrogen significantly increased inflorescence density in our experiment but, although the number of pure seeds per inflorescence tended to increase with increasing nitrogen input, we could not attribute the increased yield to larger inflorescences.

The maximum seed yield of 97 kg/ha at 200 kg/ha N for Jarra represents one of the few recordings for seed production of this relatively new release. In north Queensland, Jarra has produced commercially acceptable yields of up to 100 kg/ha of good quality seed per crop, by header harvesting (Oram *et al.* 1993).

Seed quality

Fungal attack on signal grass seed during germination tests is common. The problem may have been exacerbated in our experiment by the use of nylon collection bags. Natural abscission of immature seed occurs, and the slack seal between the lemma and palea of the immature seed provides a harbour for fungal spores, which can then multiply amongst the other seeds in the bottom of the collection bag. Fungal growth is also promoted by leaching of solutes from an aging caryopsis.

Signal grass is limited by 'long-term' dormancy, which is related to the presence of the palea, lemma and glumes enclosing the caryopsis. Removal of these allows up to 100% germination (Whiteman and Mendra 1982). The seed coat may limit oxygen diffusion, causing dormancy, and with its removal mean germination time is reduced to less than 36 hours. If germination has not occurred after a day, the embryo is bisected longitudinally and tetrazolium added. The rest of the seed is left to germinate. This type of tetrazolium viability test permits one to by pass the germination test when seed is fresh and dormancy is still a problem (Hopkinson *et al.* 1996).

Nitrogen did not affect purity, germination or viability of seed of any of the species investigated. Many instances of irregular seed quality responses to nitrogen have been recorded (Humphreys and Riveros 1986). Seed viability of Signal and Jarra was substantially higher than their germination percentages, which were probably still affected by dormancy. No minimum standards for seed quality of signal grass are now in place. In general, the quality of signal grass seed has markedly improved and buyers expect 80% or even 90% tetrazolium viability (J. Hopkinson, personal communication). The quality of purified signal grass seed produced in this experiment could then be said to be relatively low (65–82% viability; 33–37% germination). Similarly, the quality of gamba grass produced in this experiment was exceptionally high (71–77% germination and 93–96% purity). In the Northern Territory, 'pure seed' levels of 55–75% with a pure seed germination of 40–70% are usual (Harrison 1987), while former Queensland DPI Standard Regulations for Seed Quality (1984) state a minimum germination of 30% purity and 10% germination. Minimum standards or reported quality values could not be found for the commercially developed *Digitaria milanjiana* cv. Jarra.

It is recommended that signal grass seed be stored for 6 months post harvest to allow for removal of 'long-term' dormancy; the most effective way of treating dormancy is by scarification with concentrated sulphuric acid (Whiteman and Mendra 1982). When field sowing, this is necessary only with freshly harvested seed (Hopkinson and English 1982). From our results, it would appear that gamba grass does not suffer from dormancy as much as signal grass, if at all. However, the quality of Jarra seed did improve with storage time.

Seed yield components

The individual component data presented in this paper may be of use to those planning commercial seed production, for example when attempting to increase yields of signal grass seed in Thailand. In our signal grass experiment, the tiller density, inflorescence density and tiller fertility observed were much lower than those reported by Stur and Humpreys (1985), of 1595/m^2, 1040/m^2 and 81%, respectively. As mentioned previously, burning may have reduced the experiment's initial plant and tiller densities, which may have already been low.

The principal effect of fertiliser nitrogen on tropical grasses is to increase seed yield, usually through the production of more inflorescences (Loch 1980). In the experiments reported in this paper, the only seed yield component significantly influenced by nitrogen application was inflorescence density, which was raised when nitrogen was applied to both Jarra and gamba. However, nitrogen application did not consistently raise inflorescence density in signal grass, a result that must be regarded as un-interpretable in consideration of only a single crop in a single season.

With high seed yields, high purity, good germination, and very good dry season growth, there is great potential for gamba seed production and for its widespread commercial use. The lower yields and greater nitrogen requirement for signal and Jarra grass are barriers to the wider use of these species, even though both exhibit advantages over ruzi grass. However, the ease of ruzi seed production by the smallholder farmer will ensure that it remains one of the main pasture species used commercially.

Acknowledgements

We thank: Khun Sri ChiangYeun for his technical assistance; Khun Saowapha Yonthabin and Khun Nipha Kisarang for seed analysis; and Khun Pimpaporn Pholsen, Khun Chaisang Phaikaew, Khun Supachai Udchachon, Dr Kenji Kataoka and Dr Trevor Gibson for their advice and support.

References

HAGGAR, R.J. (1966) The production of seed from *Andropogon gayanus. Proceedings of the International Seed Testing Association*, **31**, 251–259.

HARRISON, P.G. (1987) Gamba grass — Management for seed production. *Agnote No. 256, December 1987. Department of Industries and Development, Northern Territory of Australia.*

HOPKINSON, J.M. and ENGLISH, B.H. (1982) Seed production of Signal grass. *Queensland Agricultural Journal*, **108**, 317–322.

HOPKINSON, J.M., DE SOUZA, F.H.D., DIULGHEROFF, S., ORTIZ, A. and SANCHEZ, M. (1996) Reproductive physiology, seed production and seed quality of *Brachiaria*. In: Miles, J.W., Maase, B.L. and do Vallee, C.B. with the collaboration of Kumble. V. (eds) Brachiaria: *Biology, Agronomy and Improvement*. pp. 124–140.

HUMPHREYS, L.R. and RIVEROS, F. (1986) Tropical pasture seed production. *Plant Production and Protection Paper 8. FAO, Rome*.

ISTA (International Seed Testing Association) (1985) International rules for seed testing. *Seed Science and Technology*, **13**, 299–513.

LOCH, D.S. (1980) Selection of environment and cropping systems for tropical grass seed production. *Tropical Grasslands*, **14**, 159–168.

HALL, T.J., WALDUCK, G.D. and WALKER, R.W. (1993) *Register of Australian herbage plant cultivars*. A. Grasses, 23. *Digitaria* (b) *Digitaria milanjiana* (Rendle) Stapf. (finger grass) cv. Jarra. *Australian Journal of Experimental Agriculture,* **33** (5), 674–676.

QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES (1984) Agricultural Standards Regulations. *Queensland Government Gazette*, **277**, 1783.

SCHULTZE-KRAFT, R. (1992) *Andropogon gayanus* Kunth. In: Mannetje, L. 't and Jones, R.M. (eds) *PROSEA — Plant Resources of South East Asia 4. Forages*. pp. 44–46. (Pudoc: Wageningen).

STUR, W.W. and HUMPHREYS, L.R. (1985) Burning, cutting and the structure of seed yield in *Brachiaria decumbens*. *Proceedings of the XV International Grassland Congress, Kyoto, 1985*. pp. 303–304.

WHITEMAN, P.C. and MENDRA, K. (1982) Effects of storage and seed treatments on germination of *Brachiaria decumbens*. *Seed Science and Technology*, **10**, 233–242.

WHYTE, R.O., MOIR, T.R.G. and COOPER, J.P. (1959) Grasses in agriculture. *Agricultural Studies No. 42. FAO, Rome.*

(Received for publication June 29, 1999; accepted June 23, 2000)