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ALEXANDER GRASS SEED PHYSIOLOGY AND PRODUCTION: A STEP TOWARDS THE CONVERSION OF A WEED INTO A FORAGE PLANT

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ALEXANDER GRASS SEED PHYSIOLOGY AND PRODUCTION: A STEP TOWARDS THE CONVERSION OF A WEED INTO A FORAGE PLANT

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ALEXANDER GRASS SEED PHYSIOLOGY AND PRODUCTION: A STEP TOWARDS THE CONVERSION OF A WEED INTO A FORAGE PLANT

por

JULIANO ROSSI OLIVEIRA

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To GISPA's scientific initiation group

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To my knowledge, the emergence of so large group, of such completely new cultivars, in so short space of time, is certainly unique in the history of world agriculture. The cultivars will bring in their train a land-use revolution; not in northern Australia alone, but, ultimately, throughout the tropical world.

A piece written in 1966,

by John Redrup, about the tropical forages expansion, in his text “Some reflections on the growth of the tropical seeds industry” (World first Grassland Society Meeting – Brisbane, Queensland, Australia, 1966)

ABSTRACT

OLIVEIRA, Juliano Rossi. Alexander grass seed physiology and production: a step towards the conversion of a weed into a forage plant. 277 f. Thesis (Agronomy Doctorate) – Agronomy Graduate Program (Concentration area: Plant Production), Federal University of Technology - Paraná. Pato Branco, 2017.

Alexander grass is a *Brachiaria* species with great potential to produce plentiful and high quality forage. It is broadly found in Southern Brazil, and taken most of the time as a weed given the habit to develop spontaneously in fields of grain crops. Several studies assessed grazing and confirmed its characteristics as a good forage plant, especially in integrated production systems. Regardless, its use stills limited by the lack of knowledge on reproductive traits that could *(1)* endorse the establishment of an organized seed production to spread it as a pasture and *(2)* help to design control strategies when the plant is not desired. The major aim of this work was to compile experiment results and literature review to provide a big picture on the Alexander grass seed physiology, from the seed development until the dispersal. Forage characteristics are also discussed to provide a systematic and complete understanding of the plant behavior. The reproductive morphology was assessed through quantitative traits such as the number of inflorescences produced, the seasonal timing of inflorescence production, branching of the inflorescence, number of seeds according to the inflorescence organs, inflorescence and racemes length, shattering timing, shattering speed, shattering intensity, and other characteristics according to the panicle age and the plant phenology. Maturation and germination of the seeds are discussed according to reproductive components such as thousand seed weight and seed dry mass percentage; relativized yet to the elapsing of the cycle. Seed gathering methods are compared according to the physiological quality of the seed and practicability. Plant response to environmental stimulus to flowering and germination are presented and theorized. Further, treatments to release dormancy and improve the seed performance were tested, looking to establish a production management and to understand the seed biochemical responses. Behavior of soil seed bank under environmental influences were reviewed and discussed, and seed borne pathogens *i.e.* potential microbiological threatens are presented. On the base of this information, some guidelines were established for the overall management to sow, produce and harvest Alexander grass. Scarce literature and data are found on the species. Fortunately, lessons and previous experience with *Brachiaria* widely used as pasture in Brazil helped the comparisons and supported the conclusions. It was found that ground-sweeping method is the most proper way to harvest Alexander grass seed. Defoliation management did not influence the synchrony and the amount of panicle emerged. Alexander grass presents high panicle production per area, reaching near 1,750 panicles m^{-2}. Seed shattering starts rapidly, after 11 days from the panicle emergence near 30% of seed already shed, after 20 days near 60% of the seed already shed. Shattering also influences the distribution of the thousand seed weight along the

panicle. Alexander grass presents smaller racemes, smaller seeds, longer panicles and more racemes per panicle than most of the Brachiariagrasses widespread in Brazil. Seed maturation and filling follows the same direction of the shattering, happening from the distal to the proximal fraction of the panicles (basipetally). Seeds threshed from the panicle present low germination and low shelf life. Generally, seeds present large variability even when collected from the ground. Seeds collected after the natural shatter present better germination than seeds collected directly from the panicle. The higher the thousand seed weight, the higher the seed germination. After six-month storage, one minute of physic scarification in a rotational machine with sandpaper was enough to promote the germination; Substrate imbibition with KNO_3 at the dose of 0.4% promotes the germination and H_2SO4 acid scarification is deleterious to the seed.

Keywords: creeping Signal grass, *Brachiaria, plantaginea*, *Urochloa,* crop-livestock systems.

RESUMO

OLIVEIRA, Juliano Rossi. Alexander grass seed physiology and production: a step towards the conversion of a weed into a forage plant. 277 f. Tese (Doutorado em Agronomia) – Programa de Pós-Graduação em Agronomia (Área de Concentração: Produção vegetal), Universidade Tecnológica Federal do Paraná. Pato Branco, 2017.

O papuã é uma espécie do gênero *Brachiaria* que apresenta elevado potencial de produção de forragem de alta qualidade. A planta é comumente encontrada no Sul do Brasil e tomada na maioria das vezes como uma invasora de cultivos de grãos, dado seu hábito de emergir espontaneamente do banco de sementes do solo. Vários estudos avaliaram o pastejo de papuã e confirmaram sua alta capacidade em produzir forragem, todavia, o uso apropriado da planta ainda está limitado pela falta de informações a respeito do seu comportamento reprodutivo, informações estas que poderiam *(1)* embasar o estabelecimento de um sistema de produção de sementes para disseminar a espécie como pastagem e, em contraponto, *(2)* apoiar o desenvolvimento de estratégias de controle quando a planta não é desejada. O objetivo deste trabalho foi compilar resultados de experimentos e revisões de literatura visando apresentar uma análise geral da fisiologia das sementes do papuã, desde o início do seu desenvolvimento até a dispersão. Características forrageiras foram ocasionalmente discutidas, com vistas a relacionar as conclusões ao comportamento sistemático da planta. A morfologia reprodutiva foi avaliada por meio de características como o número de inflorescências, a emergência das inflorescências ao longo do tempo, a ramificação da inflorescência, o número de sementes, o comprimento das inflorescências e dos racemos, o tempo e a intensidade da degrana, o sentido da degrana na panícula, entre outros; todas relacionadas com a idade das panículas. Ainda, a maturação e a germinação das sementes foram discutidas de acordo com componentes reprodutivos como o peso de mil sementes e a porcentagem de massa seca. Métodos de coleta foram comparados de acordo com a qualidade fisiológica da semente. As respostas da planta aos estímulos ambientais para germinação e indução floral foram apresentadas e teorizadas. Tratamentos para melhorar o desempenho e a qualidade das sementes e quebrar mecanismos de dormência foram testados, buscando estabelecer tanto manejos para a produção bem como entender as respostas bioquímicas das sementes. O comportamento do banco de sementes do solo é apresentado e por fim são feitas algumas considerações a respeito dos patógenos que atacam as sementes do papuã. Com base nas informações coletadas alguns rumos foram estabelecidos para o manejo de produção, colheita e plantio do papuã. A literatura encontrada tratando da espécie é vaga, todavia, experiências e dados apresentados para outras espécies de *Brachiaria* amplamente cultivadas para pastejo e produção de sementes no Brasil, serviram de suporte para as conclusões. De forma geral, o método de varredura é o mais apropriado para a colheita das sementes de papuã. O manejo de cortes de uniformização não influenciou a sincronia e a quantidades de panículas produzidas. A espécie produz grande

quantidade de panículas por área, atingindo em torno de 1.750 panículas m^{-2}. A degrana natural das sementes acontece de maneira rápida, 11 dias após a emergência das panículas em torno de 30% das sementes já se desprendeu, após 20 dias este valor sobe para em torno de 60% das sementes. A degrana também influencia na distribuição do peso de mil sementes ao longo da panícula. O papuã apresenta racemos menores, sementes menores, panículas mais longas e mais rácemos por panícula do que a maioria das *Brachiarias* comumente utilizadas no Brasil. A maturação e enchimento das sementes ocorre na mesma direção da degrana, acontecendo da parte distal para a parte proximal da panícula. Quanto maior o peso da semente, maior a germinação. Depois de seis meses de armazenamento um minuto de escarificação física usando um escarificador rotacional com lixa é suficiente para promover a germinação do papuã. A embebição do substrato de germinação com KNO_3 na dose de 0.4% v.v. promove a germinação, e o uso de escarificação ácida com H_2SO_4 é deletério para a semente.

Palavras-chave: papuã, capim marmelada, *Brachiaria*, *plantaginea, Urochloa*, integração lavoura pecuária.

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KEY TO INSTITUTIONS NAME

CIAT	Centro Internacional de Agricultura Tropical
CSIRO	Commonwealth Scientific and Industrial Research Organization
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária
IAC	Instituto Agronômico de Campinas
IPEAN	Instituto de Pesquisa Agropecuária do Norte
MAPA	Ministério da Agricultura, Pecuária e Abastecimento
UNIPASTO	Associação para o fomento à pesquisa de melhoramento de forrageiras
USDA	United States of America Department of Agriculture
UTPFR	Universidade Tecnológica Federal do Paraná

KEY TO ABREVIATIONS

a.i.	Active ingredient
a.s.l.	Above sea level
ABA	Abscisic acid
AR	Accumulation rate
ASR	Average stocking rate
CEC	Cation exchange capacity
CP	Crude Protein
DM	Dry mass
DWG	Daily weight gain
GA	Gibberellins
LWG	Live weight gain
PLS	Pure live seeds
PS	Pure seeds
PUP	Pasture utilization period
PVS	Pure viable seeds
SSB	Soil seed bank
TSW	Thousand seed weight

KEY TO UNITS

cm	Centimeters
ha	Hectare
Kg	Kilograms
l	Liters
m	Meters
ml	Milliliters
T	Tons

KEY TO SPECIES COMMON *X* SCIENTIFIC NAME

Alexander grass	*Brachiaria plantaginea* (Link) Hitchc.
Alfalfa	*Medicago sativa* (L.)
Bahia grass	*Paspalum notatum* (Flügge)
Bermuda grass	*Cynodon dactylon* (L.) Pers.
Blue grama	*Bouteloua gracilis* (L.)
Buffel grass	*Cenchrus ciliaris* (L.)
Crab grass	*Digitaria horizontalis* (Willd.)
Creeping Vigna	*Vigna parkeri* (Baker)
Dallis grass	*Paspalum dilatatum* (Poir.)
Fescue	*Festuca arundinacea* (Schreb.)
Fingergrass	*Digitaria milanjiana* (Rendle) Stapf
Gamba grass	*Andropogon gayanus* (Kunth.)
Guinea grass	*Panicum maximum* (Jacq.)
Hairy beggarticks	*Bidens pilosa* (L.)
Italian ryegrass	*Lolium multiflorum* (Lam.)
Itch grass	*Rottboellia cochinchinensis* (Lour.) Clayton
Jaragua grass	*Hyparrhenia rufa* (Nees) Stapf
Koronivia grass	*Brachiaria humidicola* (Rendle) Schweick.
Molasses grass	*Melinis multiflora* (Beauv.)
Morning glory	*Ipomea purpurea* (L.) Roth
Narrowleaf Carpetgrass	*Axonopus fissifolius* (Raddi) Kuhlm.
Oat	*Avena sativa* (L.)
Palisade grass	*Brachiaria brizantha* (A. Rich.) Stapf
Para grass	*Brachiaria mutica* (Forsk.) Stapf
Pitted Bluesteem	*Bothriochloa decipiens* (Hackel) C. E.
Rhizome Peanut	*Arachis pintoi* (Krap. & Greg.)
Rhodes grass	*Chloris gayana* (Kunth)
Ribbed paspalum	*Paspalum malacophyllum* (Trin.)
Ruzi grass	*Brachiaria ruziziensis* (Germain & Everard)
Sabi grass	*Urochloa mossambicensce* (Hack.) Dandy
Setaria	*Setaria sphacelata* (Schumach.)
Sideouts grama	*Bouteloua curtipendula* (Michx.) Torr.
Signal grass	*Brachiaria decumbens* Stapf
Sorghum	*Sorghum bicolor* (L.) Moench
South African lovegrass	*Eragrostis plana* (Nees.)
Stargrass	*Cynodon plectostachyus* (K. Schum.) Pilger
Stylo	*Stylosanthes guianensis* (Aubl.) Sw.
Subterranean Clover	*Trifolium subterraneum* (L.)
Tanner grass	*Brachiaria arrecta* (Th. Dur. & Schinz) Stent
Ubon paspalum	*Paspalum atratum* (Swallen.)
Vasey grass	*Paspalum urvillei* (Steud.)
White clover	*Trifolium repens* (L.)

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INTRODUCTION

Worldwide 3.4 billion hectares of grazing land and a quarter of the crop production fields are used for livestock feeding. This accounts for two thirds of the agricultural area of the planet, placing forage species as a prominent feature in almost every landscape (CIAT, 2013).

Grasses, by its time, dominate 45% of the herbaceous community of natural environments (STANLEY, 1999). They occur in each habitat available to flowering plants except the seabed, being found in sugarcane fields, canebrakes, natural or artificial grasslands and cereal crops – over all, its maximum growing potential is found in savannas of tropical areas (MOSER et al., 2004; CHAPMAN, 1990). These plants rank among the most important crops in many countries and contribute to the sustainability of single and integrated production systems (CIAT, 2013). It is well known that they constitute the feeding basis of most of the world population.

In the last fifty years, grasses have been cultivated in Brazil as never before in the human history. The process resulted in nearly 200 million hectares of pasture, which summed to the natural savanna corresponds for 23% of Brazilian land (FAO, 2013), and is equivalent to all the planted forests and crops of the country (JANK et al., 2011). Nowadays, near 90% of the nutrients required by the Brazilian herd are obtained directly through grazing (EUCLIDES, 2010).

Brachiaria highlights in this scenario as the most important forages of America (85% of the tropical pastures area) and the broadest distributed sown forage of the tropical world (MOREIRA et al. 2009; BARBOSA, 2006; FISHER & KERRIDGE, 1996). The genus brought great increases in productivity, matching concomitantly the attendance of food security regulamentations and marketing advantages, particularly after the bovine spongiform encephalopathy disease contamination in some world players of the market (JANK et al., 2011; VALLS & PENALOZA, 2004). It is assumed that the development achieved by the livestock in the entire South American continent would not have been possible without the use of these plants (PANCERA Jr., 2011).

Brazil has more than 200 million heads of cattle (IBGE 2011), the largest commercial herd in the world (14.8 % of world's herd – FAOSTAT 2011). It had around 150 million heads in mid 90s, which means that in two decades the number of animals increased in 50 million, while the surface used as pasture remained the same (IBGE, 2006). All these traits consolidate the country as the great beef exporter since 2004 (JANK et al., 2011).

Beyond this robust expansion, the environmental limitations of native biomes and land sharing with grain crops started to limit the growing of the pasture area. These issues stimulated the development of better management to achieve higher production in the same fields. Renovation and intensification demanded new cultivars, more productive and better in quality, even with the requirement of more inputs. Long-term persistence gradually became less important giving space to animal performance and soil improvements, especially in systems involving crop-pasture rotation (MILES et al., 2004). These new forage cultivars came to the market with the responsibility to shorten the time to slaughter, reduce the production seasonality and, as a consequence, increase profits for the involved in the sector (VALLS & PENALOZA, 2004). All these traits also apply to Alexander grass, the plant studied in this work.

Crop Livestock Forest Integration (CLFI) systems acted as a catalyst to the sector. These production systems are linked to one of the major events involving warm season grasses in the county – in the 70s, after a cycle of booming expansion, some problems began to appear in the Brazilian savanna. As result of decades of extensive *Brachiaria* monoculture pests emerged and soils became invariably degraded, and the integration with crops started to be recognized as a strategy to reclaim the land productivity (LOCH E FERGUSSON, 1999).

Regardless, CLFI is a long-standing technology. Reports mention Palisade grass (*Brachiaria brizantha*) performing well under the shade of coconut trees in mid 50s, in Sri Lanka (ANKEN-LAGEFOGED, 1955); and familiar ranchers of Southern Brazil raising dairy cattle, corn and wheat integrated in the 60s. Several benefits are reachable with these systems: the current solutions to deal with red rice in waterlogged crops (Rio

Grande do Sul coast planes); nematodes in soybean (central Brazil); glyphosate resistant Italian ryegrass (*Lolium multiflorum*) (Subtropic); animal thermal comfort (Tropic); improvement of soil structure (physical and chemical) by incorporation of organic matter and reduction of compaction; etc. all increasing profitability and intensification of the land use.

Taken by the ongoing situation Brazilian forage seed industry advanced as well. New cultivars and constant rotation demanded supply of propagation material and, although vegetative planting is common in some regions of the world, most pastures are established easily by seed (HACKER & LOCK, 1997). Even in developing countries as Lao, Vietnam and Indonesia, smallholder farmers buy 1-2 Kg of forage seed to form a nursery, for further expansion using rootstocks (HARE & HORNE, 2004). Although possible, vegetative practices are labor intensive, demand specific climate conditions, and are riskier in comparison to sowing.

Seeds are easily transported and stored for long time (SOUZA, 2001; HOPKINSON et al., 1996). Sowing is a relatively simple and usual operation in most farms, allowing the use of several types of equipment (HACKER & LOCK, 1997). It permits not just to reduce expenses but support new forages to become popular, spreading technology quickly and increasing productivities. Kept some rare exceptions, seeds are a crucial input for livestock and agriculture (JANK et al, 2011; PHAIKAEW et al., 1997; HOPKINSON et al., 1996).

Considered the above, availability of *Brachiaria* seeds supported the rapid adoption of the genus in the 70s in Brazil, situation fostered by the prolific behavior of these plants: a good harvest from 1 ha can be enough to sow up to 400 ha (HOPKINSON et al., 1996). Surprisingly, nowadays shortage of seed has been cyclically reported, a productive phenomenon that also echoes in other countries, and completely applies to the plant studied in this work. Some cases are presented: *(1)* The value of Signal grass (*Brachiaria decumbens*) was known in Queensland since the 1940s (SCHOFIELD, 1944), yet its adoption was delayed until the 1960s when a combination of factors as the recognition of seed dormancy, discovery of suitable seed growing districts and use of

combine harvesters stimulated the first large scale C_4 forage seed production in the world (GROF, 1968); *(2)* The adoption of Koronivia grass (*Brachiaria humidicola*) cv. Llanero, in Colombia, which happened just after the successful local seed production (HOPKINSON et al., 1996); *(3)* In Malaysia, the lack of seeds and the further importation from Australia (IDRIS et al., 1995); *(4)* The reports of limitation in pasture development by the lack of seed in Nepal (PANDE & PRADHAN, 1997); *(5)* The lack of seeds in Ethiopia when the country was trying to establish a cultivated forage production (ABULE et al., 2011); etc.

Historically, these concerns on availability of seed reach the productive sector first, but affect also the forage breeding programs in the end (AGUILERA et al., 2002; SANTOS FILHO, 1996). Poor seed at a high price certainly result in little adoption, case of several legumes in Brazil (JANK et al, 2011) and of some *Brachiaria* hybrids in other countries. It is possible to say that the success of livestock systems based on pastures are conditioned by supplying sufficient amounts of good quality seeds (LOCH et al., 2006; MARCOS FILHO, 2007b; SOUZA, 2001; HOPKINSON et al., 1996). Since the acceptance of a species/cultivar follows this path, the seed technology is fundamental to the Alexander grass case.

The understanding of these concepts was one of the main factors that turned Brazil into the first world producer, consumer and exporter of tropical forage seeds (LIMA, 2012; JANK et al., 2011; DEMINICIS et al., 2010; SOUZA, 2003; HOPKINSON et al., 1996). *Brachiaria* is the genus with the greatest share of the market in the country (86%) equaling in monetary value to the major grain crops (JANK et al., 2011; SANTOS FILHO, 1996). Data from UNIPASTO (Brazilian association of forage seed companies that foster research and breeding of tropical forage grasses) indicate that just Palisade grass, the champion in sales of the genus, accounts for over R$ 1.3 billion (EUCLIDES, 2010). The sector formally involves more than 600 seed producers cultivating an area of nearly 150 thousand hectares in several Brazilian regions (UNIPASTO, 2015), producing more than a thousand tones $year^{-1}$ (NERY et al., 2012). Exports reach Guatemala, Honduras, Panama, Argentina, Paraguay, Bolivia, Venezuela

and some countries of Africa and Asia (NERY et al., 2012; ARAUJO, 1981). In fact, in Brazil it is produced the vast majority of the world tropical forage seed supply (LOCH, 2004).

With the recognized position in this market and the unprecedented cultivation area, Brazil should as any other country be a source of new forage options to the world. Keeping this responsibility, a determined group of researchers of several universities and research institutions of Southern Brazil has been dedicated to assess the Alexander grass forage production, an interesting forage plant to the livestock sector. The findings are unanimous in endorsing this plant ability to contribute to the feeding of the herd. Despite the wide presence in the subtropic its seeds were never formally commercialized.

Today the use of Alexander grass as forage stills prevented by two major issues: the concerns about its potential as a weed and the unavailability of seeds in the market – or even the lack of any knowledge to start an organized production.

This work compiles reviews and experiments to present a big picture of Alexander grass seed physiology and production and, to some extent, a summary of its role as a forage plant. The major aim was to provide information to produce fodder with this species in the Integrated Crop-Livestock Systems of Southern Brazil, but at the same time looking ahead for any system in which the plant could fit worldwide. Understanding subjects such as the phenology, reproduction and the behavior of the soil seed bank can also support the management of the plant when it is not desired, demystifying some worries about its endurance in the agricultural systems. Above all, we desire to provide information capable to turn a potential weed into a successful forage plant.

Overview: the main issues related to Alexander grass forage and seed production

CHAPTER 1

1. PATHWAY OF *BRACHIARIA* SEED PRODUCTION IN BRAZIL

While *Brachiaria* have been consciously and deliberately exploited by African pastoralists for millennia, serious interest in sown and manage these grasses only began in the 1960s. This occurred first on a limited scale in humid, coastal, tropical Australia, and subsequently in tropical South America, starting in Brazil in the early 1970s (MILES et al., 2004). One of the main reasons for Australia pioneering – besides a pasture based dairy sector – was the decision to organize the world first tropical pasture seed industry, which readily responded to the demand created by the "tropical pasture revolution" (ANDRADE et al. 1999; ANDRADE, 1997).

Cattle raising in the tropical world was initially based on natural pastures (ANDRADE et al., 1999). The first reports of *Brachiaria* germplasm moving internationally date from 30s, when the Signal grass accession that becomes cv. Basilisk reached Australia from Uganda (MILES et al., 2004). Systematic collections were made during 1950s (KELLER-GREIN et al., 1996), most with material exchanged among institutions in East Africa, that found its way into overseas collections such as of CSIRO and USDA. From these, small subsets were then introduced into tropical America, mostly in Brazil, but also in other countries as Colombia (MUFIOZ & BONNA, 1987).

The first official accession to enter Brazil was brought in the 50s by the IPEAN, in Belém - Pará State, for experimental purposes (ARGEL & KELLER-GREIN, 1996; KELLER-GREIN, 1996). Large scale use, however, began just 20 years late (SANTOS FILHO, 1996), a process which brought to the light of the world the *Brachiaria* potential, first known just 40 years before (a short time) in restricted ecological niches of tropical Australia (MILES et al., 1996).

At this point in Brazilian history the few areas with cultivated pastures were planted with Guinea grass (*Panicum maximum*) cv. Colonião, Stargrass (*Cynodon plectostachyus*), Molasses grass (*Melinis multiflora*) and Jaragua grass (*Hyparrhenia rufa*), all African grasses introduced accidentally in the country in the XVIII century probably by slave traffic ships (PARSONS, 1972). Except for Stargrass – which was propagated vegetatively – seeds were produced in a primitive way. It was normally

harvested by peasants or ranchers in fields of other farmers or even in roadsides where the forage grew spontaneously. These areas had no management except the removal of grazing cattle and the harvesting by the pile method. Production usually supplied just the local market and the seed had poor physical and physiological quality, since given the low performance sometimes farmers choose to plant with tillers instead of seeds (SOUZA, 2001). In the early 70s, these species still accounted for some of the seed commercialized in Brazil but loss of the interest gradually occurred given its weak persistence. It happened especially in the Amazon region, low fertility soils and areas with mismanagement. Fortunately, this coincided with the expansion of Signal grass throughout Brazilian savanna (SOUZA, 2001).

Seeds of Signal grass started to be imported from Australia, making this period a new era to Brazilian livestock (NERY et al., 2012; HOPKINSON et al., 1996; GROF, 1968). Cattle meat prices reached a peak in 1974, simultaneously to the government implementation of a support program that injected credit for pasture improvement. The measure encouraged international enterprises to enter the seed market helping also to improve the technology in the sector (ARAUJO, 1981). It should be said that the popularity of Brachiariagrasses owe much to the marketing developed by these seed traders (SOUZA, 1980) as national research institutes had no capillarity to deliver these technologies in such large scale as needed for Brazilian producers.

New agricultural boundaries of the Brazilian savanna were opened. After the fire, forage was sown initially for grazing and then to keep a soil coverage until rice or soybean could be cropped (ABEAS, 2007). The team Zebu and *Brachiaria* were the front train on the opening of Cerrado, that became today one of the major agricultural regions of the country. Signal grass drastically changed the landscape of central Brazil: the grass tolerates sandy, low fertility and acid soils, was high yielding and provided reasonable forage quality, being far superior in forage production during the dry season in comparison to the species previously available or the natural savanna forage plants (VALLE et al., 2009; USBERTI & MARTINS, 2007; SANTOS FILHO, 1996).

In this meantime other *Brachiaria* also started to be imported, including Ruzi grass (*Brachiaria ruziziensis*) and Koronivia grass (LIMA, 2012; SOUZA 2001); and huge expansion in pasture area stimulated advances in the Brazilian seed production (VALLE et al., 2009). In the late 70s Signal grass seeds harvested by manual ground sweeping began to conquer a growing share of the market. Other modern practices started to be developed and farmers gradually specialize in the activity, turning some forage fields into crops especially for seed production (SOUZA, 2001). Importation that grew remarkably between 1971 and 1974 stabilized in 1977, and then decreased. In the beginning of the 70s 90% of the seed were imported, 10 years later 90% of the seed were produced in the country (ARAUJO, 1981).

The quick changes in this scenario can be explained by some factors: *(1)* Australia was not able to supply Brazilian needs, the seed quality was never exceptional and prices huge inflated by the the sudden demand – US$ 10,00 for a kg that contained only 10% of pure live seed; *(2)* The oil crisis of 1973 helped to overly increase the freight prices, which added to the importation price made the use unfeasible for some regions; *(3)* The production techniques were rapidly developing in Brazil; *(4)* The massive expansion of the pastures allowed a large scale organized production; *(6)* After 1974 there was a decrease in meat price and after 1977 almost no government credit aid was provided, forcing ranchers to develop new strategies to reduce costs; *(7)* The mid 70s regulamentation of Brazilian Agriculture Ministry worked to control the entrance of plant diseases, complicating the importation process, and; *(8)* The Brazilian currency (Cruzeiro) devaluated in the late 70s, making international trading less interesting (SANTOS FILHO, 1996; ARAUJO, 1981; SOUZA, 1980).

Great expectations were built for Signal grass as a 'miracle grass', however, the limitations soon became apparent. Populations of spittlebugs (*Mahanarva* spp.; *Deois* spp.; *Notozulia* spp.) endorsed by the vast monocultures of susceptible host devastated large areas of the pastures (SOUZA, 2001; VALERIO et al., 1996). Nonetheless, a hepatic disorder in the cattle associated with Signal grass grazing was found to cause photosensibilization, weight loss and even death, particularly in young

animals. The cause of this phenomenon stills not entirely understood (LASCANO & EUCLIDES, 1996), besides new evidences suggest the presence of a saponin in the grass that causes lesions in the liver.

As a partial solution Koronivia grass was used, especially after 1973, when researches from IAC discovered that the species was capable to produce viable seed despite strong dormancy (SOUZA, 1980). Further experience however showed that, although Koronivia grass is tolerant to spittlebug, it stills an excellent host for the nymph, and when high populations are present severe damage can occur (SANTOS FILHO, 1996). Resistance to these pests is until today a major priority in *Brachiaria* breeding programs (SOUZA, 2001).

A solution to the problem came in 1984 when EMBRAPA released Palisade grass cv. Marandu, a resistant cultivar with high level of antibiosis to the insect. The cultivar began to displace Signal grass and other tropical grasses such as Guinea grass, Bermuda grass (*Cynodon dactylon*), and Rhodes grass (*Chloris gayana*). Further the pest resistance Palisade grass was also better adapted to medium-high fertility soils than available Guinea grass (USBERTI & MARTINS, 2007; SOUZA, 2001; SANTOS FILHO, 1996).

Marandu marked the phase of cultivars developed by the official Brazilian research system (SOUZA, 2001). The cultivar was the first successful product of the germplasm collected in the early years. Beyond that, a great expedition of germplasm collection was organized in the mid-80s by *(1)* the CIAT, *(2)* the International Livestock Centre for Africa, *(3)* the International Board of Plant Genetic Resources and, *(4)* the national agricultural research institutions of the six countries where the germplasm was collected (Kenya, Ethiopia, Tanzania, Zimbabwe, Rwanda, and Burundi). Approximately 800 accessions, comprising 23 *Brachiaria* species, were collected (KELLER-GREIN et al., 1996). Unfortunately, none of these expeditions reported Alexander grass in the material.

Meanwhile Brazilian farmers kept looking for techniques to collect shed seed from the ground. With the use of ground sweeping method, the resulting product was a mixture of ripe seed, soil, weeds, and other kinds of dirt. This seed attended at

first the internal market and then began to enter neighboring South American countries as Venezuela, Paraguay, and Bolivia (SANTOS FILHO, 1996). Actually, worldwide consumers usually do not place a high priority on cultivar uniformity and stability even today and are reluctant to pay the extra cost for it (MOSER et al., 2004). Some examples were found in Asia, where some pasture programs of the public sector were very charitable, giving large quantities of seed for free or selling it at cost price. Contemporary seed programs in Thailand subsidize prices and sell seeds at values only a little above wholesale paid to growers. This created a mentality that pasture seed must be cheap, and so many farmers are unwilling to pay higher prices for the quality provided by seed companies (HARE & HORNE, 2004).

These cases reverberate in Brazil as well. Farmers were used to buy the cheapest seed, making the decision on a price per kilo basis. Low genetic and physical purity were a common characteristic of these lots, which is probably responsible for several failures in pasture establishment (ABEAS, 2007). These choices created opportunity for dishonesty and make the regulamentation a difficult task (ANDRADE, 1997), a problem that hit tropical forage seed until the 2000s when normative instruction number 57 (December 2002), from the Brazilian Agriculture, Livestock and Supply Ministry regulated some of the marketing and production standards.

Similar situation in a worst level was reported in India, where the majority of forage seeds are uncertified, being produced and distributed in a complex network of farmers, middlemen, merchants and traders (HARE & HORNE, 2004). In Ethiopia, the sector is treated as a dual business, but prioritizing the seed production, that takes place when the farmer expects a good seeding year and favorable market for seed. If not, fodder production for feeding livestock is practiced (ESGPIP, 2010). Nowadays in Brazil, high quality seed (*i.e.* purity up to 95% and germination about 80%) can be easily found. It is, however, not always practical to sow a small quantity (*e.g.* 3 kg) of seed uniformly over a hectare. As broadcasting is common in Brazil sowing it is often easier when a product of lower quality but higher volume is used (*e.g.* 10 kg/ha of seed of 24% PLS) (SANTOS FILHO, 1996).

Notorious advances have been achieved and primitive forage seed production is already minimal compared to the size of the market. Over supplies and legislation led growers to compete for sales by raising their quality standards, which then turn into the expectation (RAINS et al., 1993). Consumer is gradually becoming more conscious of quality factors, characterizing a growing demand for sane seeds of high physiological quality and free of pests (SOUZA, 2003). These increases in demand were related also to the popularization of crop livestock systems, used in Brazil in several cases for pasture renovation (LOCH et al., 2004).

Another factor makes this sector complex: forage seeds have no major alternative use than for propagation (LOCH& FERGUSSON, 1999). Seeds of rice, corn, bean, soybean, failing to reach legal standards can be destined to industry as grain. This is however not suitable for forage, since in these cases the only destiny is to discard. Companies should so develop marketing strategies to avoid surplus at the end of the main sale season *i.e.* the high costs linked to stock, build and maintenance of warehouses threaten to make the business unprofitable.

The demand for forage seed is also more instable. This value is determined by the amount of animal product that the seeds can result, meaning that the demand for meat and dairy products drive the forage needs, and the forage drives the demand for seed (HARE & HORNE, 2004). This makes the strategy notably more complex in comparison to grains (SOUZA, 2003; HARE & HORNE, 2004), a situation reported in Australia as the one of the main reasons for growers to abandon the seed sector, looking for more stable crops such as sugarcane (HACKER & LOCK, 1997).

To avoid the abandoning of the activity some countries adopted pluralized strategies. Thailand, for example, developed a successful contract seed cropping system in which smallholder farmers produce most of the seed. The production is then bought, processed and marketed by the government (PHAIKAEW et al., 1997). In the north of the country it became the main commercial crop (HARE & HORNE, 2004), since over 3,000 farmers harvest and sell seeds annually to the government, reaching better profits than the previous crops of cassava and rice (HARE et al., 2013). A similar strategy

could be adopted for forage seeds as Alexander grass to replace systems that failed to sustain small farms in Southern Brazil.

These markets are very diverse, ranging from smallholder 1 ha areas in Thailand, to farms with more than 1,000 ha under production in central Brazil (HACKER & LOCH, 1997). To deal with the globalization, the formation of trade blocks can ease the commerce of seeds among countries, and open new opportunities for the microeconomic pasture seed industry (ANDRADE, 1997).

Nowadays the discontinuity of investment on the tropical pasture programs of other world institutions helped Brazil to get the leadership of tropical forage breeding. The more significant programs are developed by EMBRAPA, which invested in various forage genera in the last three decades (especially *Brachiaria* and *Panicum*) – today, more than 70 % of the cultivars in used worldwide were released by EMBRAPA and its partners (VALLE et al. 2009). Unfortunately, Alexander grass stills not included in these programs.

2. ALEXANDER GRASS CLASSIFICATION ACCORDING TO THE *BRACHIARIA* GENUS AND THE CORRELATED WARM SEASON GRASSES

C_4 photosynthetic system occurs in 18 families of flowering plants, including the grass family (*Poaceae*) which contains about 60% of these species (MOSER et al., 2005). Within that, *Paniceae* – the tribe that contains the *Brachiaria* genus – is highly diverse and rich as well, assembling 2,000 species and comprising one-fifth of the family (DUVALL et al., 2001). *Brachiaria*, equal, is a large and poorly delimited genus with nearly 100 species distributed most in the tropics, but present in all continents except Europe. It grows naturally in a wide range of habitats from swamps and forest shade to sunny semi desert areas, since most species are typically found in savannas (RENVOIZE et al., 1996).

The great diversity in these groups made different evolutionary schemes to be proposed. Recent findings brought the phylogeny of *Paniceae* to some changes, but the taxonomical delimitations still unclear (ZULOAGA et al., 2000; DUVALL et al., 2001; GIUSSANI et al., 2001; ALISCIONI et al., 2003). Together with *Eriochloa, Urochloa, and Panicum, Brachiaria* form a closely related group (RENVOIZE et al., 1996). Taxonomic allocation is not satisfactory for species relation neither in the inter-relations with other genus (RENVOIZE et al., 1996). Some authors contend that many *Brachiaria* species, including Alexander grass and other economically important, should be classified as *Urochloa*. Webster (1987) argument is that species that the upper floret disarticulates from the rest of the spikelet deserved recognition as a distinct genus, separated from those species which upper floret disarticulates below the lower glume. Monrone and Zuloaga (1992) followed the same proposition (GONZÁLEZ & MORTON, 2005). Alexander grass specifically was not included in the changes by these last authors.

To demonstrate the confusion, in some of these studies there is a proposal to transfer Guinea grass also to *Urochloa* (WEBSTER, 1987), and Alexander grass is reported as one of the closest species to Guinea grass (GIUSSANI et al., 2001; ALISCIONI et al., 2003). A detailed study developed by Reinheimer (2005) comparing

Alexander grass to Guinea grass morphologically and anatomically provided rich information in relation to the axis *Panicum-Urochloa*. As a major conclusion the author found several differences among the species and disagreed with the classification changes.

Orthodox taxonomists defend the traditional *Brachiaria* as species such as Palisade grass and Tanner grass (*Brachiaria arrecta*), which have relatively large, oblong or elliptic spikelets, arranged in a regular row along one side of a flattened ribbon-like rachis (ASSIS et al., 2003; RENVOIZE et al., 1996). However, many species do not conform to this pattern. Renvoize et al. (1996) reviewed 8 species of the genus *Brachiaria* in which morphological characters revealed a remarkable diversity making correlations difficult. This explains why previous authors were unable or reluctant to establish credible infrageneric divisions.

As mentioned, *Urochloa* is supposed to be distinguished from *Brachiaria* by the orientation of its spikelets. This, however, becomes indeterminate when spikelets are paired (as in Alexander grass) or in long pedicels. This means that other features are needed to differentiate *Urochloa, such as* its planno-convex, cuspidate spikelets (Which may also occur in *Brachiaria*) and mucronate upper lemma. Numerous species of *Brachiaria,* however*,* have an apiculate upper lemma, and other species have a mucro of 1 mm long. While these characters certainly circumscribe a group of allied species, and the two genus could well be united under the name *Urochloa*, on the other hand the placing of marginal species is open to subjective interpretation. In addition, the deciduous upper lemma does deserve recognition and the name *Brachiaria* could therefore be maintained, which is not a satisfactory solution (RENVOIZE et al., 1996).

In conclusion to the case of Alexander grass, it is resorted to one of the most recent studies on *Brachiaria* classification, developed by Renvoize et al. (1996), which identified nine groups within the genus. The four world economically important species belong to two of the nine: Signal grass, Palisade grass, and Ruzi grass are closely related (groups 5), while Koronivia grass falls in a separate group (group 6).

Alexander grass, in turn, was placed in Group 4 – an intermediate position between species such as Palisade grass, Ruzi grass and Signal grass (Group 5) and Tanner grass and Para grass (*Brachiaria mutica*) (Group 3). Group 4 (and 3) has some distinctive appearance from the others, largely because of the flat ribbon like rachis which imposes more order on the arrangement of the spikelets on the raceme. The spikelets have short pedicels in neat rows, and are either dense and at an angle or spread out and appressed. The morphological description of the group follows: two to several racemes, usually scattered along a central axis, ascending or spreading; rachis is narrow, bearing solitary spikelets on short pedicels, with spikelets appressed and lax or spreading and dense. Spikelets are ovate or narrowly ovate, turgid or compressed. Lower glume: cuff like, stipitate. Upper lemma: rugulose (RENVOIZE et al., 1996); which precisely matches Alexander grass description.

It is important to point, though, that morphological characters have been used as identity signatures, building a poor basis since it is an indirect measure of genetic composition (environmental influences). A better approach will be obtained when molecular characters start to be used, revealing genetic differences more precisely and offering substantial advantages in terms of discrimination (ASSIS et al., 2003). A phylogenetic analysis performed by Torres-González (1998), based on nucleotide base sequence polymorphisms of the internal transcribed spacer region of nuclear ribosomal DNA did not separate *Brachiaria* and *Urochloa*. Nonetheless, higher variability can be found within the species, among the accessions: a study achieved 24% of the variability in the relations among Palisade grass, Signal grass, Ruzi grass and Tanner grass; and 76 % within each species, among accessions and cultivars (AMBIEL, 2008). These findings raise questions yet about the genetic variability in the Alexander grass indigenous biotype that despite not presenting evident morphological variations in the region of Southern Brazil can hide valuable variability in genetic basis for a breeding program. This information stills open to conjecture.

Due to the lack of consensus, for this work it was chosen to keep using *Brachiaria plantaginea* as the scientific name for Alexander grass.

3. WARM SEASON GRASSES ECOPHYSIOLOGY AND ENVIRONMENTAL REQUIREMENTS FOR SEED PRODUCTION

Most *Brachiaria* cultivars used in Brazil are wild plants as Alexander grass, collected in the nature and spread out for pasture with no genetic manipulation. Selections were performed firstly following the primary role of the genus in tropical agriculture: to provide forage on low-fertility soils (MILES et al., 2004), as the case of Signal grass in central Brazil (SANTOS FILHO, 1996). Still, nowadays forage grasses are submitted to a far more complex evaluation process.

Increasing consumer demands forced programs to evolve and – despite soil adaptation that keep as a guideline in the programs – other goals were added as the adaptation to subtropical environments, adaptation to low temperature, tolerance to shade, resistance to drought, more uniform distribution of production through the year, palatability and absence of toxins (SANTOS FILHO, 1996); increases in forage quality and yield (VALLE et al., 2009; SANTOS FILHO, 1996) and pest resistance (VALLE et al., 2009; MILES et al., 2004). Alexander grass is a bearer of several of these characteristics.

The list of goals in tropical forage breeding also evidences the fact that these plants are usually selected to maximize biomass production (specially leaves) – since their value are determined by animal use these grasses will achieve its purpose when able to be converted into products as meat, milk, leather, wool, etc. (VALLE et al., 2009). Unfortunately, this characteristic generally competes with seed production (VERZGNASSI, 2015; HUMPHREYS & RIVEROS, 1986; SANCHEZ et al., 1982). Modern approaches, however, also emphasize seed production potential as one of the major parameters to the initial selection of genotypes (VERZGNASSI, 2015; VALLE et al., 2008), since if the cultivars are not able to produce decent amounts of seed it will not be widely adopted.

Another aspect that complexes the selection is that best conditions for seed production rarely coincide with those for biomass production (VERZGNASSI, 2015; DEMINICIS, 2010; ANDRADE et al., 1999; PHAIKAEW et al., 1997; HOPKINSON et al., 1996). Some examples are cited: *(1)* Koronivia grass not capable to produce seed on

humid tropic lowlands; however, it is well adapted to produce biomass in these regions (ANDRADE et al., 1999). *(2)* Palisade grass do not produce seeds on latitudes lower than 10^{o}, but it is a remarkable forage producer there (HOPKINSON et al., 1996). *(3)* Many tropical grasses flower continuously in Malaysia – a country located near the equator line – besides they are used in other locations just for pasture (IDRIS, et al.,1995).

One of the major concerns thus is the regional adaptability *i.e.* the sum of many biotic, edaphic and climatic effects that will determine the seed crop performance (LOCH et al., 2004). It raises demands for knowledge about some key-issues to achieve good seed productivity. Even tough, much of the early information relating to C_4 grass seeds still coming from forage trials (LOCH et al., 2004) or weed trials in the case of Alexander grass. As most of these factors are not controllable, the choice for the production site is of central importance to maximize yields (SOUZA, 2001).

Little is known about the *Brachiaria* genus to provide a single picture of their reproductive behavior (HOPKINSON et al., 1996). An advantage on this matter is that – despite the size – the family *Poaceae* is a very coherent one among flowering plants (CHAPMAN, 1990). Successful commercial seed production sites in summary must combine conditions for vigorous vegetative growth, proper stimulus for flowering and effective seed set, and a dry period for harvest (MILES et al., 2004; ANDRADE et al., 1999; HOPKINSON et al., 1996).

Many tropical grasses, as well as several *Brachiaria* species, present yet some sort of juvenility (HOPKINSON et al., 1996). These plants will be insensitive to stimulus during a period, which appears to end when the tiller accumulate sufficient photoassimilates or reach a minimum number of nodes, making the plant 'ripe to flower' (LOCH et al., 2004; CONTRERAS, 2007b). This phase is usually short and difficult to identify, and is not always represented by chronological time but by the development of the plant. In other words, situations as mineral deficiencies, low irradiance, water stress, defoliation, cold, etc. tend to alter this phase, influencing then the overall management (CONTRERAS, 2007).

Exceeding the juvenility and receiving the proper stimulus the plant will reach floral initiation, marking the beginning of the reproductive phase. These events conceptualize as physiological changes that allow the development of reproductive primordia (MARCOS FILHO, 2007a). It will culminate in the formation of flowers and its reproductive organs, when much of the yield potential is determined: initially vegetative shoot apex elongates, initiates racemes, and degenerates; the racemes develop “ridges" that differentiate into spikelet and then into floral parts (HOPKINSON et al., 1996). The next step will be the actual flowering or anthesis, which marks the exposure of anthers and stigmas to the pollination agents. It is thus possible to say that providing suitable flowering condition is fundamental to a good pasture seed production (IDRIS et al., 1995)

In summary, the region should provide ample availability of light, rain and temperature for vegetative growth; and in some cases favorable photoperiod (daylength) for floral induction (ESGPIP, 2010; ANDRADE et al., 1999; HOPKINSON& ENGLISH, 1985). Some of these factors are detailed below:

3.1 Radiation and Photoperiod

Tropical grasses seed production is endorsed by high radiation and sunny weather (ESGPIP, 2010; HUMPHREYS, 1975). Reductions in light availability promote decrease specially in biomass production and carbohydrate accumulation (RODRIGUES & RODRIGUES, 1987) reducing consequently the amount of reserves further used for seed filling in the late phases of the cycle (ESGPIP, 2010).

