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Research Paper

Germination of tropical forage seeds stored for six years in ambient and controlled temperature and humidity conditions in Thailand

Germinación de semilla de forrajeras tropicales durante seis años de almacenamiento bajo condiciones ambientales y condiciones de temperatura y humedad controladas en Tailandia

MICHAEL D. HARE[1,2], NADDAKORN SUTIN[2], SUPAPHAN PHENGPHET[2] AND THEERACHAI SONGSIRI[2]

[1]*Faculty of Agriculture, Ubon Ratchathani University, Ubon Ratchathani, Thailand.* www.ubuenglish.ubu.ac.th
[2]*Ubon Forage Seeds Co. Ltd., Jaeramair, Muang, Ubon Ratchathani, Thailand.* www.ubonforageseeds.com/en/

Abstract

The germination performances of fresh seed lots were determined for 5 tropical forage species: Mulato II hybrid brachiaria [*Urochloa ruziziensis* (syn. *Brachiaria ruziziensis*) x *U. decumbens* (syn. *B. decumbens*) x *U. brizantha* (syn. *B. brizantha*)], Mombasa guinea [*Megathyrsus maximus* (syn. *Panicum maximum*)], Tanzania guinea [*M. maximus* (syn. *P. maximum*)], Ubon paspalum (*Paspalum atratum*) and Ubon stylo (*Stylosanthes guianensis*), stored under ambient conditions in Thailand (mean monthly temperatures 23–34 ºC; mean monthly relative humidity 40–92%) or in a cool room (18–20 ºC and 50% relative humidity) for up to 6 years. The first paper of this study showed all seeds, except unscarified Ubon stylo seed, were dead after a single year of storage in ambient conditions. This second paper shows that cool-room storage extended seed viability, but performance varied considerably between species. Germination percentage under laboratory conditions declined to below 50%, after 3 years storage for Mombasa guinea seed and Tanzania guinea seed, 4 years for Ubon paspalum seed and 4–5 years for Mulato II seed. Ubon stylo seed maintained high germination for 5 years, in both cool-room storage (96%) and ambient-room storage (84%). Apparent embryo dormancy in acid-scarified Mulato II seed steadily increased with time in cool-storage and this seed had to be acid-scarified again each year at the time of germination testing to overcome dormancy. Physical dormancy of Mulato II seeds, imposed by the tightly bound lemma and palea in unscarified seed, was not overcome by length of time in cool-storage and these seeds had to be acid-scarified to induce germination. Hardseeded percentage in Ubon stylo seed remained high throughout the study and could be overcome only by acid-scarification. The difficulties of maintaining acceptable seed germination percentages when storing forage seeds in the humid tropics are discussed.

Keywords*:* Embryo dormancy, hardseededness, humid tropics, seed storage, seed viability.

Resumen

En Tailandia se determinó la germinación de semilla de 5 cultivares de forrajeras tropicales: *Urochloa* híbrido cv. Mulato II, *Megathyrsus maximus* cv. Mombasa, *M. maximus* cv. Tanzania, *Paspalum atratum* cv. Ubon, y *Stylosanthes guianensis* cv. Ubon stylo, almacenadas bajo condiciones ambientales (temperaturas promedio mensuales 23–34 ºC; humedad relativa 40–92%) o controladas en cuarto frío (18–20 ºC; 50% humedad relativa) durante 6 años. Mientras en un estudio previo se encontró que bajo condiciones ambientales todas las semillas, excepto las de Ubon stylo no escarificadas con ácido, perdieron su viabilidad después de 1 año de almacenamiento, en este segundo estudio se encontró que el almacenamiento en cuarto frío prolongó su viabilidad, aunque con una alta variabilidad entre especies. La germinación bajó a <50% después de 3 años de almacenamiento para *M. maximus* cvs. Tanzania y Mombasa, 4 años