Beyond that, the period that the plant is exposed to luminosity can influence the flower induction as well. Flowering in many C_4 grasses is under some form of photoperiodic control (ESGPIP, 2010; LOCH & FERGUSSON, 1999; LOCH et al., 2004; CONTRERAS, 2007b; HOPKINSON et al., 1996), since the daylength plus the temperature (*further discussed*) are the two primary environmental cues that regulate these plants flowering (CONTRERAS, 2007b). According to photoperiodic responses plants can be

classified so as short-day, long-day and indifferent. This could also be detailed yet as qualitative (obligate) and quantitative (non-obligated).

Species may differ markedly in their response, even when originating from the same latitudes (LOCH, 1980; ISON &HOPKINSON, 1985). Short-day responses are most common near the equator, a behavior that is perhaps a form to delay seed ripening until the seasonal dry period in tropical Africa (center of origin of several of these grasses) (LOCH et al., 2004). At higher latitudes in the subtropics, in contrast, long-day responses become more prevalent, possibly in combination with lower temperatures before flowering can occur (*e.g.*, Narrow leaf carpetgrass - *Axonopus fissifolius*). These species tend to flower as the days lengthen in late spring and summer, avoiding thus potentially damaging temperatures in late autumn or early winter, when short-day grasses flower (LOCH et al., 2004).

Qualitative plants generally show a sharp division between growth phases, remaining purely vegetative unless reached a critical daylength. In quantitative grasses, in turn, vegetative and reproductive phases are not as well-defined (LOCH, 1980), since the plant keep producing new shoots even after some tillers became reproductive (indeterminate). Empirical observations on Alexander grass evidence that this grass tend to fit better in the quantitative model.

For some world important species some reports gave indications about the responses over photoperiodic stimulus:

(1) In the tropical humid region Koronivia grass flowering is stimulated by long-days (MILES et al., 2004; HOPKINSON et al., 1996), presenting a single flowering peak.

(2) *Brachiaria dictyoneura* seems to behave similar to Koronivia grass (VELA et al., 1991; CIAT, 1986)

(3) Ruzi grass present quantitative responses to short-days (WONGSUWAN, 1999; HOPKINSON& ENGLISH, 1985). Synchronized flowering occurs about

March in the Brazilian subtropic, with a single peak and strong flowering (HOPKINSON et al., 1996).

(4) Palisade grass flower in artificial continuous light, which could give clues about an indifferent photoperiodic response (ISON & HOPKINSON, 1985). In high latitudes of tropical America, however, it will present 2 flowering peaks (SOUZA, 2001) and reproductive seasons will be recognizable in a long-day response (MILES et al., 2004; HOPKINSON et al., 1996).

(5) Signal grass present two flowering peaks (SOUZA, 2001), particularly in high latitudes (MILES et al., 2004), which for Hopkinson et al. (1996) infer a long-day response. In low latitudes it flowers constantly along the year (MILES et al., 2004), as well as under controlled continuous light, which for some authors can indicate insensitivity (ISON & HOPKINSON, 1985)

(6) Rhodes grass has a quantitative short-day response (MARCOS FILHO, 2007a).

(7) Souza (2001) suggest that Guinea grass behave as a short-day plant, however other authors state that in short or medium-day controlled environment it flowers unrestrictedly, evidencing a daylength insensitive response (LOCH & FERGUSSON, 1999; ANDRADE et al., 1983)

(8) Para grass its a short-day qualitative plant (MARCOS FILHO, 2007b).

(9) Dallis grass (*Paspalum dilatatum*) and Bahia grass (*Paspalum notatum)* are qualitative long-days plants (LOCH & FERGUSSON, 1999).

(10) Bermuda grass is a long day plant (LOCH & FERGUSSON, 1999)

(11) Rhodes grass is daylength insensitive (LOCH & FEGUSSON, 1999)

For further information on daylength response of other warm season grasses see the summarized table in the Appendix (pg.356).

The knowledge of flowering responses will determine where and when seed crops of a particular species could be grown away from their native environments (LOCH et al., 2004), a fundamental information for a future Alexander grass seed production activity. Usually greater difficulties arise at low latitudes, near the equator, where the photoperiod variation is too short to trigger the flowering (HARE & HORNE, 2004; HOPKINSON et al., 1996). A clear example comes from Colombia, where at about 5° N Koronivia grass flowers but fails to set seed, and seed production of Signal grass and Palisade grass are very low. Only *B. dictyoneura* cv. Llanero (further classified as *B. humidicola*) flowers and sets seed enough to permit commercial production (SANCHEZ & FERGUSSON, 1992). Reports about that also are found in Asia, in regions including Malaysia, Indonesia, Cambodia, Vietnam, and southern parts of Thailand (HARE & HORNE, 2004).

This, however, is not the case of Southern Brazil where Alexander grass better develops (˜25^{o}S). Variation in daylength increase around 75 min for each 10° of latitude (LOCH et al., 2004; HOPKINSON et al., 1996) and thus this region will present sufficient seasonality for most daylength sensitive plants. Alexander grass, as mentioned, performs better in these high latitudes (subtropical or tropical transition zones) considerably reducing its vigor in regions under 20^{o} or above 30^{o}. As a hypothesis, the poor performance in low latitudes could have some sort of daylength influence, since the high temperatures encountered in these tropical zones (close to 40^{o}C) seems not to be a problem to the plant when it is placed in proper moisture environments of the subtropic.

3.2 Temperature

Together with daylength, air temperature is a major factor governing the growth of warm season grasses and can same way influence the seed crop phenology (CONTRERAS, 2007b; LOCH et al., 2004; LOCH, 1980). This condition will be determinant to vegetative period, floral induction, inflorescence differentiation, flower opening, pollen germination and subsequent seed set and maturation (ESGPIP, 2010).

As well as for photoperiod, optimum temperature for growth is usually different from the optimum temperature for high seed yield (ESGPIP, 2010). Besides that, a strong correlation for the reproductive and vegetative phases is accepted. To put it in numbers for all grasses a basal temperature is established, on which vegetative development cease or become irrelevant (VILLA NOVA, 2007). The index has a superior and an inferior limit and values depend on the species and region where the plant comes from (ALCANTARA et al., 1993; RODRIGUES et al., 1993). In general, tropical species withstands higher values (VILLA NOVA, 2007).

Based on basal temperature a thermal time is determined. For the calculation, air temperatures above the basal temperature are accumulated – when it reaches the thermal time the plant is induced to flower. Below the basal temperature, growing is irrelevant or so slow that could be dismissed. Tropical and subtropical grasses require warm conditions, with minimum temperatures of near 16°C (LOCH & FERGUSSON, 1999). It matches with the estimated for Signal grass and Palisade grass, that corresponds for 17^{o}C and 15^{o}C, respectively (MENDONÇA & RASSINI, 2006). For Alexander grass the basal temperature stills not determined – despite Paula & Streck (2008) estimated the value between zero and 17.5^{o}C, this result is far from conclusive.

The presence of Alexander grass in subtropical climates signals to a cooler environment adaptation and a lower basal temperature than other *Brachiaria*. This is reinforced by the findings on the phyllochron of the plant, varying from 37.8 to 71.7^{o}C day leaf^{-1} (MIGLIORINI, 2012), lower than those presented for Palisade grass of 98.4 to 133.4 ^{o}C day leaf^{-1}, for example (SBRISSIA, 2004).

Nonetheless, temperature looks to influence directly not just in Alexander grass cycle but also in seed behavior, once it constructs stimulus for germination itself. Dantas et al. (2000) stated that Alexander grass seeds germinate in temperatures between 20^{o}C and 30^{o}C, but it is possible that seed base temperature reaches 10^{o}C (KALSING, 2011). Carrolo et al. (1997) observed that the plant presented germination from 326 accumulated hours; optimum however will take place around 624 and 720 hours of thermal sum, which corresponds to average temperatures of 26^{o}C to 30^{o}C. This justify why in South American countries Alexander grass seeds germinate mainly in the early spring months. Particularly in Southern Brazil seedlings will emerge from the soil seed bank mainly in mid-October (KALSING, 2011).

For all these issues temperature extremes can considerably reduce seed productivity. Controlled environment experiments have shown that high day temperatures and low night temperatures can inhibit inflorescence production. The consequences in plant physiology can be related to phenological triggering or simply to the accumulation and translocation of photoassimilates (LOCH, 1980).

Inhibition of inflorescence production by low temperatures were observed in Gamba grass (*Andropogon gayanus*) (LOCH et al., 2004); reductions in seed set in Rhodes grass; irregular flowering and increases in the time that anthers remained pendant without dehiscing in *Paspalum* and; non exertion of anthers and male sterility in *Pennisetum* and *Brachiaria* species (LOCH & FERGUSSON, 1999). Similar situation was reported in Southern Queensland where seed crops develop and ripe very slowly during winter, with reduced rates of inflorescence emergence and anthesis, and further reduced seed set (LOCH 1980). Examples become even more important as latitude and altitude increase - in the Cauca Department of Colombia (3" N) a strong relation between performance, latitude and altitude has been observed (FISHER & KERRIDGE, 1996). These environment effects (particularly cold) are important for Alexander grass since autumn determines the end of its cycle. Particularly in the subtropical region if this climate condition hit the plant when reproductive phase is not concretized yields and seed quality can be drastically reduced.

Lower temperature at higher altitude is also reported to stimulate early flower induction, even in the absence of a distinct photoperiod stimulus (MILES et al., 2004). Particularly for Koronivia grass it seems that flowering, seed production, and seed quality are boosted in higher altitudes (not performing well at low latitudes). These effects of temperature need to be investigated further, as it has important implications for the release and adoption of new species or cultivars (FISHER & KERRIDGE, 1996).

Complex interactions involve thus temperature and daylength. Other climate factors are already accepted, influencing firstly flowering induction but also other behaviors (LOCH et al., 2004; LOCH & FERGUSSON, 1999; LOCH, 1980). Alexander grass growing in hotter months presents smaller phyllochron values and *vice versa*. A hypothesis is that photoperiod plays some role in Alexander grass vegetative period affecting for example the leaf emission, as happens in wheat (STRECK et al., 2003).

3.3 Rainfall and humidity

Temperature and daylength usually are the most important influents for flowering induction, however some others factors can also impact the phenology of the plant. Among these providing good water availability is fundamental (LOCH, 1980; CIAT, 1982).

During the plant development there is three critical stages in which seed yield is strongly influenced by water deficit: *(1)* Flower initiation/inflorescence development, when seed number is determined; *(2)* Anthesis and fertilization, when seed set is determined and; *(3)* Seed filling, when important traits of seed physiological quality are fixed (HOPKINSON, 1977; LOCH, 1980; LOCH et al., 2004). Indeterminate species as Alexander grass has some advantages, since the plant places inflorescences at different moments and avoids the shortages to hit all the flowers at the same time. Besides the worst effects in critical periods, distribution of rainfall during other moments of the cycle is also important (LOCH, 1980) – in Thailand, for example, there

are reports of erratic rainfall at the start of the season causing problems for many seed crops of warm season grasses (GOBIUS et al., 2010).

Excessive humidity, in contrast, can bring complications as well. For some authors water lack after a vigorous growing period is important to induce abundant flowering, preventing a continuous vegetative sward. Still, drought appears to improve tiller synchrony, presumably by reducing the sward density and by allowing N absorption to temporarily stop, and later be suddenly released in abundance when the drought breaks (HOPKINSON et al., 1996).

As mentioned, Alexander grass is a plant well adapted to produce forage in humid and warm climates. For seed crops in which sward mass is not controlled by grazing or cut, however, lodging can easily appear. This phenomenon is also reported in regions above 20^{o} latitude of Southern Asia as Northern Laos, Vietnam and Myanmar (HARE & HORN, 2004), same latitude of Southern Brazil. Sites with strong winds worsen the problem, influencing yet premature shattering (ISGPIP; 2010; SOUZA, 2001).

Wet periods can influence seed quality after the seed shed as well (MARCOS FILHO, 2007d). This will be particularly important for crops harvested from the ground. Sporadic rainfall has no harm beyond delays, but if it becomes more frequent, losses in seed physiology can occur (SOUZA, 2001). The problem is also a particular inconvenient for Koronivia grass in Brazil that is harvested in the plant, presents synchronized inflorescence emergence and a very short window before seed shatter.

Generally, most of warm season grasses cultivated in Brazil will depend on high rainfall regimes (<800 mm) to perform well (LOCH, 1980). An average annual rainfall well distributed of at least 800 mm with upper limit of 1500-2000 mm provides good moisture (ISGPIP, 2010). For the Alexander grass in Southern Brazil, in most places total annual rainfall will certainly be enough (around 1800 mm).

3.4 Soil and Nutrients

The importance of proper soil conditions for forage seed production has been emphasized for half a century. This increases the yield and lower the costs, as well as varieties that have been regarded as shy seeders are capable to reach high productions when grown under a suitable fertilization regime (HUMPREYS & DAVIDSON, 1967). Physical and Chemical soil needs will vary among species, but for *Brachiaria* a good picture can be constructed.

Usually seed producers who chose the ground sweeping harvest will prefer a sandy or mid-sandy ground (HARE & HORNE, 2004; SOUZA, 2001). The choice follows the fact that in the presence of clay soil clods the seed processing can be complicated. It frequently results in decreases in lot purity, even at cost of considerably losses in the separation. Another point presented in clay soils is the formation of cracks in the surface, through which seeds can get lost by burying (SOUZA, 2001).

In contrast, soils with sandy texture commonly have low water-holding capacity (HARE & HORNE, 2004) and low fertility levels (SOUZA, 2001), which despite fertilization management fallouts in lower potential productivity. Regardless, as a broad option this is the preference since at least the first point is relatively manageable. Even most sandy to mid-sandy soils being acid and low in organic matter, nitrogen, phosphorus and sulfur, tropical grasses will grow decently with fertilizer addition.

In Brazil there is little research to define fertilizer levels for forage seed cropping. These rates are based essentially in evidences from pasture production and experiences accumulated with grain crops (ANDRADE, 2001). Nonetheless, fertilizations for forage production stimulate the development of vegetative structures (tiller, leaves, etc.), as in seed production reproductive structures are supposed to be prioritized (CATUCHI et al., 2012). This statement is even more prevalent for nitrogen, particularly in well responsive species as Alexander grass.

N is imperative for seed production (LOCH, 1980), the nutrient compose around 3 to 5% of dry mass, and when provided present responses in important processes as: *(1)* increases in tillering and – consequently – inflorescence number per

area (VENDRUSCULO, 2014; PANCERA JR et al., 2011; TORRES et al., 2009; ANDRADE, 2002; JORNADA, 2002; GOBIOUS et al., 2001; WONGSUWAN, 1999; HOYOS et al., 1997; HOPKINSON et al., 1996; CONDE & GARCIA, 1988a; MECELIS & OLIVEIRA, 1984; LOCH, 1980; BOONMAN, 1972); *(2)* enhance of vegetative growth; *(3)* improvements in fertile tillers determination (CANTO et al., 2012); *(4)* increases in seeds per panicle (TORRES et al., 2009; JORNADA, 2002); *(5)* increases in racemes number (CONDE & GARCIA, 1988a); *(6)* increases in thousand seed weight (MARCOS FILHO, 2007c; CANI, 1980); *(7)* improvements in general seed quality (DEMINICIS, 2010; CONDE & GARCIA, 1988a) and, finally; *(8)* increases in seed yield and pure seed yield (CATUCHI, 2013; PANCERA et al., 2011; DEMINICIS, 2010; TORRES et al., 2009; DEMINICIS et al., 2003; SATYRO et al., 2003; GOBIOUS et al., 2001; CONDE & GARCIA, 1988a). Some evidences indicate yet that nitrogen metabolism needs to be boosted for floral induction in short-day plants (ABEAS, 2007). Improvements in tiller density highlight as the most – and sometimes the only – affected component by N fertilization (ANDRADE, 2001), which is not a problem once field management becomes generally a matter of stimulating the highest density of seed heads as close synchronized as possible (LOCH, 1980).

To maximize this nutrient benefit, it is convenient to use the suitable fertilizer amounts. The optimum levels for *Brachiaria* seed crops vary among authors: 70 Kg N ha^{-1} (HOYOS et al., 1997); 100 Kg N ha^{-1} (BOGDAN, 1977; BOONMAN, 1972), 130 Kg N ha^{-1} (LIMA, 2012); 120 to 150 Kg N ha^{-1} (CONDE & GARCIA, 1988a), and; 160 Kg N ha^{-1} (CONDE & GARCIA, 1988a). In the last case the author reported a 3 times increase in gross productivity and a 10 times increase in viable pure seeds production, in relation to the control treatment with no N application (CONDE & GARCIA, 1988a). Mineral sources could be replaced by manure, a better option specially for smallholder agriculture. 5-10 T ha^{-1} potentially provide the same results of 100 – 150 Kg urea ha^{-1} (ESGPIP, 2010). Unfortunately, there is no nitrogen level data specifically for Alexander grass seed production.

It is important to point that fertilization efficiency will be correlated to previous soil levels: the lower the soil levels, the higher the responses. Other prevalent

factors can be the grass stage (HUMPREYS & RIVEROS, 1986), the row spacing (CIAT, 1982) and the application fractioning (LOCH, 1980). Thus, timing will be essential: there is usually a relatively short time between tiller appearance and floral initiation. It is accepted that to promote maximum yields, N should be applied as a single dressing as soon as possible after the uniformization cut.

For the other two major nutrients (P, K) responses are diverse. Phosphorus generally do not present effects on grass seed yields (GROF, 1969; DEMINICIS, 2010), being more important on legumes (MEJIA et al, 1978). Despite that, Rao et al., (1996) observed increases in roots and shoots in Brachiariagrasses with P addition. Potassium presents also unclear results, since positive effects can be observed (CATUCHI, 2013) or not (DEMINICIS et al., 2010) depending on the situation.

Over any particular aspect, complex interactions among factors will take place in the field and thus areas are best regarded as suitable rather than ideal (SOUZA, 2001; LOCH, 1980). Although production is possible under a wide range of conditions, it is efficient only in few places. Relevant factors are mostly local and the alternatives to make seed production commercially viable can integrate the activity with other uses such as grazing, hay, and rotation, in a crop-livestock system (HOPKINSON et al., 1996).

Yet, sites cannot be characterized in a general form as 'Warm grass seed production suitable and profitable' (HOPKINSON et al., 1996; LOCH, 1980). A micro-geographical mosaic of suitability traits appears in different districts, and even this may change with time as the economical patterns and demand fluctuates (HOPKINSON et al, 1996). Brazil has no climatic zoning for tropical forage seed production (VERZIGNASSI, 2015), which makes even complex the decision for the proper location.

4. CHALENGES ON PHENOLOGICAL BEHAVIOR OF WARM SEASON GRASSES

Commercial C_4 forage seed production embodies a challenge on agronomical matters. In agriculture history modern tropical pasturing itself is a recent activity, even when compared to temperate species: it started in the early XX century at Southern Africa and Eastern Australia by the hand of smallholder ranchers and got considerable expression just after the 70s (SOUZA, 2001; LOCH & FERGUSSON, 1999; HACKER & LOCH, 1997; CIAT, 1982). If compared to grain crops as corn and soybean that have been domesticated around 8,000 BC and 7,000 BC, respectively, it is possible to have the dimension of these statements on the forage crop evolution.

Breeding for these grasses are also a recent science. Only in the last decades the germplasm collections were organized, accessions characterized, data documented, and seeds conserved in the short and long term (JANK et al., 2001). The majority of forage grasses still as wild plants, product of mass selection that have not been substantially altered by breeding and their behavior is so similar to the wild form (HACKER & LOCH, et al., 2004; SOUZA, 2001; ANDRADE et al., 1999; LOCH & FERGUSSON, 1999; SIMPSON, 1990). Despite, new techniques allowed breeders to develop *Brachiaria* hybrids, which are progressively changing the way grass breeding is faced. Alexander grass itself is a great forage plant, but maybe its real place in the production system can be achieved after some interspecific cross.

This scenario put on the table a young sector. In many cases seed producers still learning how to manage and process these plants, once few controlled environmental studies have been conducted on its reproductive physiology (LOCH et al., 2004). Detailed knowledge about flowering habits and growth requirements are lacking (LOCH & FERGUSSON, 1999), but at the same time, some traits that complicate the achieving of high productivities are present in the majority of the species, and thus deserve to be underlined. The main examples are the prolonged inflorescence emission, low number of tillers producing panicles, irregular anthesis, stigma exsertion within the panicle, low seed set, shattering and seed dormancy (LIMA, 2012; PANCERA JR., et al., 2011; WONGSUWAN, 1999).

4.1 Irregular Inflorescence emergence and shattering

Independent on tiller production, most warm season grasses lack synchrony on panicle emergence. This is empirically observed in Alexander grass as well (Figure 1) and will has a notably influence on harvest processes and total seed yield (HARE et al., 2015; MASCHIETTO et al., 2003; SOUZA, 2001; BOONMAN, 1971).

Figure 1. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) panicles emerging in late December (2014). Some tillers are already fertile while others keep the vegetative development (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Not enough, variability within the C_4 grasses inflorescence is also present (BOONMAN, 1971). Indeterminate inflorescences contain simultaneous reproductive and vegetative development, with flowers forming usually first on the oldest part of the panicle and rachis *i.e.* these are the first gems that differentiate during the changes in the primordia (MCDONALD & COPELAND, 1997). As example, the average time for an inflorescence to complete anthesis reaching both distal and proximal portion of the panicle, is 4.3 to 4.6 days for Bahia grass, 5.6 days for Dallis grass, 8.1 days for Ribbed

paspalum (*Paspalum malacophyllum*), and 8.2 d for Vasey grass (*Paspalum urvillei*) (LOCH et al., 2004). In practical terms, it means that chopping an inflorescence with some ripe seeds in the apex, emulating what happen in mechanical harvest, some seeds will shed and others (immature) will keep attached to the rachis, being potentially squeezed and damaged by the machine. The same inflorescence will have also empty spikelets and florets on early anthesis (MASCHIETO, 1981). Data on maturation time within the inflorescence for Alexander grass (and other Brachiariagrasses) is not available.

A great complication about the heterogeneity issues is that in most Tropical Panicoid grasses the seeds physically developed (not the same of mature) will be readily shattered. Morphologically, shattering is the collapse of the abscission layer that holds the seed, which appears as a ribbon of thick walled cells, extending across the pedicel (Figure 2). About a week after anthesis the abscission cells elongate and collapse, small lacunae is initiated adjacent to the vascular strands increasing in size until crush the vascular and pith cells to a complete disintegration (Figure 3). Spikelets can sometimes remain attached to the pedicels by the epidermis (BURSON et al., 1978).

Figure 2. Tip of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) raceme. Detail in the whitish abscission layer evident especially in the distal spikelet. While the rachis presents a notably fibrous aspect, the abscission layer discontinues the longitudinal fibers, being fragile and collapsing after the seed development (*Picture Source: J.R. Oliveira - OLIVEIRA, 2017*).

Figure 3. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) raceme. Spikelets in the proximal portion (*right*) and abscission layer scars in the distal (*left*) (*Picture Source: J.R. Oliveira - OLIVEIRA, 2017*).

Tropical grasses differ from temperate grasses because the abscission layer places below the glumes rather than above (LOCH & FERGUSSON, 1999; Figure 2), making the seeds to fall immediately after the disruption (LOCH & FERGUSSON, 1999; SENDULSKY, 1978). In temperate species, it will be kept encapsulated in the glumes. Still, this phenomenon is particularly present in *Brachiaria* species, being stimulated also by pouring rain, strong winds or deficiencies in nutrients, water and light (SOUZA, 2001).

The relative importance of these limitations varies from species to species. In most situations, the team immature seeds and shedding are responsible for the heaviest losses in production. Although it may be minimized through careful selection of harvest date and method, it easily exceeds 50% when opted for combines. This will probably not be reduced until a gene controlling spikelet abscission gets incorporated to forage cultivars. Unfortunately, no such gene has been identified (HACKER & LOCH, 1997; LOCH & FERGUSSON, 1999), and breeding keeps trying to deal with that searching for accessions with lower shattering and better synchronized

flowering/maturation (VERZIGNASSI, 2015). Reports suggest also that seed retention is controlled as a qualitative trait, involving a series of expression genes, which will require even more recurrent selections to fix (YOUNG, 1991).

Other impasses can appear as forage naturally is selected by its capacity to produce leafy herbage continuously throughout the season - attributes not readily compatible with commercial seed production where dense uniform flushes of inflorescences are desired (LOCH, 1980). Selection for improved seed retention in Kleingrass, for example, showed some promise but has not led to the release of a cultivar because these accessions lack other important attributes of a forage plant (LOCH et al., 2004).

For the current popular Brachiariagrasses used in Brazil a panorama can be traced. On usual management, Koronivia grass present well-synchronized flowering, allowing just about 3 days for combine harvest before a considerable part of seed is shed (HOPKINSON et al., 1996; MECELIS & SCHAMMASS, 1988). Following, there are Ruzi grass and Signal grass that, besides not so vulnerable, can have 50% of the seed shattered in approximately a week. Palisade grass, in turn, is the less coordinated: if performed just one combine harvest it will be collected about 10% of potential seed production and these seeds will present low viability (HOPKINSON et al., 1996). There is no kind of information about these questions for Alexander grass.

4.2 Dormancy

Further seed maturity and shattering, other major issue is the presence of dormancy in tropical grasses seeds. Usually, fresh seeds will be in a physiological state in which germination fails even under optimum moisture, oxygen and temperature conditions (LOCH et al., 2004; ADKINS, 2002; CARVALHO & NAKAGAWA, 2000; HILHORST, 1995). The phenomenon is boosted by the ability of the plant to endow seeds with different dormancy intensities (CARVALHO & NAKAGAWA, 2000), creating

tough problems for testing and pasture establishment (HOPKINSON et al., 1996; HERRERA, 1994).

Dormancy has an obvious value for seed survival in the savanna ecosystems where most of these plants originated (HOPKINSON et al., 1996). This is essentially a natural protective strategy against environment harsh that makes the seed to sense the environment and block metabolic activity, preventing germination in unfavorable situations and ensuring better chance of establishment and long-term survival of the species (LIMA, 2012; ESGPIP, 2010; FOWLER & BIANCHETTI, 2000; LOCH et al., 2004).

Extensive domestication and selective breeding of modern grain crops removed this characteristic from the seeds, loading it with rapid and uniform germination (ADKINS et al., 2002; BEWLEY, 1997). With that, a good establishment is easily determined by the time of sowing (SIMPSON, 1990). When dealing with C_4 forage grasses, however, even the determination of the sowing rate is of greater complexity (a simple procedure in crops).

For some authors the survival of dormant seeds in the soil can contribute to pasture persistence through natural reseeding (HACKER & LOCH, 1997). Some degree of dormancy is also important during seed development, preventing the trigger of germination while the seed stills in the panicle (viviparity) or just after the shed, since if germination begins in this moment there will be loss in seed quality (CARMONA, 1992).

In an overall look, however dormancy is an undesirable characteristic. Unlike natural grasslands, modern arable pasture needs to be frequently re-established as part of a rotational cropping system. Seed dormancy can lead to disorderly in the process and failures in the pasture formation. It is opposite to a synchronized and vigorous germination that reduce hazardous effects of competing weed during the establishment and advance the grazing beginning (CONTRERAS, 2007a; USBERTI & MARTINS, 2007; HOPKINSON, 2005; HERRERA 1994; SHANMUGAVALLI et al., 2007).

Dormancy is conspicuous in Paniceae tribe, and strongly developed in the *Brachiaria* genus (HOPKINSON et al., 1996; HERRERA, 1994). Weediness studies using

Alexander grass already observed this trait present in the species as well, since it is stated that seeds present strong primary dormancy (SALVADOR, 2007; LORENZI, 2000; BONNA& LASCANO, 1992).

Even with the availability of some scientific information, many of the fundamentals on how dormancy prevents the embryo to develop remains not well understood (FINCH-SAVAGE &LEUBNER-METZGER, 2006; LOCH et al., 2004; HILHORST, 1995). To summarize a simple, generally accepted, classification distinguishes dormancy as primary or secondary, depending on the way it installs in the seed (CARVALHO e NAKAGAWA, 2000).

Primary or innate dormancy refers to that installed during seed development and maturation (CARVALHO & NAKAGAWA, 2000; HILHORST, 1995; WHITEMAN & MENDRA, 1982; KHAN & KARSSEN, 1980), being genetically programed to happen independently of the environmental influence (CARVALHO & NAKAGAWA, 2000). Secondary or induced dormancy describes processes enabled when some biochemical trigger is stimulated by a particular environment condition, usually following maturation (KHAN & KARSSEN, 1980) – it can occur even after the seed dispersal, and is often associated with annual dormancy cycles in the seed bank (HILHORST, 1995). This last kind of dormancy can be lost and re-introduced repeatedly according to the seasons until the required germination conditions become available (*e.g.* through soil disturbance, moisture, temperature, light, gases, etc.; FINCH-SAVAGE & LEUBNER-METZGER, 2006; HILHORST, 1995).

A difficulty in the differentiation between these types of dormancy is the fact that the last one could be installed also during the maturation process (CARVALHO & NAKAGAWA, 2000). Nonetheless, *Brachiaria* seeds usually present more than one dormancy mechanism, with causes often not clarified. Guidelines assume that these seeds present some type of embryo-physiological dormancy when young (short-term physiological dormancy) and other type related to tegument permeability further (long-term physical dormancy) (ESGPIP, 2010; ADKINS et al., 2002; CARMONA et al., 2002; WHITEMAN & MENDRA, 1982; HOPKINSON et al., 1996; KIGEL, 1995; SIMPSON 1990).

4.2.1 Tegument

Despite both can be tricky in the seeding process, the coat or tegument dormancy is more popular when speaking about grasses. It was developed probably by the relation between *Poaceae* and grazing vertebrates, when the hypsodont tooth first appeared around 60 million years ago. Since that time, the plant fossils progressively evolved the basal and the intercalary meristems to gain in sprouting/tillering, the rhizomes to resist trample, and the hardiness of lemma and palea (*i.e.* seed husk or seed coat) to protect ingested seeds; leading to the acceptance of the co-evolution hypothesis (STANLEY, 1999; HOPKINSON et al., 1996).

Besides agronomical complications, the husk gained important roles in the seed germination and protection. It *(1)* keeps the seed parts together; *(2)* protect meristematic and storage tissues against impacts and abrasion; *(3)* block the invasion of microorganisms and pests; *(4)* regulate the water intake; *(5)* works as a water reservoir to supply the inner tissues during germination; *(6)* regulate gas exchanges, and; *(7)* promote seed dispersal (CARVALHO & NAKAGAWA, 2000). Artificial release mechanisms, thus, should be careful outlined to avoid impair these processes and harm the seed performance.

The coat dormancy work essentially imposing a strong mechanical resistance to uptake, release or exchange of water (ESGPIP, 2010; FINCH-SAVAGE & LEUBNER-METZGER, 2006; HILHORST, 1995; KIGEL, 1995), gases (ESGPIP, 2010; KIGEL, 1995; HILHORST, 1995; WHITEMAN& MENDRA, 1982), organic molecules or/and minerals between the environment and the seed. This is physiologically explained by the presence of impermeable layers (FINCH-SAVAGE & LEUBNER-METZGER, 2006) located most of the time in the glumes – palea and lemma (ADKINS et al., 2002; LOCH & FERGUSSON, 1999; DESAI, 2004; HOPKINSON et al., 1996; CARMONA, 1992; WHITEMAN & MENDRA, 1982).

4.2.2 Biochemical compounds

Another source of coat dormancy is the prevention of radicle extension or embryo constraining (LOCH et al. 2004; VOLL et al., 2001). In most cases, it is accepted for legumes, besides this mechanism was already speculated in Alexander grass itself (SALVADOR, 2007). In parallel, a more robust approach for grasses is the intrinsic interaction between a coat and a biochemical method, by the blocking of chemical inhibitors to leave the embryo, or by the releasing inhibitors from the coat to the embryo (BEWLEY, 2013; ADKINS, 2002; DESAI, 2004; KIGEL, 1995). These compounds are essentially phytohormones involved in growth regulation. Its role is to work as signal/sense/messenger molecules in tiny concentrations, being triggers to complex processes chains including the germination (BEWLEY, 2013; LOCH et al., 2004).

Dormancy or dormancy release may be a matter of changing the balance of these inhibitors or promoters inside the embryo (LOCH et al., 2004; DESAI, 2004). This model predicts dynamism over time, possibly in response to environmental factors (LOCH et al., 2004). For the current data, it is accepted that the major compounds that encourage germination are gibberellins (GA) and cytokinins (LOCH et al., 2004), and major inhibitors are abscisic acid (ABA) (LOCH et al. 2004; HILHORST, 1995), coumarin (CARVALHO & NAKAGAWA, 2000), cyanide (DESAI, 2004), catechins, tannins and phenols (LOCH et al. 2004).

Among those, ABA is the most notable, being accepted as a 'master controlling compound' (MARCOS FILHO, 2007c; LOCH et al., 2004; BASKIN, 2001; HILHORST, 1995; FINCH-SAVAGE & LEUBNER-METZGER, 1996). ABA is an isopropenoid formed by the cleavage of carotenoid precursors and found in seeds, leaves, roots, tubers, ripening fruits and dormant buds. It was named based on its influences on leaf abscission, although now it is more closely associated with responses to environmental stresses. The ABA role in seed development includes important process as *(1)* Promotion of synthesis of seed storage proteins (LEA proteins – late embryogenesis abundant); *(2)* Acquisition of desiccation tolerance; *(3)* Induction of dormancy,

suppression of precocious germination (viviparity), and; *(4)* maintenance of dormancy after shedding (BEWLEY, 2013; BENNET, 2007b; HILHORST, 1995).

The chemical issues related to dormancy introduction are far from conclusive, but there is no doubt ABA is intimately involved (HILHORST, 1995). The dormancy installing strongly coincides with a transient rise in ABA content during seed development. In most of cases, ABA increases during the first half of seed development and declines during the maturation phase in parallel to the seed water content (BEWLEY, 2013). Studies with seeds of *Arabidopsis thaliana* proved the hormone role, since ABA free mutants showed no tolerance to seed drying – ABA is related somehow to osmotic regulation, burned as a fuel to the process balance (HILHORST, 1995). In the same way, it is accepted that ABA could potentially inhibit water absorption by blocking embryo cell walls to soften, decreasing its flexibility (related to cell elongation); and changing the osmotic environment preventing water absorption by cell turgor reduction (HILHORST, 1995).

Still, during the seed formation, it is necessary high moisture in the tissues to endorse translocation, enzyme synthesis and organic molecules formation (MCDONALD, 2007b), on the other hand, in the presence of water, the partial developed embryo could be stimulated to germinate, and so the ABA will act blocking this process. Once the maturation elapses, the moisture gradually decrease and the stimulus to germination will decrease as well, allowing the plant to reduce the amount of ABA in the seed with no physiologic loss. Not by fortune, the plant can keep remnants of ABA in the seed, maintaining thus the dormancy state after shedding.

There are evidences indicating that in dormant grass seeds the germination just occurs if ABA levels are reduced or null (HILHORST, 1995; BLACK, 1991). One of the major factors of decrease in the natural environment is the prolonged washing that promotes leaching of the inhibitors. Some desert seeds, for example, require a large amount of water to germinate, a process closely related to the seasonal and climatic changes (BENNET, 2007b; DESAI, 2004).

As ABA, another phythormones accepted as major influent in seed germination are the Gibberellins (GA), in this case, however, acting as an antagonist to ABA effect, promoting the seed germination (LOCH et al., 2004; KORNNEFF, 2002; HILHORST, 1995). As well as ABA, GAs are found in developing seeds (BEWLEY, 2013; BENNET, 2007b), being synthetized in the endosperm when it stills in a liquid phase (CARVALHO & NAKAGAWA, 2000). Further, embryo is capable of again synthetize new GA when re-moisturized (CARVALHO & NAKAGAWA, 2000), bringing a situation which dormancy release and germination will be product of ABA degradation and enhance of GA biosynthesis (FINCH-SAVAGE & LEUBNER-METZGER, 2006).

Physiologically the main function of GA is to trigger the activity of hydrolytic and proteolytic enzymes in the seed that act mobilizing the food reserves from endosperm to the embryo (LOCH et al., 2004). These hormones stimulate the aleurone layer (a digestive tissue) to secrete a variety of enzymes (particularly amylases) that break down cell walls, starch and storage proteins, making it simple sugars and amino acids available for uptake by the growing seedling (BEWLEY, 2013; CABI, 2006; CARVALHO & NAKAGAWA, 2000; DESAI, 2004). Nonetheless, gibberellins (together with auxins) are known to be involved in cell division and elongation (DESAI, 2004), fundamental to the break of the primary root surrounding seed tissues during germination (MARCOS FILHO, 2007c).

Several authors tried to elucidate the mechanisms of dormancy by studying the artificial application of these substances to the seeds. Since the regulators are found endogenously in seeds, it is argued that if these chemicals are supplied externally it should act in a similar manner (LOCH et al., 2004; DESAI, 2004). Beside some species can present some positive responses it keeps remote from the total solution. Most of the cases trial GAs, however, an important issue seems not to be considered: Gibberellins are a large group classified based on both structure and function, named GA_1...GA_n in order of discovery, summing nearly 150 types identified from plants, fungi, and bacteria. In seeds the gibberellins GA_1 and GA_4 are the main active forms, occurring naturally, but for most experiments the commercially available

GA_3 is the used form (BEWLEY, 2013) and so it is hypothesized that this difference can influence the responses.

Unfortunately, these theories are hard to address experimentally. The embryo blocks are not necessarily caused by inhibiting chemicals and may result from deficiency in some essential compound, which by its time could need some biochemical stabilization to accumulate and permit germination (BASKIN, 2001). In addition, it is very difficult to isolate and identify an inhibitor/promoter from an embryo giving its tiny magnitudes in the tissues (DESAI, 2004). Besides the assurance of the involvement of some substances in the dormancy maintenance and release, the way it works in the seeds stills just partially understood.

4.2.3 Gases

Compounds as the air gases can also influence germination. Again, an association of chemical and mechanical blockage can be involved, promoting limitations on exchanges of oxygen (uptake) and CO_2 (release). This will be intimately linked to the seed respiration, energy production, and consequently the embryo development (BENNET, 2007; LOCH et al., 2004; DESAI, 2004).

During germination, endosperm is degraded to supply a growing embryo axis, a process that needs oxidation to produce adenosine triphosphate (ATP) and intermediate substances for anabolic processes. The oxygen thus is elementary to germination (MCDONALD, 2007b; CARVALHO & NAKAGAWA, 2000; DESAI, 2004). Limitations in oxygen supply are often attributed to the presence of fixing compounds in the coat (SANTOS, 2009; CARVALHO & NAKAGAWA, 2000). For most authors, these are phenolic molecules, which can be present in the seed husk and in the embryo surrounding tissues (BEWLEY, 2013).

Another matter in the absence of oxygen is that in early germination energy is provided by anaerobic respiration. With it, ethanol accumulates as a sub product – if the oxygen is not supplied to the seed it will sense a non-suitable condition

to germination, and then change the metabolism to block the process (Characterizing a secondary dormancy form; BEWLEY, 1997; CARVALHO & NAKAGAWA, 2000; DESAI, 2004).

4.2.4 Water

Concerning about water uptake can take place when dealing with some kind of coat block as well. Moisture itself is the first trigger to enable the germination process, so there is no doubt on the effects of this resource shortage for the embryo (BEWLEY et al., 1997). It is directly related to reserve mobilization, energy production and respiration, enzyme and hormonal activity, and dilution of the protoplasm to increase metabolism for successful embryonic growth (MARCOS FILHO, 2007d).

Although temperature and relative humidity play important roles in water uptake, the seed morphology also directly affect seed permeability. For the water, impermeability is caused mostly by sclereid cells layers with thick lignified walls, and by the presence of other repellent compounds such as cutin, suberin, waxes, phenolics, and callose (CONTRERAS, 2007a; LOCH et al., 2004). Besides the reports of limitations in C_4 grasses (LOCH et al., 2004) studies specifically with Alexander grass concluded that dormant seeds present great water uptake, and so dormancy may not be properly related to water impermeability of the husk (VOLL et al., 1997). For Voll et al. (1997) these seeds presented a linear increase uptake until 48 hours of imbibition.

4.2.5 Artificial methods to break dormancy

For the commercial production, the most widely used, practical, and cost-effective manner to deal with physiological dormancy is to store the seed and let it in a resting time, waiting for biochemical stabilization (LOCH et al., 2004). For coat dormancy, artificial treatments are more frequently performed, once it usually takes more time to a self-release.

In natural environment, when the seed is dispersed, biotic and abiotic factors can be enough to promote the changes in the husk and consequently the germination state. Natural combination of time and exposure to elements as cold, moisture, heat, fire, gases, mechanical shocks, solar radiation, light, gut passage, temperature variations, microbial action, predation, etc. are potentially actors (DESAI, 2004). Any of these influents can favor or inhibit germination depending on the species and on the seed state *i.e.* inhibiting factors and stresses could have profound long-term effects on seed physiology, releasing some type of blocking but potentially inducing secondary dormancy at the same time, requiring another set of factors to release it again (DESAI, 2004).

As a general guideline, coat dormancy is overcome when the seed coat and pericarp weakens or/and breakdown (CONTRERAS, 2007a; LOCH et al., 2004). In C_4 grasses, the more tough structures encapsulating the caryopsis are the palea and the lemma, main target of artificial treatments as acid or physical scarification (BENNET, 2007a; LOCH et al., 2004; LOCH & FERGUSSON, 1999). Sulfuric acid is the most used and dissolves palisade layers of the seed tegument allowing the substance exchange (DESAI, 2004; WHITEMAN & MENDRA, 1982). This practice, however, is far from universal: for several species acid treatment is harmful, once with an abrasive substance there always the imminent risk to damage the embryo.

Physical methods by its time will cut, pierce or sand the seeds (LOCH et al., 2004; BRASIL, 2009), which besides less invasive can also damage the embryo by mechanical shocks. Hand cutting methods are the safest one, but practical just for research purposes. For larger seed amounts, the process has to be executed using equipment with abrasive parts set according to rotation speed, sandpapers granulometry, scarification time, etc.

A major influent in these treatments is the seed moisture content that can soft or hard the scarified structures (DESAI, 2004). Despite, the drying process itself can be influent since the temperature is already reported as stimulatory for *Brachiaria* seed germination (LOCH et al., 2004; DESAI, 2004; LIMA& CARDOSO, 1996). In the

environment, temperature takes an even highlighted place as a guiding trigger for the seasonal variations. Annual summer species germinate in spring or summer, and the resulting plants complete their life cycle usually in early autumn (as Alexander grass). At maturity, in late summer, seeds are already dormant or conditionally dormant, which makes it germinate just at high temperatures (BASKIN, 2001). Agronomically, this information will be precious when deciding which time to perform the sowing.

Another factor influencing dormancy is the soil fertility *i.e.* the concentration of some minerals in the seed substrate. Many ions have been investigated but only nitrate and nitrite were found to affect the dormancy state (BASKIN, 2001). To provide these substances artificially the most used compound is KNO_3 (potassium nitrate), whose action in germination is related to nitrate reduction and conversion into nitrite, leading to a NADPH reoxidation, stimulation of the penthosis pathway and the Shikimic acid pathway through Eritose–4–Phosphate.

These routes are fundamental to biosynthesis of new compounds to germination: Penthosis pathway will synthetize Ribulosis–5-Phosphate used on nucleotides (part of nucleic acids, RNA e DNA) and coenzymes. During early germination stages, it could be the most important of electron transport systems. According to Roberts (1974), just after the growing beginning the metabolism will change from the phosphate penthosis pathway to the glycoses system, Krebs cycle and cytochrome electron transport chain (CARVALHO & NAKAGAWA, 2000). Shikimic acid pathway, by its time, is important to the biosynthesis of some essential amino acids (Tryptophan, phenylalanine and tyrosine) and secondary phenolic compounds (CARDOSO, 2011; CARVALHO & NAKAGAWA, 2000). Other reasons to the action can be the KNO_3 oxidative power, and the work as a nitrogen source (BONOME et al., 2006).

Unfortunately, no effect is observed when reduced forms of nitrogen as ammonia, urea or amino acids are used. It is accepted that the interaction need an oxidized form to act in the routes as an electron receptor (CARVALHO & NAKAGAWA, 2000). In the soil, nitrate levels will naturally vary, following several patterns of depth, moisture, temperature, soil type, microbial activity, etc.

4.2.6 Light

C_4 grasses seed might also be sensitive to light type and intensity (BRASIL, 2009; SALVADOR et al., 2007; FINCH-SAVAGE & LEUBNER-METZGER, 2006). The strategy, as the other dormancy mechanisms, was developed by the plant to increase the chance of survival in a competitive or harsh environment (CONTRERAS, 2007a; LOCH et al., 2004), being a response to situations where the seed is buried, covered by straw or by a dense canopy of vegetation. Alexander grass itself is a pioneer species in the successional sequence and do not tolerate constant shadow during the adult plant development. Still, in the case of buried seeds germination deep in the soil can make the seedling not able to reach the surface, which is even worse in the case of small seeds with fewer reserves. Alexander grass is taken for a long time as photoblastic positive *i.e.* that needs light to germinate (Figure 4).

An important discovery was made by Flint & McAllister (1935), which observed that depending on the spectral trait of the light (wavelength), germination could be inhibited or stimulated. Long light waves penetrate deeper into soil and, so, little red light reaches the zone immediately above permanent darkness (BASKIN, 2001). Light is then sensed by a photoreceptor in the seed called phytochrome system, a soluble chromoprotein that changes its isomeric form between red (P_r, 660 nm, inactive form) to far-red (P_{fr}, 730 nm, active form) depending on the spectral trigger. When ratio P_{fr}/P_r is elevated, there is stimulus to some functions of cellular membranes, hormone synthesis, genetic transcription, and consequently germination (VIVIAN et al., 2008; LIMA & CARDOSO, 1996; TAYLORSON e BORTHWICK, 1969). New substantial progress was achieved by Borthwick (1952), which discovered that this process is dynamic: the red light promoting effect for germination is totally reversible by the far red, and *vice versa i.e.* in a light sensitive seed the germination process will be related to the quality of light that reaches it at last. Besides wavelength, it is important to point that the exposing time is also fundamental.

Figure 4. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) natural emergence from soil seed bank, after corn no-till direct seeding. Emergence was observed particularly in the row where the soil was moved by the seeder mechanism (*Picture source: OLIVEIRA, 2013*).

The relation between the response of artificial and natural conditions stills unclear. The lab model also does not reproduce entirely the effects of the environment. Several species that require light to germinate do not express sensitivity just after the harvest, installing it after some external influences, particularly when the seed is buried (CARVALHO & NAKAGAWA, 2000; BEWLEY & BLACK, 1982). It can mean thus that light dormancy is strongly inclined as a non-innate dormancy type.

Dormancy behavior depends also on a complex net of interactions among promoting and releasing factors. The lack of success of artificial treatments in trigger germination can be result of combined action of these effects (DESAI, 2004), and it may be necessary to examine the dormancy phenomenon from a much wider perspective (HILHORST, 1995).

For C_4 grasses, temperature is accepted as a guide factor, but connected to stimulus as light and nitrate (BENNET, 2007b; BASKIN, 2001). As example, in the process of dormancy release, phytochrome receptors synthesis is performed in the

cellular membrane. When temperature becomes favorable to germination, the membrane consistency is changed allowing the flux of receptors to the surface, where they are activated by nitrates. Active receptors, then, combine with the phytochrome which is enabled after light receive. There is gibberellic acid synthesis, which joins to their receptor and triggers a signal to the germination (HILHORST, 1995)

In addition, temperature is related to: *(1)* oxygen availability, as higher the temperature, lower the O_2 solubility during germination (BENNET, 2007b; CARVALHO & NAKAGAWA, 2000; DESAI, 2004); *(2)* Hormone concentration, as higher the temperature, higher the effectiveness of ABA in inhibiting germination (HILHORST, 1995) and; *(3)* moisture level (BASKIN, 2001).

Interactions relating light and hormones are reported too, in this case operating in the balance of promoters and inhibitors in the embryo (LOCH et al., 2004). It has been determined that P_{fr} induces germination by promoting GA synthesis (CONTRERAS, 2007a) or endorsing its transport routes (AMORIN, 2000). In the other way, application of GA can overcome the light requirement in some species (LOCH et al., 2004).

Light is also antagonistically influent for some inhibitors as ABA and coumarin (AMORIN, 2000; CARVALHO & NAKAGAWA, 2000), and synergic with nitrate/nitrite to promote germination (BENNET, 2007b; BASKIN, 2001). As presented, these substances are close to gas exchange processes (O_2) (CARVALHO & NAKAGAWA, 2000), which means light can indirectly be related to respiration as well.

It is evident that dormancy is a tricky and complex trait in C_4 grasses seeds and thus several artificial treatments can be used to encourage germination: *(1)* exposition to oxidizing agents; *(2)* exposition to plant hormones; *(3)* temperature fluctuations; *(4)* light regimes; *(5)* dry heat; *(6)* removal of the pericarp *(7)* oxygen enriched atmospheres; *(8)* microwaves; etc. (LOCH et al. 2004). These treatments, even combined, will lead to a partial solution, since no fully effective treatment was encountered to release all seeds from dormancy, independently of the seed age. To

worsen that, dormancy is controlled by a large number of genes, complicating the removal by breeding (KOORNNEFF et al., 2002).

When marketed within the same region at least 4-5 months normally elapse between harvest and sowing, so there is a considerable time for dormancy be eliminated by natural aging. However, when seed is exported for other regions purchasers may wish to sow it immediately, and better techniques for dormancy release are still needed (HACKER & LOCH, 1997). Even though, some *Brachiaria* species need more than a year to stabilize the seed at an acceptable point for sowing, generating expensive costs for storage and market lost, endorsing very well a better understanding on dormancy mechanisms and the methods to overcome it.

5. SEED FIELD MANAGEMENT TO DEAL WITH THE WILD BEHAVIOR

Understanding the C_4 grasses inherent production constraints provides a sound basis for how to design the crop management. Regardless the inability to eliminate genetically some traits, several problems can be at least reduced with the proper manipulation of the field. The management should thus promote vigorous growing during vegetative phase, maximize flower synchrony during reproductive phase, and support a good recovery of viable seed during harvest.

5.1 Uniformization cuts

A well-accepted and broadly used technique in tropical forage seed crops is the uniformization defoliations, frequently combined with nitrogen fertilization (HOPKINSON et al., 1996). During the vegetative phase a cut should be carried out – by slashing, mowing, or close grazing – and after, N fertilizer applied (ESGPIP, 2010).

This combination encourages at first concentrated production of new similarly aged tillers in the regrowth, basis for a synchronized inflorescence emergence and a further more uniform seed maturation (ESGPIP, 2010; SOUZA, 2001; WONGSUWAN, 1999). There is no general rule for number and intensity of the cuts, but it is settled that the higher the cut number and the lower the cut height, the better will be the effect on synchronization. Depending on the intensity, these managements can also influence the number of seed heads (SOUZA, 2001; LOCH, 1985; LOCH, 1980).

Defoliation is effective firstly because apical dominance is removed and light penetrates better to bud sites (HOPKINSON et al., 1996). By changing light quality and quantity inside the canopy, some morphogenetic variables such as leaf elongation and tillering rate are affected, changing consequently some structural characteristics of the sward such as final tiller density and final tiller size (WONGSUWAN, 1999; BARTHRAM et al*.,* 1992).

Besides light issues, after the elimination of the apical dominance the plant physiology automatically drives reserves (before used to growing in height) in

favor of axillar gems (JORNADA, 2002; CARVALHO & NAKAGAWA, 2000). Defoliations help also to control some agronomical topics as: *(1)* set the better time for harvest, according the availability of machinery or climatic seasonality – changing the cycle and the flowering moment, and so the end of the maturation process. *(2)* Reduce leaf mass, avoiding lodging and favoring harvest, especially by ground sweep method; *(3)* Help the weed control, and; *(4)* Provide animal feeding by hay, silage or grazing (SOUZA, 2001; CARVALHO & NAKAGAWA, 2000).

Grazing in forage seed crops were worldwide common in the past as well, being now used just in most traditional systems. It could be compatible with good yields if animal removal criteria are strictly followed, same way a mechanical cut after that still recommended to standardize the height of the tillers (SOUZA, 2001). Leaving of grazing however was motivated by some problems by the trampling, which increases the soil rugosity and complicates the ground sweeping harvest (ANDRADE, 2001). In addition, overgrazing can exhaust the plant and drastically reduce the seed yields, and it is more difficult to control.

In small scale systems of Thailand there were reports of farmers facing the defoliation as a difficult practice since it is done manually and there is too much forage for them to handle. These seed producers do not need the forage because they do not raise livestock. Even at the cost of lowering the potential productivity, they prefer to plant the seed crops later and not have to cut it (HARE, 2014). This can be an option for Alexander grass if the farmer is not willing to perform the defoliations. Thinking in Southern Brazil, however, this will probably not be an issue, because most of farms have at least some access to mechanization and/or raise livestock.

Even with the defoliations, little can be done about the heterogeneity within individual inflorescences (LOCH 1980). The practices will not be fully efficient in promoting a sharp synchronization, but will at least make the plant behavior closer to that.

5.2 Harvest

Harvest is the most constrained operation by the wild behavior of tropical grasses. Not by fortune most of the management is performed thinking in the harvest procedure (HOPKINSON & ENGLISH, 1985). Giving the lack of synchronization and shedding of most C_4 forages (Including Alexander grass) in any moment of the cycle just a fraction of viable seeds can be collected in a single harvest directly from the panicle (CIAT, 1982). Alternatively, methods that recover shed seed from the ground or perform multiple non-destructive harvests can be chosen. The option will consider environment and agronomical topics as size of the area, availability and relative costs of labor and machinery, and climatic factors as rain and cold (HOYOS et al, 1997; HOPKINSON et al., 1996). About the plant behavior, in summary, if synchronization is present a single act of severing the seed from the plant could be used. If harvesting is done by repeatedly collecting shaken-off seed or accumulated fallen seed, synchronization is less important (HOPKINSON et al., 1996).

Highest productivity and seed quality are obtained using manual methods (SOUZA, 2001; BOONMAN, 1972). In Koronivia grass (well synchronized), for example, combine harvest recover 60%, and tractor beating machine 50%, of the seed obtained by manual ground sweeping (CARDOZO et al., 1991). Regardless, manual methods are progressively decreasing once labor is frequently scarce and expensive (SOUZA, 2001). Just this operation takes around a third of the labor employed in a crop (50-90 person-day ha^{-1}) depending on the level of refinement (ANDRADE, 2001; LOCH & FERGUSSON, 1999).

Manual methods widely vary in the way they are performed, even over a same species. In Asia, for example, a non-destructive harvest is commonly used, tying the seed heads into sheaves and knocking it daily into a receptacle (KOWITHAYAKORN & PHAIKAEW, 1993). This evolved to a system where the seed heads are shaken with long sticks into an agricultural trailer tractioned between the rows, or into a piece of fabric covering the ground in narrower spaces (NERY et al., 2012; HOPKINSON et al., 1996).

Another option is the pile method, very used in Brazil in the past for Guinea grass (SOUZA, 2001), Jaragua grass, Molasses grass and Gamba grass (NERY et al., 2012). In this method, inflorescences were cut and piled over a clean soil surface in a pile near 1m of height. The material is covered with a ~10 cm layer of leaves and stems (NERY et al., 2012) and keep maturating 4 to 7 days, depending on the climate. The principle involved is that the water in the inflorescence branches makes the maturation of seed to continue within the pile, making also the number of viable seeds increase – its important that inflorescences get well covered to avoid premature drying. Further, piles are open and the inflorescences shaken to detach the seed. This method will result in good yields (twice of the productivity achieved comparing to combines), with also higher purity and germinability (SOUZA, 2001).

Manual pile is a good example of a proved efficient method to achieve good result in small-scale production. Keeping that, Alexander grass seeds are not available to purchase and this can be so a method to multiply seeds for initial production. For this purpose, yet, the manual ground sweeping can be used, which is accepted as the most labor-effective among manual methods. It consists simply in allow the seeds to fall and accumulate on the soil surface or among the grass leaves, mow the sward close to the ground level, remove the leaf mass with rakes, and then swept and recover the material that contains the seeds (SOUZA, 2001).

Ground sweeping gradually became mechanized, which perhaps is the main reason that nowadays it is the most widely used method to harvest tropical forage seeds in large scale (SOUZA, 2001). The first two operations (cutting and windrowing) were converted early, with the use of tractor mounted hay machines (LOCH & FERGUSSON, 1999) *i.e.* cutting operation is performed with lateral disk mowers or, alternatively, some farmers transform old combine harvesters into mowers (ANDRADE, 2001); and windrowing is done using rotary rakes.

With the development of sweep harvesters, all operations became mechanized. These machines are pulled and powered by tractors as well, and work with large rotary brooms transversely mounted, having a working band of almost 2 meters

and being capable of covering 2-3 ha day^{-1} (LOCH & FERGUSSON, 1999). The modern machinery is also equipped with sieves and fans that pre-process the material in the field, taking out part of the impurities (ANDRADE, 2001; SOUZA, 2001).

The mechanization of ground sweeping had great impact in the pasture production in Brazil. Considering that labor for harvesting accounted for a wide share of final seed costs, its elimination increased the profits in the market. With the adoption, one of the main concerns of forage seed production could be at least partially forgotten: Shattering and strict maturation synchrony is not a vital limiting when fallen seed is allowed to accumulate and recovered from the ground (MILES et al., 2004; ANDRADE, 2001).

Preference for seeds harvested from the ground took place in Brazil. In late 90s it already shared around 80% of total volume marketed (SANTOS FILHO, 1996). This is a result mainly of the better quality and maturation of the shed seed, in the vast majority of the cases presenting higher germinability, vigor and shelf life in comparison to those combine harvested (LIMA 2012; SOUZA, 2001). For some, this seed present also less expression of dormancy possibly to lixiviation of inhibitors and fermentation processes in the soil surface (SOUZA, 2001; CASTRO et al., 1994). Yet, the propagules do not need drying processes because the period in the ground reduces its moisture to safe levels (SOUZA, 2001).

In contrast, low purity and sanitary issues are notably the worst trait of the seed lots sweep harvested. Besides inert material as soil, rocks and sticks, the product can carry weed seeds, nematodes, pathogen spores and seeds of other forages (SOUZA, 2001; LOCH & FERGUSSON, 1999; CASTRO et al., 1994). Crude seed lots present 1 to 40% of pure seeds depending on the management and the number of sieve operations (SOUZA, 2001), and despite the market availability of commercial lots with more than 90% purity, several cases present less than 50% (LOCH & FERGUSSON, 1999).

Even with the serious problems generated by the use of low purity seeds, producers keep the choice for that, someway taking advantage of this trait. In Brazil the broadcast sowing using limestone spreaders is common, which do not permit to set

sowing rates lower than 10 Kg of material per hectare. When high quality seed lots were used the sowing rate need to be lower than that (around 4 Kg), demanding a different equipment to spread proper amount of seeds (SOUZA, 2003).

Beyond the preference, an exception to the sweeping is Koronivia grass, since the prostrate growth of the plant makes this harvest method impracticable (SOUZA, 2001). Actually most important tropical grasses can be harvested by combines if considered and accepted the losses inherent to that. The major problem, as mentioned, is that usually just a small fraction of potential production is collected on the standing crop. Combines are usually chosen when convenience outweighs any other considerations (LOCH & FERGUSSON, 1999). These machines mow, collect, thresh, sieve and discard in the same operation, reducing astonishingly the amount of labor and time for the harvest (SOUZA, 2001).

Combines are also expensive, but at the same time very common in Brazilian farms, especially those that produce grains. Usually in the forage harvest season this machines are idle, and the use helps to justify economically its presence in the farm. In regions where rainfall is a treat, time reducing in the harvest operation can be interesting as well (SOUZA, 2001). Another issue is that the sward is not destroyed as in ground sweeping and the area can be further used as pasture (SOUZA, 2001).

In opposite to sweeping, combine harvest results in better purity, but low physiological seed quality, with little germination and viability. It collects high amounts of immature seeds and makes the variability of the seed lot even higher (HOPKINSON& ENGLISH, 1985). Mechanical damage by threshing can be severe; the crop has to be vigorously knocked to detach the seed, reducing both dormancy and shelf life (HOPKINSON et al., 1996). Yet, when seed is combine-harvested, drying is needed (NERY et al., 2012)

Even with correct management and machinery adjustment, the method lacks productivity efficiency. In Signal grass, for example, almost 60% of mature seed can be lost, recovering around 80% of the standing seed, but just 30% of the gross potential production (HOPKINSON & ENGLISH, 1982). Cardozo et al. (1991) combine-

harvested an average of 50% of total production in *B. dictyoneura* crops (well synchronized). Hoyos et al. (1997), same way, collected with combine just 50% of the manual harvesting in Koronivia grass (also well synchronized). Depending on the harvest time for Signal grass and Palisade grass (poor synchronized) ground sweeping can result in yields 8 times higher than the seed collected with combines (ANDRADE, 1997).

Other less used methods keep as alternatives. For intermediate levels of production, tractor-mounted beater systems have been designed (RAMOS, 1991). Using wires stretched in front of a collecting box, these machines are driven along the crop in high speed forcing the seeds to detach with the impact and fall into the container. This method is usually performed in several non-destructive partial harvests along the reproductive cycle (SOUZA, 2001). In terms of efficiency it will collect 30-40% of the standing crop (CARDOZO et al., 1991), getting advantages in physiological quality when comparing to combine harvest. It is a good option to intermediate farms, where combines do not economically justify, and ground sweeping cannot be performed.

In summary, harvest is an important determinant of the seed cost, physiological quality, and purity, being the correct choose determinant to the production success. The use of each method will depend on the field size, the labor and the equipment availability. It is sure that each one can accomplish an important role in a particular production system (CARDOZO, et al. 1991). In Brazil, the tendency is the sweeping to keep growing. The long dry season occurring in some regions of the country, the increasing attention to seed processing and to field management can help to overpass the imminent problems that stills in this method.

6. WIDESPREAD *BRACHIARIA* SPECIES CORRELATED TO ALEXANDER GRASS

Several Brachiariagrasses have high potential as livestock forage source in the tropics. Nowadays, however, the broadly commercially exploited Brachiariagrasses belong just to four African species: *B. brizantha* (Palisade grass), *B. decumbens* (Signal grass), *B. humidicola* (Koronivia grass), and *B. ruziziensis* (Ruzi grass*)*; summed yet to three species with less expression but used as pasture as well: *B. mutica* (Para grass), *B. arrecta* (Tanner grass) and *B. dictyoneura* (Dictyoneura) (AMBIEL, 2008; MILES et al., 2004; HOPKINSON et al., 1996). The *B. dictyoneura* was listed particularly by cv. Llanero (recent studies classified the species as *B. humidicola*; RENVOIZE et al., 1996).

A solid characteristic of this market is the historical predominance of relatively low number of cultivars (SOUZA, 2001). In contrast to temperate grasses, warm grass breeders are traditionally concerned in finding new species of high forage value, besides developing cultivars of mainstream species (*e.g.* in temperate grasses Fescue (*Festuca arundinacea*), Italian ryegrass, Alfalfa (*Medicago sativa)*, Oat (*Avena sativa*), etc.) (LOCH et al., 2004; LOCH & FERGUSSON, 1999; HACKER & LOCH, 1997). Nowadays just few cultivars are regularly commercialized in Brazil, being the most originated as direct selection from African germplasm (MILES et al., 2004).

These species importance is greater in tropical America where extensive adoption over the past several decades had a revolutionary impact on the productivity of vast areas previously underused (MILES et al., 2004). Their origin is in central-east Africa (including Alexander grass) in a wide range of environments, which gave the genus the consistent characteristic of resistance to poor edaphic traits and harsh weather.

Signal grass and Ruzi grass have similar distributions, ranging only few degrees of latitude from the Equator line in Eastern Africa. Palisade grass, in contrast, is found throughout all tropical Africa, and it is far more diverse morphologically than the other Brachiariagrasses (KELLER-GREIN et al., 1996). While these grasses are normally considered lowland species, only Palisade grass has been collected at truly low elevation sites (80 m asl.). All species are found at well over 2000 m asl., with the exception of

Ruzi grass. Koronivia grass originated also in a comparatively wide N-S range, concentrating in the far eastern Africa. All four are found in sub-humid to humid environments, with relatively short (<5 mo.) dry season, with the exception of Palisade grass (found also in areas with <600 mm annual rainfall and 7 mo. dry season) (MILES et al., 2004). No precise natural distribution is available for Alexander grass, but it is hypothesized that the specie evolved in higher latitudes since it better adapts to subtropical climates.

Besides its natural distribution, cropping of Brachiariagrasses is performed in a notably wider latitude range. Signal grass and Ruzi grass, for example, can be found developing well during the summer in latitudes of 22° S in Brazil or 19° N in Thailand (MILES et al., 2004). Alexander grass presents an even wider range, being found growing spontaneously in America from the Southern United Stated to Southern Brazil (KISSMAN & GROTH, 1997).

Aiming to clarify the major differences among the main commercial *Brachiaria* species a short description is presented in the Table 1 according EMBRAPA (2017). Data for Alexander grass will be further discussed in the chapters ahead.

Table 1. Characteristics of *Brachiaria* species popular in Brazil (Source: EMBRPA, 2017; for Alexander grass (*Brachiaria syn. Urochloa plantaginea*) chapters ahead, this publication).

Species	*B. plantaginea*	*B. decumbens*	*B. ruziziensis*	*B. humidicola*	*B. dictyoneura*	*B. brizantha*			Hybrid
Cultivar	-	Basilisk	-	Tuly	Llanero	Marandu	Xaraés	Piatã	Ipyporã
Growth habit[1]	DC	SP	I	P	SP	I	SE	SE	SP
Average sward height (cm)	60	43	47	41	45	62	60	53	87
Leaf blade length (cm)	?	9	10	8	10	11	15	11	9
Leaf blade width (mm)	?	14	16	7	10	19	24	15	18
Average raceme number	9	3	7	2	4	9	3	4	5
Basal raceme length	8	7	7	4	6	11	6	15	11
Spikelets in basal raceme	36	42	33	15	19	44	41	52	41
Fertility level needed	medium/high	low/medium	medium/high	low/medium	low/medium	medium	medium	medium	medium
Fertilization response	high	medium	high	low	medium	high	high	high	high
Acid soil tolerance	medium	very high	low	Very high	high	medium	medium	medium	medium
Drought tolerance	medium	high	low	medium	medium	high	medium	medium	medium
Subtropic adaptation	high	low	low	low	low	low	low	low	low
Spittlebug resistance	?	very low	very low	medium	medium	high	very high	high	high
TSW (g)	4.0 - 5.5	5.0 - 5.5	5.0 - 5.5	5.0 - 6.0	5.0	8.0	8.0	7.5	10.0
Forage Crude protein (%)	11 - 18	7 - 10	7 - 12	6 - 8	6 - 8	7 - 10	9 - 11	7 - 10	6 - 10
Seeding rate (S.P.V)	˜4.0	3.5 - 5.0	3.5 - 5.0	3.5 - 5.0	4.0 - 5.0	4.0 - 6.0	4.0 - 6.0	4.0 - 6.0	4.5 - 6.5
Desiccation susceptibility	high	high	high	low	low	medium	high	medium	high

[1]DC = Decumbent; SP = Semi prostrated; I = Intermediate; P = Prostrated; SE = Semi erect; [2]TSW = Thousand Seed Weight; [3]Kg P.S. = Kilograms of Pure seed

6.1 Interspecific Hybrids

Breeding programs recently dedicated to produce new *Brachiaria* hybrids, aiming to combine the qualities of the species as: *(1)* the high forage quality and determined flowering cycle of Ruzi grass; *(2)* the yield and resistance to spittlebugs of Palisade grass, and; *(3)* the vigor and adaptation to acid, infertile soils of Signal grass (VALLE et al., 2010; MILES & VALLE, 1996).

Some hybrids cultivars are already available in the market, despite serious seed set abnormalities have been observed in the older ones (cv. Mulato – *B. brizantha x B. ruziziensis*) (EUCLIDES et al., 2010). The reasons could be that more than 65% of pollen grains in these hybrids were sterile due to some chromosome abnormalities (RISSO-PASCOTTO et al., 2005). Also, irregularities in the apomictic reproduction is documented (MILES et al., 2004). The newer cultivars (as Mulato II – *B. brizantha x B. ruziziensis x B. decumbens;* or Ipyporã – *B. brizantha x B. ruziziensis*) at least partially solved the problem. Today these grasses are gaining a crescent share of the market, presenting solid expansion especially in the Southern Asia and Brazil. With that the seed industry was developing as well: average good yields for cv. Mulato II for example are 300-400 Kg ha^{-1} of clean seed, since reports of top yields present until 600 Kg ha^{-1} (HARE et al., 2015; HARE et al., 2007c).

Brachiaria seed yields are very dependent on several factors such harvest method, crop management and the location of the field (HARE et al 2013; LIMA, 2012; PANCERA JR., 2011). Productions per hectare can strongly range (LOCH et al., 2004; HOPKINSON et al., 1996), varying from more than 1,000 Kg ha^{-1} to less than 100 Kg ha^{-1} in the same species (HOPKINSON et al., 1996). Even with this reservations some reports can be presented (Table 2).

Table 2. Seed yields of Brazilian popular Brachiariagrasses.

Species		Yield	Source
Palisade grass (*B. brizantha*)	*	cv. Marandu, 750 - 1000 Kg ha^{-1}	Souza (2001)
	*	cv. Piatã, 150 Kg ha^{-1}	EMBRAPA (2009)
	*	cv. Xaraés, 100 - 120 Kg ha^{-1}	EMBRAPA (2009)
	**	283 - 320 Kg ha^{-1}	Martins et al. (2004)
	**	500 - 600 Kg ha^{-1}	França et al. (2005)
Signal grass (*B. decumbens*)	*	81 – 123 Kg ha^{-1}	Gobious (2011)
	*	70 - 150 Kg ha^{-1}	Hopkinson et al. (1996)
	*	196 – 259 Kg ha^{-1}	Martins et al. (2004)
	*	230 Kg ha^{-1}	Oliveira (2002)
	**	750 - 1000 Kg ha^{-1}	Souza (2001)
	**	300 - 800 regularly, top yields 1000 Kg ha^{-1}	Hopkinson et al (1996)
	**	Better results up to 850 Kg ha^{-1}	Pancera Jr. (2011)
	**	500 – 600 Kg ha^{-1}	Hopkinson et al. (1996)
Ruzi grass (*B. ruziziensis*)	*	104 – 154 Kg ha^{-1}	Idris et al. (1995)
	**	531 Kg ha^{-1}	Satjipanom (1995)
Koronivia grass (*B. humidicola*)	*	122 Kg ha^{-1}	Sanchez & Fergusson (1992)
	**	Average 140, higher reports up to 400 Kg ha^{-1}	Hopkinson et al. (1996)
	**	120 - 425 Kg ha^{-1}	Diulgheroff et al. (1990)

*PS = Pure Seed; **PVS = Pure Viable Seed.

Despite the lower total production in comparison to crop grains Brachiariagrasses are exceptional seed producers. This is clarified by the comparison of the thousand seed weight: for corn ~340 g (~3,000 seeds Kg^{-1}); for Soybean ~165g (~5,000 seeds Kg^{-1}); for *Brachiaria* ~5 g (200,000 seeds Kg^{-1}). One-hectare harvest of Brachiaria seed so is enough to sown until 400 hectares of pasture.

It is important to mention however, that harvest index of tropical grasses is very low. A comparison with cereals can be done: in modern rice cultivars the harvest index is about 50%, result of reduction in the vegetative production and increase in grain yield. Forage plants on the other hand are bred to produce leaves. Considering seed yields of 50 and 1,000 kg ha^{-1}, and assuming a dry mass production of 10,000 kg ha^{-1}, harvest index will range from 0,5 % to 10 % (LOCH & FERGUSSON, 1999; CIAT, 1982). Modern producers however are not involved exclusively in increasing these yields, but look to boost the seed quality and the amount viable seeds produced. Management of the crop can be designed thus to benefit a better seed filling and a good photoassimilate sharing.

7. A CLOSER LOOK ON *BRACHIARIA PLANTAGINEA* (ALEXANDER GRASS)

Alexander grass occurs naturally in central Africa tropical zones, from Democratic Republic of the Congo to Cameroon. It was introduced probably accidentally in America (Brazilian coast) by the use of its hay as ground bed in slave ships during the colonial period (KISSMANN & GROTH, 1997; SEIFFERT, 1980).

The species is widespread in tropical and subtropical America (RODRIGUES, 2002), with strong expression in Brazil (HARVARD, 1991). Given it is remarkably ability to propagate spontaneously it is taken in most regions as a weed of grain crops. With proper humidity, the seedlings emerge in early spring, developing an annual cycle and disappearing in the autumn, especially with the occurrence of frosts (RODRIGUES, 2002; PASSINI, 2001). In Southwestern Brazil where latitude is lower than in the Southern and frost is scarce, it can be found all year long, appearing especially in sugarcane fields (THEISEN & VIDAL, 1999).

Stems are herbaceous and glabrous. Plants can reach 1 m height, but having the decumbent growth it will keep a sward around 70 cm, since the extended tillers will easily length double the height of the sward. Present intense tillering forming tussocks, rooting readily in the nodes in contact with soil (Figure 5; OLIVEIRA, 2013; RODRIGUES, 2002). This behavior is one of the factors that endorse its vigorous and aggressive space occupation, supporting traits as competitiveness with other plants, quick recovering after physical stresses and better nutrient use (SIMPSON, 1990).

Alexander grass spikelets are 4-5.6 mm long, 2-2.5 mm wide, glabrous, greenish when linked to the plant and brownish after drying. Purplish melanism occurrence can be sporadically observed when the spikelet is attached to the plant (Figure 6), although no physiological differences were detected in this kind of seeds. The causes of this phenomenon are not clear.

Figure 5. (A) Alexander grass (*Brachiaria syn. Urochloa plantaginea*) node developing roots; **(B)** Alexander grass node rooting – on the right there is the mother tussock and on the left rooting of the stem growing close to the soil (*Picture Source: J.R. Oliveira - OLIVEIRA, 2017*).

Figure 6. Melanism occurrence in Alexander grass spikelets (*Brachiaria syn. Urochloa plantaginea*) (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Inferior glume overlaps the other organs in the spikelet base (Figure 6), proximal lemmas are seven nerved. Inflorescence is a panicle including 2–14 primary branches, arranged alternately along a main axis. Secondary and tertiary branches are reported (REINHEIMER, 2005), however, this does not express in the biotype found in Southern Brazil. Since Reinheimer (2005) research was developed in Argentina, in low altitudes (Santa Fe province; 31°S latitude; 25 m asl.) some environmental variation can be involved. Rachis is 1 to 1.5 mm wide (REINHEIMER, 2005). Spikelets are subtended by short pedicels, alternate inserted in two rows along the the rachis (Figure 7) (LORENZI 2000, KISSMAN 1997).

Figure 7. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) raceme - spikelets disposed unilaterally and arranged alternately in a flat rachis (*Picture source: J.R. Oliveira - OLIVEIRA, 2017*).

7.1 Reproduction

Except for sexual diploid Ruzi grass, all the commercial Brachiariagrasses cultivars are apomicts (MILES et al. 2004), following the trend of tropical grasses majority (60%) (JANK et al., 2011). Apomixis mechanisms englobe the formation of an embryo sac with non-reduced chromosome number, opposite to what happens in sexual species. All the process is similar to a cloning *i.e.* the resulting plants are genetically identical to the mother plant which originated it.

Advantages involving apomixis are mainly related to fixing the characteristics obtained in the breeding or selection process. Production field isolation is also easier, since spacing is needed just to avoid seed contaminations (and no pollen, as usual in cross-pollinate species). Even with no influences in the zygote,

genetics pollination is required to trigger the endosperm formation, independent if the plants reproduce sexually or apomictically (VALLE & SAVIDAN, 1996).

Alexander grass reproduction and pollination method stills unprecedented in the literature. In annual warm season grasses, sexual autogamous pollination is common. This strategy is considered a better evolved reproductive method or advanced than cross pollination (allogamy), because it allows a great amount of pollen to be released close to the stigma, making the fertilization process more safe (ABEAS, 2007). The small flowers of grasses are difficult targets for wind-borne pollen; in addition, grass pollen is the shortest-lived among the angiosperms, being viable for only a few hours, resulting in a limited pollination range under most circumstances. Further, grass flowers open for only 2–3 hours, perhaps to minimize the introduction of pathogenic fungal spores during anthesis. All these factors reduce cross-pollination potential success. Some small percentage of allogamy in autogamous plants, though, guarantees the genetic diversity and avoids the evolutionary dead end (STANLEY, 1999).

Other reproductive adaptation found in grasses includes the development of Cleistogamy, which is the self-fertilization prior to the flower opening. The phenomenon is quite common in grasses, known to occur in at least 300 species (STANLEY, 1999), and present in major crops as Soybean, Bean and Tomato.

Previous empirical observations during the development of this work, raised questions about the reproduction method of Alexander grass. In the field, spikelets usually do not expose the flowers as other *Brachiaria* (Figure 8), and when it does, their appearance is blackish and dry, indicating a probably dead necrotic tissue. As a longitudinal section is performed in maturing Alexander grass spikelets a chamber is evidenced in the distal tip (Figure 9), where in most cases dry reproductive structures can be identified. All these observations support the hypothesis that Alexander grass reproduce as an autogamous cleistogamic plant, and thus pollination probably occur in the same flower within the spikelet, before the flower opening.

Figure 8. Signal grass (*Brachiaria decumbens*) raceme with exposed inflorescences (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Figure 9. Longitudinal section of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) spikelets. Detail in the chamber in the distal portion of the seed, where dry flowers are present characterizing an internal fertilization. Also useful to observe the sharp division (scutellum) between the embryo axis and the endosperm of the seeds (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

To detail and support this hypothesis, a process of fixation of some spikelets in early anthesis was executed in FAA solution (formalin : acetic acid : 70% ethanol, 10 : 5 : 85, v/v). This methodology is typically developed aiming to facilitate the observation of the seed structures in stereomicroscope. FAA solution was prepared in the Chemical Laboratory of Technological Federal University of Paraná – Pato Branco, and racemes were immersed for 24 hours using plastic germination boxes (Figure 10A). The resulting material was packed in glass containers filled with Alcohol-70% (Figure 10B), and submitted to microscopic embryo sac analysis.

Further observations elucidated that the species has bi-floral spikelets in which the distal floret is hermaphroditic and the proximal is neutral – supposed initially to be male, as the pattern present in most *Paniceae*[1] (LOCH & FERGUSSON, 1999). The botanical composition of the spikelet is very similar to the description proposed by Reinheimer (2005), who cites a process where both the florets initially develop as hermaphroditic and further the proximal floret ceases its growth resulting in sterility. The analysis of the spikelets in anthesis evidenced also ripe stigmas inside the glumes. Opening the anthers some ripe pollen was observable, which again reinforced the hypothesis of Cleistogamy occurrence (Figure 11; *Dr.* Cacilda Borges do Valle, EMBRAPA Gado de Corte, *personal communication*).

According to these findings, it was concluded that Alexander grass is an autogamous plant and presents a cleistogamic reproduction.

[1] In *Paniceae* (*Panicoideae*, *Poaceae*) spikelets usually have two florets: The inferior is a staminate (male) flower and the superior is a staminate and pistilate (hermaphroditic) flower. Some exceptions were found when the lower – or proximal – floret is sterile; or two hermaphrodite flowers were encountered in the same spikelet. For the last case an aberration reported in some accessions of Palisade grass with causes not well determined (FALCÃO, 2003).

Figure 10. **(A)** Alexander grass (*Brachiaria syn. Urochloa plantaginea*) racemes immersed in FAA solution (formalin : acetic acid : 70% ethanol, 10 : 5 : 85, v/v), for fixation process and further stereomicroscope embryo sac analysis; **(B)** Alexander grass racemes conserved in Alcohol 70% after FAA fixation process, further forwarded to stereomicroscope embryo sac analysis (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

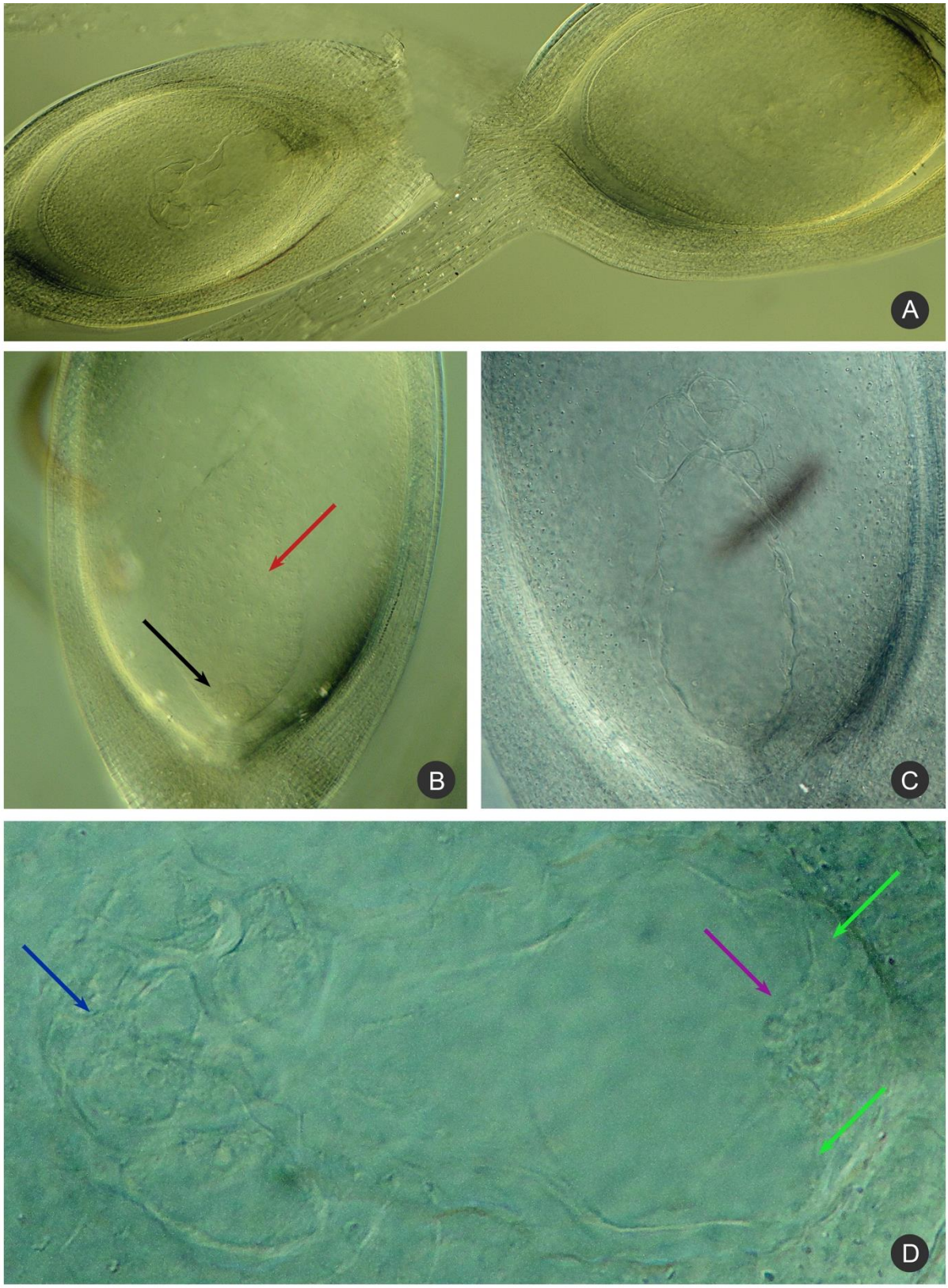

Figure 11. Stereomicroscopic images of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) embryo sac during anthesis. **(A)** fixed ovaries containing typical Polygonum (meiotic) embryo sacs; **(B)** Embryo (*black arrow*) and endosperm (*red arrow*) already formed, typical of cleistogamy; **(C)** polygonum sac typical of sexual plant; **(D)** Alexander grass, antipodals (*blue arrow*), 2 polar nuclei (*green arrows*) egg cell (*pink arrow*) (Picture source: Dr. Cacilda Borges do Valle – EMBRAPA Gado de Corte - Brazil. Special analysis for this work).

Other refined details keep demanding elucidations. As mentioned, some few spikelets of Alexander grass expose its reproductive parts during anthesis, for reasons yet unknown. A proposition could be the existence of some percentage of 'ecological Cleistogamy', a phenomenon that results from a genotype-environmental interaction. This kind of pollination is used mostly as a safeguard pollination under unfavorable conditions *i.e.* the presence or absence of Cleistogamy is conditioned by environmental factors as drought, heat, cold, shade, nutrition, etc. (FRANKEL & GALUM, 1977). Some examples are presented: *(1)* In Itch grass (*Rottboellia cochinchinensis*) incidence of Cleistogamy is affected by the photoperiodic regime. Yet, short day lengths have been found to increase the level of Cleistogamy in Pitted Bluestem (*Bothriochloa decipiens*) (HESLOP-HARRISON, 1959 *apud* LOCH et al., 2004). Experimentation with Alexander grass under different climates can help to answer these remaining questions.

Following successful pollination and fertilization, three semi-independent processes begin in the developing of an Alexander grass seed: the development of the embryo, endosperm, and seed coat. Technically, Alexander grass seeds are indehiscent dry fruits because some of its protective coverings arise from the ovary wall that produces the pericarp. In a practical context this distinction does not matter and the term 'seed' is commonly used (LOCH et al., 2004; SOUZA, 2001).

Alexander grass (as other grasses) produce only one caryopsis per flower, which is surrounded by bracts, the dorsal is called lemma and the ventral is called palea (LOCH et al., 2004). In the case of Alexander grass the set caryopsis, palea, and lemma is enclosed yet by the sterile glumes (Figure 12 A, B, C).

The process of seed development or maturation involves an organized sequence of changes from the ovule fertilization to the point that the seed becomes independent from the parent plant (MARCOS FILHO, 2007c), The ovule – located inside the ovary – forms the actual seed (Figure 12 D). It contains the embryo sac where a fusion of the egg nucleus and the sperm nucleus forms the zygote that, by its time, will turn into the embryo. The embryo axis, at the end of the process, will be

composed of a plumule surrounded by the coleoptile at one tip, and the radicle surrounded by the coleorhiza at the other. The single cotyledon is the scutellum, located between the embryo and the endosperm (Figure 13), serving in the future as a filter between the embryo and the endosperm. The integuments form the seed coat. Finally, the endosperm is formed by the fusion of remaining sperm nucleus with two polar nuclei, and turn mostly into dead reserve tissue, with the exception of the aleurone layer (CONTRERAS, 2007b; CABI, 2006; LOCH et al., 2004).

Figure 12. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) spikelets and its components: **(A)** Whole spikelet, with sterile glumes covering all the other organs of the caryopsis; **(B)** Sterile glumes open, exposing lemma; **(C)** Glumes removed, palea seated in the lemma - the harder part of the spikelet, also called husk; **(D)** Naked seed – Sterile glumes, palea and lemma removed (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

In Alexander grass, most of the seed weight increase accounts for the endosperm. Grass embryos do not store reserves during seed development, except a little volume of lipids in the scutellum – a flattened cotyledon (BEWLEY, 2013). Nonetheless, robust carbohydrate reserve is polymerized into the endosperm (starch), and protein reserves accumulated in the aleurone layer (CARVALHO & NAKAGAWA,

2000), as well as tiny quantities of minerals, vitamins, hormones and some other substances. Despite the chemical composition of endosperm being determined by genetic factors it can widely vary according to environmental influences (DESAI, 2004). This information will be helpful to determine timing and intensities in the management practices of Alexander grass seed crops, aiming to maximize the seed weight and, consequently, its physiological quality.

Figure 13. Longitudinal sections of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) spikelets (*dry and fresh*). Detail on the chamber formed on the distal portion of the spikelet, within the seed husk, where flowers (already dry in this picture) are enclosed (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Beyond the reproduction, an equal important point for breeding of the species is the ploidy level. This knowledge will support the design of possible interspecific crosses and strategies to make the grass compatible with other species. A detail of ploidy levels and modes of reproduction of Brachiariagrasses is presented by Miles et al. (2004) as follows (See also Table 3):

Ploidy levels differ among and within Brachiaria species (VALLE & SAVIDAN, 1996). Sexual biotypes tend to be diploid (2n = 2x = 18: e.g., Ruzi grass and several sexual accessions of Signal grass and Palisade grass; FERGUSSON & CROWDER, 1974) or tetraploid (2n = 4x = 36: e.g., Koronivia grass; VALLE & GLIENKE, 1991), having regular meiosis with bivalent chromosome pairing. Apomictic biotypes have higher ploidy levels than sexual of the same species (e.g., apomictic accessions of Signal grass and Palisade grass are tetraploid (2n = 4x = 36), and of Koronivia grass are hexaploids (2n = 6x = 54). Apomictic polyploids are generally meiotically irregular.

Table 3. Ploidy levels in 10 and mode of reproduction in 18 species of *Brachiaria*, based on flow cytometry and embryo sac analysis, respectively. Source: Miles et al. (2004).

Species	Accessions analyzed	Ploidy levels					Accessions analyzed	Mode of reproduction	
		2n	4n	5n	6n	7n		Sexuals‡	Apomicts§
B. adspersa	--	--	--	--	--	--	1	1	0
B. arrecta	5	--	5	--	--	--	4	4	0
B. bovonei	--	--	--	--	--	--	2	0	2 (11–14%)
B. brizantha	222	2	157	41	22	--	275	1	274 (0–63%)
B. comata	--	--	--	--	--	--	1	1	0
B. decumbens	51	23	23	5	--	--	65	24	41 (0–56%)
B. deflexa	--	--	--	--	--	--	1	1	0
B. dictyoneura	8	--	6	--	2	--	8	1	7 (0–43%)
B. dura	2	--	--	--	2	--	3	3	0
B. humidicola	60	--	22	18	19	1	64	3	61 (0–66%)
B. jubata	30	4	12	13	--	1	43	8	35 (047%)
B. nigropedata	21	--	19	--	2	--	21	0	21 (5–20%)
B. platynota	2	2	--	--	--	--	4	3	1 (61%)
B. plantaginea	--	--	--	--	--	--	1	1	0
B. ruziziensis	29	24	5¶	--	--	--	36	36	0
B. serrata	--	--	--	--	--	--	2	2	0
B. subquadripara	--	--	--	--	--	--	2	2	0
B. subulifolia	--	--	--	--	--	--	5	0	5 (7–38%)
Total	430	55	249	77	47	2	538	91	447

† References: Penteado et al. (2002); Valle and Savidan (1996); C.B. Valle, unpublished data, 1999.
‡ Aposporous sacs were not observed.
§ Variation in potential sexuality (% of meiotic sacs) observed in apomictic accessions.
¶ Colchicine-induced tetraploid accessions

The only accession of Alexander grass analyzed was reported by this author as sexual; however, no ploidy level or chromosome number is presented. The grass is anyway identified by Harvard (1991) as tetraploid, with n = 9 / 2n = 4x = 36 (*also Cacilda Borges do Valle, EMBRAPA Gado de Corte – Brazil, personal communication*)

7.2 Alexander grass as a weed

Worldwide some of the most successful pasture species have been targeted as potential weeds. In the *Brachiaria* genus, particularly, many of the attributes that make successful forages – as rapid vegetative propagation, tolerance to poor soils, and ability to withstand frequent, defoliation – are also associated with weediness (MILES et al., 2004). Nonetheless, several of these grasses occur in crops (RENVOIZE et al., 1996), roadsides (RENVOIZE et al., 1996; HARVARD, 1991), forests and orchards inter-row (CARMONA, 1995).