Correspondence: Michael D. Hare, Ubon Forage Seeds Co. Ltd., Muu 1 602 Tha Bor Road, Jaeramair, Muang, Ubon Ratchathani, Thailand.
Email: michaelhareubon@gmail.com

para *Paspalum atratum* cv. Ubon y 4–5 años para *Urochloa* híbrido cv. Mulato II. La semilla de *S. guianensis* cv. Ubon-stylo mantuvo una alta germinación durante 5 años de almacenamiento tanto en cuarto frío (96%) como bajo condiciones ambientales (85%). La dormancia del embrión en las semillas de cv. Mulato II, escarificadas con ácido, aumentó constantemente con el tiempo de almacenamiento en cuarto frío; por tanto, para romperla fue necesario escarificar la semilla con ácido nuevamente cada año en el momento de la prueba de germinación. De la misma forma, la dormancia física de las semillas del cv. Mulato II impuesta por la lemma y pálea fuertemente unidas en semillas no escarificadas con ácido, no se rompió con el tiempo de almacenamiento en cuarto frío, por lo que fue necesario escarificar con ácido para inducir la germinación. El porcentaje de semilla dura de *S. guianensis* cv. Ubon-stylo permaneció muy alto durante todo el estudio y la germinación solo se pudo inducir mediante escarificación con ácido. Se discuten las dificultades para mantener la germinación de las semillas y almacenar semilla de forrajeras en el trópico húmedo.

Palabras clave*:* Almacenamiento de semilla, dormancia del embrión, dormancia física, dureza de semilla, trópico húmedo, viabilidad.

Introduction

Many tropical forage seeds produced and sold in Thailand are stored under ambient conditions in store rooms and shops where there is no control over temperature and humidity. The seeds are stored in conditions similar to those used to keep other grains for animal feed but which are not required to germinate. Forage seeds are sometimes carried over between years. There have been increasing concerns and reports about the declining germination quality of these forage seeds. In Australia, Hopkinson and English (2005) stored tropical grass seeds in a cool-room (10 ºC and 50% relative humidity, RH) and found that germination rates of seeds initially with high viability remained high after 6 years cool-room storage. It was important for us to find the ideal storage conditions in Thailand that would maintain seed germination of our commercial forage seeds at acceptable levels for more than 1 year.

We undertook an experiment on the germination of commercial tropical forage seeds stored under ambient conditions or under conditions of controlled temperature and humidity. Species represented were Mulato II [*Urochloa ruziziensis* (syn. *Brachiaria ruziziensis*) x *U. decumbens* (syn. *B. decumbens*) x *U. brizantha* (syn. *B. brizantha*)], Mombasa guinea [*Megathyrsus maximus* (syn. *Panicum maximum*)], Tanzania guinea [*M. maximus* (syn. *P. maximum*)], Ubon paspalum (*Paspalum atratum*) and Ubon stylo (*Stylosanthes guianensis*). All are commercial lines that are produced and sold in Thailand.

The experiment commenced in January 2011. Germination results for the first 2 years (January 2011–January 2013) were reported in a previous paper (Hare et al. 2014). After 1 year of storage under ambient conditions, seeds of all grasses tested were almost dead. After 2 years cool-room storage (18–20 ºC and 50% RH), germination percentage of Mombasa guinea, Tanzania guinea and Ubon paspalum seeds had not declined. We also found that apparent embryo dormancy and also physical dormancy in Mulato II and hardseededness in Ubon stylo persisted under storage. However, embryo dormancy in Mombasa and Tanzania guinea grasses was overcome within 6 months in cool-room storage (Hare et al. 2014).

We used a commercial seed store (15 x 7 x 4 m) set at 18–20 ºC and 50% RH. In this paper we report the performance of the initially tested seed lots under prolonged cool-room storage at temperatures which were higher than that used by Hopkinson and English (2005) but with similar humidity.