An example is given with Signal grass, a world settled forage that frequently behave as a weed when a permanent pasture is converted into another crop. This can be ascribed mostly to the ability of the grass to germinate after variable periods of dormancy in the soil, making chemical control tough. Signal grass is considered 1 of 13 "major" weeds of crops in tropical Australia. In the eastern Andean ridge of Colombia, the grass is a common weed of grain crops and African oil palm, particularly during establishment (MILES et al., 2004). It also reported some alelochemical action, having the capacity to reduce Eucalyptus growth, when incorporated to the soil (SOUZA et al., 2003), a trait also observed in Koronivia grass (SOUZA FILHO et al., 2005).

Alexander grass itself highlights as a typical weed in Brazil (VELHO et al., 2012; GALON, 2010; KOZLOWSKI & ARTUZI, 2010; KARAM et al., 2009; NICOLAI, 2009; KARAM et al., 2006; VOLL et al., 2001; PEREIRA et al., 2000; KISSMAN & GROTH 1997) especially in soybean, corn, sugarcane and bean fields. The species grows all around

the country (LORENZI, 2000; ARAUJO, 1967), but stands out mostly in Central, Southeastern and Southern regions. The aggressive behavior is supported by traits as the vigorous vegetative growth that leads to the formation of a dense sward (MARTINS et al., 1994).

Given the ability to overshadow other plants in disturbed environments (GRIMME, 1979), Alexander grass will frequently be the dominant species in the community. Duarte Jr. et al., (2013) report the species corresponding for a share of 55% of the spontaneous group after 20 days of the winter crop harvest. Control is so fundamental to obtain good yields in grain crops, since in high populations of free growing Alexander grass competition for light, water, minerals and space can compromise the productivity (KISSMAN & GROTH, 1997; FLECK, 1996; VOLL et al., 1996b)

Nonetheless, in the end of the cycle Alexander grass supply the soil seed bank with a vast array of seeds loaded with different levels of dormancy, spreading the emergence fluxes over time in the next warm season (CONTRERAS, 2007a). Further the heterogeneity, the plant is known as a bold seed producer (FLECK, 2002).

Despite the aggressive behavior, established plants are easy to control. The plant is susceptible to the spraying of various herbicides available in Brazil, which are registered for all major crops, and often integrates in the registration for more than one. Some examples are reported:

1. Mesotrione promoted a 90 to 100% of Alexander grass control (corn, selective spraying; FOLONI, 2002);
2. Mesotrione + Atrazine, just seven days after spraying, already resulted in 87% Alexander grass control (corn, selective spraying; ADEGAS et al., 2011);
3. Total control of Alexander grass was achieved with Sulfentrazone (400 g i.a. ha^{-1}), Imazapic (147g i.a. ha^{-1}), Tebuthiuron (1200g i.a. ha^{-1}),

Clomazone (1100 g i.a. ha^{-1}), Clomazone + Hexazinone (880+220 g i.a. ha^{-1}) (sugarcane; selective spraying; NICOLAI, 2009);

4. Control of Alexander grass was efficient using Mesotrione and Nicosulfuron (corn; selective spraying; ZAGONEL et al., 2010);
5. Even with late applications and Alexander grass in advanced development, Clethodim reached control of 99% (soybean; selective spraying; FLECK et al., 2002);
6. Tebuthiuron soil application, after 20mm rainfall, resulted in total control of Alexander grass 21 days after spraying (greenhouse; desiccation; NEGRISOLI et al., 2007);
7. A single application of Clethodim can keep the total control of Alexander grass during all the soybean cycle (soybean; selective spraying; MARTINS et al., 1994);
8. Clethodim, Sethodim and Fluazifop-p-butyl total controlled Alexander grass, despite using sub-doses (bean; selective spraying; KALSING, 2011);
9. Alexander grass control level of 97.6% with Fluazifop-p-butyl (150 g i.a. ha^{-1}), 99.8% with Haloxyfop-methyl (50 g i.a. ha^{-1}), and 100% with Sethoxydim (230 g i.a. ha^{-1}) (greenhouse; desiccation; MARQUES, 2009);
10. Near 100% control with pre application of S-metolachlor (1620 g i.a. ha^{-1}), or Atrazine + Nicosulfuron (1250 + 28 g i.a. ha^{-1}) (corn; selective spraying; GALON et al., 2010);
11. 99% of Alexander grass control with Tebuthiuron (desiccation; FACCO, 2010);
12. 100% control of Alexander grass using Atrazine + Nicosulfuron + Oil (1000 + 8 + 600 g i.a. ha^{-1}) and Atrazine + Mesotrione + Oil (1000 + 48 + 600 g i.a. ha^{-1}). These doses correspond to 50% the levels recommended by the manufacturer, still, 100% and 75% of the dose promoted the same result, with increase in the action speed. (corn + Alexander grass intercrop; selective spraying; OLIVEIRA, 2013).

The experience in Southern Brazil also provides information that the species is very susceptible to the broad action herbicides commonly used for desiccation (*i.e.* Glyphosate, Paraquat, Diquat and Ammonium Gluphosinate). Besides the susceptibility, it is important to point that contact herbicides will injure but not control a developed sward.

An Alexander grass biotype resistant to Sethoxydim (ACCase inhibitor), was reported in the Northern Paraná State – Brazil in late 90s (GAZZIEIRO et al. 2004; CHRISTOFFOLETI et al. 2001; GAZZIERO et al. 2000; GAZZIERO et al. 1997). However, after thirteen years of the most recent study (GAZZIEIRO et al. 2004), reports about the resistance were no found anymore. It is hypothesized that the biotype was eliminated with the expansion of Roundup Ready® Soybean technology (RR), which uses Glyphosate as base to control weeds in the crop. Furthermore, the resistance was very specific and involved just the herbicide Sethoxydim. The same author who identified the biotype also tested other herbicides of the same class (ACCase - Clethodim and Tepraloxydim), and for those he achieved high levels of control (GAZZIERO et al., 2004).

There is no doubt that one of the main limitations to the use of Alexander grass as a forage is the weed potential of the plant. However, discussing the concept of weed is important to clarify some points about the place of Alexander grass in the agricultural system. Some concepts are presented: Weed is *(1)* Any plant that grows where is not desired; *(2)* Any plant that interferes in human objectives and; *(3)* A plant that directly or indirectly harm some human activity, and so, any plant can be considered a weed if occurring in a place and time that affects negatively an activity (SILVA et al., 2007).

Yet, a good and recurrent example of the concept *(3)* is the presence of corn plants in soybean fields of Southern Brazil, as both plants are resistant to Glyphosate, the most used herbicide in these crops. In the same region, also, soybean is the main weed of hibernal pastures in early autumn (*i.e.* Oat and Italian ryegrass), emerging from seeds that fall to the ground during the mechanical harvest in the late

summer. These examples are cited intending to parallel Alexander grass classification as weed, since it will directly depend on where the grass is allowed to develop and how it is managed.

Even with the legitimated concerns about the Alexander grass competition with crops, the consortium between Corn and Alexander grass evaluated by Oliveira (2013) evidenced the capacity to keep both species together without losing grain yields. Still, the already settled consortium systems of Brazilian savanna use *Brachiaria* which in comparison to Alexander grass are harder to eradicate (GAJEGO et al., 2013b – Ruzi grass; CORREA& SANTOS, 2003 - Signal grass) and more competitive to the crop (CARVALHO et al., 2011 - Palisade grass), presenting however good and profitable results.

Nowadays with modern practices of integrated management Alexander grass lost the position of key weed in most crops, giving space to plants with far more serious problems of resistance and dispersion abilities (*e.g. Amaranthus spp.*, *Conyza spp*., *Digitaria spp.*, etc.). The problem with Alexander grass was justified just in the past when chemicals were not available and mechanical control was the only option for the farmers. Cultural management – as reducing row spacing – is also reported as helpful to control Alexander grass, allowing reducing 50% of the herbicide doses (PIRES et al., 2001 – Soybean). Moreover, plants are not a problem in no-till proper managed areas, since the presence of straw coverage is known to suppress efficiently its emergence (THEISEN et al., 1998).

As part of the Panicoid tribe, Alexander grass present low dispersion capacity (LOCH et al., 2004), which happens essentially by *(1)* water runoff (hidrocory); *(2)* animals – transported in the mud attached to hulls or by bird that consume the seeds (zoocory), or/and; *(3)* agricultural machinery (antropocory) (KALSING, 2011; FAVRETO & MEDEIROS, 2004). This trait eases the species containment in the target areas, strongly diminishing its weed potential in comparison to species that present feathery seeds (wind dispersed).

Bermuda grass cv. Tifton 85 and Italian ryegrass, perhaps the two most contemporary important forage species of Southern Brazil in summer and winter, respectively, were essentially weeds when brought to agronomical use and breeding. Italian ryegrass stills as an important weed of wheat crops, which did not prevent the plant to become one of the best winter forage species around the country.

Finally, it is possible to state that the main reason that makes Alexander grass a problem in some production systems is their seed production behavior and aggressiveness. Its weed potential does not rest in the dispersal capacity or in its control, but in the continuous promotion of a seedling flux after the community elimination, due to the great seed banks in the soil. A better understanding of these seed issues is fundamental to suppress or endorse the species development, depending on the goal of the production system.

7.3 Alexander grass as a forage

Despite the broad use of *Brachiaria* in Brazilian livestock, Alexander grass remains modest for this purpose. Comments about its use in production are sparse, except for areas in smallholder agriculture where it spontaneously develops.

To present Alexander grass as a forage plant, its merit can be defined comparing the species to some other successful ones. An important question is why to use and develop a wild plant since others that already have been studied are available? The strongest argument resides in the match of an excellent environmental adaptation with many characteristics desirable in a forage plant, which have not undergone genetic manipulation and can be boosted by a breeding program.

Brachiaria is notorious for being "infinitely forgiving of mismanagement", recovering readily from heavy trampling and overgrazing. These statements fit Alexander grass to some extent, once the grass is decently resistant to grazing – a feature supported, among other factors, by the node rooting when the stems contact the soil. If pressure is excessive, however, the pasture can decay.

When properly managed, in contrast, it presents vigorous forage production, with high accumulation rates (BORTOLINI et al., 2012; SEIFERT, 1980). *Brachiaria* genus already highlights among the highest yielding tropical forage grasses (MILES et al., 2004), and Alexander grass even stands out. Some data of experiment that evaluated it as forage are presented (Table 4).

Table 4. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) productive indexes in Southern Brazil - Adapted from Oliveira (2013).

Source[3]	D.W.G.	L.W.G.	A.S.R.	A.F.M.	T.F.P.	A.R.	C.P.	P.U.P
(1) MARTINS et al. (2000)	850	286	3.3	*u.d.*	6.3	34	6.4	73
(2) RESTLE et al. (2002)	1.054	668	3.6	2,8	11.1	*u.d.*	10.0	98
(3) SARTOR; ADAMI; (2009)	*u.d.*	*u.d.*	5.7	3,2	17.1	126	17.6	135
(4) SOUZA (2009)	616	347	3.4	2,9	15.9	*u.d.*	18.1	84
(5) ROSO (2011)	816	730	*u.d.*	*u.d.*	9.3	94	13.3	85
(6) COSTA et al. (2011a)	766	590	4.9	3,9	*u.d.*	161	16.7	109
(7) GLIENKE (2012)	864	545	5.2	3,0	*u.d.*	108	14.3	*u.d.*
(8) MIGLIORINI (2012)[1]	14	46	6.6	2,8	*10.6*	123	22.6[2]	*86*
(9) SALVADOR (2016)	1,170	461	4.6	3.0	*u.d.*	99	11.4	85

D.W.G: Daily weight gain (g day^{-1}); **L.W.G.:** Live weight gain (Kg ha^{-1}); **A.S.R.** Average Stocking Rate (Animal Unit; 450 Kg L.W.); **A.F.M.:** Average forage mass (T DM ha^{-1}); **T.F.P.:** Total forage produced (T DM ha^{-1}); **A.R.:** Accumulation rate (Kg DM ha day^{-1}); **C.P.:** Crude protein (%); **P.U.P.:** Pasture utilization period (days); ***u.d.*:** unavailable data. Management parameters: **(1)** 14% forage offer; 0, 100, 200 Kg N ha^{-1}; **(2)** 2t DM ha^{-1}; 300 Kg N ha^{-1}; **(3)** 3 and 1.5 t DM ha^{-1}; 0, 200, 400 Kg N ha^{-1}; **(4)** 40 cm sward; 45 Kg Nha^{-1}; **(5)** 8 and 12% forage offer; 70 Kg N ha^{-1}; **(6)** 3t MS ha^{-1}; 67 Kg N ha^{-1}; **(7)** 11.3% forage offer; 70 Kg N ha^{-1}; **(8)** Pasture height 10, 20, 30, 40 cm; 200 Kg N ha^{-1}; **(9)** Forage offer 13%; 0, 100, 200, 300 Kg N ha^{-1}; [1]Finished goats; [2]Just leaf blades; [3]For all sources, continuous stocking.

Similar animal production results are observed if compared Alexander grass to other widely established annual forages. It was found in the study of Restle & Barreto (2000) with pearl millet, one of the most popular annual warm season grasses in Southern Brazil (live weight gains of 626 Kg ha^{-1}). Same situation with the same species is reported by Costa (2009). Comparison of daily weight gain (D.W.G.; Table 4) can be done also to other warm season grasses: 742 g day^{-1} with Guinea grass cv. Tanzania; 590 g day^{-1} with Guinea grass cv. Mombaça; 637 g day^{-1} with Bermuda grass cv. Coastcross; 680g day^{-1} Signal grass cv. Basilisk (COSTA & SANTOS, 2003), and; 756 g $day^{-1}$with Palisade grass cv. Marandu (VALLE et al., 2009).

The forage presents good digestibility and crude protein (CP) rates (Table 4), being superior to all Brachiariagrasses typically used as pasture nowadays. CP reach double the values found in Signal grass, Ruzi grass and Palisade grass, those considered by Miles et al., (2004) as members of the high CP group in the genus. For crude protein content Eloy et al. (2014) reported values 34.8% superior to requirement of Alexander grass grazing heifers, assuming an average daily gain of 0.860 kg.

The plant presents good stem: leaf ratio, and even if leaf sheaths were ingested they have good digestibility. As the sward structure is not considerably changed in the end of the cycle, bromatological characteristics were not substantially changed as well. Leaves aspect can give a gross visual indicator about the digestibility statement, easy bending downward in the middle as low fiber is found in the composition (Figure 14).

There were no documented toxic effects by the forage consumption. The plant does not cause photosensibilization, neurological disorders or hepatic constrains as observed in Signal grass. The plant presents great palatability and acceptance by animals (RODRIGUES, 2002), and architecture suiting both for big and small animals (decumbent growing habit).

Figure 14. (A) Top view of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) sward in the vegetative phase; (B) Side view of Alexander grass sward in the vegetative phase. Detail in the aspect of the leaves bending downward, a gross visual indicator of low fiber composition (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

A noteworthy work was developed by Aspiazu et al. (2012), where Alexander grass and hairy beggarticks (*Bidens pilosa*) strategies to deal with water shortages were compared. Observations evidenced that hairy beggarticks has high capacity to extract water from the soil, besides not being remarkably efficient in its use. The species is capable of keeping water absorption in soil hydric potential whose other plants will totally cease it. Alexander grass, on the other hand, has a distinct strategy to survive water deficit, being not so efficient in extracting it from the soil, but efficiently using the resource. The grass closes stomata when light level is lower than the active photosynthetic radiation, keeping photosynthesis even with low percentages of water in the dry mass, a interesting behavior related essentially to a strictly transpiration control (ASPIAZU et al., 2010).

When plenty of water and high temperatures are available, in contrast, vigorous growing is achieved. Besides being better adapted to cooler climates than most *Brachiaria*, Alexander grass will present astonishing accumulation rates in warm climates (Table 4). In *Brachiaria* genus shoot and root growth increase directly with the increase of temperature to an optimum between 30 and 35°C. Most species grow vigorously at 35°C, some even up to 38°C (MILES et al., 2004). In the Subtropical Brazil no symptoms of stresses are observable in Alexander grass even in the hottest days of the year (Frequently, those when the plant grows better), statements as this for equator regions still lack information.

Low temperature, on the other hand, influences Alexander grass growth. As all Brachiariagrasses it presents reasonable and low resistance to cold and frost, respectively, and if considered the genus average, little growth is supposed to occur below 15°C (MILES et al., 2004). Nonetheless, as already mentioned, Alexander grass basal temperature still not been determined – standing among 0 to 17,5^{o}C (PAULA & STRECK, 2008) –, but field observations clearly evidence that this grass is more tolerant to lower temperatures than other Brachiariagrasses. This statement is confirmed by Nicolai (2009), when comparing Signal grass and Alexander grass and by the higher latitudes where the grass better develops.

It was observed that Alexander grass tolerates short time flooding (5 days). After a long rainfall period in the 2015/2016 summer water accumulated in the sward base and no stress symptoms were observed (Figure 15). Poor drainage, actually, is a major edaphic constraint to forage production in the tropics. Widely planted cultivars such as Basilisk and Marandu are not adapted to poor drained soils (MILES et al., 2004), as other Brachiariagrasses as Koronivia grass and Para grass develop particularly well in this condition (ESGPIP. 2010). Besides present in flood rice, when the water level is uneven (GALON et al., 2014), data about Alexander grass growing in waterlogged places were not documented. It is probable that the plant does not fit to this situation, once natural occurrence in swamps is not observed.

Figure 15. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) plants in temporary waterlog (5 days). No injury symptoms were observed (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Alexander grass develops in most tropical and subtropical soils. The plant occurs in poor soils. As the fertility increase, the plant vigor increases proportionally (COSTA et al., 2009). In general, Alexander grass outstands when compared to other subtropical forage grasses is their ability to produce abundant forage under conditions of low soil fertility, low pH and Al toxicity; a statement also reported for most Brachiariagrasses (MILES et al., 2004)

The plant presents robust response to nitrogen fertilization increasing dry mass yields and forage quality (ADAMI, 2009). If the N dose increases, crude protein and total digestible nutrients increases also, and neutral detergent fiber reduces (SALVADOR, 2014). Comparing the doses 0 and 400 Kg N ha^{-1} the CP levels increased from 15.2 to 19.9% (SALVADOR, 2014), which is very close to the Martins et al. (2000) findings, whose reported that for each N Kg applied in the grass there was an increase of 0.0175% in the CP rates. For the same doses comparison (0-400) the neutral detergent fiber reduced from 66.4 to 61.6%, and total digestible nutrients increased 65 to 68% (SALVADOR, 2014).

Alexander grass does not produce tussocks of hard elimination or tough lignified material in the plant base. If observed management criteria, can produce good nutritional quality hay, as observed during harvests in Southern Brazil where the plant develops spontaneously among other forage species.

In crop-livestock areas, Alexander grass usually provides fodder at very low costs being used after corn harvest, a low forage availability period. In these cases, animals can feed on spontaneous plants that developed during crop cycle and on corncobs that fell to the ground during the harvest (ADAMI, 2009). A better option is the intentional composition of an intercropped system among the forage and corn, which boost the forage mass availability of the system and can keep equal grain yields (OLIVEIRA, 2013). Other associations with Alexander grass (as legumes, for example) are generally not successful once the aggressive growth suppresses the other species development.

The plant occupies the space quickly. There is dense tillering (substantially endorsed by a good nitrogen provided), helped also by the node rooting. It can be used in hilly sites, since after the establishment it provides good soil protection forming a net of stems anchored by rooted nodes.

The plant easily propagates by seedlings. A classic example was the conventional tillage systems where the mechanic removed Alexander grass plants have to be shaken to release the soil attached to the roots, by the risk of a new infestation in good moisture conditions. It presents yet high vigor in buds, which can be interesting in seedling obtaining.

As a negative, in free growing Alexander grass is highly prone to lodge. The decumbent habit and vigorous growing plus a low lignin level make the plant falls and form a stem bed in the sward base (Figure 16). Besides interesting to environmental dominance and for soil protection, this condition can endorse serious forage loses, reduce seed set and stimulate diseases development (ANDRADE et al., 1983; LOCH, 1980). Still, the accessibility of the leaves for the animals is worsened.

For a pasture, however, this situation can be easily controlled by a correct management of grazing/cutting height. In seed crops it is common that faint defoliation management (WONGSUWANG, 1999), heavy nitrogen application (ANDRADE, 2001; GOBIOUS et al., 2001), and humidity excess (LOCH, 1980) results in lodging of the stand.

As well as most of *Brachiaria* species Alexander grass seed production seems to be poorly synchronized, factor that summed to the genus shattering susceptibility present a great constraint if cropped for seed. Besides a great potential of natural reseeding (BORTOLINI, 2012), seeds present dormancy and a soil seed bank usually provides a seedling flux in early spring (Figure 17; SICHONANY, 2012). Seeds were not easily spread, but when it does it present a highly colonization potential, especially if new areas match with ruderal plants necessity (GRIMME, 1979).

Figure 16. Lodge in Alexander grass (*Brachiaria syn. Urochloa plantaginea*) sward. The phenomenon was observed in January 2015 possibly as a result of *(1)* the natural decumbent growth habit; *(2)* the low fiber content; *(3)* The occurrence of high rainfall and strong winds; *(4)* the warm climate; *(5)* the high nitrogen fertilization, and; *(6)* the absence of cut or grazing after december 2014 (*Picture source: J.R. Oliveira - OLIVEIRA, 2017*).

The behavior of Alexander grass seed in the soil seed bank is so concrete that the vast majority of researches which evaluated Alexander grass establish the pasture just performing a light harrowing to stimulate the seeds to germinate (ELOY et al., 2014; SALVADOR, 2014; OLIVEIRA, 2013; BORTOLINI et al., 2012)

About that, a management that promotes the pasture natural reseeding is very interesting for the livestock phase of the system. However, if the seed bank is stimulated in grain crops phase it can complicate the weed control (FAVRETO, 2004). In the soybean-winter pasture integrated system of Southern Brazil, an example of equivalence has already been reached: the Italian ryegrass produces seeds in the late winter and germinates from soil seed bank in the early autumn, at the end of the soybean cycle. Another combination could be the wheat cropping with naturally reseeding legumes as subterranean clover (*Trifolium subterraneum*) and alfalfa, used

in Southern Australia, Northern Africa and Eastern Asia (AMEZIANE et al., 1989). Some adjustments in the systems management can help to achieve somehow the same result with Alexander grass.

Figure 17. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) natural emmergence, from soil seed bank, after light harrowing in a white clover (*Trifolium repens*) pasture (At the top of the image the remaining pasture, where mechanichal management was not performed; also, sheeps and dairy cattle in mixed grazing). The system aims to replace the legume for Bermuda grass cv. Tifton 85 (*Cynodon dactylon*) – After Tifton 85 seedlings get planted in the first year, Alexander grass is allowed to freely develop to provide early forage to the herd. The annual grass gradually lose participation in the composition of the sward, giving place to the permanent one (*Picture source: J.R. Oliveira, 2013 – Tapejara – RS, Brazil - OLIVEIRA, 2017*).

Despite natural reseeding represents an alternative to pasture establishment it is a risky option since it is directly dependent on climatic issues as rainfall and temperature; and also, on the consistency of reseeding of the previous year. If some of these factors fail, there are chances of the grazing point be delayed and the feeding of the herd be impaired (OLIVEIRA, 2013; COSTA, 2009). These statements also reinforce the need on knowledge about this species seed production.

Alexander grass is susceptible to *Colaria scenica* attack (Hemiptera). There is no information about Spittlebug tolerance. Allelopathics are speculated, but not proved. In normal conditions, this phenomenon is not observed, once evidences were constructed on high concentrated solutions. Besides the existence of some statements about the limitation of other plant growing by Alexander grass straw, the phenomenon is attributed mainly to a physical barrier. There is no data available for Alexander grass fire resistance, shade tolerance (and silvipastoralism), nitrogen fixing bacteria associations and genetic variability.

Finally, away from field management, Costa et al., (2016) investigated the possibility of using Alexander grass as an alternative source of shikimic acid. The author observed that when sprayed with glyphosate sub-doses Alexander grass produces high concentrations of the substance. After 6 days of exposure to the herbicide levels of shikimic acid presented 345% higher compared to unsprayed plants.

Despite the occurrence in all tropical and subtropical America, Alexander grass present greater expression in the regions of Southern and Central Brazil, among latitudes around 15^{o} and 25^{o} S. As cited by Hacker & Loch (1997) many of the tropical forages released for grazing were initially thought for 'niche' environments rather than having a more widespread role, as examples of several species released in Australia in the 1960s. It is debatable that developing cultivars adapted to such restricted markets can be justified, however, new species released initially for a niche market could turn out to be more broadly adapted and have a larger market than originally envisaged (*e.g.* Fingergrass (*Digitaria milanjiana*) cv. Jarra, Creeping Vigna (*Vigna parkeri*) cv. Shaw, and Rhizome peanut (*Arachis pintoi*); HACKER & LOCH, 1997). This situation, likewise, can happen to Alexander grass, once the species can grow away from the Brazilian borders as a pasture for similar climate regions as the Southern Asia and the central Africa, its origin center.

Alexander grass reproductive morphology according to the phenological evolution – the quantitative responses

CHAPTER 2

1. INTRODUCTION

Selection of new forages often considers just the plant capacity to produce leaves along the season. Modern approaches, however, have been accenting seed production as one of the major parameters to search in breeding (VERZIGNASSI, 2015; VALLE et al., 2008). It happened since the efforts in develop good pastures are in vain if these plants were not able to produce reasonable amounts of seed to spread the technology. Understanding the reproductive behavior, thus, is a crucial point even for systems where grasses are used just for fodder production.

Little is known to provide a single picture of the *Brachiaria* reproductive behavior (HOPKINSON et al., 1996). This is even worsened in Alexander grass, a plant with positive characteristics for a good pasture, but known most of the time just by its habit to emerge spontaneously in managed environments. Few studies are found on the specie and supportive information on its reproduction is lacking.

Alexander grass seems to present faint synchrony on panicle emergence, a trait that influences notably the crop management and the final seed production (HARE et al., 2015; MASCHIETTO et al., 2003; SOUZA, 2001; BOONMAN, 1971). Other complications are the lack of synchrony within the inflorescence and the seed shattering: chopping an inflorescence of this plant some seeds will shed and others (immature) will keep attached to the rachis. In the same panicle it will have also empty spikelets and florets on early anthesis (MASCHIETO, 1981).

To reduce the expression of these characteristics a well-accepted and broadly used technique is the uniformization cuts (HOPKINSON et al., 1996). This encourages at first concentrated production of new similarly aged tillers in the regrowth, basis for a synchronized inflorescence emergence and more uniform seed maturation (ESGPIP, 2010; SOUZA, 2001; WONGSUWAN, 1999). Depending on the intensity, these managements can also influence the number of seed heads (SOUZA, 2001; LOCH, 1985; LOCH, 1980) and other components as the raceme number per inflorescence and the spikelet number per raceme (HUMPREYS & RIVEROS, 1986).

Beyond the management during the cycle, the decisions on the seed crop need to start even before the field establishment. A major concern is the regional adaptability *i.e.* the sum of many biotic, edaphic and climatic influents that determine the plant development (LOCH et al., 2004). These factors are often not handle (SOUZA, 2001), making the choice of the location a central topic to a successful production. Understanding the plant responses to stimulus as photoperiod, rainfall and temperature are thus the base to encounter a suitable crop site. In summary, a proper environment must combine conditions for vigorous vegetative growth, appropriate stimulus for flowering, effective seed set, and a dry period for harvest (MILES et al., 2004; ANDRADE et al., 1999; HOPKINSON et al., 1996).

Some experiments were developed with Alexander grass looking to understand the reproductive behavior of the plant. In this case, especial attention was given to reproductive yield components and the inflorescence morphology, according to the influences of environmental factors and the cut management. Beyond the sharp effects the dynamics of the plant along the cycle were valued in the analysis.

2. MATERIALS AND METHODS

The trials were established at the experimental station of the Federal University of Technology – Paraná – Pato Branco (26°10'40" S; 52°41'18" W; 750 m asl.). Region climate is Cfa transition to Cfb, according to Maak (1968) classification. At early September 2014, samples were collected to perform soil chemical analysis. Data is presented in Table 5.

Table 5. Soil chemical data at the site used for Alexander grass (*Brachiaria syn. Urochloa plantaginea*) experiments. Experimental station of the Federal University of Technology of Paraná – Pato Branco (2014).

Index	Value[1]	Unit
Organic matter	5.7	%
P	28.2	mg dm^{-3}
K	1.0	$cmol_c$ dm^{-3}
Al^{+3}	0.09	$cmol_c$ dm^{-3}
$H + Al^{+3}$	7.13	$cmol_c$ dm^{-3}
Ca	3.8	$cmol_c$ dm^{-3}
Mg	2.3	$cmol_c$ dm^{-3}
Bases sum	7.10	$cmol_c$ dm^{-3}
V	49.9	%
Aluminum saturation	1.25	%
pH	4.6	$CaCl_2$
CEC	14.2	

[1] Analysis developed at the Soil Laboratory of Federal University of Technology – Paraná – *Câmpus* Pato Branco. 2014.

2.1 Experiment 1 – The panicle emergence

The major aim of this experiment was to characterize the dynamic of panicle emergence and to identify the total production of panicles in Alexander grass according to defoliation treatments.

It was used an area with established soil seed bank where Alexander grass emerged naturally. No soil mobilization was performed and there was no mulch covering the soil. The Experiment was conducted in a randomized block design: 16 m^2 were divided in 16 plots of 1 m^2, involving 4 treatments with 4 replications. The treatments were 0, 1, 2 and 3 defoliations, performed at 20 cm when the plant reached 40 cm of sward height – based on Migliorini (2012) – with a back brushcutter equipped with a metal blade (Figure 18). 200 Kg N ha^{-1} was applied using urea 45% N, for all plots (even "no cut") just after the first defoliation in treatments 1, 2 and 3 cuts. In mid-October (2014) Metsulfuron-methyl was sprayed at the dose of 5 g a.i. ha^{-1}, using Ally ® (Du Pont) to control spontaneous broad leaves species that grew together with Alexander grass.

Figure 18. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) plots according to number of defoliations, based in the sward height (40 cm total height, cut at 20 cm). On the left "no cut" treatment, on the center "1 cut" treatment, on the right "2 cuts" treatment (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Plants were periodically observed since the emergence, mowing every time the height reached the parameter of 40 cm according to the treatments. The panicle count started as the first reproductive tillers appeared (late December). Leaf sheaths that presented booting inflorescences and emerged inflorescences were marked with a cotton string to avoid double counting (Figure 19). Guideline was to execute counting each 7 days, however, rainfall conditions did not allow to keep strictly the periodicity, prevailing the counting once a week in slightly day variable intervals. Experiment end was determined for late March 2015. In this occasion, also, plants were chopped close to the ground and basal tillers were counted.

Figure 19. Cotton strings tied to Alexander grass (*Brachiaria syn. Urochloa plantaginea*) leaf sheaths, used to mark the panicles for counting (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Variables composed with data collected were:

1. Panicle emergence rate: the number of panicles that emerged since the previous counting.
2. Accumulated panicles per area: The number of panicles that emerged since the previous counting summed to the number of panicles that emerged after the cut in all counting performed before.
3. Tiller number: the number of basal tillers.

Data was catalogued and Statistical analysis performed using 'R' program (R DEVELOPING CORE TEAM, 2011), and 'Genes' (CRUZ, 2006). Regression analysis and graphs were developed using Sigmaplot®. Data was submitted to analysis of variance. Further, to analyze 'panicle emergence rate' a bi-segmented polynomial regression was developed, and to analyze 'accumulated panicles per area' polynomial regression was developed. For all, significance level considered was 5% probability.

2.2 Experiment 2 – The panicle age

The major aim of this experiment was to characterize the morphological evolution and the shattering behavior of Alexander grass seed heads, according to the panicle age.

The experiment was developed at the experimental station described in the *caput* of this session. No soil mobilization was performed, and there were no mulch covering the soil. 30 m^2 were used. Two cuts were performed at 20 cm when the plant reached 40 cm, using a back brushcutter equipped with a metal blade. 200 Kg N ha^{-1} was applied using urea 45% N just after the first cut. In mid-October (2014) Metsulfuron-methyl was sprayed at the dose of 5 g a.i. ha^{-1}, using Ally ® (Du Pont), to control spontaneous broadleaf species that grew together with Alexander grass.

After the grass development tillers were marked to establish an initial point according to which the panicle age was determined – this ages corresponded also to the treatment factor. The stage chosen to establish the point zero in the counting was the range between "Booting 49" and "Booting 52" (Beginning of heading: tip of the inflorescence visible to 20% of the inflorescence visible) according to the BBCH Scale (MEIER, 2001; Figure 20). It is important to state that this was an adaptation of the scale commonly used for cereals according to Meier (2001) classification, a solution encountered for the issue that no phenological scale is available specifically for Alexander grass, or even for Brachiariagrasses. Also, it was known that the age "zero" is just nominal, used to count the time after the very first appearance of the panicle, once it actually was already developing since the meristem differentiation.

Figure 20. (A) Alexander grass (*Brachiaria syn. Urochloa plantaginea*) panicle just after the emergence from the leaf sheath. The stage is analogous to the interval between "Booting 49" and "Booting 52" (Beginning of heading: tip of the inflorescence visible to maximum 20% of the inflorescence visible) according to the cereals BBCH Scale (MEIER, 2001). In Alexander grass the transition between these points occurs in less than a day and characterizes the day zero in the counting of panicle age for seed and panicle assessing; (B) Same panicle of 'A' after removal of enclosing leaf and sheath (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Giving the lack of synchrony a period until substantial number of tillers became reproductive elapsed – the initial point was marked thus at early February 2015. In this occasion, the panicle stems were tied with cotton strings looking for all the tillers that represented the stage zero in the plots. The strategy was developed to guarantee leftovers, making the moment of the main harvest for the analysis random. In addition, there was no estimative of how long the evaluation period would last and the end of the experiment was determined to when the panicles degradation did not allow evaluations anymore. In summary, seed ages in which panicles were collected (levels of the treatment) counted in days after the initial marking were 6, 11, 14, 20, 24, 28, 34 and 38.

30 panicles (observations) were collected for each age, chopping the stem below the last node. After that, panicles were taken to the Federal University of Technology Seed Laboratory, where the evaluations occurred. Leaves and leaf sheaths were removed and the following variables were assessed:

1. Number of intact racemes: counted manually; characterized by racemes that presented the tip spikelet in the rachis (Figure 2) or the scar of the tip spikelet.
2. Number of cut/detached racemes: counted manually; characterized by the racemes that did not present the tip spikelet in the rachis or the scar of the tip spikelet.
3. Raceme length: measured manually using a 1mm scale rule, from the rachis insertion in the inflorescence axis to the tip of the distal spikelet on the rachis. Racemes that presented collapse in the rachis were discarded from the analysis. Expressed in centimeters;
4. Inflorescence axis segment length: measured manually using a 1mm scale rule, from the insertion of each raceme in the inflorescence axis to the insertion of the next raceme in the inflorescence axis, following the

sequence from the distal part of the inflorescence to the proximal part. Expressed in centimeters;

5. **Number of seed attached to the raceme:** counted manually, for each raceme;
6. **Number of detached seed in the raceme:** counted manually through the number of scars in the rachis, for each raceme (Figure 3);

After these evaluations some other variables were composed based on the data collected:

7. **Inflorescence axis length:** the sum of all inflorescence axis segments lengths. Expressed in centimeters;
8. **Total seeds produced in the raceme:** The sum of seed attached and detached of the raceme;
9. **Shatter percentage:** The relation between total seeds produced in the raceme and seeds detached of the raceme, multiplied by 100 (Rule of thumbs). Expressed in percentage;

Racemes were named seeking identification for further statistical analysis and comparison, from the distal portion to the proximal portion of the panicle, in a crescent order. Data was catalogued and Statistical analysis performed using 'R' software (R DEVELOPING CORE TEAM, 2011), and 'Genes' software (CRUZ, 2006). For the racemes variables, comparisons were performed for the racemes that occurred in at least four observations (panicles). Regression analysis and graphs were developed using Sigmaplot®. For all variables analysis of variance and Scott e Knott tests were performed considering a significance level of 5% probability.

3. RESULTS AND DISCUSSION

3.1 Experiment 1

The experiment carried out with no influence of pests, weeds or diseases. Alexander grass vigorously developed in response to the high fertilization and favorable climatic conditions. These observations confirmed the capacity of the grass to quickly occupy the ecological niche and cover the soil, as observed by Oliveira (2013) when intercropping it with corn.

Analysis of variance identified differences among the cut treatments ($P < 0.05$) for the variable panicle emergence rate, however, no single polynomial model was found to adjust properly to the data. For the representation it was used thus a bi-segmented curve (broken line regression), which adapted in the first section to a linear crescent model and in the second to a negative quadratic model. Analysis of confidence interval was also used to compare the peak in the panicle emergence, which happened in the 54th day after the first panicles emergence (Figure 21).

Panicle emergence started slowly at late December (Figure 21; Figure 22). A poor synchronized behavior was observed at first, presenting increasing rates until the 48th evaluation day in daily increases of 2.19, 2.57, 2.58, 0.97 panicles m day^{-2} with 0, 1, 2, and 3 cuts, respectively. At the 54th day, the plant expressed response to some sharp trigger, since in the 6 days that elapsed from the previous evaluation (48thday) the rates of emergence leaped to 54, 54, 33 and 10 panicles m day^{-2}, in the treatments 0, 1, 2 and 3 cuts, respectively (for some treatments, a five times increase in comparison to the 48th day evaluation). Still, in the next evaluation (58th day) the emergence rate returned to the levels close to the previously observed (48th day), and kept decreasing until reach a small panicle production at the end of the warm season (Figure 21).

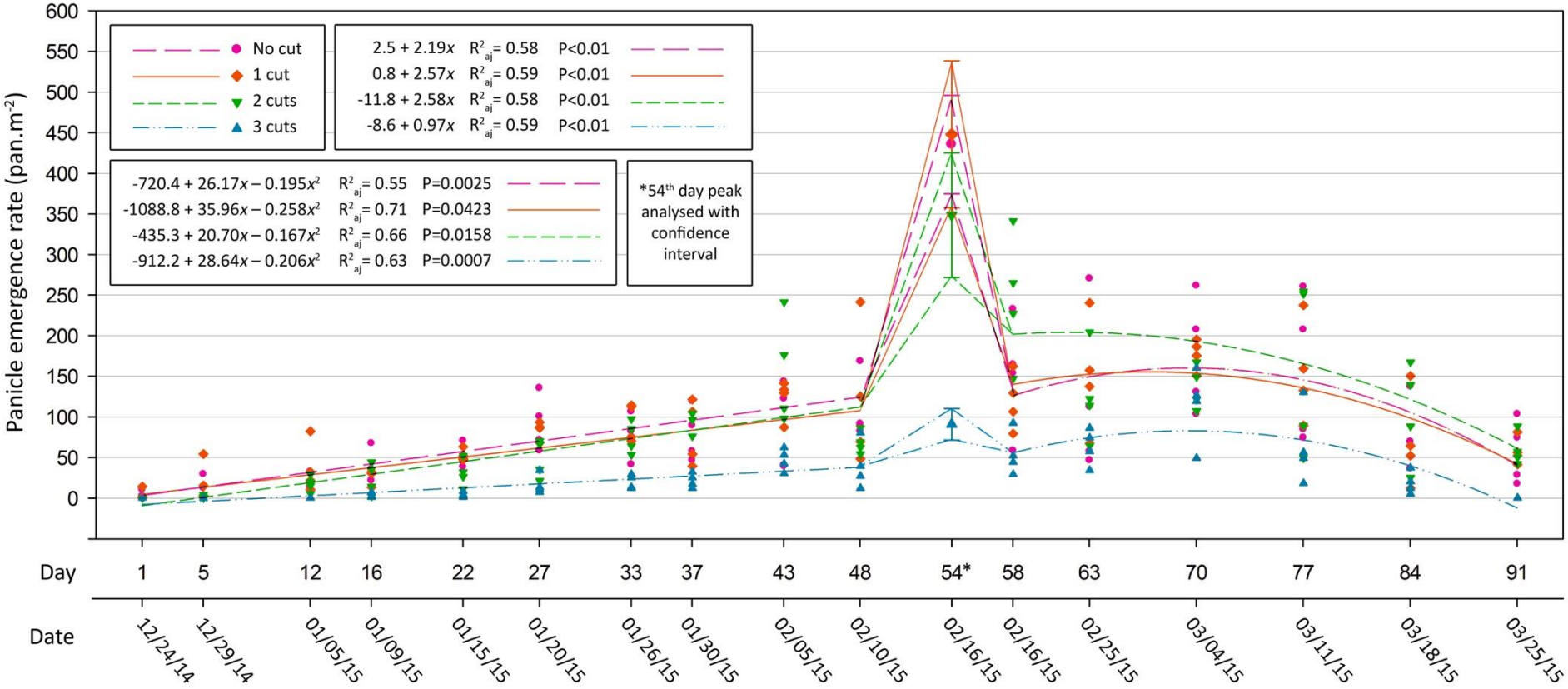

Figure 21. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) panicle emmergence rate according to number of cuts, performed at 20 cm, when the sward reached 40 cm (*OLIVEIRA, 2017*).

Figure 22. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) panicle emmergence beginning (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Comparatively, Alexander grass behave as Koronivia grass and Ruzi grass, presenting one flowering peak, since Palisade grass and Signal grass can present two or three peaks, spaced 30 to 40 days between each other depending on the climate and management (SOUZA, 2001). Even with this, the decision to rank Alexander grass as a poor or sharp synchronized plant keeps an issue. Despite the evident sharp increase in the rates of mid-February, in this occasion just a share of the total panicle production emerged, being 25.3 %, 24.7%, 20.59% and 16.4 % for the total production with 0, 1, 2 and 3 cuts, respectively. Assuming that, just a quarter of the seed would be reclaimed in a single destructive harvest (in the better treatment), ignoring also some potential losses by precocious shatter.

As stated, most Brachiariagrasses shows lack of synchronism (MILES et al., 2004; SOUZA, 2001, HOPKINSON et al., 1996). Following the rank presented by Hopkinson et al., (1996) which classify Brachiariagrasses in a decreasing synchronization as (1^{st}) Koronivia grass, (2^{nd}) Ruzi grass, (3^{rd}) Signal grass and (4^{th})

Palisade grass (*See Chapter 1 – pg.61*), Alexander grass will fit somewhere between the 2nd and the 3rd specie. Even though, the specie is relatively synchronized in relation to the panicle emergence.

Thinking about the crop management, some cycle reference for the timing of inflorescences emergence will be opportune. The last cut was performed at December 12th 2014, and first panicle appearance was at December 24th for 0 and 1 cut, December 29th for 2 cuts, and January 9th for 3 cuts (Figure 21). This indicates firstly that 2 and 3 cuts delay at some extent the first panicles appearance. Regardless, this did not significantly influence the emergence peak of mid February, which happened at the same time for all treatments. It means thus that cutting is not a satisfactory solution to establish the reference point for flowering time – which was proposed by Gobious (2001) for Signal grass, presenting inflorescence emergence in the species 52 days after the defoliation.

Benteo et al. (2016) evaluating Palisade grass proposed the N fertilization as a reference for flowering, reporting full anthesis 22 days after the fertilizer application and also the beginning of flowering 13 days before that. This statement actually is against the known characteristic of Palisade grass to be poorly synchronized (HOPKINSON et al., 1996) indicating the emergence of inflorescence in 9 days. Also, fertilization can be delayed and vary among the overall management as well.

Another option could be the counting from the species emergence, which happened for Alexander grass in late September. In this case the peak in the panicle emergence will happen, independently of the number of cuts, approximately 130 days after the emergence (late September to early February). Environmental issues as thermal sum and daylength are possibly involved in the flower induction process – which can be a more precise guideline in comparison to the field management if taken an overall looking on warm season grasses.

To discuss the flowering induction it is important to point out that this process may precede actual flowering emergence by several days, weeks, or even months (MARCOS FILHO, 2007a). In a general approach for Brachiariagrasses, Stur and

Humphreys (1987) cite a near 38 days period for the process, assuming the spikelet differentiation beginning 10 days before flower initiation, and first inflorescences emerging about 28 days later. Through a study on Signal grass, Stur (1986) showed that in this 38 days the tiller should perform four important processes: *(1)* raceme initiation; *(2)* spikelet initiation; *(3)* spikelet differentiation and; *(4)* inflorescence exsertion.

To harden these questions there is the fact that each individual tiller will take its own time to differentiate. This statement is confirmed by the differences in panicle emergence even within the same plant, as observed in Alexander grass (Figure 21). Also, Stur (1986) reports that the primordia evolution of Brachiariagrasses are far harder to identify than in cereals *i.e.* the initial increase in apex length was much shorter, and the 'double ridge' stage traditionally used to define the floral initiation is not easily detected.