Materials and Methods

Seeds were harvested by village farmers from a number of villages in Northeast Thailand and Laos (Hare 2014) in October 2010 (Ubon paspalum 5,000 kg, Mombasa guinea 36,000 kg and Tanzania guinea 7,000 kg), November 2010 [Mulato II 12,000 kg: seed hand-knocked from seed heads (Hare et al. 2007a)] and January 2011 [Mulato II 16,000 kg and Ubon stylo 6,000 kg: seed swept from the ground (Hare et al. 2007a; 2007b)] and bulked within species, harvesting method and season. All harvested seeds were sun-dried to moisture levels in Table 1, cleaned and processed and entered storage in late January 2011. For the experiment, Mulato II seeds (hand-knocked and ground-swept) and the Ubon stylo seeds were divided into two 3 kg sublots before storage; the first sublot was scarified in sulphuric acid (96% normal) for 10 minutes, then washed and sun-dried to moisture levels in Table 1, while the second sublot was left untreated (unscarified). All seed lots and sublots consisted of 3 kg of seed drawn randomly from the total bulk of seed of each cultivar for the 2010/11 season, and placed into separate large (100 x 50 cm) commercial polyethylene bags, hand-tied tightly at the top.

The 3 kg bags of seeds consisting of one lot per bag were placed in 2 storage rooms, i.e. ambient conditions and a cool-room (Hare et al. 2014). The ambient seed

room was a storage shed at Ubon Ratchathani, Northeast Thailand (15º N, 104º E), where mean monthly temperatures were minimum 23 ºC, maximum 34 ºC and mean monthly RH was minimum 40%, maximum 92%. The cool-room was maintained at 18–20 ºC and 50% RH throughout the study.

Seed samples were withdrawn from all storage lots in January of each year and tested for germination and moisture percentage. For each germination test, 3 replications of 100 seeds, randomly selected from each cultivar lot and sublot, were placed into covered petri dishes on filter paper wet with a 0.2% potassium nitrate solution and placed in a germination cabinet set to provide 16 h dark at 25 ºC and 8 h light at 35 ºC. The numbers of germinated seeds (normal seedlings), fresh ungerminated seeds or hard seeds, dead seeds and empty seeds were counted 7 and 14 days after wetting down. The ungerminated seeds were tested using the tetrazolium (TZ) assay test to determine if they were fresh ungerminated (dormant), hard or dead.

For germination testing of acid-scarified Mulato II seeds, further acid-scarification [sulphuric acid (96% normal) for 10 minutes] was conducted at testing on half the samples. To determine moisture percentage on each occasion, 3 samples of 10 g of seeds for each lot and sublot were weighed fresh and again after drying in an oven at 130 ºC for 1 h (ISTA 1993). No seed moisture levels were measured in 2017.

Data from the experiment were subjected to analysis of variance using the IRRISTAT program from the International Rice Research Institute (IRRI). Each seed lot was analyzed separately with 7 years in storage as the treatments with 3 replications. The entry means were compared using Fisher's protected LSD (P≤0.05).

Results

Moisture content

Moisture contents of seeds stored in the cool-room varied between 10.9 and 8.6% for the grasses and 8.3 and 5.1% for Ubon stylo (Table 1). Acid-scarified Mulato II seeds contained less moisture (9.1%) overall than untreated Mulato II seeds (9.8%). Mombasa guinea, Tanzania guinea and Ubon paspalum seeds averaged 9.9% seed moisture in cool-storage, similar to untreated Mulato II seeds (9.8%). Moisture level of untreated Ubon stylo seeds stored under ambient conditions was similar (5.5%) to that of untreated Ubon stylo seeds in cool-storage (5.2%).

Seed germination

Seeds of all grass cultivars maintained their germination for 2–3 years in cool-storage before germination started to decline steadily and dead and empty seeds increased (Table 2). After 6 years in cool storage, most seeds were either dead [Mulato II hand-knocked (Table 2), Mombasa and Tanzania guinea grasses (Table 3)], or had very low germination [Ubon paspalum 2% (Table 3)] or had less than 10% germination [Mulato II ground-swept 9% (Table 2)]. Only ground-swept Mulato II, that had been acid-scarified upon entering cool-storage and acid-scarified again when the germination test was conducted, gave a slightly better seed germination of 15% after 6 years in storage. The germination performance of Mulato II seeds, harvested by

Table 1. Effects of storage conditions on moisture contents of seeds of tropical forage cultivars during 2011–2016.

Cultivar	2011	2012	2013	2014	2015	2016
Cool-room[1]						
Mulato II ground-swept, acid-scarified[3]	7.5	8.5	9.9	8.0	10.1	9.6
Mulato II ground-swept, unscarified4	10.6	8.8	10.2	8.6	9.4	9.8
Mulato II hand-knocked, acid-scarified	8.9	8.6	10.0	8.3	10.2	9.8
Mulato II hand-knocked, unscarified	10.5	9.3	10.7	9.0	10.8	10.2
Mombasa guinea	10.3	9.2	10.4	9.2	10.7	9.9
Tanzania guinea	10.1	9.0	10.4	8.9	10.4	9.7
Ubon paspalum	10.4	8.9	10.3	9.5	10.9	10.4
Ubon stylo acid-scarified	8.3	7.2	8.0	6.7	8.5	7.8
Ubon stylo unscarified	5.1	5.2	5.2	5.4	5.4	5.1
Ambient-room[2]						
Ubon stylo acid-scarified	9.3	9.2[5]				
Ubon stylo unscarified	5.1	5.2	5.8	5.7	5.4	5.5

[1]18–20 °C and 50% RH. [2]Range in mean monthly temperatures - minimum 23 ºC, maximum 34 ºC; range in mean monthly RH - minimum 40%, maximum 92%. [3]Scarified in sulphuric acid for 10 min, washed and dried. [4]Not treated with acid. [5]Seeds dead.

Table 2. Effects of cool-room storage conditions (18–20 ºC and 50% RH) on germination of differently treated seeds of Mulato II hybrid brachiaria during 2011–2017.

Seed treatment	2011	2012	2013	2014	2015	2016	2017	LSD (P≤0.05)
	14-day germination (%)							
Mulato II ground-swept, acid-scarified[1]	85	62	63	53	33	3	1	8.1
Mulato II ground-swept, acid-scarified, more acid with test[2]	90	90	89	84	75	42	15	8.4
Mulato II ground-swept, unscarified[3]	5	7	7	9	9	8	7	ns
Mulato II ground-swept, unscarified, acid with test	84	75	81	79	65	40	9	8.1
Mulato II hand-knocked, acid-scarified	70	63	68	20	19	1	0	17.9
Mulato II hand-knocked, acid-scarified, more acid with test	86	82	84	62	46	8	0	13.0
Mulato II hand-knocked, unscarified	0	1	1	3	4	1	1	ns
Mulato II hand-knocked, unscarified, acid with test	51	75	86	61	41	3	0	10.3
	Fresh ungerminated seeds (%)							
Mulato II ground-swept, acid-scarified[1]	11	29	27	31	42	39	14	3.6
Mulato II ground swept, acid-scarified, more acid with test[2]	8	9	8	1	5	4	1	2.2
Mulato II ground-swept, unscarified[3]	90	89	86	81	71	12	8	11.7
Mulato II ground-swept, unscarified, acid with test	12	19	14	14	15	10	9	ns
Mulato II hand-knocked, acid-scarified	28	25	18	12	10	5	0	3.2
Mulato II hand-knocked, acid-scarified, more acid with test	10	11	10	8	4	4	0	4.5
Mulato II hand-knocked, unscarified	97	91	89	40	8	0	0	3.3
Mulato II hand-knocked, unscarified, acid with test	46	20	10	9	7	6	0	6.5
	Dead and empty seeds (%)							
Mulato II ground-swept, acid-scarified[1]	4	9	10	16	25	58	85	7.3
Mulato II ground swept, acid-scarified, more acid with test[2]	2	1	3	15	20	52	84	9.1
Mulato II ground-swept, unscarified[3]	5	4	7	10	20	48	85	5.6
Mulato II ground-swept, unscarified, acid with test	4	6	5	7	20	50	82	10.3
Mulato II hand-knocked, acid-scarified	2	12	14	68	71	94	100	18.9
Mulato II hand-knocked, acid-scarified, more acid with test	4	7	6	30	50	88	100	10.9
Mulato II hand-knocked, unscarified	3	8	10	57	88	97	99	5.3
Mulato II hand-knocked, unscarified, acid with test	3	5	4	30	52	91	100	10.3