Keeping these reservations some inferences can be made about the flower induction in Alexander grass: it was historically (and empirically) observed in unmanaged plants of Alexander grass in Southern Brazil that just scarce flowering appears before December, which can indicate a possible daylength response (a parameter fixed among the years). In this trial (latitude ~26), 13 hours of daylength was reached in February 13, just in the period in which the flowering peak appeared (Figure 21; Figure 23). Yet, considering a 38 days gap between flower induction and the actual flowering proposed by Stur & Humphreys (1987), induction should have happened in this case at January 6th, in a daylength of and 13 hours and 41 minutes. If considered in contrast the first panicle emergence that occurred at December 24th, minus the 38 days' gap, one arrives at November 16th, when the daylength was 13 hours and 26 minutes. For instance, in a general analysis, if some photoperiodic response is involved in the Alexander grass flower induction it should be around 13 hours and a half of daylength, making the grass a long-day plant. Even considering the variations within the same plant and the indeterminate flowering, this could be refined as a quantitative long-day response (non-obligate), the same observed in Signal grass

and Palisade grass (MILES et al., 2004; HOPKINSON et al., 1996). Koronivia grass also fits partially to this stimulus since it also presents long-day responses (MILES et al., 2004; HOPKINSON et al., 1996), but having the sharp flowering it is inferred an obligate characteristic.

Besides photoperiod, another influence hypothesized can be the temperature *i.e.* the thermal time. Unfortunately, there is also lack of basic information on Alexander grass to establish assuredly this influence. Several data still open to conjecture once a broad range of experiments in several latitudes and altitudes are necessary to establish reliably and unequivocally this phenological index (LOCH et al., 2004). To have at least a guideline some calculations can be presented.

Firstly, Alexander grass basal temperature is not determined. As a parameter, the general value of 16^{o}C for tropical/subtropical grasses was presented by Loch & Fergusson (1999); and 17^{o}C and 15^{o}C were estimated for Signal grass and Palisade grass, respectively, by Mendonça & Rassini (2006). Having the recognized characteristic of Alexander grass to adapt to cooler climates a hypothetical base temperature around 13^{o}C could be a credible value. Also, a juvenility period is often involved in the capacity of these plants to sense temperature stimulus. No data on juvenility is available for Brachiariagrasses but for maize – a grass rigorously responsive thermal time – Sylvester et al. (2001) identified a juvenility period lasting 4 to 5 weeks. On that, 30 days will be used for calculation for Alexander grass.

Considering the medium air temperature data from the experimental period, presented in Figure 24, and the thermal time accumulated by Alexander grass from October 20th (Already considering a 30 days juvenility counted from the emergence) until flower induction (estimated at January 6th, or 38 days before the flowering peak; STUR, 1986; Signal grass), the result will be 771^{o}C. This estimative make sense if compared to the present day commercial maize cultivars that need 800^{o}C to 900^{o}C, depending on the cycle of the cultivar (ZUCARELI et al., 2010).

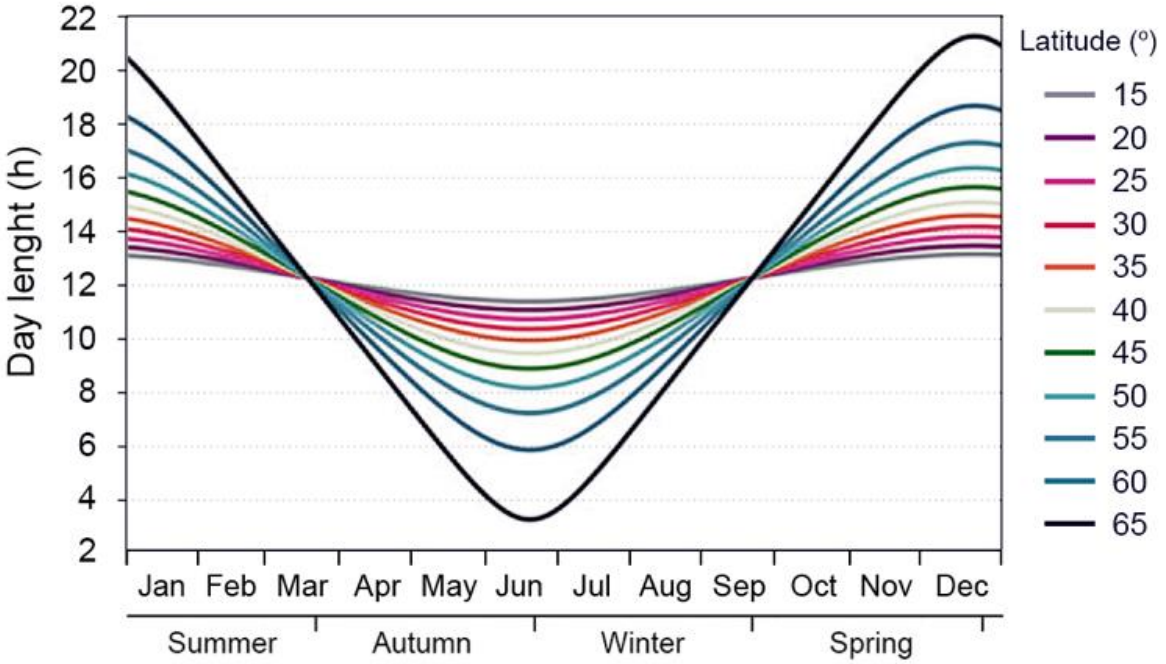

Figure 23. Seasonal Day length variation according to the latitude (Seasons in the x-axis are relative to Southern Brazil; for Pato Branco – PR, latitudes will be near 26°; *Adapted from:* Wilczek, 2010).

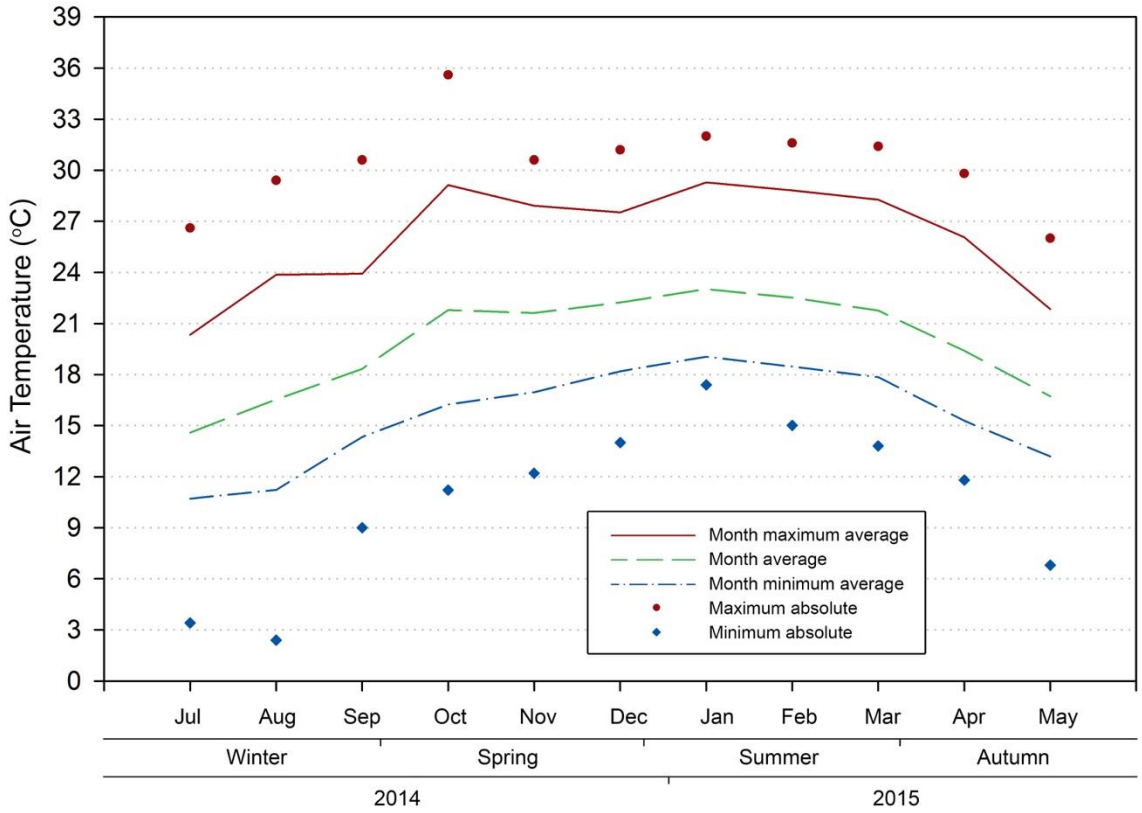

Figure 24. Air temperature from July 2014 to May 2015 (Seasons in the *x*-axis are relative to Southern Brazil; *Data source*: Instituto Agronômico do Paraná – IAPAR, Meteorological Station of Pato Branco- PR, Brazil).

Finally, effects on the flowering induction of Alexander grass can also be influenced by moisture or rainfall. This factor however is accepted as supplementary, not being a proper phenological stimulator but a vegetative phase vigor regulator (*See also Chapter 1 – pg.55*; HOPKINSON et al., 1996). For this case, the experimental period was particularly rainy with frequent occurrence of windy storms that, including, stimulated the grass to lodge. In the 7 months from September 2014 to March 2015, the rainfall summed 1,559 mm (Figure 25).

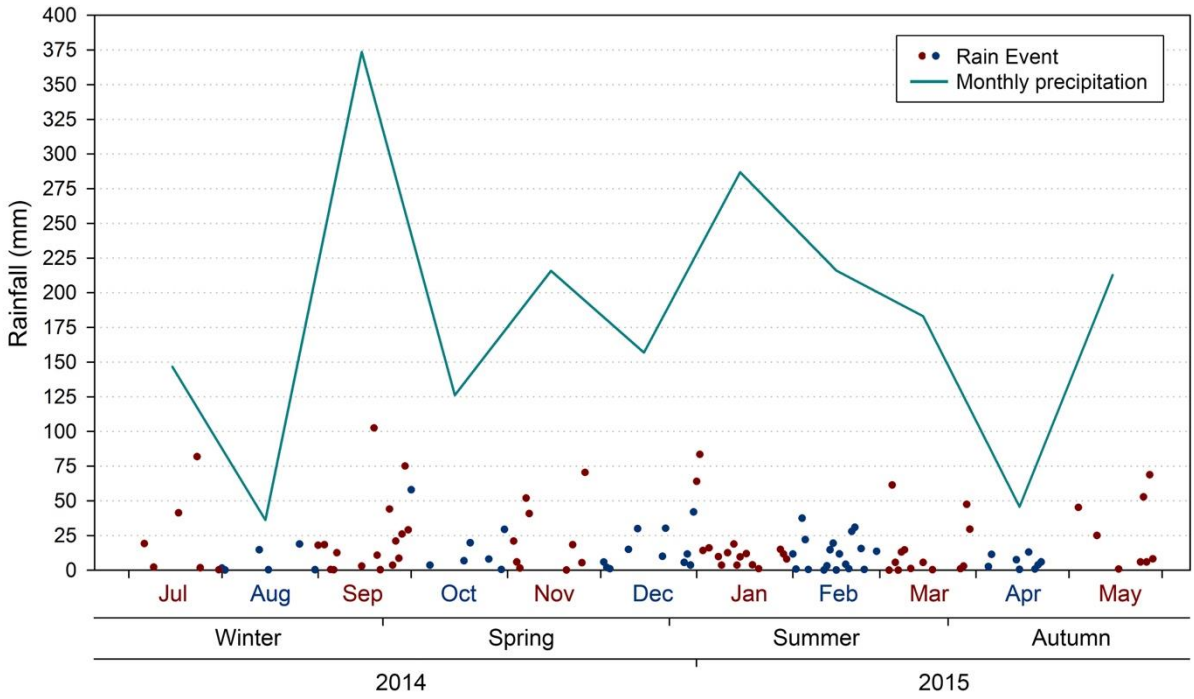

Figure 25. Rainfall from July 2014 to May 2015 (Seasons in the *x*-axis are relative to Southern Brazil; *Data source*: Instituto Agronômico do Paraná – IAPAR, Meteorological Station of Pato Branco- PR, Brazil).

Besides some reduction in the rainfall from January to April, period which the plant developed its reproductive phase, there were no water shortages. The intense rain events (Figure 25) guaranteed a constant supply of moisture. This fact perhaps had some effect in the spreading of the early panicle emergence and in the delay of the general flowering. Despite that, no substantial influence of water availability was identified.

Emergence rate analysis allowed understanding how the inflorescence appearance dynamic developed along the cycle, which is valuable information for the crop management. The stimulus for the plant flowering is a difficult subject once it directly depends of many environments conditions and years of evaluation. Despite the major environmental trigger, stills unclear the inferences presented here are good guidelines for the studied latitude. In a broader approach, integrations are a strong possibility, as happen in pearl millet with the interaction between temperature and daylength.

Analysis of variance also identified differences among treatments for the variable 'accumulated panicles per area' ($P < 0.05$). The data adapted best to the polynomial cubic model as presented in Figure 26.

Data on the 'accumulated panicles per area' followed the 'panicles emergence rates' behavior, presented higher increases during the month of February (Figure 26). Lower results for the final panicle number and average emergency rates were observed with 3 cuts (Table 6). As a major reason it is possible that the third cut removed the plant primordia (elevated by the stem elongation), removing potential inflorescences that could may be already in the differentiation process. In addition, in this condition the plant had to dedicate some time and photoassimilates to recompose the tillers before a new differentiation to the reproductive phase. If the environmental stimulus has already been triggered to induce flowering the tillers do may not accumulate reserves to further produce inflorescences, resulting in a slower emergency rate, a lower final number of tillers and lower number of seed heads with the treatment (Table 6).

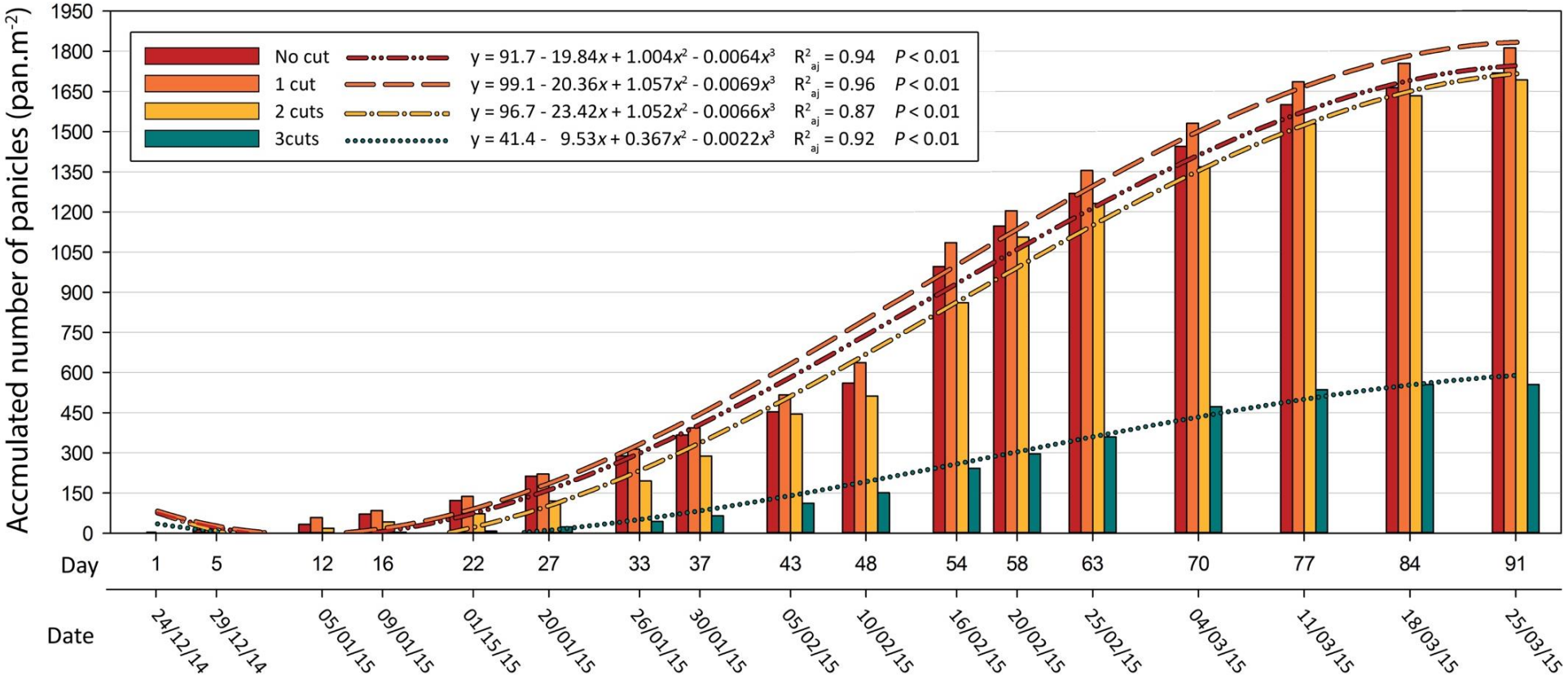

Figure 26. Alexander grass *(Brachiaria syn. Urochloa plantaginea)* accumulated panicle emmergence on number of cuts, preformed at 20 cm, when the sward reached 40 cm (*OLIVEIRA, 2017*).

Table 6. Morphologic indexes in Alexander grass (*Brachiaria syn. Urochloa plantaginea*) according to number of cuts (*OLIVEIRA, 2017*).

Uniformization cuts[1]	Average emergency rate[2] (panicles day^{-1})	Final panicle number[2] (panicles m^{-2})	Final basal Tillering[2;3] (Tillers m^{-2})
0	18.89 a	1719 a	1,062 a
1	19.91 a	1812 a	1,194 a
2	19.60 a	1693 a	1,247 a
3	6.09 b	555 b	431 b
C.V.:	22.4%	22.4%	29.2%

[1]Period between 12/24/2014 and 03/25/2015; Defoliations performed at 20 cm height when the pasture reached 40 cm; [2]Means followed by the same letter compose statistically homogeneous group; Scott & Knott; $P > 0.05$; [3]Vegetative plus reproductive tillers.

Generally, great amounts of seed heads were produced with the treatments 0, 1 and 2 cuts, reaching the average of 1,741 panicles m^{-2}. If compared to other *Brachiaria* species Alexander grass presents as one of the major panicle producers: Following Hopkinson et al. (1996) – Koronivia grass ~2000 panicles m^{-2}; Signal grass and Ruzi grass ~700-1000 panicles m^{-2}, and; Palisade grass ~200 panicles m^{-2}. This agrees with Souza (2001) which state that panicle production in Koronivia grass is high, in Signal grass and Ruzi grass intermediate, and low in Palisade grass. These numbers however will broadly vary depending on the management of the seed crop and the field location, which is confirmed by the additional data of Table 7.

Table 7. Seed head (panicle) emergence in *Brachiaria* according to species.

Species	Panicles	Source
Palisade grass (*B. brizantha*)	153 panicles m^{-2}	Benteo et al. (2016)
	203 panicles m^{-2}	Senra (2006)
	171 panicles m^{-2}	Argel (2000)
Signal grass (*B. decumbens*)	144 – 168 panicles m^{-2}, depending on N level	Vendruscolo (2014)
	218 to 410 panicles m^{-2}, depending on N level	Pancera Jr. et al., (2011)
	93 panicles m^{-2}	Macedo (2007)
	168 panicles m^{-2}	Gobious (2001)
	1040 panicles m^{-2}	Stur and Humphreys (1987)
Koronivia grass (*B. humidicola*)	2000 panicles m^{-2}	Andrade Thomaz (1982)
Hybrids	Average of 166 pan. m^{-2}, maximum of 886 pan. m^{-2}, in a evaluation of 16 hybrids in Thailand	Hare et al. (2015)
	407 panicles m^{-2}, cv. Mulato	Hare et al. (2007c)
	293 panicles m^{-2}, cv. Mulato II	Argel (2007)

Beyond the high number of panicles a main conclusion is that the uniformization cut management was not efficient in promoting neither a better emergence synchrony (Figure 21), neither a higher number of panicles (Figure 26) – a result also observed by Vendruscolo (2014) in Palisade grass. This is said based on the similarity of the results with the treatments 0, 1 and 2 cuts, and on the worst results with the treatment 3 cuts. Perhaps other intensities of this management could promote better performance, since the cutting of the grass at 40-20 cm was relatively light. When changing this intensity to 10 cm, for example, even the time of the defoliations will change, happening early in the cycle.

The behavior for the 'basal tiller number' was similar to the final panicle number (Table 7). Analysis of variance identified differences among the treatments ($P < 0.05$), and Scott & Knott test evidenced similarity among the treatments 0, 1 and 2 cuts, separating in a inferior group the treatment 3 cuts ($P < 0.05$; Table 7).

Tillering is actually one of the main elements of the final seed production in a forage crop. The development of these structures will determinate the number of 'seed head slots', which by its time is the main positive correlated variable with the final seed production. The higher the tiller density, the higher the seed produced (QUADROS et al., 2012; MILES et al., 2004; SOUZA, 2001; WONGSUWAN, 1999).

Tillers eventually develop their own root systems, becoming largely independent from the parent plant, although still attached to it (LOCH & FERGUSSON, 1999). In a major extent it will increase the capacity of the sward to absorb nutrients. Alternatively, increasing other yield components as number of racemes or number of spikelets per raceme will make most seeds dependent on the same radicular system.

In experiments that evaluated the Alexander grass forage production it is reported a vigorous tillering. This variable is however highly dependent on nitrogen fertilization and grazing management. Values in seed crops usually are lower than the observed in grazed pastures, as – until certain levels – the higher the grazing intensity, higher the tillering. Some data are presented in the Table 8 to compare this variable among Alexander grass and with other species of the genus.

Table 8. Tillering in *Brachiaria* according to species and management (grazing or seed production).

Species		Tillers	Source
Alexander grass (*B. plantaginea*)	**	1,165 tillers m^{-2}	Salvador et al. (2016)
	**	1,232 tillers m^{-2}	Salvador (2011)
	**	1,431 tillers m^{-2}	Salvador (2014)
	**	1,169 tillers m^{-2}	Eloy et al. (2014)
	**	700 tillers m^{-2}	Migliorini et al (2012)
Signal grass (*B. decumbens*)	**	1,838 tillers m^{-2}	Luna (2012)
	**	1,864 tillers m^{-2} (summer), 1,788 (autumn), 1,573 (winter), 1,916 (spring).	Fagundes et al. (2005)
	*	305 tillers m^{-2}	Gobious (2001)
	*	272 tillers m^{-2}	Vendruscolo (2014)
	*	378 to 427 tillers m^{-2}, depending on N level	Pancera Jr. et al. (2011)
	*	1,595 tillers m^{-2}	Stur & Humphreys (1987)
	*	600 to 400 tillers m^{-2}	Wongsuwan (1999)
Palisade grass (*B. brizantha*)	*	500 tillers m^{-2}	Semra (2006)
	*	100 to 206 tillers m^{-2}, depending on the cultivar	Quadros et al. (2012)
	*	242 tillers m^{-2} cv. Piatã, 206 tillers m^{-2} cv. Xaraés	Luna et al. (2012)
	*	206 tillers m^{-2} cv. Xaraés, 100 tillers m^{-2}cv. Marandu	Quadros (2012)
	**	1,471 tillers m^{-2}	Fialho (2012)
	**	1,300 tillers m^{-2}	Sbrissia (2004)

*Seed production; **Grazing.

Higher tillering in grazed pastures usually results from the light that better penetrates the sward and hits the buds. After the removal of the aerial part, the plant also moves reserves from the roots or stems to the remaining leaves and other buds to stimulate the canopy regrowth and, consequently, the tillering. As the plant enters the reproductive phase, the tillering generally declines, even before inflorescences emerge (LOCH, 1980). In the case of indeterminate plants that respond to non-obligate stimulus, however, tillers can keep growing even after others already started to produce panicles. This seems to be the case of Alexander grass (reinforcing again the characteristic of the plant to a quantitative response).

An important evidence in this trial was the great number of aerial tillers production, a phenomenon also called culm branching and based on the development of the axillary buds in the leaf sheaths (LOCH & FERGUSSON, 1999). During the panicle emergence, the same tiller can branch in the nodes and produce another panicle on the same basal tiller. With that, a complex hierarchy of tillers gradually builds up.

'Primary' aerial tillers arise and produce inflorescences a little later than the parent. These can also produce 'secondary' and even 'tertiary' aerial tillers if the sward continues to grow (LOCH et al., 2004). The phenomenon is reported for several tropical grasses, including particularly the *Brachiaria* genus (WONGSUWANG, 1999)

Culm branching is stimulated when soil moisture and N are freely available, in heavily fertilized crops (LOCH et al., 2004), with low intensity cutting (WONGSUWAN, 1999) and light hitting the buds (LOCH et al., 2004), management that matches the performed in this trial (200 Kg N ha^{-1}; Figure 25; 20-40 cm defoliation). Several authors cite that, besides the genetic control, tillering is influenced by the management and the environment factors (SANTOS et al., 2013; LUNA 2012; PANCERA et al., 2011; SENRA, 2006; SBRISSIA, 2004), specially by N nutrition (PANCERA JR., 2011; JORNADA et al., 2005; GOBIOUS et al., 2001; CONDE & GARCIA, 1988a) and the defoliation (SENRA, 2006). The behavior of Alexander grass could indicate also that its buds are easily activated by the light. An example of the phenomenon is presented in the Figure 27, in which seven panicles emerged from a single basal tiller.

The occurrence of culm branching may be a contributing factor to the lack of synchronization in panicle emergence. Once a single tiller can develop until several branches, delay in the appearance of the panicles can appear. This can be, thus, a reason to the behavior observed on the Figure 21. Still, for situations like that, if a single combine harvest is performed based on the moment that the first tillers appear probably those will be main contributors to the final yield (LOCH et al., 2004).

Figure 27. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) tiller with high bud fertility due to culm branching. One basal tiller developed into seven fertile aerial tillers (*Picture source: J.R. Oliveira – OLIVERIA, 2017*).

It is important to point out that the example of the Figure 27 is presented to characterize the phenomenon, but do not represent the average of the tiller population, as for that an index of 'tiller fertility' can be composed. This variable is an important yield component that varies according to management and environment, and ranges from less than 5% to more than 80% (PANCERA et al., 2011; SBRISSIA, 2004; GOBIOUS et al., 2001). In the case of Alexander grass, it is perhaps a contribution in the outstanding seed production, once if considered the aerial tillers for the ratio, the tiller fertility will be near 100%, and; if considered just the basal tillers for the ratio, on the better treatment it can exceed 160%.

There is a consensus that efficiency in seed yield depends on a better understanding of the tiller population evolution (NABINGER & MEDEIROS, 1996). Despite most studies evaluate the tillers and inflorescences at the time of harvesting, little is known about how factors influence the dynamic of this component (ANDRADE, 1997). Also, besides the inflorescence density is the closest correlated component to seed yield, a constant tiller emerging can influence other reproductive components, since they all are related to each other in the final productivity (LOPES & FRANKE, 2011). Too much inflorescences associated with high number of spikelets will alter the sharing of the photoassimilates, and so may prejudice the seed filling. In contrast, a low fertile tiller crop can compensate the deficiency increasing seed weight (JORNADA, 2002). Density and tiller survival, seeds per inflorescence and seed set are usually inverse correlated (ABEAS, 2007). The fact that Alexander grass has smaller seeds than most of Brachiariagrasses (*further discussed– Chapter 3 – pg.167*) could be a result of these compensatory effects.

3.2 Experiment 2

As well as the panicle emergence climate was very favorable for the panicle age experiment (Figure 24; Figure 25). No influences of weeds, diseases or pests were observed in this trial also. Alexander grass presented plenty of panicles, which assured the proper and random sampling.

Panicles were sane and structured at early ages (Figure 28). At the point of the marking (zero days), however, the inflorescences were not enough structured to measure and count the morphological indexes, and after some point they are too degraded to permit some assessments. After the 24th day counted from the marking the panicles started to present a condition that could reduce the reliability of the data when fractionating was needed (Figure 29), so just the evaluation that considered all the panicle proceeded. This explanation is given with the intention to clarify some differences that will appear among the ages in the discussion of this session.

Figure 28. (A) Alexander grass (*Brachiaria syn. Urochloa plantaginea*) 6 days age panicles. Integriy is observed for all organs in the inflorescence, shatter barely started and there were no fallen racemes; (B) Alexander grass 11 days age panicles. Some shattering is observed particularly in the distal portion of the inflorescene. Still, there were no fallen racemes (*Picture source: J.R. Oliveira - OLIVEIRA, 2017*).

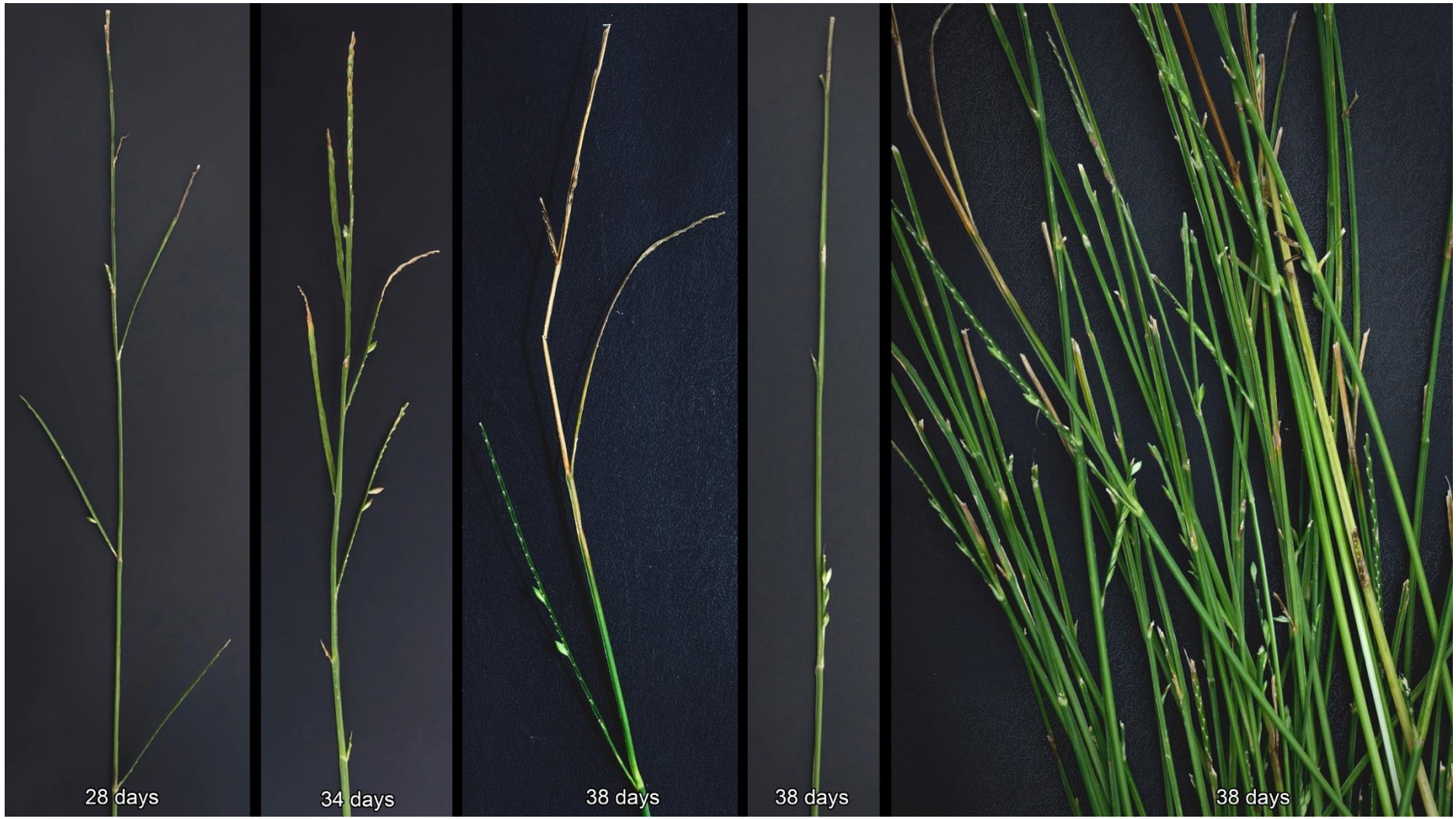

Figure 29. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) panicles in advanced ages: almost all the seeds shattered, racemes are lacking and the distal fraction of the panicle in some cases present necrosis in the axis and rachis (*Pictures source: J.R. Oliveira – OLIVEIRA, 2017).*

The analysis of variance identified differences in the variables racemes number, detached racemes and attached racemes ($P < 0.05$) as presented in the Figure 30.

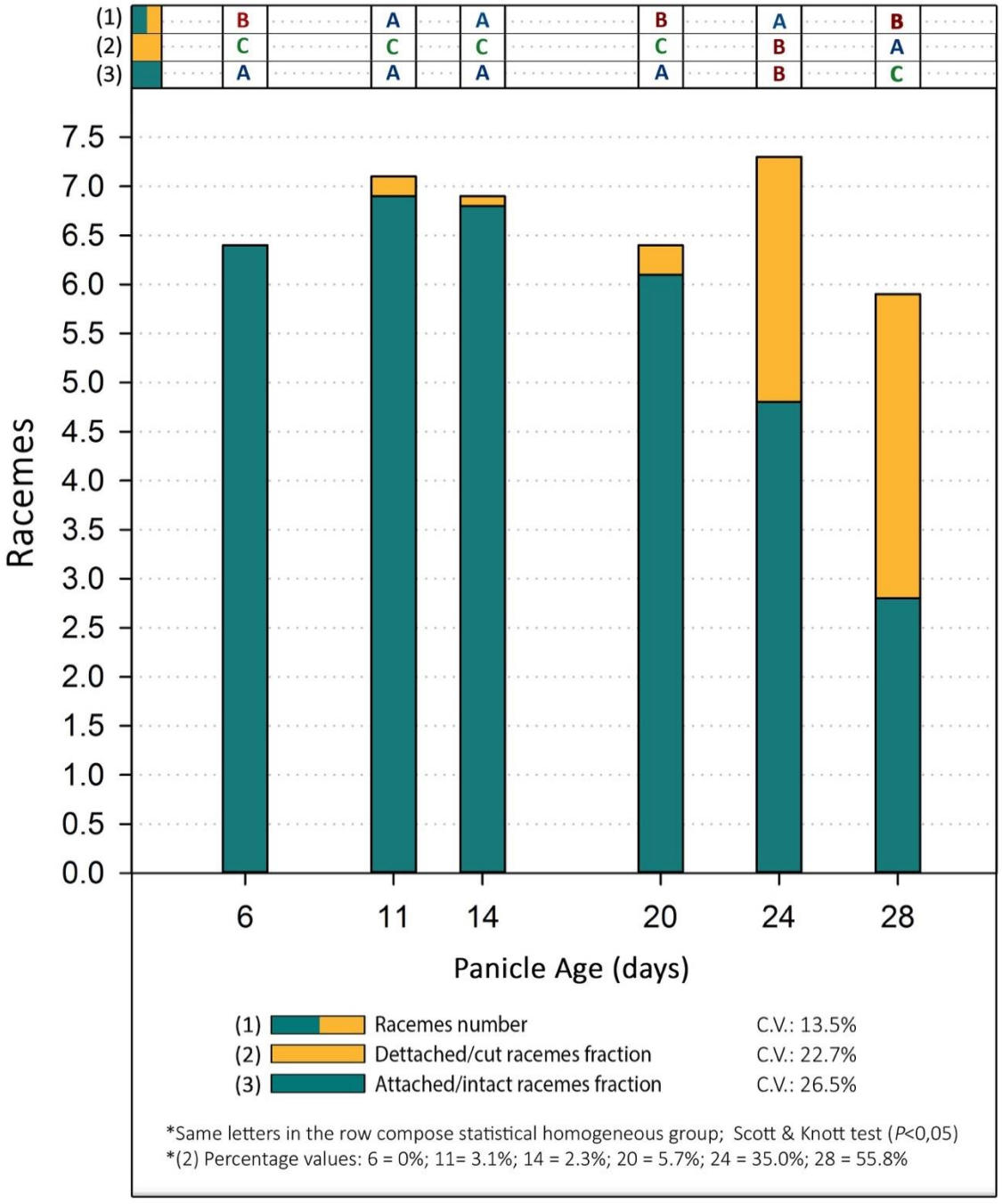

Figure 30. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) racemes per panicle (*green + yelow*), detached/cut racemes (*yellow*) and Atached/intact racemes (*green*) per panicle according to inflorescence age (*OLIVEIRA, 2017*).

The relationship between racemes attached and detached evidenced well the process of degradation of the panicle as it aged. The causes of the shedding of entire racemes from the plant are not documented in the literature. Nonetheless, since the early ripening of the seeds and the beginning of seed shattering racemes were observed fallen to the ground (Figure 31).

Figure 31. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) shed seeds at February 17th, 2015. Closer look will identify also entire racemes on the ground, fallen due to reasons not well determined. It is speculated the action of grain birds (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Both biotic and abiotic factors could have contributed to these results. One of the common occurrences in the field was the presence of grain birds as sparrows and canaries, which feed from the Alexander grass seeds. This behavior was reported by Bonna & Lascano (1992), in rice fields. In the process, the birds could detach entire racemes from the panicle, which were further discarded when single spikelets were removed and eaten. In addition, the windy and rainy experimental period (Figure 24) potentially promoted the violent shaking of the panicles and then the collapse of the rachis as well.

As the raceme is exposed during the panicle emergence the seed filling readily starts (*Discussed further, in Chapter 3 – pg.167*). This is supported by the cleistogamic reproduction of Alexander grass (*See chapter 1 – pg.94*) that can advance the fertilization and allow the spikelets a quicker development. This is observed in the Figure 28 where, even in 6 days panicles, the spikelets are at good developing stages, a trait that helps the raceme to readily become heavy and prone to collapse.

A closer look on the rachis insertion evidences also a particular morphological construction very similar to the abscission layer of the spikelets (Figure 32; Figure 2). This is stated with no intention to characterize an abscission layer for the raceme, but to present that a less fibrous part can be involved in the raceme falling as well.

Figure 32. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) panicle. Detail on the proximal portion of the rachis (insertion of the rachis in the inflorescence axis). A witish layer is observed where collapse ocasionally happen (Data in Figure 30; *Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Concrete behavior was not observed in the variable 'total racemes number'. Multiple comparisons test divided the treatment levels in two groups that did not followed any tendencies. At first, it was expected the number of racemes to keep relatively constant once when the panicle is exposed the racemes were already differentiated. The mean test was able to identify the differences however there were just slight variations in relation to the mean. This is maybe a product of the high variability of warm season grasses broadly reported in the literature (*See Chapter 1 – pg.61*).

Above all, Alexander grass presented consistent formation of the panicles with good number of racemes (Figure 28), particularly when compared to other Brachiariagrasses: Assis et al. (2003) observed a raceme number of 4.0, 3.3, 3.1 and 5.2 racemes per panicle for Palisade grass, Signal grass, Koronivia grass, and Ruzi grass, respectively. Hare et al. (2015) reported a mean of 3.9, with maximum of 5.8 racemes per panicle in 16 *Brachiaria* hybrids. Hare et al. (2007a) report 5.2 racemes per inflorescence in hybrid cv. Mulato 2 and Semra (2006), observed 3.7 racemes per panicle evaluating Palisade grass.

Beyond the means presented in the Figure 28, the distribution of the number of racemes among all the observations evidenced the frequency that raceme number occurred. Almost 2/3 of the panicles presented 5, 6 or 7 racemes (Figure 33). Besides small frequency, panicles with 12 racemes were encountered and no panicles with less than 3 racemes were produced. These results are close to the presented by Reinheimer (2005), who describes Alexander grass panicles with 2 to 14 racemes.

The analysis of variance identified differences in the variables racemes length and in the variable panicle axis segment length ($P < 0.05$), for both comparisons among racemes, and among panicle ages. The analysis was further detailed by the Scott e Knott test ($P < 0.05$), as the results presented in the Figure 34.

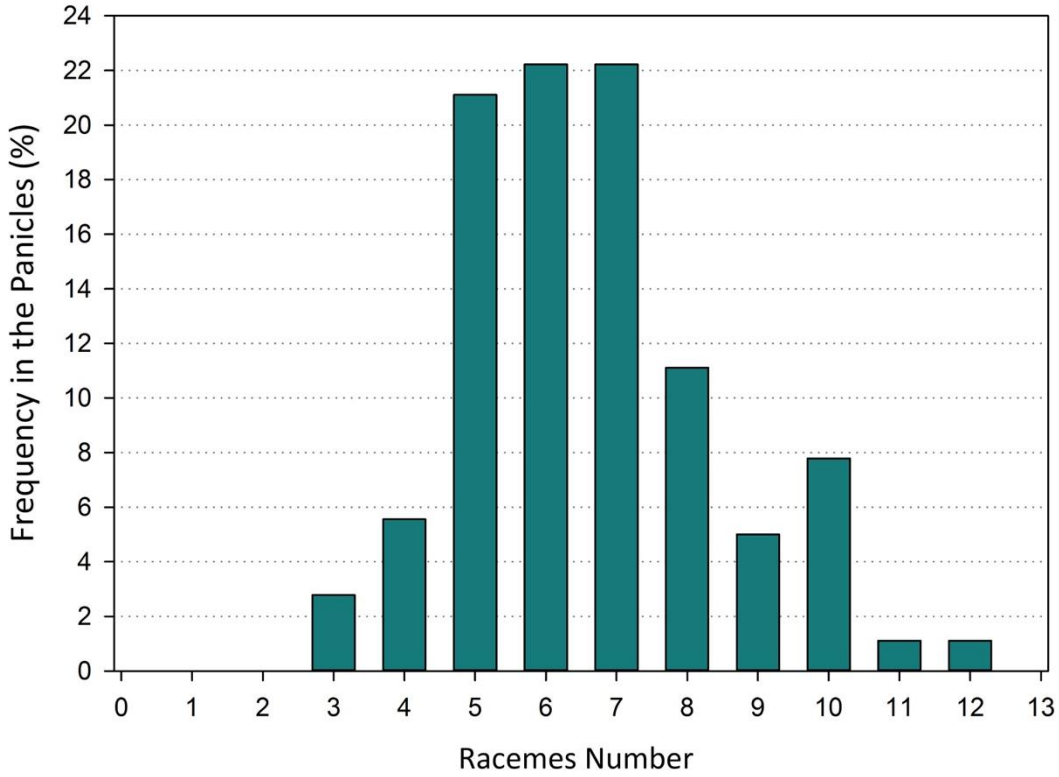

Figure 33. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) frequency of raceme number in the panicle population (Descriptive values; 180 observations – *OLIVERIA, 2017*).

The raceme length behaves in a crescent length following the direction of the distal to the proximal portion of the panicle, which was observed in the length of the segment of the inflorescence axis as well. This is a known characteristic of panicoid inflorescences, which in an overall look present a triangular form (OLIVEIRA et al., 2006).

Alexander grass racemes were shorter than other Brachiariagrasses. Benteo et al (2016), evaluating Palisade grass, reports an average of 8.4 cm in racemes of the grass, as Quadros et al. (2012), observed that the maximum values for the same species reached 14.9 cm for cv. Marandu and 15.4 cm for cv. Xaraés. Assis et al. (2003) reported lower numbers, for the author there were average lengths of 5 cm for Signal grass, 4.9 for Koronivia grass and 6.7 for Ruzi grass. Perhaps as a compensative response among the morphological components Alexander grass concomitantly generate shorter racemes and higher number of racemes in the panicle.