[1]Scarified in sulphuric acid for 10 min, washed and dried. [2]Scarified with sulphuric acid before storage and again before germination testing. [3]Not treated with acid.

hand-knocking, deteriorated more quickly with time in storage than that of ground-swept Mulato II seeds (Table 2). After 4 years in storage, mean germination percentages of all lots of hand-knocked Mulato II seeds were below 50%, but it took 5 years in cool-storage for similar results to be reached with ground-swept Mulato II seeds.

Maximum seed germination of Mombasa guinea grass (68%) was reached after 1 year in cool-storage and those of Tanzania guinea grass (63%) and Ubon paspalum (85%) after 2 years in cool-storage (Table 3). By the third year in cool-storage (2014), the germination of these 3 cultivars had declined rapidly to low levels (Table 3) and by the sixth year (2017), seeds were either dead (Mombasa and Tanzania) or had negligible germination (Ubon paspalum). The percentage of fresh ungerminated seeds for all cultivars quickly declined after the second year in cool-storage to levels well below 10% and the percentage of dead and empty seeds increased rapidly at the same time (Table 3).

Unscarified Ubon stylo seeds, when treated with acid at germination testing, maintained high germination percentages (>80%) for up to 5 years in both cool- and ambient-storage (Table 4). After 6 years in cool-storage, germination percentage of unscarified Ubon stylo seeds, treated with acid at the time of germination testing, was 3 times that of seeds acid-scarified following harvest (63 vs. 21%). Unscarified Ubon stylo seeds still displayed 45%

Table 3. Effects of cool-room (18–20 ºC and 50% RH) storage conditions on germination of seeds of Mombasa guinea grass, Tanzania guinea grass and Ubon paspalum during 2011–2017.

Grass	2011	2012	2013	2014	2015	2016	2017	LSD (P≤0.05)
	14-day germination (%)							
Mombasa guinea grass	35	68	65	27	14	7	0	9.8
Tanzania guinea grass	43	56	63	30	31	12	0	11.1
Ubon paspalum	73	79	85	51	37	7	2	7.2
	Fresh ungerminated seeds (%)							
Mombasa guinea grass	56	24	3	2	1	0	0	10.7
Tanzania guinea grass	51	36	7	5	3	1	0	12.9
Ubon paspalum	21	14	6	5	3	2	0	4.6
	Dead and empty seeds (%)							
Mombasa guinea grass	8	8	32	71	85	93	100	10.4
Tanzania guinea grass	6	8	30	65	66	87	100	8.5
Ubon paspalum	6	7	9	44	60	91	98	8.8

Table 4. Effects of storage conditions on germination of seeds of Ubon stylo during 2011–2017.