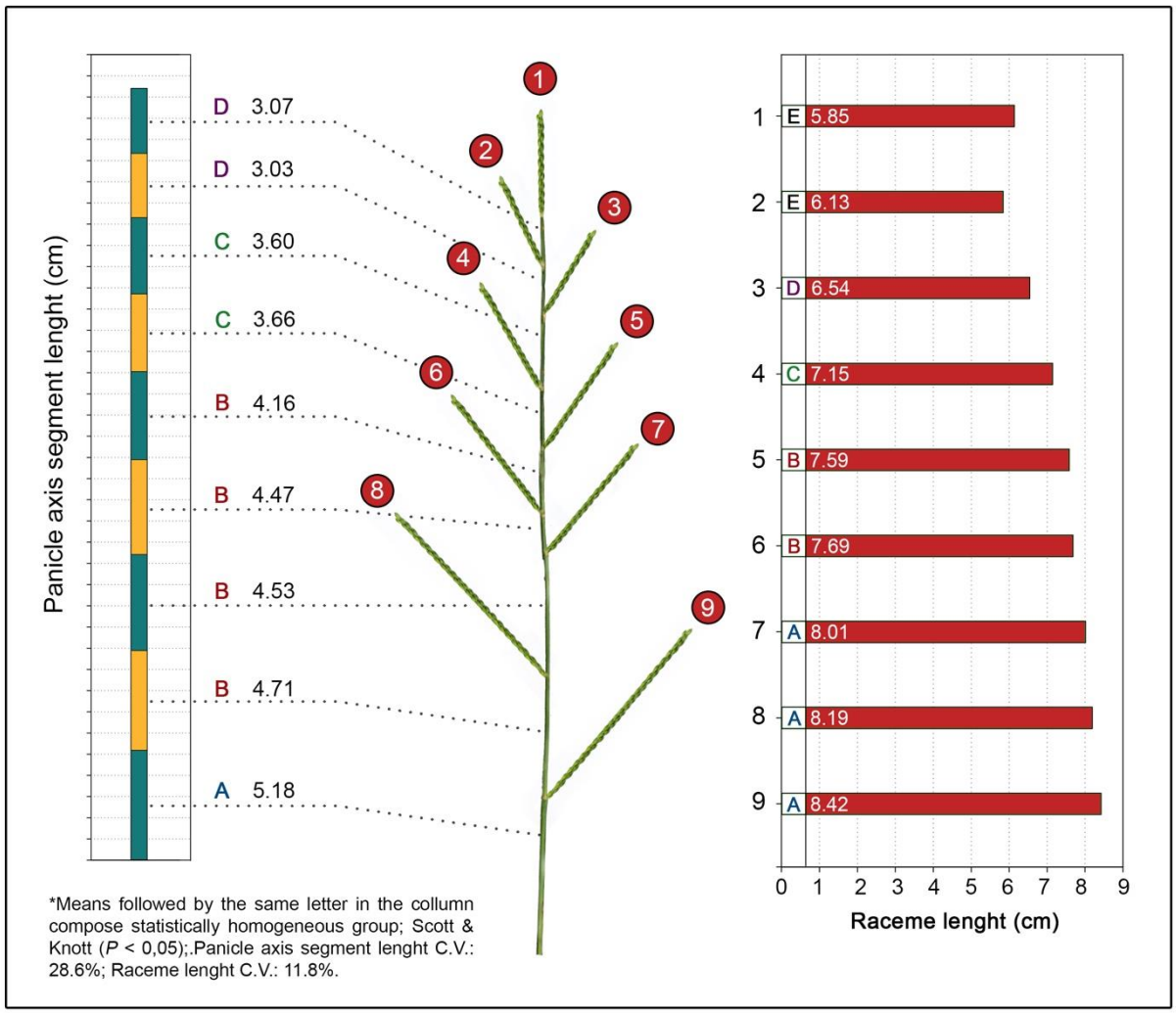

Figure 34. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) average panicle axis segment length and average raceme length; Means followed by the same letter in the scheme column and in the table row compose statistically homogeneous group (Scott & Knott; $P < 0.05$; *OLIVEIRA, 2017*).

The maximum length observed in the panicle was thus at the 9th raceme, which measured 8.4 cm in length. For this analysis, also, the comparison just considered the racemes with no damages in the rachis. Some racemes reached near 12 cm, being however very rare and presenting not enough number of observations in the sample range to perform a consistent statistical analysis (Figure 35).

Figure 35. Alexander grass raceme measuring near 12 cm, pen for scale *(Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

No significant differences were found for the total inflorescence axis length according to the age of the panicle ($P > 0.05$; Table 9). The average value presented was 21.2. cm, close to the range reported by Bayer (2016) of 10-20 cm for Alexander grass. Nonetheless, Alexander grass presented the longer inflorescence among the commercial Brachiariagrasses. Benteo et al (2016) reported an average length of 10.8 cm in Palisade grass. Assis et al. (2003) reports the value of 8.6 cm for Palisade grass, 6.1 cm for Signal grass, 7.4 cm for Koronivia grass and 11.1 cm for Ruzi grass.

Table 9. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) inflorescence axis total length (*OLIVEIRA, 2017*).

Panicle age (days)	Total inflorescence axis length (cm)
6	19.4 [ns]
11	19.9
14	20.7
20	23.4
24	22.0
28	22.0
Mean	21.2
C.V.:	13.93%

[ns] Means do not differ among panicle ages; $P > 0.05$; Scott & Knott; Assessment performed from the tiller distal node to the insertion of the distal raceme in the inflorescence axis.

Total seed number in the panicle presented no differences according to the Analysis of variance ($P > 0.05$; Figure 36). The differentiation of the spikelets occurs just after the flower induction, previous in several days from the actual panicle emergence, which help to explain this result: after this phase new seeds are supposed to not be formed, independently of the panicle age.

According to Lopes & Franke (2011), 'seeds per panicle' is an important attribute for the seed yield. Results for Alexander grass presented the average number of 206 seeds per panicle. On that, the plant also evidenced the variability usually found in warm season grasses: samples with more than 350 seeds were observed. This, summed to the high number of panicles m^{-2} discussed before (Figure 26) helps to confirm the empirical consensus that Alexander grass is a great seed producer – despite the unprecedented data on the issue, several authors have related the grass as a very prolific plant (SICHONANY, 2012; LORENZI, 2000; THEISEN et al., 2000).

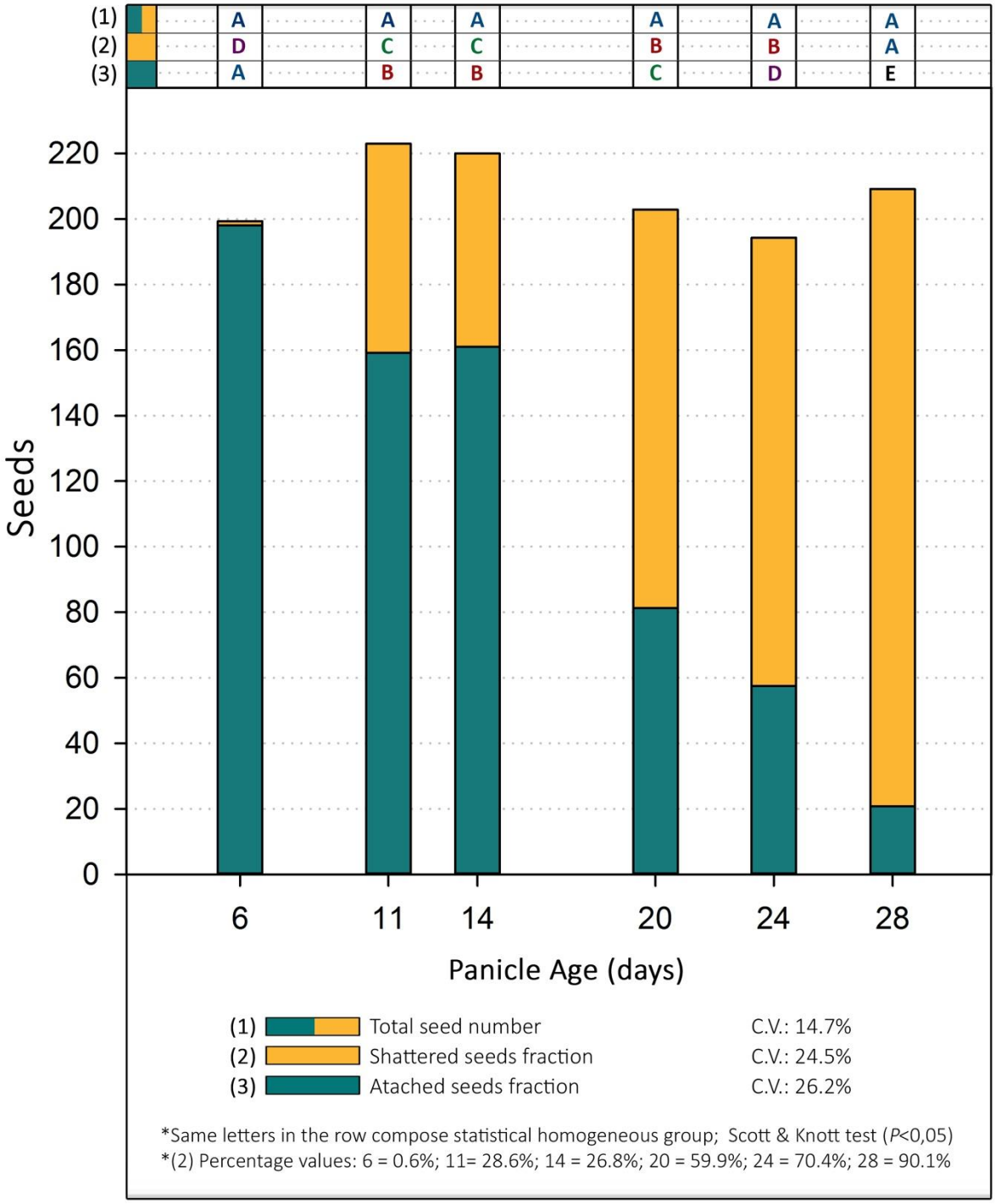

Figure 36. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds per panicle (*green + yellow*), detached seeds fraction (*yellow*) and atached seeds fraction (*green*) acording to inflorescence age. Means with the same letter in the row compose statistically homogeneous group (Scott & Knott; *P* > 0.05; *OLIVEIRA, 2017*).

Yields of pure seed are highly variable, and have meaning only within their specific context of locality, management system, and harvesting method. As most tropical grasses, Brachiariagrasses are potentially high yielding, but fall well short of their potential. Restrictions not well understood of environment and management such as harvest inefficiency and unreliable weather are the main contributors to reductions (HOPKINSON et al., 1996).

Same way, an estimative of the potential number of seeds Alexander grass can produce per hectare was developed: Based on the average of treatments 0,1 and 2 cuts (Figure 26), it was used the number of 1,741 panicles m^{-2}. 1 ha = 10,000 m^2, multiplied by number of panicles m^2, and the number of 206 spikelets per panicle (Figure 36), will give 358,646,000 spikelets ha^{-1}. Nearly 350 million spikelets ha^{-1} are estimated for Alexander grass, and so considering 4 g for thousand seeds a potential of 1.400 Kg of seed ha^{-1} will be achieved. Important considerations on viability should be kept since just a share of that will probably set and fill (*Further discussed in Chapter 3 – pg. 177*). Also, this is a potential yield achieved in experimental conditions, as commercial large scale production in heterogenic fields will probably does not reach this level, and the mechanical harvest will naturally lose some of the seed.

To provide better understanding seed production within the panicle is detailed according to its distribution. Firstly, comparisons are presented among the racemes in the panicle: independently of the panicle age, the proximal racemes will produce more seeds than those in the distal portion of the panicle, a situation that can be endorsed by the shorter size of those in the distal fraction (Table 10). According to Benteo et al. (2016), this is a normal and genetically determined characteristic of non-domesticated panicoid grasses. The same authors did not found influences of fertilization in the number of spikelets per raceme studying Palisade grass, which helps to support the hypothesis of genetic inheritance of this trait.

As the data indicated a shorter raceme in Alexander grass, the number of spikelets tends to be also lower in relation to another species of the genus. For Palisade grass Quadros et al. (2012) related the general average of 50 seeds per

raceme, Hare et al. (2007a) observed 36.6 seeds per raceme, and Benteo et al. (2016) 30 seeds per raceme. For Signal grass, Gobious (2011) related 12 to 21 seeds per raceme. Hare et al. (2015), finally, evaluating 16 *Brachiaria* hybrids, reported 48.4 seeds per raceme as maximum. Assis et al. (2003) used a less detailed approach, evaluating just the basal raceme for the number of spikelets observing 32.2, 29.5, 16.7 and 35 for Palisade grass, Signal grass, Koronivia grass and Ruzi grass, respectively.

Comparisons among the number of spikelets in the raceme according to the panicle age were also performed (Table 11). Analysis of variance and mean test identified differences within some racemes ($P < 0.05$), and no differences for others ($P > 0.05$), however, no tendency or pattern established among the racemes. These observations are probably a result of the natural variability of the plant.

Table 10. Total seeds produced in Alexander grass (*Brachiaria syn. Urochloa plantaginea*) racemes according to panicle age. Racemes are ordinated as "1" for distal and "9" for proximal (See scheme in Figure 34). Comparison among racemes *(OLIVEIRA, 2017).*

Raceme	Age (Days)						Mean
	6	11	14	20	24	28	
1	22.8 d	20.8 d	26.6 c	23.4 b	20.0 c	25.5 d	23.2
2	27.1 c	22.0 d	29.5 c	25.2 b	23.8 c	32.9 c	26.8
3	30.4 b	27.3 c	31.4 b	30.5 a	23.4 c	33.4 c	29.4
4	34.3 a	30.4 b	33.7 b	33.1 a	29.4 b	36.5 b	32.9
5	33.9 b	33.8 b	34.5 b	34.5 a	32.5 b	38.3 b	34.6
6	36.0 a	35.8 a	33.9 b	33.5 a	33.5 b	39.2 b	35.3
7	36.2 a	37.5 a	34.8 b	35.2 a	35.7 b	41.7 b	36.8
8	35.5 a	40.4 a	31.4 a	36.4 a	34.7 b	45.0 a	37.3
9	38.3 a	40.3 a	38.3 a	33.0 a	41.0 a	50.0 a	40.1
Mean	32.7	32.0	32.7	31.6	30.4	38.1	32.9
C.V.:	11.26%						

*Means followed by the same letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$.

Table 11. Total seeds produced in Alexander grass (*Brachiaria syn. Urochloa plantaginea*) racemes according to panicle age. Racemes are ordinated as "1" for distal and "9" for proximal (See scheme in Figure 34). Comparison among ages *(OLIVEIRA, 2017).*

Age (Days)	Raceme									Mean
	1	2	3	4	5	6	7	8	9	
6	22.8 a	27.1 b	30.4 a	34.3 a	33.9 ns	36.0 ns	36.2 ns	35.5 b	38.3 ns	32.7
11	20.8 b	22.0 c	27.3 b	30.4 b	33.8	35.8	37.5	40.4 a	40.3	32.0
14	26.6 a	29.5 b	31.4 a	33.7 a	34.5	33.9	34.8	31.4 b	38.3	32.7
20	23.4 a	25.2 c	30.5 a	33.1 a	34.5	33.5	35.2	36.4 b	33.0	31.6
24	20.0 b	23.8 c	23.4 c	29.4 b	32.5	33.5	35.7	34.7 b	41.0	30.4
28	25.5 a	32.9 a	33.4 a	36.5 a	38.3	39.2	41.7	45.0 a	50.0	38.1
Mean	23.2	26.8	29.4	32.9	34.6	35.3	36.8	37.3	40.1	32.9
C.V.:	11.26%									

*Means followed by the same letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$.

Beyond the total seed number, analysis of variance identified differences for shattered seeds per panicle and attached seeds per panicle, detailed also by the mean test ($P < 0.05$; Figure 36). As well as the observed for the raceme number (Figure 30), the shattering increased constantly according to the panicle age. The data evidenced abrupt losses mainly after the 14th day, once at the 20th day panicles have already shattered almost 60% of the seeds, and further, in the 28th day, more than 90% of the seeds were already detached of the panicle.

The results showed that the shattering of Alexander grass seeds starts very early, just after the panicle emergence. Mean test already identified differences between the 2 first ages evaluated (6th days and 11th days). The data presented can be also an indicative of the physical development of the seed, as the fallen seeds are in the vast majority filled mature seeds (*Discussed further, in Chapter 3 – pg.167).* Obviously, as shattered seeds number increased according to the seed age, linked seeds decreased, in an inverse relation.

Alexander grass shattering behavior also presented a very coherent direction in the raceme. First seeds to fall were those in the tip of the rachis, making the process to develop from the distal to the proximal portion (Figure 37). This is not a strict rule but just few exceptions were observed, when spikelets detach firstly in the mid-section of the raceme.

The results also allowed to identify the amount of attached seed according to the racemes (Table 12; Table 13) and so the behavior of the shattering within the whole inflorescence. Analysis of variance and mean test identified differences for all levels ($P < 0.05$). As the panicle ages, the racemes which most contribute to the attached seed are those in the bottom *i.e.* those which present a great number of seeds even after the panicle deterioration. This information could be helpful if management is designed with the intention to harvest the crop using combines or beating machines.

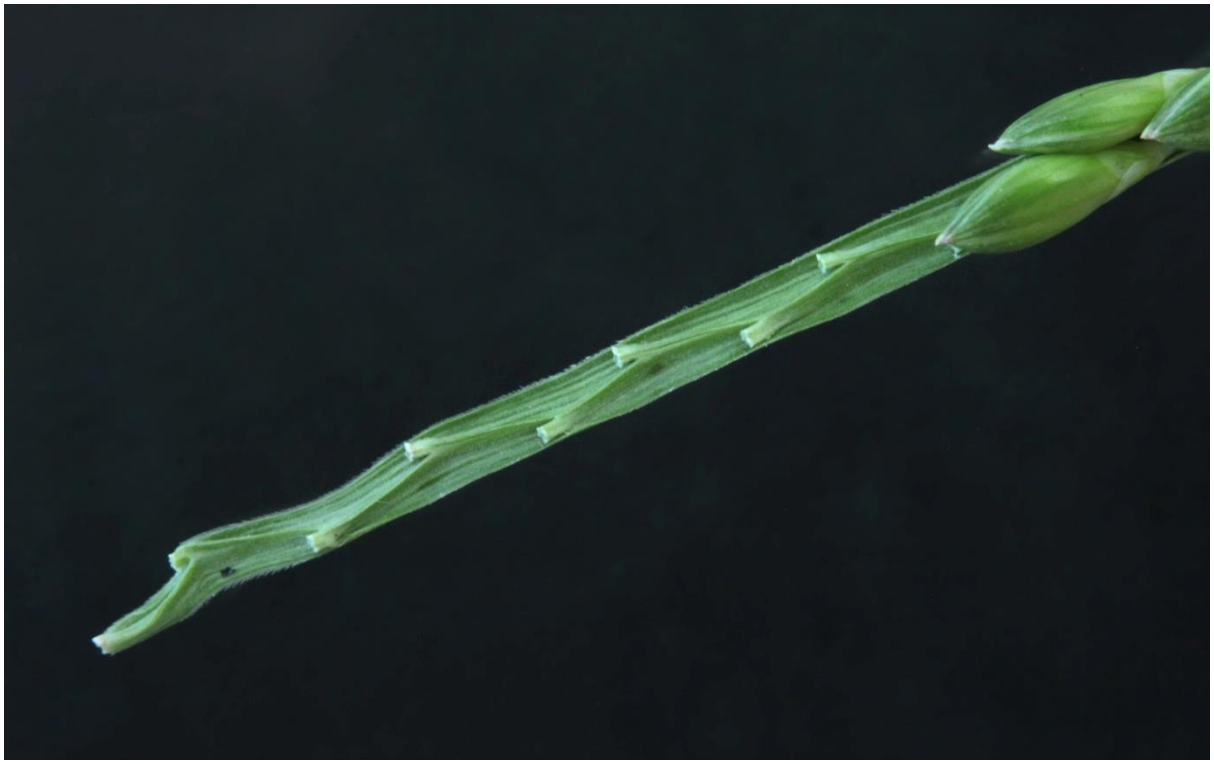

Figure 37. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) raceme with scars of shattered spikelets. There were a strong tendency on the shattering to start in the distal portion of the raceme (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

Statistical differences were evidenced by the analysis of variance and by the mean test for most levels comparing shatter among the racemes as well (Table 14; $P < 0.05$). Just in the youngest panicles level (6 days) no differences were observed, as in those panicles shatter barely started. In panicles of 11 days the data already presented the direction of the shattering, which were reinforced as the panicles aged.

This phenomenon happened very quickly, particularly for the racemes in the tip of the panicle: 11 days after the panicle emergence shattering already reached more than 2/3 of the seeds in the distal raceme (Table 15), and for the 2nd distal raceme, reached half of the seeds. These rates are already reported for other warm season grasses: (1) In *Panicum maximum* Burson et al. (1983) reported the shattering to start 12 days after the emergence of the panicles and; Loch & Fergusson (1999), with the same plant, reported a period of 6 days for the seed maturation, plus 6 days for shedding. The rapid process in Alexander grass can have been catalyzed by the climatic condition (wind, rain) of the experimental year, factor already reported as a determinant in these issues (SOUZA, 2001)

Giving the presented data so far, it is possible to trace the directions of the shattering within an Alexander grass panicle, as: *(1)* the shatter starts in the tip of the raceme and evolves towards the insertion, and; *(2)* the shatter starts in the distal racemes and evolves towards the proximal ones. It is probably a behavior related strictly to the differentiation of the spikelets order, a statement supported by what is observed in Figure 20, in which it is visible that in a 'zero days' panicle, the distal racemes are more developed than the proximal ones. This behavior was already reported in a general approach for warm season grasses, by Loch & Fergusson (1999), assuming the pollen dispersal and stigma extrusion not occurring synchronously along the inflorescence, but in a way that the first spikelets that extrude anthers were around the mid-tip of inflorescence branches.

Table 12. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds attached to the raceme according to panicle age. Racemes are ordinated as "1" for distal and "9" for proximal (See scheme in Figure 34). Comparison among racemes *(OLIVEIRA, 2017).*

Raceme	Age (Days)						Mean
	6	11	14	20	24	28	
1	22.1 b	7.5 e	6.1 d	4.0 c	4.1 d	2.3 d	7.7
2	26.9 b	11.3 d	13.2 c	7.8 b	7.7 c	2.4 d	11.5
3	30.2 a	17.2 c	21.0 b	9.0 b	6.0 d	4.8 c	14.7
4	34.2 a	23.6 b	26.2 b	15.6 a	11.4 b	6.3 c	19.5
5	33.9 a	29.5 a	31.3 a	18.4 a	12.4 b	8.3 c	22.3
6	35.9 a	31.0 a	33.3 a	19.6 a	14.0 b	8.8 c	23.8
7	36.1 a	33.3 a	33.4 a	21.3 a	18.9 a	13.3 b	26.1
8	35.5 a	35.6 a	30.5 a	18.0 a	19.4 a	21.3 a	26.7
9	38.3 a	37.6 a	35.5 a	18.8 a	22.5 a	25.0 a	29.6
Mean	32.6	25.2	25.6	14.7	12.9	10.3	20.2
C.V.:	25.56%						

*Means followed by the same letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$.

Table 13. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds attached to the raceme according to panicle age. Racemes are ordinated as "1" for distal and "9" for proximal (See scheme in Figure 34). Comparison among ages *(OLIVEIRA, 2017).*

Age (Days)	Raceme								
	1	2	3	4	5	6	7	8	9
6	22.1 a	26.9 a	30.2 a	34.2 a	33.9 a	35.9 a	36.1 a	35.5 a	38.3 a
11	7.5 b	11.3 b	17.2 b	23.6 b	29.5 a	31.0 a	33.3 a	35.6 a	37.6 a
14	6.1 b	13.2 b	21.0 b	26.2 b	31.3 a	33.3 a	33.4 a	30.5 a	35.5 a
20	4.0 c	7.8 c	9.0 c	15.6 c	18.4 b	19.6 b	21.3 b	18.0 b	18.8 b
24	4.1 c	7.7 c	6.0 d	11.4 d	12.4 c	14.0 c	18.9 b	19.4 b	22.5 b
28	2.3 d	2.4 d	4.8 d	6.3 e	8.3 d	8.8 d	13.3 c	21.3 b	25.0 b
Mean	7.7	11.5	14.7	19.5	22.3	23.8	26.1	26.7	29.6
C.V.:	25.56%								

*Means followed by the same letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$.

Table 14. Shatter percentage in Alexander grass (*Brachiaria syn. Urochloa plantaginea*) racemes according to panicle age. Racemes are ordinated as "1" for distal and "9" for proximal (See scheme in Figure 34). Comparison among racemes *(OLIVEIRA, 2017).*

Raceme	Age (Days)						Mean
	6	11	14	20	24	28	
1	2.7 ns	64.8 a	75.3 a	82.3 a	78.3 a	91.3 ns	65.8
2	0.8	50.4 b	50.5 b	67.2 a	67.6 a	93.0	54.9
3	0.8	36.2 c	32.0 c	70.0 a	72.9 a	87.2	49.9
4	0.3	23.4 d	21.4 d	53.5 b	60.3 a	83.1	40.3
5	0.0	14.1 e	9.3 e	47.4 b	61.0 a	78.6	35.0
6	0.2	14.1 e	1.8 f	40.9 b	57.1 a	77.8	32.0
7	0.2	2.1 e	3.3 f	40.0 b	46.8 b	68.1	26.7
8	0.0	12.6 e	3.3 f	46.5 b	45.5 b	52.0	26.6
9	0.0	8.7 e	6.7 e	40.9 b	34.1 b	50.9	23.5
Mean	0.6	25.2	22.6	54.3	58.2	75.8	39.4
C.V.:	40.33%						

*Means followed by the same letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$.

Table 15. Shatter percentage in Alexander grass (*Brachiaria syn. Urochloa plantaginea*) racemes according to panicle age. Racemes are ordinated as "1" for distal and "9" for proximal (See scheme in Figure 34). Comparison among ages *(OLIVEIRA, 2017).*

Age (Days)	Raceme									Mean
	1	2	3	4	5	6	7	8	9	
6	2.7 c	0.8 d	0.8 d	0.3 d	0.0 e	0.2 e	0.2 d	0.0 c	0.0 b	0.6
11	64.8 b	50.4 c	36.2 c	23.4 c	14.1 d	14.1 d	2.1 c	12.6 b	8.7 b	25.2
14	75.3 a	50.5 c	32.0 c	21.4 c	9.3 d	1.8 e	3.3 d	3.3 c	6.7 b	22.6
20	82.3 a	67.2 b	70.0 b	53.5 b	47.4 c	40.9 c	40.0 b	46.5 a	40.9 a	54.3
24	78.3 a	67.6 b	72.9 b	60.3 b	61.0 b	57.1 b	46.8 b	45.5 a	34.1 a	58.2
28	91.3 a	93.0 a	87.2 a	83.1 a	78.6 a	77.8 a	68.1 a	52.0 a	50.9 a	75.8
Mean	65.8	54.9	49.9	40.3	35.0	32.0	26.7	26.6	23.5	39.4
C.V.:	40.33%									

*Means followed by the same letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$.

Abscission, by its time, is an issue common to all commercial *Brachiaria* species. Prolonging the retention, however, apparently does little to improve in the yield if the method chosen was harvesting from the ground – which for Alexander grass seems to be the most proper having the early and intense shattering (Figure 36; Table 15). As the abscission layer is between the glumes and the pedicel, methods assessed in grasses to improve retention such as adhesives spraying and selection of plants with tightly enclosing glumes are little promising (HOPKINSON et al., 1996).

Some shattering less susceptible Brachiariagrasses accessions were reported (YOUNG, 1986), the bigger problem is to find an accession which match at the same time good performance as forage with good seed retention. For now, seed heterogeneity associated with shattering keeps as one of the constraints of warm forage seeds production.

4. CONCLUSIONS

- The ground sweeping method is the most proper for Alexander grass seed harvest;
- Cut did not influence positively the synchrony and the amount of panicle emerged in Alexander grass;
- Alexander grass presents high panicle production per area, reaching near 1,750 panicles m^{-2};
- Shattering starts rapidly in Alexander grass, after 11 days from the panicle emergence near 30% of seed already shed, after 20 days near 60% of the seed already shed;
- Alexander grass presents smaller racemes, smaller seeds, longer panicles and more racemes per panicle than most of the Brachiariagrasses (Signal grass, Palisade grass, Ruzi grass and Koronivia grass) widespread in Brazil.

Alexander grass seed qualitative factors: outcomes of panicle age and harvesting methods

CHAPTER 3

1. INTRODUCTION

Brachiaria are known among C_4 grasses as vigorous seed producers. On the average, a good harvest can yield 500 Kg ha^{-1} of seed (HOPKINSON et al., 1996) with thousand seed weight around 5 g (1 Kg ~200,000 seeds). In a major extent, it means that 1 ha of harvest will reclaim around 100 million seeds.

A cause for concern, however, is the physiological quality of this seed. Tropical grasses usually present recurrent problems of low viability and poor germinability. Alexander grass itself is a forage plant that produces plenty of seed, but just a fraction seems to be truly viable. Besides some studies were developed on the issue (VOLL et al., 1996a; FREITAS et al., 1990), all of those select specific seed classes to germinate (usually the best), aiming to evaluate the response to extrinsic treatments.

Nowadays *Brachiaria* seed producers actually are not focused just in the yield increase, but also in boosting the seed physiology and the viability of the lot. One of the major factors influencing that is the harvest method, which for Alexander grass is a key issue when looking to the proper way to produce the seed.

In Brazil there are two methods broadly used for forage seed harvesting: the mechanized ground sweeping and the combine harvest. For the first, better physiological quality is achieved, once the seeds are kept in the plant until the natural shattering, and a more complete maturation is allowed. This happens however at the cost of collecting high amounts of dirt with the seed and so results in lower purity. Combine harvest, in contrast, scores better in purity, but fails in the physiological quality (HOPKINSON & ENGLISH, 1985).

The planning of an Alexander grass seed production system raises some doubts as: *(1)* it is possible to achieve at least a reasonable germinability with attached seed, harvested directly from the panicle; *(2)* if the option is for ground sweeping, what is the suitable moment for the seed harvest and, finally; *(3)* apart from the methods, what is the germination potential of the Alexander grass seed according to

the thousand seed weight (looking to establish sowing rates for a good pasture establishment). These answers would be also useful to determine indexes as the physiological maturation of the seed bulk. Studies that consider the seed physiological quality according to the dynamic of inflorescence evolution like this could be valuable not just for Alexander grass but even for other Brachiariagrasses.

2. MATERIALS AND METHODS

The major aim of this experiment was to identify Alexander grass seed germinability according to the panicle ages and the method the seed was collected. Seed filling evaluations were performed looking to identify indicators of the physiologic maturation point and seed development.

The experiment was carried out at the experimental station of the Federal University of Technology – Paraná, in Pato Branco ($26^{o}10'40"$ S; $52^{o}41'18"$ W; 750 m asl.). The region climate is Cfa transition to Cfb, according to Maak (1968) classification. At early September 2014 samples were collected to perform soil chemical analysis, data is presented in Table 5.

No soil mobilization was performed, and there was no mulch covering the soil. 30 m^2 were used. Two uniformization cuts were performed at 20 cm when the plant reached 40cm, using a back brushcutter equipped with a metal blade. 200 Kg N ha^{-1} was applied using urea 45%, just after the first cut. In mid-October (2014) Metsulfuron-methyl was sprayed at the dose of 5 g a.i. ha^{-1}, using Ally ® (Du Pont), to control spontaneous broadleaf species that grew together with Alexander grass.

Three kinds of seeds were collected: *(1)* those threshed directly from the panicle (attached); *(2)* those naturally shattered, using special nets, and; *(3)* those collected from the ground in the end of the cycle, simulating a ground sweeping method:

To collect the **seeds attached to the panicle**, the following procedure was performed**:** tillers were marked to establish an initial point according to which the panicle age was determined – these ages corresponded also to the treatment factor. The stage chosen to establish the point zero in the counting was the range between "Booting 49" and "Booting 52" (Beginning of heading: tip of the inflorescence visible to 20% of the inflorescence visible) in the BBCH Scale (MEIER, 2001; Figure 20). It is important to state that this was an adaptation of the scale commonly used for cereals according to Meier (2001) classification, a solution encountered for the issue that no phenological scale is available specifically for Alexander grass, or even for Brachiariagrasses. Also, it was known that the age "zero" is just nominal, used to count the time after the very first appearance of the panicle, once it actually was already developing since the meristem differentiation.

Giving the lack of synchrony a period until substantial number of tillers became reproductive elapsed – the initial point was marked thus at early February 2015. In this occasion, the panicle stems were tied with cotton strings looking for all the tillers that represented the stage zero in the plots. The strategy was developed to guarantee leftovers, making the moment of the main harvest for the analysis random. In addition, at this moment there was no estimative of how long the evaluation period would last, and the end of the experiment was determined to when the panicles degradation did not allow evaluations anymore. In summary, seed ages in which panicles were collected (levels of the treatment), counted in days after the initial marking were 6, 11, 14, 20, 24, 28, 34 and 38. An additional control treatment was established gently shaking a plastic tray against the seed heads in the 38th day, stated in the results as "Shaken seeds".

30 panicles (observations) were picked out for each age, chopping the stem below the last node. Panicles were then taken to the Federal University of Technology Seed Laboratory, and divided into 3 sections: distal (4 first racemes from the top, basipetally), middle (5th, 6th and 7th racemes basipetally) and proximal (8th to basal raceme, basipetally).

Racemes were then threshed manually and individually, dividing the seed according to the raceme position. All the first raceme seeds, of all panicles, were put into a box, all seeds from the second raceme put into another box, and so on. Seeds where then bulked according to the inflorescence sections (Distal, middle and proximal) and taken for the germination test.

To collect the **shattered seeds in the net**, the following process was performed – Fabric nets were made in a size to accommodate an Alexander grass panicle without limiting its development. The nets were placed in the reproductive tillers just after the panicle emergence (early February 2016) and tied to the leaf sheath using rubber bands and cotton strings (Figure 38; Figure 39). After the shatter the seeds started to fell into the nets, which further were taken to the laboratory at each panicle age (according to the trial of seeds attached to the panicle), to perform the germination test and evaluations. This is an adaptation of the method suggested by Gobius et al. (2001), in which little nets were fixed in the individual racemes to collect the seeds.

Figure 38. Nets enclosing Alexander grass (*Brachiaria syn. Urochloa plantaginea*) panicles to collect shattered seeds (*Picture source: J.R. Oliveira - OLVIEIRA, 2017*).

Figure 39. Net enclosing Alexander grass (*Brachiaria syn. Urochloa plantaginea*) panicle to collect shattered seeds (*Picture source: J.R. Oliveira –OLIVEIRA, 2017*).

To collect the **shed seeds from the ground –** A simulation of a ground sweeping was performed at late March 2015. For that, the sward was chopped close to the ground using a back bushcutter equipped with a metal blade. The biomass was let drying for 5 days, since the high temperatures of the period helped to detach the seeds that remained linked to the panicles, and reduced the moisture of the seeds on the ground. The leaf and stem mass was removed, and the exposed seeds were collected using a garden vacuum Trap SF 3000®. Seeds were placed into bags for processing. The raw material was blown and sieved to separate the gross impurities. To improve the cleaning a Laboratory seed blower model South Dakota was used, separating 10 seed classes according to the weight of the seed (Figure 40).

Germination test was performed at the Seed Laboratory of Federal University of Technology – Paraná – Pato Branco, in a completely randomized design. This test was chosen since it is accepted as the most standardized test to evaluate seeds quality (LIMA, 2012). Still, there was no methodology of the official seed rules to assess Alexander grass – and the trial rates were established according to the environmental adaptation of the grass and the levels used for other related species of the genus.

Germination was evaluated in plastic transparent boxes (Gerbox; 11 x 11 cm wide x 3 cm depth), recommended for Brachiariagrasses in Brazilian seed testing rules (BRASIL, 2009). Boxes were washed with dish soap, intensively rinsed, sprayed (sterilized) with alcohol 70%, and then dried with paper towels. Four germination paper sheets were used in the base of each box, moistened until saturation (BRASIL, 2009; LOCH et al., 2004; BASKIN, 2001). Boxes were covered with a transparent plastic lid to avoid water loses. Even so, it was not hermetically closed, and tiny amounts of water had to be added weekly to replace evaporation and preserve the same amount of humidity in the substrate. Four replications were made for each treatment.

Figure 40. Alexander grass (*Brachiaria plnataginea* syn. *Urochloa*) seeds harvested by the ground sweeping method and separated in South Dakota seed blower, classified according to the Thousand Seed Weight (*Pictures source: J.R. Oliveira - OLIVEIRA, 2017*).

Fifty seeds were uniformly distributed in each box using tweezers, over the paper sheets on the bottom, with no paper cover. Some authors prefer the use of 100 seeds for each replication; however, according to the Brazilian official seed rules a major recommendation for germination test is that seeds should be arranged with spacing enough to minimize competition and pathogen contamination among the seedlings. The use of 25 or 50 seeds is allowed thus, when it better fits the number of seeds in relation to the size of the substrate (MORETTI, 2011; BRASIL, 2009).

In the trial all kinds of collected seeds were used, picking it randomly from the seed bulk threshed from the panicles, or from the shed seed mass. It is alternative to some experiments where just completely filled seeds are intentionally selected. For warm season grasses this decision is an important issue as partial filled caryopses are common, having the natural behavior of the plant to fail in some extent the seed set. The option for the use of all seeds independently of its state was motivated by three main reasons: *(1)* to opportunize partial filled seeds to develop a seedling, since it is potentially capable of that if the embryo is already formed, but the endosperm still in formation; *(2)* to express the real state of the germinability of the seed bulk harvested in that moment on the crop, and; *(3)* the decision to discard a seed will be subjective and so can also influence the reliability of the data.

Since the major aim of this trial was to identify the germination capacity of the seed, to avoid tegument blocks (coat dormancy) all seeds received a small incision in the distal tip with a sharp razor blade. Piercing, cutting or scarification are recommended by the Brazilian official seed rules for all *Brachiaria* species as well (BRASIL, 2009). As mentioned by CIAT (1982), despite dormancy is an inherent constraint of warm season seeds evaluation, it is not enough reason to abandon germination test, since it stills impossible to determinate the moment in which dormancy is not acting anymore in the C_4 grasses with clarity.

After the mounting of the boxes, they were placed into a BOD incubator, set to provide an environment with 11 hours of dark and 13 hours of light, simulating a daylength close to the period of emergence of Alexander grass in Southern Brazil.

Temperature was set to 20°C (dark) and 30°C (light), according to general recommendation of Brazilian seed testing rules for warm season grass species (BRASIL, 2009) and some other authors that evaluated *Brachiaria* (CARNEIRO et al., 2007; SALVADOR, 2007; GARCIA et al., 1998; VOLL et al., 1997).

Germination counting was performed at 7, 14 and 21 days after incubation. Any seed that emitted shoot were counted as germinated, independently of its size. For some classes at 21st day roots and canopy of seedlings were measured in a graduated template (Figure 41). In addition, in 21st day non-germinated seeds were pressed with tweezers to identify empty seeds and compose the seed set index – it was considered empty the seed with less than half of the filling expected for a normal seed.

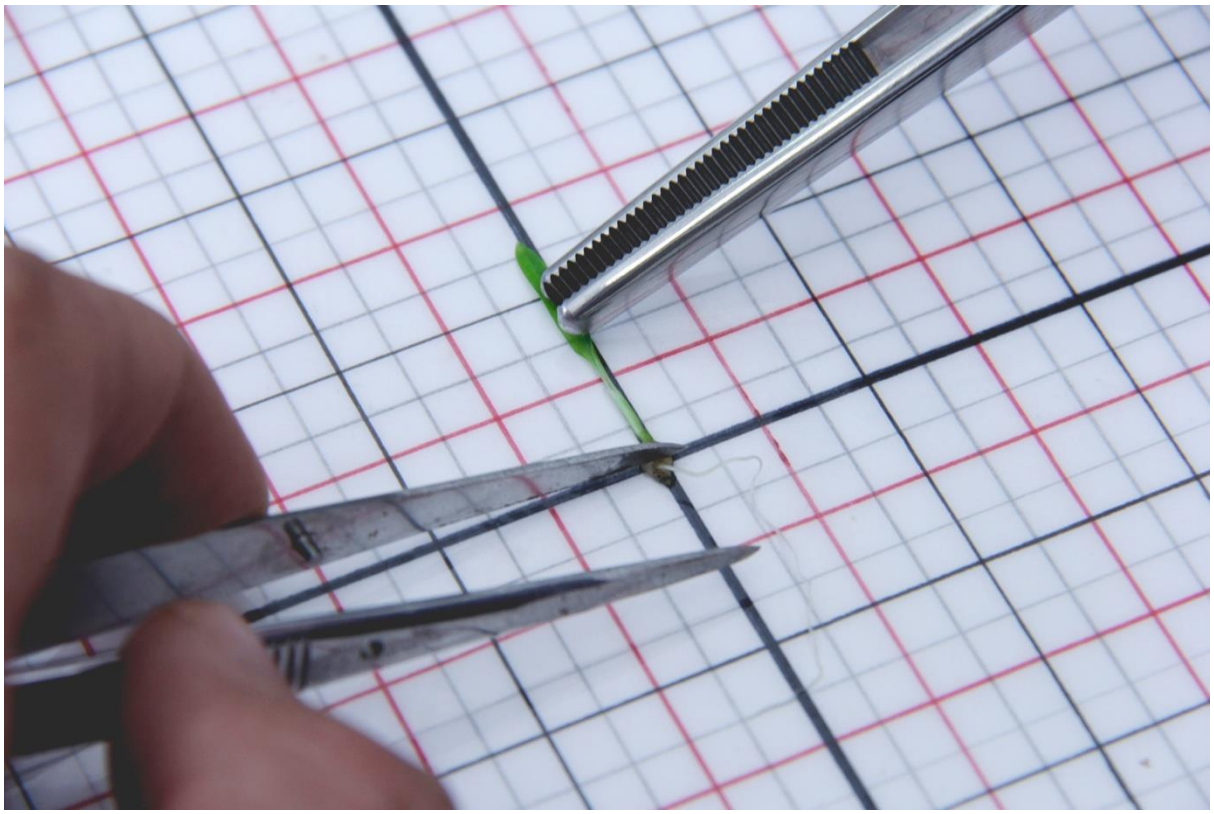

Figure 41. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seedling measuring using tweezers and a graduated template 21 days after seed incubation in germination paper (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

At the same time of the preparation of the germination test, thousand seeds were manually counted for further thousand seeds weight determination, and then weighed to determinate fresh mass in a scale of 0.01 g precision. All the remaining seeds threshed from the panicles were weighed to determinate fresh mass and submitted to drying process in air-forced oven set to 35^{o}C, until constant weight. After drying, these seeds were weighed again and dry matter percentage calculated. The value was used also to calculate the dry weight of individual seeds, and so compose the result of thousand seed weight and dry matter percentage.

Data was catalogued and Statistical analysis performed using 'R' (R DEVELOPING CORE TEAM, 2011) and 'Genes' (CRUZ, 2006). Regression analysis and graph compositions were performed using Sigmaplot. Germination data was transformed to 1/n. For all variables analysis of variance and Scott & Knott tests were performed, considering a significance level of 5% probability.

3. RESULTS AND DISCUSSION

Analysis of variance identified differences for the variable seed dry mass percentage according to the panicle ages ($P < 0.05$), and data better adapted to a cubic polynomial model regression ($P < 0.05$; Figure 42). Dry mass increased until nearly the 20th day after the panicle emergence, and remained relatively constant since then in values close to 50%. This result is usually lower in comparison to crops (MARCOS FILHO, 2007c; DESAI, 2004), in corn it places around 35%, evidencing here perhaps some different physiological processes in forage seeds. An important issue to justify that is the natural drying of forage seeds is speculated to happen just after the seed shedding. This evaluation was performed mainly to identify until each point the seed still submitted to increases in dry mass, aiming to determine the physiological maturation point determination according to days elapsed from the panicle emergence.

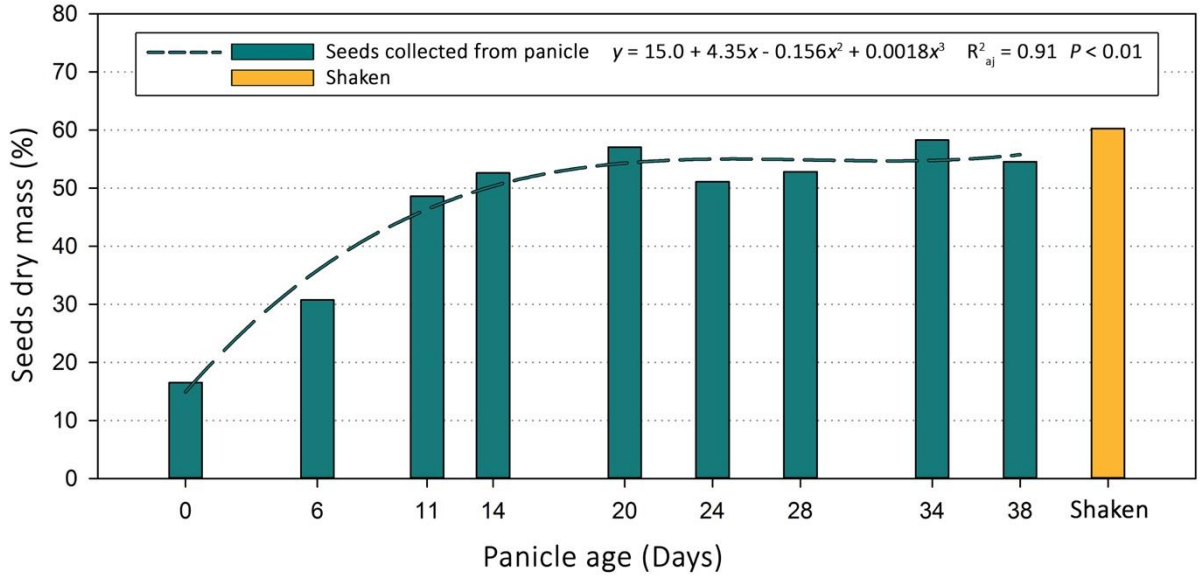

Figure 42. Dry mass percentage of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds according to panicle age. Shaken seeds were colected gently shaking a plastic tray against the seed heads in the 38th day after panicle emergence ($P < 0.05$; *OLIVEIRA, 2017*).

Seed maturation at all is a process that includes a sequence of morphological, physical, biochemical and physiological changes in which the moisture of the seed is directly involved. To support the several process of embryo histodifferentiation and the endosperm reserves accumulation during the early and mid-maturation, the seed have to keep a good amount of water in the tissues (Ovule moisture content at the time of fertilization is approximately 80% *i.e.* dry mass 20%). After the development, the desiccation will prepare the seed to face dispersal, a mark that determine a rest in the intense metabolic activities that the egg cell suffered since fertilization (MARCOS FILHO, 2007c). Further, imbibition will trigger the germination enabling again the seed physiology.

All of these processes were regulated by the parent plant to reach a better equilibrium. While the caryopsis (the main sink in the plant) receives large amounts of assimilates in solution during the filling phase, the plant regulates concomitantly its water rates, maintaining constant water movement through the seed under conditions of water stress or slowing it down when the supply of water is plentiful (LOCH et al., 2004).