	2011	2012	2013	2014	2015	2016	2017	LSD (P≤0.05)
Cool-room[1]	14-day germination (%)							
Ubon stylo acid-scarified[3]	99	95	99	99	95	84	21	5.0
Ubon stylo unscarified[4]	15	19	23	14	21	19	14	ns
Ubon stylo unscarified, acid with test[5]	98	99	99	99	97	96	63	5.1
Ambient-room[2]								
Ubon stylo acid-scarified	94	0[6]						
Ubon stylo unscarified	10	3	2	1	2	2	3	5.2
Ubon stylo unscarified, acid with test	96	87	93	89	90	84	45	10.7
Cool-room[1]	Hard ungerminated seeds (%)							
Ubon stylo acid-scarified[3]	1	4	0	0	2	2	0	ns
Ubon stylo unscarified[4]	85	81	76	84	76	71	7	8.6
Ubon stylo unscarified, acid with test[5]	2	1	1	1	0	0	0	ns
Ambient-room[2]								
Ubon stylo acid-scarified	6	0[6]						
Ubon stylo unscarified	87	88	91	91	89	82	47	3.8
Ubon stylo unscarified, acid with test	3	5	2	5	4	2	3	ns
Cool-room[1]	Dead seeds (%)							
Ubon stylo acid-scarified[3]	0	1	1	1	3	14	79	5.9
Ubon stylo unscarified[4]	0	0	1	2	3	10	30	8.5
Ubon stylo unscarified, acid with test[5]	0	0	0	0	3	4	37	5.3
Ambient-room[2]								
Ubon stylo acid-scarified	0	0[6]						
Ubon stylo unscarified	3	9	7	8	9	16	50	6.9
Ubon stylo unscarified, acid with test	1	8	5	6	6	14	52	5.6

[1]18–20 ºC and 50% RH. [2]Range in mean monthly temperatures - minimum 23 ºC, maximum 34 ºC; range in mean monthly RH - minimum 40%, maximum 92%. [3]Scarified in sulphuric acid for 10 min, washed and dried. [4]Not treated with acid. [5]Scarified with sulphuric acid before germination testing. [6]Seeds all dead.

germination after 6 years in ambient-storage, when treated with acid at the time of germination testing. Ubon stylo seeds acid-scarified before entry into ambient storage, died after 1 year, but in cool-room storage maintained high germinations for 5 years (Table 4). Unscarified seeds in both cool- and ambient-storage, maintained high levels (>70%) of hardseededness for up to 5 years (Table 4).

Discussion

Germination percentages of forage grass seeds stored in a cool-room in this study varied substantially after 3 years of storage with many below 50% (which we arbitrarily define as minimal for sowing to ensure acceptable stands). The two guinea grass cultivars lost seed germination most rapidly to below 50% after 3 years cool-room storage, while Ubon paspalum seeds maintained higher germination for longer and could be kept in cool-room storage for up to 4 years before germination percentage dropped below 50%. The most durable grass seed was Mulato II with germination percentage remaining above 50% for longer than seed of the other grasses when stored in the cool-room: for 5 years if seed was harvested from the ground, but for only 4 years if seed was knocked out of the seed head at harvest. After 6 years in cool-storage seed of all grasses was either dead or had negligible levels of germination.

We define embryo dormancy as when seeds do not germinate but the embryo inside the seed is viable. We determined viability using the TZ assay test as it is the quickest test for evaluating seed viability. Embryo dormancy in seeds of Mombasa and Tanzania guinea grasses was overcome within 6 months in cool-room storage (Hare et al. 2014). On the other hand, acid scarification at the beginning of seed storage in 2011 was required to quickly overcome embryo dormancy of Mulato II seeds, but with time in cool-room storage, dormancy persisted and acid-scarified seeds had to be retreated with acid each year at the time of testing to get good germination. This secondary dormancy appears to be a physical type of dormancy, similar to that imposed by the tightly bound lemma and palea glumes over the caryopsis of unscarified seeds (Hare et al. 2008). In unscarified Mulato II seeds, aging in cool-storage did not overcome the physical dormancy attributable to these glumes, so seeds had to be acid-scarified at the time of the germination tests to achieve higher germination percentages (Table 2). Dormancy in unscarified Mulato II seeds is prolonged compared with that in other *Brachiaria* species, where dormancy has previously been measured to last only 10 months in *B. decumbens* seeds (Grof 1968) and up to 2 years in *B. dictyoneura* (now: *U. humidicola*) seeds (Hopkinson et al. 1996), while dormancy is inconsequential in *B. ruziziensis* (Hopkinson et al. 1996).

Seeds of Ubon stylo maintained high germination percentages (>85%) for up to 5 years when stored in ambient conditions, but only when they remained unscarified (Hare et al. 2014). This indicates that Ubon stylo seeds should not be scarified following harvest, if the aim is to store them for 1 year or more under ambient conditions. The situation differs in cool-storage, as Ubon stylo seeds, both acid-scarified and unscarified, maintained very high germination levels (>90%) for 4–5 years. Only in the sixth year did germination levels drop, particularly with acid-treated seeds, but they remained at levels above the low-to-zero germination levels of the grasses. Hardseededness, a type of physical dormancy, in Ubon stylo seeds was not overcome during either ambient- or cool-room storage and unscarified seeds in both storage rooms required treatment with acid each time a germination test was conducted to overcome hardseededness.

The moisture levels in grass seeds stored in the cool-room varied little from year to year, being above 10% in the first, third and fifth years of storage and 9% or less in the second, fourth and sixth years of storage. Since the bags of seeds in the study were moved around within the large cool-room, as commercial bags of seeds were introduced or withdrawn, possible variations in relative humidity in the room might have caused these moisture fluctuations. The seeds were stored in large commercial polyethylene bags and moisture exchange may have taken place. Seed life may have been extended if the seeds were dried to levels of 8% or less following harvesting and placed in sealed packages to prevent moisture exchange (Hopkinson and English 2005). However, the purpose of the study was to examine the life of our seed lots under commercial storage conditions (ambient- and cool-storage), so drying the seeds to very low seed moisture levels and packaging them in moisture-proof bags was considered impractical.

The results from this study and those from the first study (Hare et al. 2014) have important implications for the commercial storage and management of pasture seeds,

particularly grasses, in the humid tropics. Ideally, germination levels should be maintained above at least 60% for 12–15 months, until seed from the next season is ready for sale. Our first study showed that ambient-storage conditions in Thailand, even for a few months, were completely unsafe for seeds of our forage grasses, with a rapid decline in germination percentage to well below 50% within 8 months of entering storage (Hare et al. 2014). Typically, grass seeds in Thailand are harvested from October to January, cleaned, processed and placed in cool-room storage as soon as possible before the onset of the hot humid wet season in March. With this quick entry into cool-room storage, satisfactory germination levels (>70%) for most species are maintained prior to the key seed-purchasing period (March–October). The exception is Tanzania guinea seed, where it is difficult to obtain germination percentages of 70% under commercial conditions (60% is considered a satisfactory level).

Commercial seed lines rarely need to be stored for longer than 15 months in cool-storage. Conditions in the cool-room (18–20 ºC and 50% RH) we used were satisfactory for seed storage prior to sale. Hopkinson and English (2005) found that the viability of grass seeds stored at 10 ºC and 50% RH for 6–8 years remained constant. While the temperature in their room remained constant, we tested seeds in a commercial facility, where both temperature and humidity probably fluctuated (not measured) as the cool-room often remained open for 3 hours at a time to allow forklifts and trollies to enter and either deposit or remove seed.

It is important for traders who buy grass seeds (and then sell to third parties) to be made aware of the quick deterioration in viability of tropical grass seeds in ambient-storage. They should either sell the seeds within one month after purchase or, if seed is kept longer, keep it in air-conditioned rooms. Traders, for the most part, do not store grass seeds in cool conditions and many do not have access to air-conditioned storage rooms. Likewise, farmers should not buy grass seeds until they are almost ready to sow, unless they have an air-conditioned storage room. The rapid physiological deterioration of tropical grass seeds also has implications for shipping seeds internationally by sea in containers, as frequently grass seeds can be in transit by sea for 6–8 weeks; if hot and humid conditions exist, seeds should be shipped in refrigerated containers.

However, the quick deterioration in tropical grass seed germination has, to date, not limited the expansion of areas sown to improved pasture species in Southeast Asia and other humid tropical areas. Farmers may very well be increasing their seed sowing rates to allow for a possible decrease in germination. Some farmers may also conduct their own single germination tests before sowing to calculate seed sowing rates.

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