Considering the above, a hypothesis can be built for Alexander grass: the high humidity observed in the seeds can indicate that a harvest directly from the panicle will collect seeds that still developing. This is a phenomenon analogous to the observed in corn seeds, where the embryo keeps developing after the maturity (ABEAS, 2007), and despite some seeds potentially germinate in this phase (*further discussed*), even after shattered it may keep suffering histodifferentiation. This is alternative to seeds that when detached from the parent plant is just performing a natural drying process.

The concomitant developing of the embryo in parallel to the starch accumulation (usually late in development) is reported by Loch et al. (2004) in Sorghum (*Sorghum bicolor*). Nonetheless, research on other warm season forage species could be interesting to identify this behavior. If it repeats, especially for those that combine harvest are common, in practical terms this management will always be collecting seeds that can have the physiological potential boosted if kept in the plant for a longer time.

The analysis of variance also identified differences according to the panicle fractions for the seed Dry Mass, better fitting to a quadratic polynomial model for all levels ($P < 0.05$; Figure 43). The detailing of the data was done using just the evaluations from the 6th to the 24th day, once after this period the panicles are too degraded to permit the division into 3 fractions with proper amount of seeds for the reliability of the analysis (*See Chapter 2 – pg. 130*).

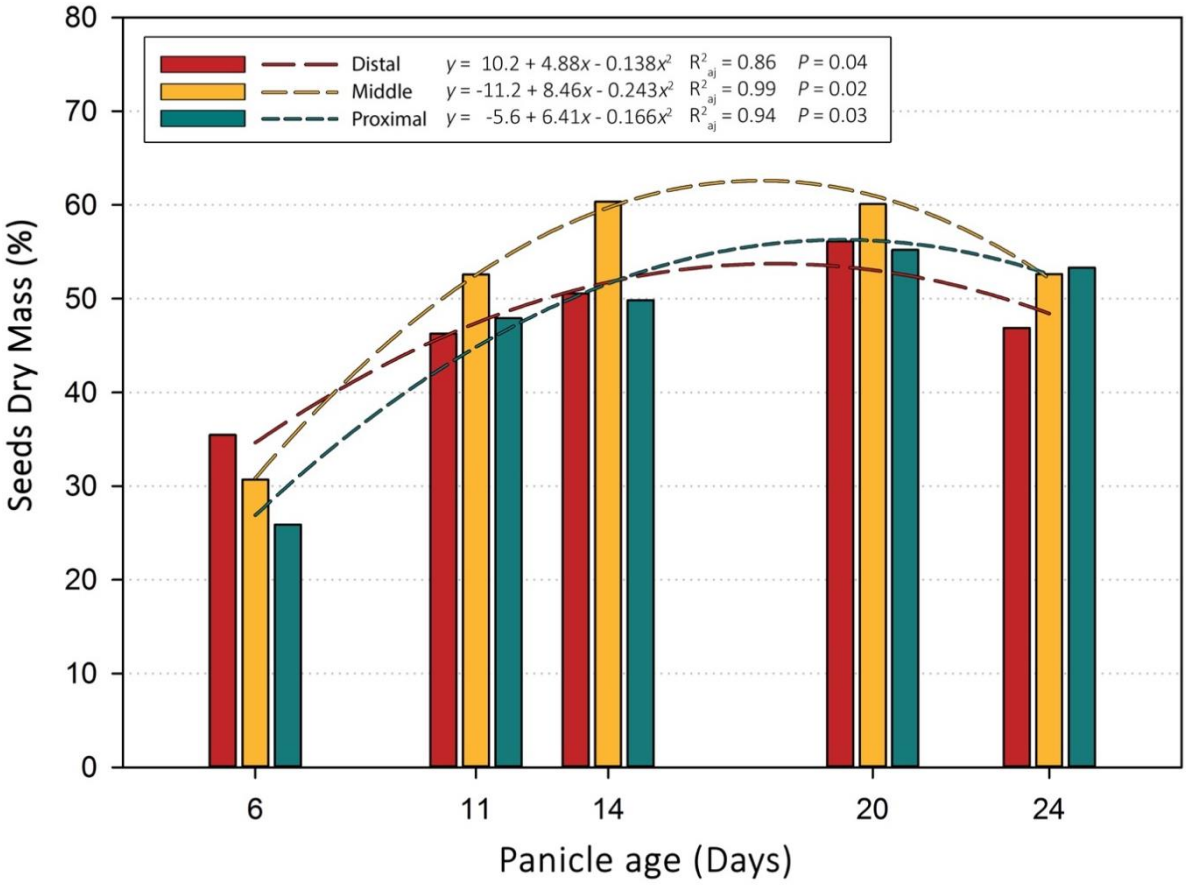

Figure 43. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds dry mass according to the panicle fractions and panicle ages. Adittional seed ages presented in Figure 41 (28, 34 and 38 days) were not analyzed in this graph since the inflorescences were too degraded to separate it into fractions (See Figure 29; *OLIVEIRA, 2017*).

The general behavior observed in the Figure 43 also matches the observed in Figure 42. Still, in young panicles (6th day) the higher dry mass was found in the Distal portion following the tendency of Alexander grass spikelets shattering in the panicle (*See Chapter 2 – pg.120*). At the ages 11, 14 and 20 days, high dry mass was observed in the middle portion of the panicle, which changed to the proximal portion in the older inflorescences of the evaluation (24th).

This is result perhaps of the complex relation among the seed filling process and the promptly shattering of the most developed seeds. With this and the shattering behavior (Table 14) the following situation can be hypothesized: *(1)* in the 6th day the spikelets are in early developing, and the distal ones are in advanced stage, as they are firstly differentiated; *(2)* In the 11th day shatter already began (Table 14),

and so some developed seeds from the distal portion already fell, reducing its contribution to increase the average dry mass of the seeds in the panicle fraction. In parallel, in the middle portion the seeds are in full process of filling, which expresses even better in the 14th day, and then started to reduce the difference between proximal and distal portions in the 20th day by the shattering effect as well, and; *(3)* In the 24th day shattering is very pronounced in the distal and in the middle sections (Table 14), but with less expression in the proximal, keeping some seeds filling in this last one.

Unfortunately, dry mass of the shattered seeds collected in the fabric nets (*further discussed*) were not evaluated in this trial, which could help to endorse these statements. Regardless, shaken seeds collected at the 38th day were better developed and presented higher dry mass (Figure 42) than the seeds attached to the panicle. Those are supposed to be ready to shed, and so could be a good indicator of the dry mass of the fallen seeds.

These conclusions are supported by the analysis of the weight of the seeds according to panicle ages. Analysis of variance identified differences among the levels for this variable ($P < 0.05$) and data better adapted to the quadratic polynomial model ($P < 0.05$; Figure 44).

A peak in the curve was observed close to the 20th day, with maximum absolute at 21.6 days. At the early ages, a relatively fast increase in the mass was observed (Figure 44) *i.e.* in 14 days panicles the mas of the seed increased nearly 2.5 times in relation to the panicle emergence moment. It supports that the seed development may start very early, even when it is within the leaf sheath (dry mass accumulation in developing seeds usually starts slowly because of the prevailing cellular division in this phase).

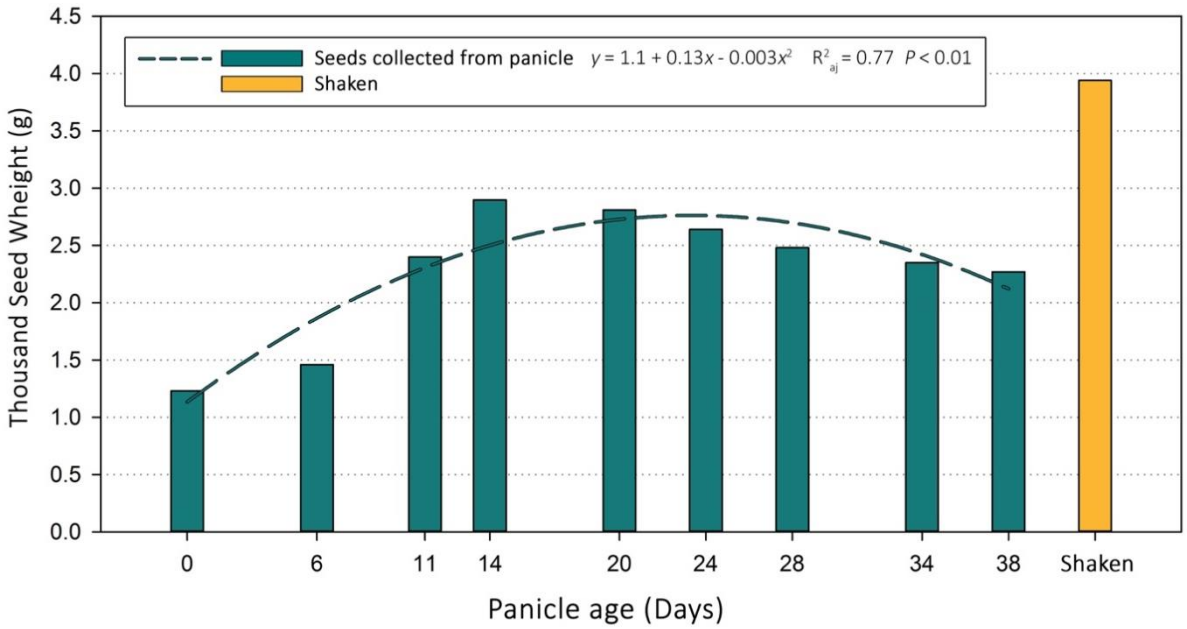

Figure 44. Thousand seed weight of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds according to panicle ages. Shaken seeds were colected gently shacking a plastic tray against the seed heads in the 38th day after the panicle emergence ($P < 0.05$; *OLIVEIRA, 2017*).

This statement agrees with those proposed by Marcos Filho (2007a), presenting the following process of the seed development: Immediately after fertilization the seed development begins, becoming the primary sink of assimilates of the plant. There are four general stages that can be characterized: The first two stages comprise intense cell division and elongation with slight increases in seed dry weight (In Alexander grass probably happening before the panicle emergence; MARCOS FILHO, 2007a; CARVALHO & NAKAGAWA, 2000). The third stage is characterized by a rapid increase in seed weight when nutrition is supplied through the funiculus mainly to fill the endosperm (from panicle emergence to near 20th day). At this point, the seed reaches maximum dry weight (near 20th day), the funiculus degenerates and the seed becomes physiologically independent from the parent plant (still containing high moisture; Figure 44). The fourth and final stage is when the seed undergoes dehydration, after the physiological maturity (MARCOS FILHO, 2007a; LOCH et al., 2004; CARVALHO & NAKAGAWA, 2000).

The major increase in grass seed weight was thus result of the growing endosperm comprising proteins, sugars, lipids and other substances, which happens later in the development and corresponds for most of the final seed mass. In Alexander grass a slightly reduction in the mass was observed in later ages (Figure 44). This is not concrete since the seed weights are supposed to do not decrease after the filling process. A main issue about this is the possibility of endosperm reserves being burned through the precocious seed respiration, overpassing the filling process – if it still happening at this point (CARVALHO & NAKAGAWA, 2000).

The shattering of the seeds already developed can also be involved. An interesting observation in the later panicles is that the seeds that remained attached to the rachis after the 20th day were those that seem to have failed to set. Inadequate pollination could be a reason. Still, the shed seeds or seeds promptly to shed are heavier, which is confirmed by the shaken seeds dry mass result (Figure 44) *i.e.* naturally shed seeds present higher values than those forcedly threshed from the panicle. Finally, the seeds collected from the ground can present even heavier seeds than those of the shaken treatment, depending on the intensity of the classification process (*Further discussed*).

The shattering influences in these results are better evidenced if the detailing of the thousand seed weight according to panicle fractions is considered. Analysis of variance identified differences for this variable as well, which better adjusted to a quadratic polynomial model regression ($P < 0.05$; Figure 45). Again, the results of dry mass closely followed the behavior observed in the dry mass percentage (Figure 42), and the explanation on the shattering of the most developed seeds following the distal-proximal direction is suitable.

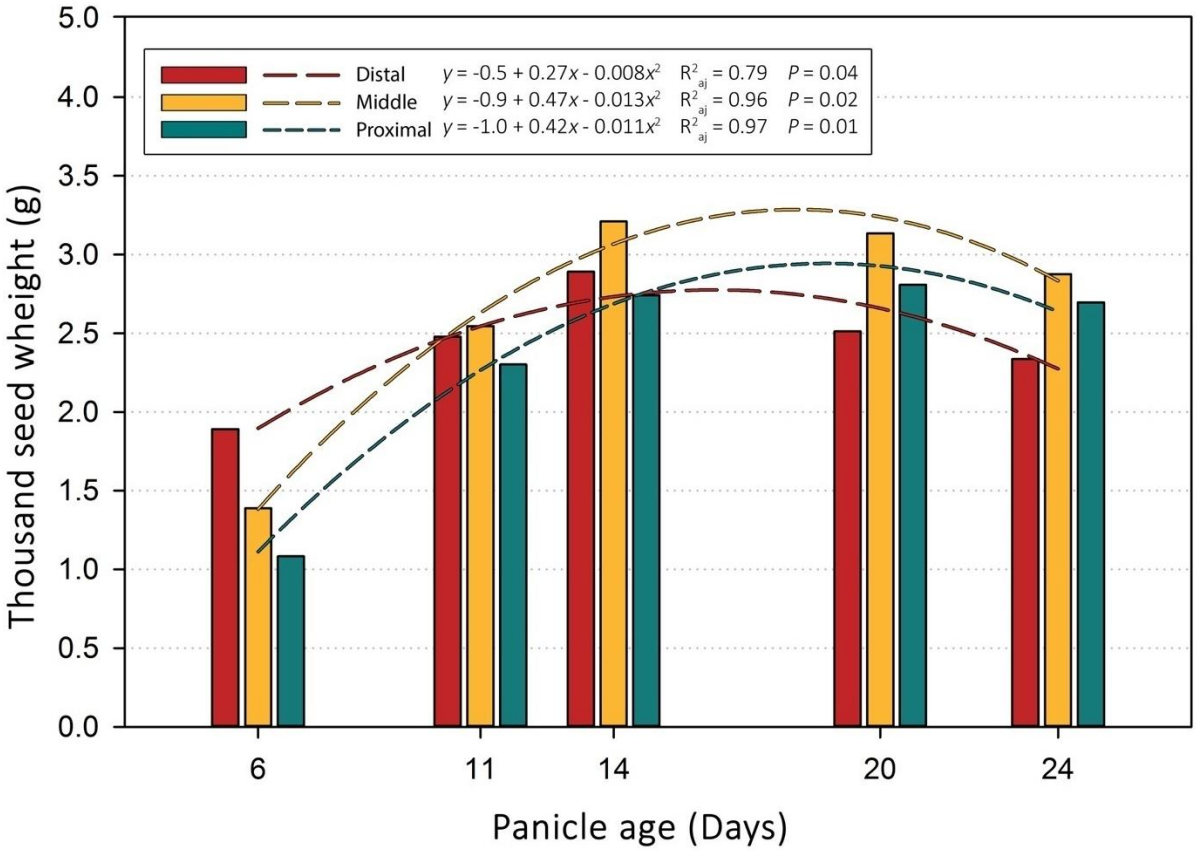

Figure 45. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) thousand seed weight according to panicle fractions and panicle ages. Adittional seed ages presented in Figure 43 (28, 34 and 38 days) were not analyzed in this graph since the inflorescences were too degraded to separate it into portions (See Figure 29; *OLIVEIRA, 2017*).

The mass accumulation in Alexander grass seeds can be used to characterize the physiological maturation point. This index is broadly accepted as the main indicator of this condition (POPINIGS, 1977). Physiological maturity identifies thus the moment that the seeds are in the maximum physiological potential, and despite shattering issues, this identification is a fundamental determinant of the field harvest time (MARCOS FILHO, 2007c).

In a summarized concept, the physiological maturity is characterized by the absence of further significant increases in seed dry weight (MARCOS FILHO, 2007c). thus, considering: *(1)* the higher dry mass percentage observed at near 20th day in the Figure 42; *(2)* the higher weight of the seed at near 20th day at Figure 44, and yet; *(3)* the spread of the shattering across all the panicle observed in the results of the Table 14; disregarding the natural variation for the seed bulk within the panicle

the physiological maturation point for Alexander grass will be reached nearly 20 days after the panicle emergence from the leaf sheath.

Giving the stated about the high humidity of the seed a physiological activity probably prevails, since even after the physiological maturation the embryo of Alexander grass probably keeps developing or physiologically stabilizing. Debate is found regarding the simultaneous expression of maximum germination, vigor and seed dry weight at physiological maturity. However, although some studies have confirmed this hypothesis species, several observations have shown that biochemical changes or metabolic adjustments happen after the reaching of maximum dry weight (MARCOS FILHO, 2007c).

There is also a lack of information for C_4 grasses (LOCH et al., 2004). Some reports are found for Sorghum, which take around 25 days to reach morphological maturity from fertilization (PAULSON, 1969 *apud* LOCH et al., 2004). Smaller grass seeds usually develop more rapidly: Rhodes grass caryopses for example mature about 17 days after anthesis and become hard and dry after another 6 to 8 days (LOCH et al., 2004), while Guinea grass cv. Gatton seeds mature and shed within 7 to 13 d of anthesis (HOPKINSON & ENGLISH, 1981).

Undoubtedly, flowering, pollination and seed maturation are not uniform processes within the plant and among the plants of the community, especially in warm season grasses. For these plants, it is particularly difficult to identify physiological maturity and optimum harvest time, giving the indeterminate flowering habit (MARCOS FILHO, 2007c) as appears in Alexander grass. Even away from genetic variability which potentially exist in the population (particularly those wilder), and assuming seeds to be almost identical, seed physiology will be yet influenced also by environmental conditions, which consequently may result in some differences in individual seeds as well (MARCOS FILHO, 2007b).

Knowing maturation of individual seeds thus is useless to determine the field management (SOUZA, 2001). This information could serve maybe as a compliment to statements about inflorescences population. It is proper so to define

the systematic practices according to the average condition of the seed population as presented here.

Beyond maturation, the mass of Alexander grass seeds observed in these trials evidenced the species as one of those that produces the smallest seeds among Brachiariagrasses (Figure 44). For comparison, some reports are presented (Table 16).

Table 16. Thousand seed weight of *Brachiaria* species according to species.

Species	Thousand Seeds Weight	Source
Palisade grass (*B. brizantha*)	7.0 g T.S.$^{-1}$ for cv. Marandu, 8.8 g T.S.$^{-1}$ for cv. Xaraés	Senra (2006)
	Average of 7.4 g T.S.$^{-1}$	Benteo et al. (2016)
	7.9 g T.S.$^{-1}$	Amorin (2000)
	From 6.8 to 8.1 g T.S.$^{-1}$	Brasil (2009)
	8.9 g T.S.$^{-1}$	Argel (2000)
	Mature seeds, 6.5 g T.S.$^{-1}$	Hopkinson et al. (1996)
Signal grass (*B. decumbens*)	Average of 4.7 g T.S.$^{-1}$	Vendruscolo (2014)
	Average of 4.7 g T.S.$^{-1}$	Gobious et al. (2001)
	From 4.2 to 5.6 g T.S.$^{-1}$	Brasil (2009)
	Mature seeds, 5.0 g T.S.$^{-1}$	Hopkinson et al. (1996)
Dictyoneura (*B. dictyoneura*)	Mature seeds, 4.8 to 5.5 g T.S.$^{-1}$	Hopkinson et al. (1996)
	2.4 g T.S.$^{-1}$	Cardozo et al. (1991)
Ruzi grass (*B. ruziziensis*)	Near 6 g T.S.$^{-1}$	Wongsuwan (1999)
	Mature seeds, 5.0 to 6.5 g T.S.$^{-1}$	Hopkinson et al. (1996)
	From 5.0 to 6.2 g T.S.$^{-1}$	Brasil (2009)
Koronivia grass (*B. humidicola*)	4.3 g T.S.$^{-1}$	Amorin (2000)
	From 3.5 to 4.1 g T.S.$^{-1}$	Brasil (2009)
	Mature seeds, 4 g T.S.$^{-1}$	Hopkinson et al. (1996)
Alexander grass (*B. plantaginea*)	Light (3 to 4.5 g T.S.$^{-1}$) and heavy seeds (+ 4.5 g T.S.$^{-1}$)	Moretti (2011)

*g T.S.$^{-1}$ = grams per thousand seeds.

The lighter seeds of Alexander grass are perhaps a reflex of the compensative rule that prevails in forage grasses. Since these plants present more panicles and more racemes than other Brachiariagrasses, this can influence the size of the seed. Reports that the seed mass is more affected by genetic issues than the management exist, but some variations can occur with N fertilization, for example (CARNEIRO et al., 2007). In *Brachiaria* genus, it is usually constant according to species, since the growing is limited by the size of the husk. Alternatively, grasses that do not enclose the seeds vary greater in seed size at maturity (*e.g.* Gamba grass, Buffel grass (*Cenchrus ciliaris*) and many *Andropogonaceae*) (HOPKINSON et al., 1996).

Independently of the seed size, most attention should be given to its proper nutrition and filling, once it will guarantee a better physiological quality and so a good geminability.

Germination in Alexander grass was then tested in several ways, seeking to identify the seed capacity to germinate according to the harvest strategies and the moments in the plant cycle. Results on the germinability of the seeds threshed directly from the inflorescence are presented in Table 17.

Table 17. Germination of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds (%). Evaluation performed with seeds threshed directly from the panicle, according to panicle ages (*OLIVEIRA, 2017*).

Panicle Age (Days)	Days After Incubation[1]			Mean
	7	14	21	
6	0 ns	0 d	0 d	0
11	5	9 b	10 b	7
14	4	11 b	13 b	9
20	3	9 b	14 b	9
24	3	9 b	13 b	8
28	2	7 b	8 b	5
34	1	5 c	6 c	4
38	0	5 c	7 c	4
Shaken[2]	1	28 a	48 a	26
Mean	2	9	13	8

C.V.(%) = 2,9%

[1]Means followed by the same letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$. [2]Shaken seeds were collected gently shaking a plastic tray against the seed heads in the 38th day.

Analysis of variance and mean test identified differences in the germination among the panicle ages in the 14th and 21st days after incubation ($P < 0.05$), on the other hand, in the 7th day no differences were observed ($P > 0.05$; Table 17). In general terms germination was very low (Figure 46), a result also observed by Freitas et al. (1990) evaluating Alexander grass, which reported that seed harvested directly from the panicle fail to germinate; and also reported by Lorenzi (2000), who cite that the fresh seeds of the species presents low germination.

Figure 46. Example of Gerbox with Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds harvested from panicle after 7 days of incubation. Low germination rates were observed (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Panicles with age of 6 days presented no germination (Table 17), possibly because the seed embryo was not formed yet, and still not viable. From 11th to 28th days after panicle emergence, the mean test separated a similar group, which presented better results among the panicle ages. Even so, the germination reached just low values, in an average 8.8% after 14 days of incubation, and 11.6% at 21 days after incubation. In panicles with 34 and 38 days, the germination decreased again in relation to the mid ages. These values are close to those observed by Benteo et al (2016), when evaluating the germination of Palisade grass just harvested seeds (from 7.6 to 15.8%).

To understand the behavior it is important to consider that the shattering issues are involved as well *i.e.* seeds well developed readily shed to the ground. This way, the seeds collected in the panicle are more immature, with exception of some in late maturation, probably almost ready to shed (those that germinated). To support that – even with low rates – the germination followed the

timing of the Alexander grass seed filling, germinating according to the moment the seed started to increase quickly its weight (Figure 44; Table 17). In warm season grasses the increase of the seed weight is mainly a product of the reserves accumulation in the endosperm (BEWLEY, 2013), which happens usually after the major histodifferentiation in the embryo and, thus, is the real determinant to make the seed germinable.

These processes happened relatively fast in Alexander grass. In Koronivia grass, for example, Mecelis & Cunha (1982) relate a period of 28 days from the fertilization until seeds became germinable. However, other species beyond the *Brachiaria* genus can develop even faster, according to Popinigs (1977) in rye, barley and sorghum the embryo are able to germinate just 5 days from the fertilization.

Besides the physiological maturation point was not reached when the first germinations occurred (Figure 44; Table 17), viability of seeds before that is common in several species *i.e.* during the first half of seed development seeds can become germinable (MARCOS FILHO, 2007ac; HILHORST 1995; LOCH et al., 2004). Loch et al. (2004) and Hilhorst (1995) cite that partially formed embryos can germinate even earlier if they are removed and incubated in nutrient medium. In addition, germination in early seed development can lead just to the protrusion of the primary root, but not the formation of a normal seedling (MARCOS FIHLO, 2007c), which is a result of the incipient reserve accumulation. On that, Alexander grass seedlings formed by these seeds clearly presented weak vigor (Figure 46), a situation also reported by Souza (2001) for warm season grasses in general.

Good germination results were presented with the treatment shaken seeds, maintaining so the hypothesis that the seeds easier to detach from the panicle are the better developed. At 21 days after incubation almost half of the seeds collected by this method germinated, which are very reasonable values considering the natural particularities of forage grasses. This means, also, that the use of beating machines to harvest Alexander grass seeds is feasible, despite the yields using this harvest method still demanding investigation. For the seed which do not germinated

there is the possibility of dormancy processes already starting to establish some blocks, bringing a complex dynamic among seeds getting mature and seeds getting dormant (a statement applied particularly to the results of 34th and 38th day; Table 17).

This pattern is applied for most warm forage seeds: theoretically, the percentage of germinable seeds should increase during maturation, reaching a maximum near the moment when seeds attain maximum dry weight (Figure 44; Table 17). This is only valid, however, for species which dormancy does not occur, as the dormancy induced during the reserve accumulation may directly affect the germinability (BEWLEY, 2013; MARCOS FILHO, 2007c). Comments on that are found even particularly for Alexander grass, reporting germination intimately linked to dormancy state in fresh seeds germination (VOLL et al, 1997).

Perhaps the first dormancy type to install in the maturation process is that related to the compounds in the developing seed (physiological dormancy). While the growing seed is accumulating reserves changes also occur in the content of other important chemicals such as the growth regulators (auxins, cytokinins, GAs, and ABA) (MARCOS FILHO, 2007c; HILHORST, 1995). ABA itself is accepted as the main blocker of the germination in the embryo, is synthetized and increase its level in the first half of the seed development, and declines as the seeds undergoes the maturation drying. At all, to affirm it surely a molecular studied which isolate these substances could be conducted.

At the late maturation phases, a second dormancy mechanism is installing. After the drying, the husk acquires a tighter consistency, and so some exchange limitations could be imposed by coat dormancy (LOCH et al., 2004). This is supported by the fact that the formation of the definitive pericarp is one of the last processes to happen in the seed development.

If analyzed the germination according to the panicle fractions some other behaviors are noted. The analysis of variance and the mean test identified differences among the fractions for all ages except 6 days ($P < 0.05$) (Table 18).

Table 18. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) maximum seed germination (%) according to panicle ages and panicle fractions (After 21 days of incubation). Comparison among panicle fractions[1] (*OLIVEIRA, 2017*).

Panicle fraction	Panicle age (days)					Mean
	6	11	14	20	24	
Distal	0 ns	11 a	14 a	14 a	13 a	10
Middle	0	9 a	11 a	9 b	9 a	8
Proximal	0	5 b	4 b	2 c	3 b	3
Mean	0	8	10	9	9	7
C.V.: 3.65%						

[1]Evaluation performed just after the seed harvest. Means followed by the same lowercase letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$. Harvest of Seeds attached to the panicle. Additional panicle ages are not presented once panicles are too damaged or to young to allow fractionation.

Besides the interaction among the ages, a clear tendency was evidenced by the mean test, since the proximal part of the panicle tended to promote the lower germination in all ages which germination occurred. This confirms again the maturing of the spikelets firstly in the distal portion of the panicle in comparison to the proximal ones, and agrees to the findings of Reinheimer (2005). The author detailed the differentiation of Alexander grass primordia: if secondary branching is formed in the inflorescence, it differentiates amphipetally (from the center to both ends), but within the raceme the spikelet differentiation will always happen basipetally (From the distal to the proximal fraction, as observed in this experiment). Still, according to the author in the balance of the whole inflorescence, the final maturation will happen basipetally, triggered by the older branch (as observed in this experiment as well; Table 14). This is however not a general rule in warm season grasses: in Signal grass and in Guinea grass for example the maturation occurs amphipetally within the panicle (REINHEIMER, 2005; STUR, 1986).

Another analysis that helped to confirm that is the comparison of the seed germination within a same panicle portion, according to the panicle age. Analysis of variance and mean test have not identified differences among the ages in the proximal fraction ($P > 0.05$; Table 19); and in the distal and middle fraction differences were observed just in the panicles with 6-days age to the rest of the levels ($P < 0.05$; Table 19). It supports the fact that heterogeneity is found just among the fractions, but not among the ages, in a same fraction (Table 19).

Table 19. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) maximum seed germination (%) according to panicle ages and panicle fractions (After 21 days of incubation). Comparison among panicle ages[1] (*OLIVEIRA, 2017*).

Panicle age (days)[2]	Panicle Fraction			Mean
	Distal	Middle	Proximal	
6	0 b	0 b	0 ns	0
11	11 a	9 a	5	8
14	14 a	11 a	4	10
20	14 a	9 a	2	9
24	13 a	9 a	3	8
Mean	10	8	3	7
C.V.: 3.65%				

[1]Means followed by the same lowercase letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$. Evaluation performed just after the seed harvest. Harvest of Seeds attached to the panicle. [2]Additional panicle ages are not presented once panicles are too damaged or to young to allow fractionation.

After knowing the germination, performance on seeds harvested directly from the panicle interest was raised about this same index according to storage time. This was done with the intention to simulate a resting time after the harvest, in a hypothetical situation that the seed will be sown in the next warm season. Results after 6 months' storage however were disappointing. Just few treatments barely expressed some germination. Analysis of variance identified differences among the treatments ($P < 0.05$), but after the performing of the mean test just faint grouping was evidenced ($P < 0.05$; Table 20).

Still, for the comparison of the stored seeds germination according to panicle ages same situation appeared: no significance was observed for most levels ($P > 0.05$; Table 21). Seeds of the 14 days panicles at the distal portion highlighted in the analysis, presenting the higher germination in relation to the rest of the samples. Even being the best results, after 21 days of incubation, just few more than a tenth of the seeds germinated (Table 21).

Table 20. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) 6 months stored seed germination (%) according to panicle age and panicle fractions. Comparison among panicle fractions[1] (*OLIVEIRA, 2017*).

Panicle fraction[2]	Panicle age (Days)[3]					Mean
	6	11	14	20	24	
	Germination after 7 days incubation					
Distal	1 ns	1 a	1 ns	0 ns	0 ns	1
Middle	0	0 b	1	1	0	0
Proximal	0	2 a	0	0	1	1
	Germination after 14 days incubation					
Distal	2 ns	5 ns	8 a	2 ns	1 ns	3
Middle	0	3	2 b	3	2	2
Proximal	0	2	0 b	0	2	1
	Germination after 21 days incubation					
Distal	2 ns	7 ns	12 a	4 ns	1 ns	5
Middle	0	5	3 b	5	4	4
Proximal	0	2	1 b	1	5	2
C.V.: 3.37%						

[1]Means followed by the same letter composed statistically homogeneous group in the column within the incubation day and panicle age; Scott & Knott; $P > 0.05$. Evaluation performed 6 months after the seed harvest. Harvest of seeds attached to the panicle. [2]Additional panicle ages are not presented once panicles are too damaged or too young to allow fractionation.

Table 21. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seed germination (%) according to panicle age and panicle fraction (6 months after the harvest[1]) (*OLIVEIRA, 2017*).

Panicle age (Days)[2]	Panicle fraction			Mean
	Distal	Middle	Bottom	
	Germination after 7 days incubation			
6	1 ns	0 ns	0 ns	0
11	1	0	2	1
14	0	1	0	1
20	0	1	0	0
24	0	0	1	0
	Germination after 14 days incubation			
6	2 b	0 ns	0 ns	1
11	5 a	3	2	3
14	8 a	2	0	3
20	2 b	3	0	2
24	1 b	2	2	2
	Germination after 21 days incubation			
6	2 c	0 ns	0 ns	1
11	7 b	5	2	4
14	11 a	3	1	5
20	4 c	5	1	3
24	1 c	4	5	3
C.V.: 3.37%				

[1]Means followed by the same letter compose statistically homogeneous group in the column within the panicle fraction and the incubation days; Scott & Knott; $P > 0.05$. Evaluation performed 6 months after the seed harvest. Harvest of seeds attached to the panicle. [2]Additional panicle ages are not presented since panicles were too damaged or to young to allow fractionation.

The germination rates were thus even lower after the storage, in comparison to the test just after the harvest (Table 17; Table 20). On that, two major factors are supposed to be involved: the dormancy and the natural seed deterioration. A dynamic process constructs if assumed that all mature, undamaged seed is dormant when newly harvested. As time passes, an increasing proportion of seeds lose dormancy, but also as the same seed ages, individuals die and survivors lose vigor (ESGPIP, 2010; SANTOS, 2009; HOPKSINSON et al., 1996; CONDE & GARCIA, 1985). This was already stated particularly for Alexander grass (VOLL, et al., 1997), Gamba grass (EIRA, 1993) and Guinea grass (CONDE & GARCIA, 1985).

The period of storage needed to brake the dormancy broadly varies, as reported in the literature: Souza (2001) relates that Signal grass, Palisade grass and Ruzi grass present dormancy for six months or more. For Guinea grass the same author relates that dormancy rarely bypasses 4 months. Hopkinson (1993) relates the need of at least 3 months for release in *Brachiaria* and *Panicum*. Conde & Garcia (1985) state that four months are enough for Signal grass and Previero et al. (1998) cite the same period for Palisade grass. Martins et al., (1998) relates six months for Palisade grass, once the same period is presented by Gobious (2001) for Signal grass. Oliveira & Mastrocola (1984) state that germination in Signal grass increased until 12 months after harvest, and Santos (2009) made the same statement for Palisade grass. For Ruzi grass, according to Renard & Capelle (1976), germination increases until 18 months of storage. Finally, for Cardoso (2011) aging did not influence Palisade grass seed germination.

In the study of Oliveira & Mastrocola (1984) Alexander grass reached its high germinability after 14 months of storage (84%), keeping these indexes until the 24th month, decreasing from then on. For the same author storage for 2 months resulted in 17% germination, and for 5 months resulted in 60% germination, since this behavior was attributed to dormancy issues.

The capacity of the storage to release dormancy in Alexander grass is also related by Voll et al. (1997). The authors observed that seeds stored for a year presented maximum germination of 67%. Just harvested seeds presented maximum germination of 14,8%. On the other hand, just harvested seeds presented higher imbibition rates (65%) than those stored for a year (55%). Also, hardening of the coat is involved in this last phenomenon (VOLL et al, 1997).

The superior germination obtained after storage by Oliveira & Mastrocola (1984) and Voll et al. (1997) is perhaps resulting of the different harvesting methods. As presented, for most tropical grasses the seeds collected from the ground are usually better in quality than those collected directly from the panicle.

Under conventional storage and testing, even for the same species, the germination peak actually may be reached in a few months or years (HOPKISNON et al., 1996), depending on several factors that can influence dormancy and degradation. The temperature is probably the most manageable among those storage conditions (HOPKINSON & ENGLISH, 2005; SOUZA, 2001; HOPKINSON, 1993; USBERTI, 1990; ELLIS et al., 1986). Looking to identify some differences, thus, Alexander grass seeds were stored in cold and in room temperatures (environment). The analysis of variance identified differences on the data, but it was expressed just in panicles with 11-days age ($P < 0.05$; Table 22). Differences evidenced better results in the seeds cold stored, which support the hypothesis of influences regarding the deterioration.

Viability decrease with seed aging is a known, universal phenomenon, observed in all species, and studied specifically for forage grasses as well (GOBIOUS et al., 2001). As this process is irreversible the best that can be done is to control its rate (MCDONALD, 2007a), such as reducing the temperature, and thus the metabolic activity of the seed.

Table 22. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seed germination (%) according to storage temperature and panicle age[1] (*OLIVEIRA, 2017*)

Storage temperature	Panicle age (days)[2]					Mean
	6	11	14	20	24	
	Germination after 7 days incubation					
Environment[3]	0 [ns]	0 *	0 [ns]	0 [ns]	1 [ns]	0
Cold[4]	0	2	1	0	0	1
	Germination after 14 days incubation					
Environment	0 [ns]	1 *	2 [ns]	1 [ns]	2 [ns]	1
Cold	0	6	4	2	2	3
	Germination after 21 days incubation					
Environment	0 [ns]	2 *	4 [ns]	3 [ns]	3 [ns]	2
Cold	0	7	7	4	4	4
C.V.: 3.37%						

[1]Means followed by ['ns'] compose statistically homogeneous group in the column within the panicle age and the incubation days; Scott & Knott; $P > 0.05$. Evaluation performed 6 months after the seed harvest. Harvest of seeds attached to the panicle; [2]Additional panicle ages are not presented since panicles were too damaged or too young to allow fractionation; [3]Room temperature; [4]5 ^{o}C.

Brachiaria dictyoneura seeds stored under environment conditions for 6 months showed poor germination (0 – 10%), while seeds stored in cold for a similar time showed 70-90% (BRADLEY & FERGUSSON, 1993 *apud* HARE et al, 2008). According to Hopkinson & English (2005), evaluating several forage grasses (*i.e.* Guinea grass, Signal grass, Koronivia grass, Setaria (*Setaria sphacelata*) and Rhodes grass), in all evaluations cold-stored seed performed better than the room temperature stored seed, with clear indications not only of higher viability but also of superior vigor.

The main concern with cold storage of tropical pasture grasses is the persistence or even the deepening of dormancy (HOPKINSON & ENGLISH, 2005). Since the dormancy release is also a product of the metabolic activity, reductions in this rates can also influence the chemical stabilization. Robust ABA degradation, for example, occurs in dry storage and high temperatures (HILHORST et al., 1995). Still, warm environment also affects the consistency of the coat – besides potentially hardening that by the tissue drying; changes also can make it porous by favoring the biotic effect of microorganisms and insects.

Dormancy release was however mentioned also as an overweighing benefit in relation to the viability preservation (Which means in practical terms to decide between cold or regular storage). Vieira et al., (1998) reports better germination of Palisade grass after 9 months storage in 28^{o}C than in 4^{o}C. Hare *et al.* (2008) found that dormancy was quickly lost in *Brachiaria* cv. Mulato seed stored at ambient temperatures, but persists strongly after 3 years in cold storage. Freitas et al. (1990) reported that Alexander grass germination was positively influenced by warm-dry storage.

Establishing a general recipe for these issues is hard. Seed structure, for example, affects seed deterioration. Simple differences in seed size can mean that smaller seeds with a greater surface area to volume ratio are more exposed, which would make them prone to deterioration more than larger seeds (MCDONALD, 2007a). In the soil, reductions in light, temperature and humidity increase seed longevity (VIEIRA et al., 2001). Air relative humidity, by its time, promotes fluctuations in moisture levels even in room storage, as the seed keep searching for a hygroscopic equilibrium (POPINIGS, 1977).

The objective of the storage is something important to consider. Gonzalez et al. (1994) reported that Signal grass seeds stored for 6 months had superior germination in environment storage (45%), being the maximum germination obtained with this treatment during all experimental period. After 20 months, however, better results were obtained in cold storage (57%). This same pattern was mentioned by Martins et al (1998): dormancy release increases germination at first but then deterioration overcame its effects. As an option, thus, cold storage could be used when the intention is to keep the seed for longer time, and if the seed will be sown in the next season environment-storage can be used (HOPKINSON & ENGLISH, 2005).

The separation of the dormancy/deterioration effects in the Alexander grass was not possible. Once these seeds were collected directly from the panicle it is probable that it presented a lower shelf life and resistance to the storage, and thus 6

months (a relatively short time) were enough to drop the germination. This situation is supported by the statements of Marcos Filho (2007c) and Conde & Garcia (1986), which reports that seeds are not capable of withstanding desiccation and storage at all the developmental stages. The ability to tolerate desiccation progressively improves during the seed formation because of physiological and morphological changes that take place as the development proceeds. One of the key strategies is perhaps the synthesis of protective substances in latter stages (as ABA). These modifications will occur mostly in the establishment of mechanisms of damage repair and replacement of lost enzymes and organelles (CARMONA, 1992).

The comparison of the panicle ages within the storage temperatures can also give some clues about what should be the best panicle age to harvest the attached seed, looking to increase at least a little the resistance to storage. Analysis of variance identified differences for the variables but grouping by the mean test appeared just in cold storage ($P < 0.05$; Table 23). The higher results were observed at 11 and 14 days' age panicles. Still, the germination levels are far from ideal to establish a concise and reliable seed production.

Explanation for low viability in Alexander grass seed harvested directly from the panicle can be supported by the analysis of the seed set presented in the Table 24. Analysis of variance identified differences among the levels ($P < 0.05$), and mean test grouped the treatments, except for the 24-days age panicles which presented no differences among the fractions ($P > 0.05$). Higher rates of empty seeds were presented in the proximal portion, in younger panicles (6, 11, 14 days), perhaps as a result of the later filling of these seeds. The distal and middle portion filled the seeds first, presenting less empty seeds until the 20th day, when the situation inverted and the higher percentage of empty seeds was observed in the distal fraction. At the 24th day, differences were not identified, once it is assumed that the advanced stage of the panicle homogenized the filling and shedding processes.

Table 23. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) stored seed germination (%) according to panicle age and storage temperature. Comparisons among panicle ages[1] (*OLIVEIRA, 2017*).

Panicle age (days)[2]	Storage temperature		Mean
	Environment[3]	Cold[4]	
	Germination after 7 days of incubation		
6	0 [ns]	0 b	0
11	0	2 a	1
14	0	1 b	1
20	0	0 b	0
24	1	0 b	0
	Germination after 14 days of incubation		
6	1 [ns]	1 b	1
11	1	6 a	3
14	2	4 a	3
20	1	2 b	9
24	2	2 b	9
	Germination after 21 days of incubation		
6	1 [ns]	1 [ns]	1
11	2	7	4
14	4	7	5
20	3	4	3
24	3	4	3
C.V.: 3.37%			

[1]Means followed by the same lowercase letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$. Evaluation performed 6 months after the seed harvested; Harvest of seeds attached to the panicle; [2]Additional panicle ages were not presented since they were too damaged to allow fractionation; [3]Room temperature; [4]5°C.

Table 24. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) empty seeds (%) according to panicle age and panicle fraction. Comparison among fractions[1]. Harvest of seeds attached to the panicle (*OLIVEIRA, 2017*).

Panicle fraction	Panicle age (days)[2]					Mean
	6	11	14	20	24	
Distal	45 b	49 b	61 b	51 a	52 [ns]	51
Middle	46 b	37 c	41 c	43 b	53	44
Proximal	82 a	98 a	95 a	41 b	47	72
Mean	58	61	65	45	50	56
C.V.: 10.48%						

[1]Means followed by the same letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$. Harvest of seeds attached to the panicle; [2]Additional panicle ages were not presented since they were too damaged to allow fractionation.

If comparisons are done among the ages, in the panicle fractions, differences were also observed ($P < 0.05$; Table 25). Clear tendencies were not identified, but in the distal fraction, the high levels of empty seeds appear in the panicles of 14-days age, as in the middle fraction it expressed in the 24th day. At the proximal fraction, the lower amount of empty seeds appeared in the older panicles (20th and 24th, later filling).

In average the percentage of empty seeds agrees with data on most Brachiariagrasses since, depending on the species, even poorest results can be observed. In regular evaluations, the amount of empty seeds is converted to an index called seed set, which represents in a gross definition the amount of seed that developed as expected. Still, this is every time a subjective evaluation, because the decision for classifying the seed as set or empty was based most of the time manually pressing it using tweezers. For the trials set seeds are considered as those which presented at least half of the filling expected for a full developed seed.

Table 25. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) empty seeds (%) according to panicle age and panicle fraction. Comparison among ages[1]. Harvest of panicle attached seeds (*OLIVEIRA, 2017*).

Panicle age (days)	Panicle fraction[2]			Mean
	Distal	Middle	Proximal	
6	45 b	46 b	82 b	58
11	49 b	37 b	98 a	61
14	61 a	41 b	95 a	65
20	51 b	43 b	41 c	45
24	52 b	53 a	47 c	50
Mean	51	44	72	56
C.V.: 10.48%				

[1]Means followed by the same lowercase letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$. Harvest of Seeds attached to the panicle. [2]Additional panicle ages were not presented since panicles were too damaged to allow fractionation.

As a technical definition from the official Brazilian seed testing rules (BRASIL, 2009), empty seeds are those empty or containing just residual filling tissues. According to some authors, this phenomenon is together with the shattering and the irregular maturation the main limitation to the wide use of *Brachiaria* seeds (LOCH & FERGUSSON, 1999; URIO, 1995), and a major source of variability in the seed lot (USBERTI FILHO et al., 1985).

Several causes can contribute to drop the seed set, for example sterile ovules (cromossomic unbalance), ovule abortion (multiple core embryos), ovules non fertilized (Pollination fails, sterile pollen, fertilization fails) or destroyed ovules (pest, diseases or mechanical action). Despite failures were reported for cleistogamic grasses (FRANKEL & GALUM, 1977), the situation is not different when dealing with apomictic reproduction, once the meiosis/mitosis relations and self-incompatibility make the genetics of the fertilization even more complex (ARAUJO et al., 2006; HOPKINSON et al., 1996).

The autogamous reproduction of Alexander grass also raise questions about what is really the main factor affecting the failure in fecundation and the presence of empty seed. When the grass is not apomictic, the pollination becomes even more important. This will better fit also for grasses wind-pollinated in which large quantities of pollen are necessary to ensure a high percentage of seed set (HACKER & LOCH, 1997). Stanley (1999) reports that the inflorescence of grasses may have evolved to compensate an inefficient pollination: an inflorescence presents many more flowers, and a larger cross-sectional area to the wind than an individual flower. Regardless, having the autogamous behavior of Alexander grass this is not a satisfactory explanation. The next hypothesis will be the operation of a self-incompatibility mechanism, but advance in studies are needed to affirm surely that. Even for popular commercial Brachiariagrasses these issues are not very clear (HOPKINSON et al., 1996).

If considered the final bulk of all seeds produced, Brachiariagrasses rarely exceeds 30% seed set. Signal grass highlights, nearing 40% (HOPKINSON et al., 1996). These rates are even lower in Guinea grass (HOPKINSON & ENGLISH, 1982), and there is a serious problem in seed production of *Brachiaria* hybrids. Hare et al. (2015), evaluating cv. Mulato II, reported fewer than 2% of the spikelets producing viable seeds, a genetic inherited phenomenon attributed to pollen sterility (HARE et al., 2014). This is, however, a good hypothesis for Alexander grass, as even the plant being autogamous the pollen viability is important to accomplish the fertilization.

Besides the questions inherent to the plant, environmental factors are involved. According to Loch et al. (2004) and Hopkinson et al. (1996), grass seed crops are very vulnerable to stresses as drought, heat and low relative humidity, especially during anthesis, which will directly determine the seed set. For this experiment, these situations were not observed during the experimental period, and the excessive humidity as happened does not appeared to restrict the fecundation/pollination process (LOCH et al, 2004). In some cases, however, cold weather or prolonged overcast periods can retard caryopsis growth, risking the spikelet abscission to precede the maturation (HOPKISNON et al., 1996).

Finally, despite the causes of this phenomenon, the high proportion of empty seeds in Alexander grass inflorescences endorse two main conclusions: *(1)* low germinability and low shelf life of the seed collected from the panicle could be, besides other influents, product of a deficient seed set, and *(2)* having this situation – and the results of germination observed until now – the harvest in a single destructive operation, that collects the seeds attached to the panicle, will recover probably the worst seeds in the field, making the combine harvest not proper for the species.

The hypothesis was thus that shed seeds have better quality than those threshed from the panicle, and another method to collect the seeds using nets was developed. Analysis of variance and mean test identified differences among the treatments ($P < 0.05$) and results are presented in Table 26.

Table 26. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) shattered seeds germination (%) according to days of incubation and panicle ages (*OLIVEIRA, 2017*).

Panicle age (days)	Days after incubation			Mean
	7	14	21	
6	8 b	12 c	17 c	10
11	9 b	18 b	21 b	13
14	5 b	24 a	28 b	14
20	18 a	30 a	38 a	24
24	3 b	16 b	22 b	9
28	1 b	4 d	12 c	2
34	0 b	2 d	4 d	1
38	0 b	2 d	7 d	1
Mean	5.4	13	18	9

C.V.: 6.17%

[1]Means followed by the same letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$. Harvest of Seeds shattered from the panicle.

The harvest using the nets was very effective (Figure 47), confirming the methodology as useful not just for Alexander grass but also possibly for all Brachiariagrasses. In other species, the result could be even better once Alexander grass presents one of the smallest seeds in the genus (Table 16).

The results of germination obtained with naturally shattered seeds were better than those with seeds threshed directly from the panicle. It was achieved until 38% germination after 21-days incubation (Table 26), which despite not being excellent (not reaching neither half of the samples) at least gave a rate plausible to establish a production strategy. It confirmed also the previous observations that superior indexes were found near the 20th day after the emergence of the panicle.

Even in the young panicles (6 days) some germinability was observed (16.5% after 21-days; Table 26), which increased until the 20th day and then progressively decreased until the end of the evaluation (This can indicate again the establishment of some blocking mechanisms in the late phase of the maturation).

A similar behavior observed both for seeds collected from the net and for seeds collected directly from the panicle was the increase in the germination according to the incubation days. The analysis of variance and the mean test identified differences for almost all levels of treatment ($P < 0.05$; Table 27). No interaction among the factors was observed in the stored seeds (threshed from the panicle), so just the means were compared. Anyway, for this last case, the tendencies were similar to the other methods.

Figure 47. (A) Net enclosing Alexander grass (*Brachiaria syn. Urochloa plantaginea*) panicle to collect shattered seeds. Panicle in mid stage of development, shattered seeds are observed loose inside the net; (B) Panicle in early stage of development, racemes still keeping the seeds attached (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Table 27. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds germination (%) according to panicle age and incubation days. Comparison among incubation days[1] (*OLIVEIRA, 2017*)

Days after incubation	Panicle Age (Days)								Shaken[5]	Mean
	6	11	14	20	24	28	34	38		
	Seeds linked to the panicle (incubation after harvest)[2]									
7	0 ns	4 b	4 b	3 c	3 c	2 b	1 b	0 b	1 c	2
14	0	8 a	11 a	9 b	9 b	7 a	5 a	5 a	28 b	9
21	0	10 a	13 a	14 a	13 a	8 a	6 a	7 a	48 a	13
	Seeds linked to the panicle (incubation after 6 months storage)[3]									
7	0	0	1	1	0	0	0	0		0 c
14	0	1	3	3	2	2	2	2		2 b
21	0	1	4	5	3	3	2	3		3 a
	Shattered seeds (incubation just after harvest)[4]									
7	8 ns	9 b	5 b	18 c	3 b	0 b	0 ns	0 ns		5
14	12	18 a	24 a	30 b	16 a	4 b	2	2		13
21	17	21 a	28 a	38 a	22 a	12 a	4	7		18

[1]Means followed by the same letter compose statistically homogeneous group in the column within the age and within the harvest type; Scott & Knott; *P* >0,05; [2]C.V.: 2.9%; [2]C.V.: 3.1%; [4]C.V.: 6.2%. [5]Shaken seeds were colected gently shacking a plastic tray against the seed heads in the 38th day after the panicle emergence.

The option to evaluate the germination until 21 days was based on the recommendation for Brachiariagrasses according to the Brazilian official rules for seed testing (BRASIL, 2009). Differences observed in the Table 27 confirm this recommendation. In several germinability studies, however, maximum germination occurs at early incubation time. Tomaz (2013) suggests that the evaluation time of germination test for Guinea grass should be reduced, once maximum germination occurred in half of the recommended time. Gaspar (2005) evaluating Palisade grass suggested the reduction of the incubation time to 11 days. These situations however should be relativized to each experiment, once several factors can influence the response of the seeds. Dantas et al. (2001) evaluated dormancy-breaking treatments over Alexander grass seed until the 18th day after the incubation, but reported that the rates increased until the last day. Voll et al (1996a), also evaluating Alexander grass, observed a maximum germination at 14 days after incubation, besides keeping the trial just until the 16th day.

Herrera (1994), reports influences of temperature in initial germination speed. For the same author, however, with the elapsing of the time the differences disappear. Loch et al. (2004) reported that for most C_4 grasses seeds, under optimal conditions, the radicle should emerge in near 24 hours, a behavior that was observed in some Alexander grass seeds. When some kind of delay appears a partial formed dormancy mechanism could be a hypothesis.

To complete the analysis of Alexander grass germination, seeds were collected from the ground in the end of the cycle, simulating a ground sweeping method. The seeds were separated according to thousand seed weights that is usually one of the major indicators of the seed development, and stored in cold and environment temperature for six months.

Even before the germination test, in the seed classification performed to establish the treatments a conclusion could be formed, related in this case to the high weight variability of the Alexander grass seed bulk. This was stated as seeds with thousand seed weight of 0.94 g to 5.5 g were found in the same material, an increase

of almost 6 times between extremes. It is concluded thus that this could be a robust source of heterogeneity in the performance of the seed, which – besides less mentioned in the literature about forage grasses – can pair other issues as the uneven maturation, the shattering, the different arrays of dormancy and the possibility to acquire secondary dormancy after the maturation. This supports the mentioned by Loch et al. (2004), who highlight the difficulties involved with laboratory tests of tropical forages in comparison to temperate grasses and grain crops.

With the development of the germination test, the first finding was related to incubations days: in seeds collected from the ground, no differences were observed *i.e.* according to the analysis of variance all the seeds presented the maximum germination promptly, after 7 days of incubation. In practical terms, this is an interesting advantage, meaning a faster establishment of the pasture, and endorsing a better competition with weeds and/or the reduction of the time to start the grazing.

Regardless, the analysis of variance identified differences in the germination among the thousand seed weights, which adjusted to a linear polynomial regression as presented in Figure 48 ($P < 0.05$). The results followed a pattern observed in most plant species: the higher the TSW, higher the germination of the seeds. Differences according to the moment of evaluation (just after harvest and stored) were not identified by the analysis of variance; for each gram increased in the thousand seed weight the germination increased 11.4%, 12.3% and 10.67% for harvest moment, 6 months environment storage and 6 months cold storage, respectively.

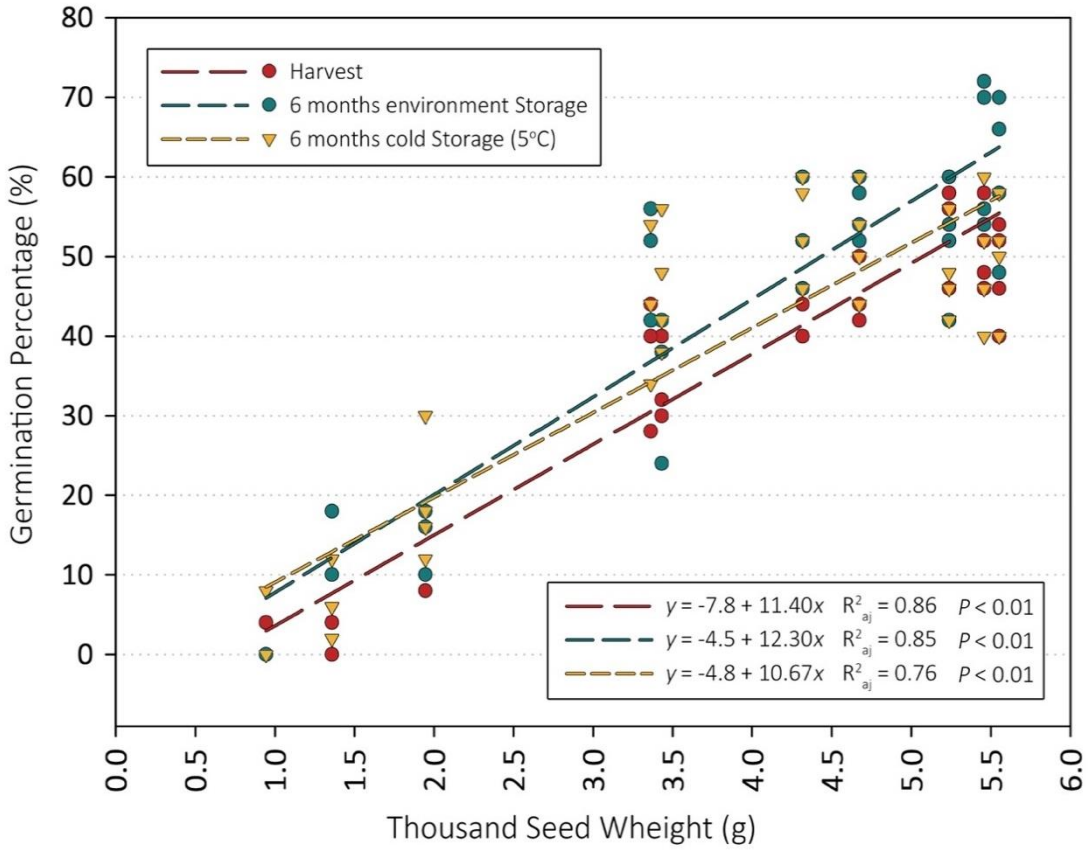

Figure 48. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seed germiantion according to Thousand Seed Weight. Seeds incubated just after the harvest (April 2015) and after 6 months storage (October 2015) in cold (5°C) and environment temperature (*OLIVEIRA, 2017)*.

TSW presenting linear relationship with physiological quality was already reported (SILVA et al., 2007; CARDOZO et al., 1991). In Alexander grass itself, Moretti (2011) split a seed lot according to weight, and observed then 20% more germination in the heavier group. Besides the results, perhaps the major achievement with this trial was the relatively high germination with some treatments. If compared to the rest of the experiments developed in this chapter the response was very substantial (61 % germination with 5.6 g of TSW, environment temperature stored for 6 months; Figure 49; Figure 50). It is reserved, however, that this is the 'better' seed harvested and corresponds just to a share of which will be the final product in a commercial production. Still, this is interesting to identify where the higher viability of the Alexander grass seed is encountered.

Figure 49. (A) Germiantion of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds of high thousand seed weight. At 14 days incubation seedling bypassed the height of the gerbox. (B) Germiantion of Alexander grass, seedlings developed from seeds with high weight after 7 days incubation. (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

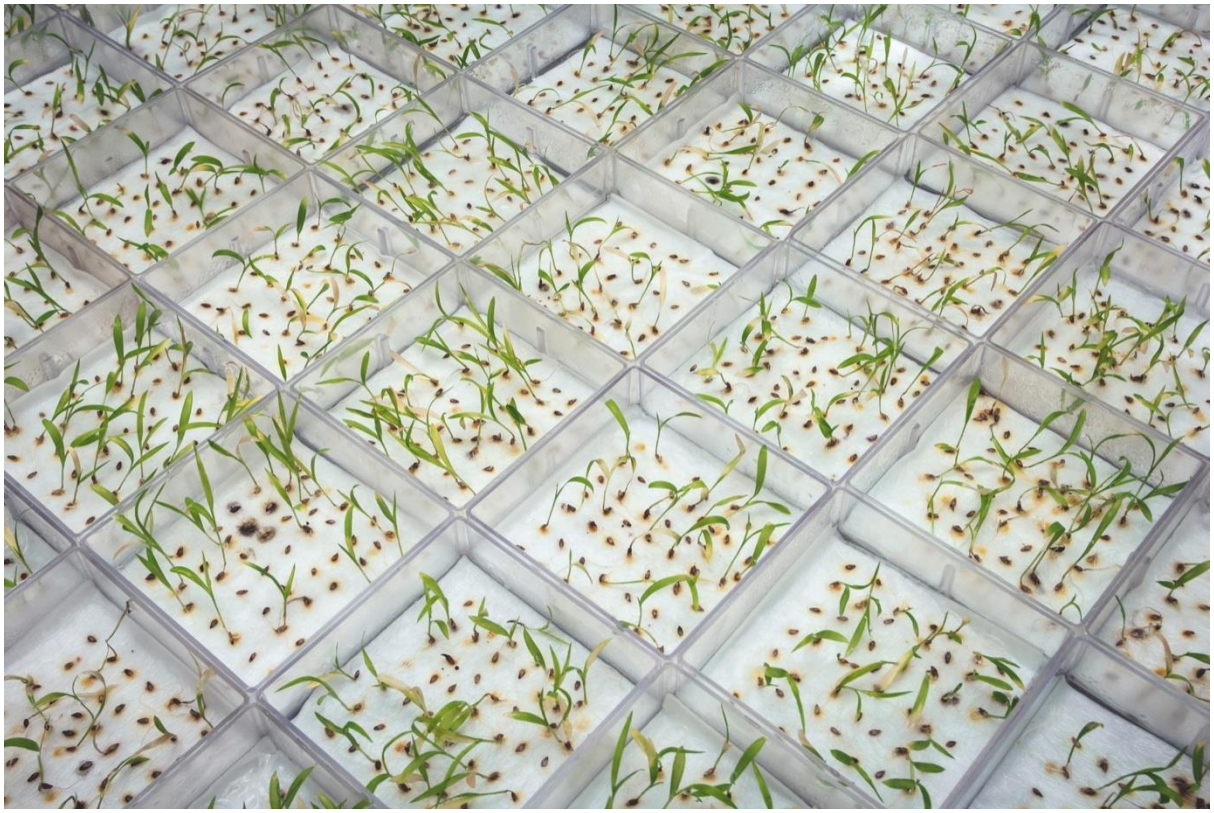

Figure 50. Germiantion test of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds according thousand seed weight, after storage in cold (5^{o}C) and environment temperature. Higher seed germinability was observed with fallen seeds than with seeds harvested directly from the panicle, particularly with the heavier seeds. (*Picture Source: J.R. Oliveira - OLIVEIRA, 2017)*.

In a broader analysis, superior vigor was observed as well. This was not directly evaluated but could be inferred from the results of some behaviors in the germination test, for example, the prompt germination of the seeds just after the incubation, and the absence of differences among the incubation days (7, 14 and 21).

Heavier seeds in the vast majority of the situations will promote greater mass transference from the reserve tissues to the embryo axis during germination, creating heavier seedlings and further higher mass accumulation (CARVALHO & NAKAGAWA, 2000). This is valid to germination on paper until some point, but some particularities appeared in these experiments: it was observed a quicker seedling development in relation to those originated from seeds threshed from the panicles. Regardless, if it is assumed that these seedlings were also noticeably more efficient in burning the reserves from the endosperm to convert into growing, the energy

accumulated quickly runs out. If the seed is placed in nutritive medium (as soil or substrate, for example) the developed roots will start the absorption of nutrients and so keep the growing, but once the germination paper is inert and no fertility is found, the seedlings presented symptoms of nutrients deficiency as chlorosis and necrosis in the tip of the older leaves (Figure 51).

Other comparison that helps to endorse this is evidenced when a seedling grown in paper (21-days incubation) is compared to a seedling grown in nutritive substrate (also 21-days incubation), which is contrasted in the Figure 51 and in the Figure 52. Despite lack of statistical analysis was performed on that, the better development of substrate-cultivated seedling is evident. Alexander grass sowing in nutritive substrate will be further discussed in Chapter 6 – *pg.271*.

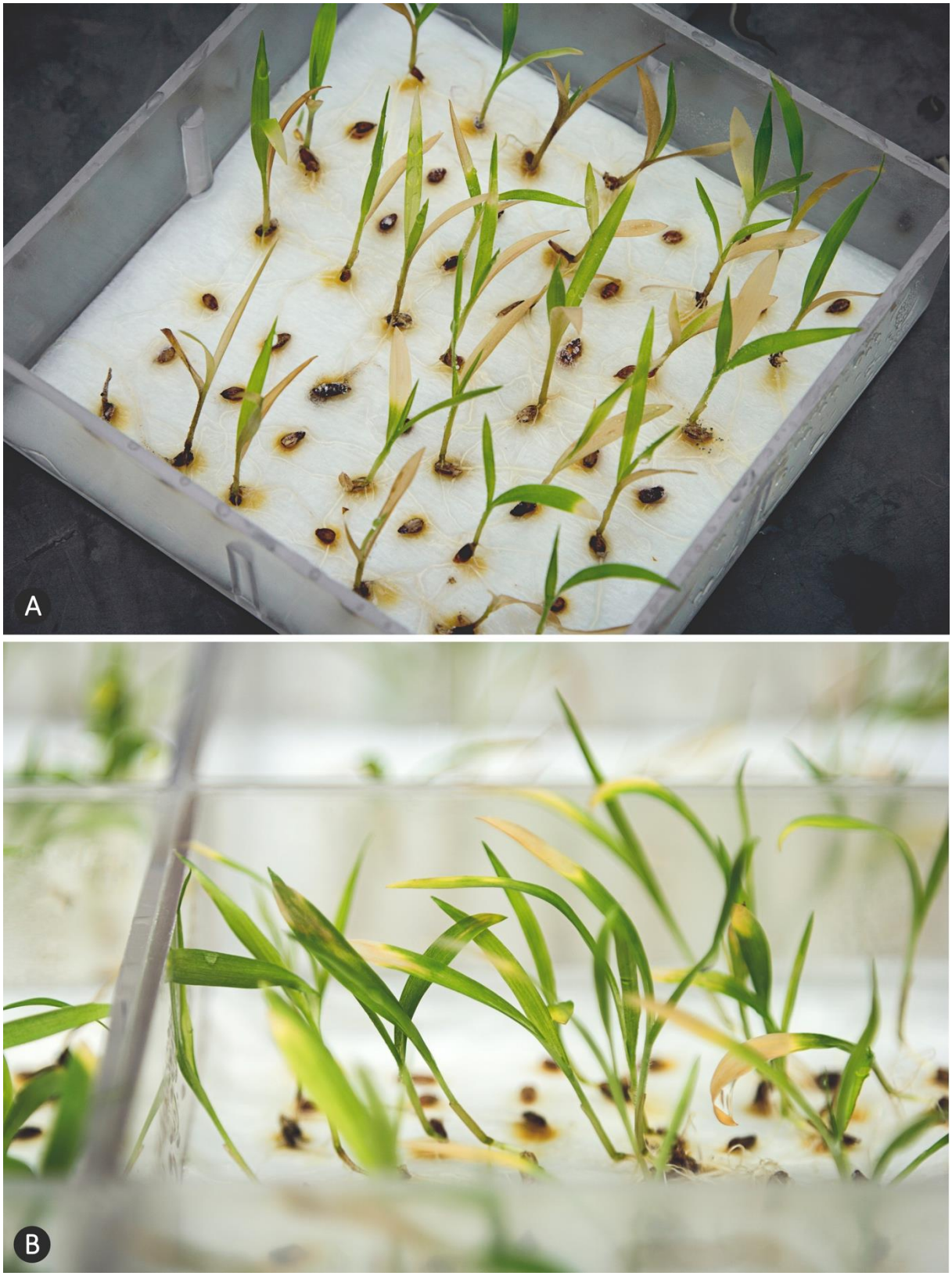

Figure 51. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seedlings presenting symptoms of clorosis and necrosis after seed reserves exaustion. As the substract is inert the seedling places in a nutrient lacking environment. **(A)** Detail in the older leaves drying in favor of the new ones; **(B)** The chlorosis starts in the tip of the older leaves and follows towards the base (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

Figure 52. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seedling grown in nutritive substate (*See chemical analysis in Table 36*), with robust developmet. The picture evidences that using nutritive substract the seedling presented notably higher development in comaprison to paper. Chlorosis or necrosis symptoms were not observed in this case as well (see also Figure 51; *Picture Source: J.R. Oliveria – OLIVEIRA, 2017*).

Searching for an indicator that relates the age of the panicle with the development of the germinated seeds (threshed from the panicle), root and canopy length of the seedlings were measured. Analysis of variance identified differences among the treatments ($P < 0.05$), and mean test separated the results in two main groups ($P < 0.05$). On that, 11 and 14 days panicles were highlighted with the lower results both for canopy and for roots (Table 28).

Table 28. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seedling length (cm) according to panicle age[1]. (*OLIVEIRA, 2017*)

Panicle age (days)	Canopy	Root
11	1.30 b	2.47 b
14	1.42 b	2.22 b
20	1.91 a	3.19 a
24	2.03 a	3.50 a
28	2.14 a	3.33 a
34	2.16 a	3.91 a
38	1.99 a	3.52 a
Shaken	2.49 a	3.73 a
Mean	1.93	3.23
C.V.:	34.9%	43.1%

[1]Means followed by the same letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$. [2]Shaken seeds were collected gently shaking a plastic tray against the seed heads in the 38th day.

The possible reasons to the shorter roots and leaves in the young panicles are the lack of seed filling. Same way, after the 14th day thousand seed weight of these seeds considerably increased (Figure 44), and so the vigor of the seedlings may increase as well. Once this evaluation considered just the germinated seeds, dormancy issues have no effects.

Similar explanation fit to the canopy length according to the panicle fractions (Table 29) and for the root length according to the panicle fractions (Table 30). Still, analysis of variance and mean test identified differences among the 11 and 14 days panicles to the other treatments ($P < 0.05$), and differences among the panicle fractions were not identified ($P > 0.05$).

Table 29. Alexander grass (*Brachiaria syn. Urochloa plantaginea)* seedling canopy length (cm) according to panicle ages and panicle fractions[1] (*OLIVEIRA, 2017*)

Panicle age (days)	Fraction			Mean
	Distal	Middle	Proximal	
11	1.48	1.05	1.00	1.18 b
14	1.54	1.17	1.34	1.35 b
20	2.02	1.97	1.75	1.91 a
24	1.99	2.08	2.00	2.02 a
Mean	1.76 ns	1.57	1.52	1.62
C.V.:37.3%				

[1]Means followed by the same letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$.

Table 30. Alexander grass (*Brachiaria syn. Urochloa plantaginea)* seedling root length (cm) according to panicle ages and panicle fractions[1] (*OLIVEIRA, 2017*).

Panicle age (days)	Fraction			Mean
	Distal	Middle	Proximal	
11	2.93	1.97	1.54	1.76 b
14	2.51	1.86	2.11	1.99 b
20	2.97	3.49	3.17	3.33 a
24	3.73	3.92	3.04	3.48 a
Mean	3.04 ns	2.81	2.47	2.64
C.V.: 45.4%				

[1]Means followed by the same letter compose statistically homogeneous group in the column; Scott & Knott; $P > 0.05$.

The evaluation of the seedlings length, however, faced methodological problems. Especially in the treatments with better development, measures were hard to perform once seedlings sometimes form more than one leave, and evaluating just one of those will underestimate the development. Yet, roots also branched and sometimes intertwined, besides occasionally piercing the substrate paper down the box, which make the removal of the gerbox very difficult and very prone to break up the root (Figure 53). Analysis is presented as a guideline, however, further studies are needed to endorse the results and make it a consistent data.

Figure 53. Intertwined roots of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seedlings in substrate paper (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

4. CONCLUSIONS

- An Alexander grass seed bulk threshed directly from the inflorescence reach maximum dry weight close to 20 days after the emergence of the panicle, which summed to the abruptly increase in the shattering and the germination performance, indicate the physiological maturation of most seeds close to this moment;
- Seed maturation and filling follows the same direction of the shattering in the Alexander grass panicles, happening basipetally, from the distal to the proximal fraction;
- Shattering process influences the distribution of the thousand seed weight along the panicle;
- Seeds threshed from the panicle in Alexander grass present very low germination and very low shelf life, thus this method is not recommended;
- Alexander grass seed storage could be done in cold environment if the intention is to use the seed in long-term, and at room temperature if intended for sowing in the short-term, which will balance the deterioration and dormancy;
- Alexander grass seeds collected from the ground present great variability: a difference of 6 times in the weight of the seeds was found;
- Seeds shattered present germinability superior than seeds threshed from the panicle;
- The higher the thousand seed weight of Alexander grass seeds, the higher the germination;
- The proper way to harvest Alexander grass seeds is by the ground sweep method.

Alexander grass dormancy issues and the potential methods to overcome it

CHAPTER 4

1. INTRODUCTION

Dormancy in warm forage seeds is a known constrain. Usually, it arises intensely in fresh seeds just after the harvest, promoting a physiological state on which even under optimum moisture, oxygen and temperature there is failure in germination (LOCH et al., 2004; ADKINS, 2002; CARVALHO & NAKAGAWA, 2000; HILHORST, 1995). This characteristic is broadly researched in Brachiariagrasses, and reported particularly in Alexander grass (LORENZI, 2000; BONNA, 1992).

The dormancy state is an undesirable characteristic in cultivated plants, since it complicates assessing and endorse establishment disorderly (AMORIN, 2000). Unlike natural grasslands, modern arable pasture systems need to be frequently re-established as part of a rotational cropping system, and the dormancy potentially leads to serious failures in the sward formation (CONTRERAS, 2007a; USBERTI & MARTINS, 2007; HERRERA 1994; SHANMUGAVALLI et al., 2007).

Nonetheless, *Brachiaria* seeds can present more than one dormancy mechanisms concomitantly, with causes not well clarified (BASKIN, 2001). Guidelines assume that these seeds present some type of embryo-physiological dormancy when young and other type related to tegument permeability further (ESGPIP, 2010; ADKINS et al., 2002; CARMONA et al., 2002; HOPKINSON et al., 1996; SIMPSON 1990).

Resting periods are commonly used as a strategy to release the dormancy (FINCH-SAVAGE & LEUBNER-METZGER, 2006; HOPKINSON, 2005). It consists in keeping the seed stored for some time, waiting for the natural degradation of the husk and the stabilization of the internal chemicals. In contrast, the sowing can be needed after a short period from the harvest, making the storage an inefficient method. The assessing of procedures to promote the seed germination in an acute form, thus, is important to make the production system more reliable.

One of the known methods for dormancy breaking in grass seeds involve disrupting of the seed husk (SHANMUGAVALLI et al., 2007). As presented by Brazilian rules for seed testing; piercing, incision, cutting or sandpaper abrasion can be efficient

to break the coat, promote exchanges and trigger the germination (BRASIL, 2009; DESAI, 2004; CONTRERAS, 2007a). Chemical action is also an option, a process that involves the immersion of the seed in compounds such as sulfuric acid until the coat degradation (CONTRERAS, 2007a; LOCH et al., 2004; HOPKINSON, 1993; AMORIN, 2000). The duration and the intensity of this treatment (both physical and chemical) are critical: too much can kill the embryo; too little and germination is not stimulated (LOCH et al., 2004; BRASIL, 2009).

These procedures, however, act essentially on the dormancy mechanisms that involve the husk, letting the physiological issues depending on some other technique. For the biochemical dormancy, the release should enable some chemical route in the seed that triggers the germination. According to the Brazilian official rules (BRASIL, 2009) the KNO_3 (potassium nitrate) potentially relates to several physiological processes as the biosynthesis of essential compounds; and stimulates the physiology in issues as the electron transport and the Krebs cycle. Other reasons for the action can be the KNO_3 oxidative power and the action as a source of nitrogen (See also *pg.72*).

Having the intentions to design a system to produce germinable seed of Alexander grass, aiming the establishment of pastures in the Southern Brazil, some of these treatments were assessed. Despite the existence of some reports in the literature testing Alexander grass seed, supplementary research is important, once results on dormancy breaking procedures widely vary according to primary factors as the seed harvest method and the seed age.

2. MATERIALS AND METHODS

The major aim of this trial was to identify the Alexander grass seeds germination according to physical and chemical dormancy breaking treatments.

The collection phase of the experiment was carried out at the experimental station of the Federal University of Technology – Paraná – Pato Branco ($26^{o}10'40"$ S; $52^{o}41'18"$ W; 750 m asl.). Region climate is Cfa transition to Cfb, according Maak (1968) classification. At early September 2014 soil samples were collected to perform chemical analysis, and the results are presented in Table 5.

No soil mobilization was performed, and there were no mulch covering the soil. 30 m^2 were used. Two cuts at 20 cm were done when the plant reached 40 cm, using a back brushcutter equipped with a metal blade. 200 Kg N ha^{-1} were broadcasted using urea 45%, in the occasion of the first cut. In mid-October (2014) Metsulfuron-methyl was sprayed at the dose of 5 g a.i. ha^{-1}, using Ally ® (Du Pont) to control spontaneous broadleaf species that grew together with Alexander grass.

The seeds were harvested by manual ground sweeping at late March 2015. For that, the sward was chopped close to the ground using a back bushcutter. Vegetative mass was let drying for nearly a week, once the high temperatures of the period helped to detach some seeds that remained linked to the panicles and reduced the moisture of the seeds. The mass was then raked, and the exposed seed was collected using a garden vacuum Trap SF 3000®. The resulting material was placed into bags and processed, being blown and sieved to separate the gross impurities. To refine the cleaning a Laboratory seed blower model South Dakota was used, composing a final seed bulk with thousand seed weight of 5.23 grams (Figure 54).

Figure 54. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds harvested by ground sweping method after the processing. Thousand seed weight of 5.23 grams (*Picture source: J.R. Oliveira – OLIVERIA, 2017*).

1.1 Experiment 1 – Physical Treatments

The experiment was developed in the Weeds Laboratory of Federal University of Technology – Paraná – Pato Branco, in a bi-factorial completely randomized design. First treatment factor was composed by five sandpaper scarification periods (1, 2, 4, 8, 16 minutes) in a rotational scarification machine (DeLeo®; sandpaper 320; 3600rpm; Figure 55), and three control treatments: Naked (removal of the palea, lemma, and glumes, with tweezers); Incision (perpendicular razor blade cut on the seed tip opposed to the embryo) and Intact (no treatment on the seed). Recommendations for the naked treatment follows Brasil (2009) and Bonome (2003), presented by these authors for Brachiariagrasses in general. Second treatment factor was the storage time, being the evaluation just after the harvest and then after 6 months, in 5^{o}C cold storage.

Figure 55. Rotational scarification machine (De Leo®) used to scarify husked seeds. The eletric motor on the right turns on the chamber on the left which is lined with sandpaper. Seeds are placed inside the chamber and the handle allows to swing the system and promote homogeneity. Level of scarification can be controled by the time of the process (*Picture source: De Leo® laboratory equipments*).

1.2 Experiment 2 – Chemical Treatments

The experiment was developed at the Weed Laboratory of Federal University of Technology – Paraná – Pato Branco, in a bi-factorial completely randomized design. First treatment was composed by periods of immersion in sulfuric acid – H_2SO_4 100% (5, 10 and 15 minutes; named in the results also as Acid Scarification). A control with no acid treatment was also evaluated. To perform the treatment seeds were submerged in the acid using petri dishes (Figure 56), gently stirring the mixture with a glass stick to homogenize the process. After that, seeds were intensely rinsed in running water for 10 minutes, to remove the acid residues on the seed surface. Seed drying was done in the shade, over a paper towel.

Figure 56. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds soaked in sulfuric acid for chemical scarification. The seeds were gently stirred with a glass stick to homogenize the scarification process (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

The second treatment factor was composed by levels of KNO_3 (potassium nitrate) in the water used to moisture the germination substrate, using 0.1, 0.2 or 0.4% KNO_3 concentrations plus a control treatment with pure water. Values are based on the general recommendations for Brachiariagrasses of the Brazilian official seed testing rules (BRASIL, 2009), which recommends 0.2% potassium nitrate solution.

1.3 Germination test

Germination test was chosen to the trial since it is accepted as the most standardized test to evaluate seeds qualitatively (LIMA, 2012). Still, this option was taken once there was no methodology in the official seed rules particularly to the assessment of Alexander grass. The levels were thus established according to the environmental adaptation of the grass and the used for other close species of the genus.

Germination was evaluated in transparent plastic boxes (Gerbox; 11 x 11 cm wide x 3 cm depth), suggested for Brachiariagrasses by the Brazilian seed testing rules (BRASIL, 2009). Four germination paper sheets were used in the base of each box, moistened until saturation (BRASIL, 2009; LOCH et al., 2004; BASKIN, 2001). Boxes were covered with a transparent plastic lid to avoid water loses. Even so, it does not get hermetically closed, and tiny amounts of water have to be added weekly to replace evaporation and preserve the same amount of humidity in the substrate. When KNO_3 solutions were used in the beginning of the test the replacement was done just with pure water. Four replications were made for each treatment.

Fifty seeds were uniformly distributed in each box using tweezers, over the paper sheets on the bottom, with no paper cover. Some authors prefer the use of 100 seeds for each replication; however, according to the Brazilian official seed rules a major recommendation for germination test is that seeds should be arranged with spacing enough to minimize competition and pathogen contamination among the seedlings. The use of 25 or 50 seeds is allowed thus when it better fits the number of seeds in relation to the size of the substrate (MORETTI, 2011; BRASIL, 2009).

Boxes were placed into a BOD incubator to provide an environment with 11 hours of dark and 13 hours of light. Temperature was set to 20°C (dark) and 30°C (light), according to Brazilian seed testing rules general recommendation for tropical species (BRASIL, 2009) and other authors that evaluated Brachiariagrasses (SALVADOR, 2007; VOLL et al., 1997; CARNEIRO et al., 2007; GARCIA et al., 1998). Germination counting was performed at 7, 14 and 21 days after incubation. On that, any seed that emitted shoot were counted as germinated, independently of the shoot size.

Data were catalogued and Statistical analysis performed using 'R' program (R DEVELOPING CORE TEAM, 2011), and 'Genes' (CRUZ, 2006). Regression analysis and graphs were made using Sigmaplot®. For all variables analysis of variance and Scott & Knott tests were performed considering the transformation of 1/n and a significance level of 5% probability.

3. RESULTS AND DISCUSSION

2.1 Experiment 1 - Germination under physical treatments

Analysis of variance and mean test identified differences in the germination in both the just harvested and the stored seeds, according to the physical treatments ($P < 0.05$; Table 31). No differences were observed among the incubations time, so the data presented is the maximum germination.

Table 31. Alexander grass (*Brachiaria syn. Urochloa plantaginea)* seeds germination (%) after physical treatments[1] (*OLIVEIRA, 2017*).

Treatment	Storage	
	0 months	6 months
1 minute	44 b	78 a
2 minutes	42 b	74 a
Scarification 4 minutes	18 c	66 b
8 minutes	6 c	59 b
16 minutes	6 c	25 c
Incision	49 b	86 a
Naked	52 b	86 a
Intact	54 a	66 b
Mean	35 B	67 A
C.V. = 20.4%		

[1]Means followed by the same lowercase letter compose statistically homogeneous group in the column; Means followed by the same capital letter compose statistically homogeneous group in the row; Scott & Knott; $P > 0.05$.

Considering the treatments that used the rotational scarification machine the better results were found in shorter sanding periods, since 1 and 2 minutes were similar; and 4, 8 and 16 minutes promoted lower germination. Still, stored and non-stored seeds presented different behavior with these treatments: just after the harvest the seeds which better germinated were those with no treatment, and thus, all the physical action was deleterious.

Treatments 4, 8 and 16 minutes plus incision were the worst, as 8 and 16 minutes promoted a 9 times reduction in germination in relation to the intact seeds. This was probably a result of damages in the embryo by the excessive action of the treatment *i.e.* it was effective in sanding the seed husk, but at the same time the machine promoted violent mechanical shocks damaging the inner tissues. Glumes shrapnel visually characterize it (Figure 57). Incision and naked seeds, however, were similar among each other, and to 1 and 2 minutes sanding, with better germination and an acceptable lower damage to the seeds.

After 6-months storage, in contrast, the treatments 1 and 2-minutes of sanding, Incision and Naked were those that presented the best results. It grouped with similar behavior, and was even superior to the intact seeds. The particularity of this group was to present the softer action among the studied procedures, evidencing that besides the hard coat of the seeds, the treatment should just make little action, creating tiny cracks to permit the exchange of substances. Still, the differences in the responses after the storage can be attributed to physical changes in the seed husk, which became probably harder and more resistant to the treatment. This is supported also by the fact that the coat dormancy usually installs after the maturation (as the husk hardens), letting the early germination inhibition to physiological mechanisms.

Figure 57. Physical scarification of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) just after the seeds harvest (Rotational scarifier; Figure 55). **(A)** Intact seeds, no treatment; **(B)** 1 minutes scarification; **(C)** 2 minutes scarification; **(D)** 4 minutes scarification (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

Germination rates were very good in the better treatments, achieving an average of 80% of the seeds (Table 31). Some points should have contributed to this result: *(1)* the good initial quality of the seed (5.3 g of thousand seed weight; Chapter 3 – *pg.167*); *(2)* The seed resting time of 6 months, which helped the chemical stabilization, and; *(3)* The action of the physical scarification treatments, endorsing permeability with no damage to the inner tissues. Even after 6 months storage, however, 4, 8 and 16 minutes sanding presented same way the worst results of the trial, which makes these treatments inappropriate for Alexander grass.

Mechanical scarification has been reported as inductive to germination in Signal grass (Castro, 1995) and Alexander grass (Dantas et al., 2001). The incision treatment presenting positive results, by its time, agrees with the reports of Harty (1972) evaluating Sabi grass (*Urochloa mossambicensce)*. According to this author, quicker germination was achieved with the method: after 65 hours of incubation 47% of the incised seeds germinated, when only 7% of the intact seed germinated under the same conditions.

This procedure was firstly performed aiming to promote exchange of water and gases, but it also helped the seedling shoot to get out the caryopsis. It may have happened once in intact seeds the shoot inner pressure has to reach several ATMs to collapse the husk. In the vast majority of incised seeds the shoot exited the caryopsis capsule by the cut in the husk (Figure 58), a explanation to the faster protrusion observed by Harty (1972) in Sabi grass with the same treatment.

The good results promoted by the incision treatment were explained essentially because in most cases the embryo is smaller than half the caryopsis length (Figure 9; Figure 13). The rest of the caryopsis is occupied by endosperm, cells that die after maturation and keep just as a supply of reserve material (AMORIN, 2000). With the sharp cut in the distal tip of the spikelet, no risk to damage the embryo exists as happen in other treatments (*e.g.* acid and sanding).

Figure 58. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seedling shoot getting out through the incision opening (Physical treatment to break coat dormancy) in **(A)** paper substrate and; **(B)** nutritive substrate (*Discussed in Chapter 6 – pg. 271*). The treatment was firstly performed aiming to promote exchange of water and gases however it also helped the shoot to get out the caryopsis (when the coat is kept intact the inner pression have to reach several ATMs to collapse the husk). This can be an explanation to the increase in gemination speed observed by some authors after this treatment (*Picture Source: J.R. Oliveira - OLIVEIRA, 2017*).

For naked seeds this situation can be at least partially applied. Having that the removal of the enclosing structures were gently done using tweezers, the risk of damaging the embryo is considerably reduced in comparison to mechanized treatments (Figure 59). The benefits of this treatment were similarly reported for other grasses: *(1)* Whiteman & Mendra (1982) reported that the removal of the enclosing structures can promote germination in Signal grass, once for the author assessments with intact seeds presented 7% germination, without glumes presented 15%, and naked caryopsis reached 96%; *(2)* In Palisade grass, Meschede et al. (2004) report that the removal of glumes was effective to promote germination; *(3)* Loch et al. (2004) reported that naked caryopses in the soil absorb moisture faster and germinated more rapidly and completely, despite being more susceptible in the absence of subsequent rainfall.

Figure 59. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds after manual removal of glumes, lemma and palea (Naked seeds) (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*)

Removal of the seed coat or other tissues surrounding the embryo, conversely, not ever promotes the germination (LOCH et al., 2006). Carrillo (2016) cites deleterious effects in Blue grama (*Bouteloua gracilis*) and Sideouts grama (*Bouteloua curtipendula*), since better germination and establishment were achieved with intact seeds. In other species as Buffel grass and Rhodes grass there was no differences in using naked or intact seeds.

Even with the better germination rates for Alexander grass, questions are raised if the removal of all the enclosing structures is really recommended in the field. As stated, the wraps of the seed were developed in the evolutionary process to perform some important roles. It includes to protect the seed from the harsh of the natural environment for example (*See Chapter 1 – pg.91*). Further shielding, one of the functions of the coat is to regulate the proper rates of water entrance in the seed during the germination. Actually, all tissues of the seeds are involved in the balance of this process once *(1)* the embryo axis absorbs water quickly and continuously; *(2)* the reserve tissues absorb water in intermediate rates, and after completing its imbibition works as a reservoir, and; *(3)* The tegument absorbs water slowly (POPINIGS, 1977). An obvious conclusion, thus, is that a naked seed is prone to absorb water faster than an entire caryopsis.

The water absorption during germination, still, develops in a triphasic process, with a rapid initial uptake (phase I, *i.e.* imbibition and embryo expansion) followed by a plateau (phase II) and a later increase in water uptake (phase III), when the embryo axis elongates and breaks through the covering layers (MCDONALD, 2007a; FINCH-SAVAGE & LEUBNER-METZGER, 2006). During germination a complex and dynamic process of repairing and reconstructing membranes occur. These scheduled and organized activities avoid potential injuries by abrupt water intakes. On that, promotion of a rushed hydration can negatively influence the order of the conversions and damage the embryo. In a molecular view, abrupt imbibition causes differential hydration in proteins that form the tissues, resulting in injuries specially in the cotyledons (BONOME, 2003), which in a major extent can impair the shoot

protrusion or even kill the embryo. This is the principle that explains osmoconditioning techniques occasionally used in grain crops.

These issues still need to be better assessed in the case of Alexander grass, particularly in the molecular level. According to the study of Freitas et al. (1990) evaluating whole caryopsis, proper water absorption occurs even when the seed is dormant. Reservations should be kept, as the presence of impermeable tissues just around the embryo are possible as well but, if assuming water absorption as not being the problem, dormancy breaking actions counting only on the water issues will be in vain. A more credible hypothesis could be about issues involving gases exchange, for example.

Incision and naked treatments however are both practical for research purposes, unfortunately making the use of the riskier mechanized method the option in the case of scale production. In an overall balance, considering the treatments evaluated until now, the use of 1-minute sandpaper scarification is the recommended in the balance effectiveness *versus* feasibility.

2.2 Experiment 2 - Germination under chemical treatments

Analysis of variance identified differences in the Alexander grass germinability among the levels of Sulfuric acid scarification, and among the KNO_3 levels in the substrate ($P < 0.05$). The results are presented in the Table 32.

Table 32. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds germination (%) after Chemical treatments[1] (*OLIVEIRA, 2017*).

KNO_3 (%)	H_2SO_4 Scarification (minutes)			
	0	5	10	15
0	60 b	2 ns	2 ns	34 ns
0.1	68 b	1	2	34
0.2	58 b	2	1	30
0.4	80 a	1	1	29
Mean	67 A	2 C	2 C	32 B
C.V.: 5.7%				

[1]Means followed by the same lowercase letter compose statistically homogeneous group in the column; Means followed by the same capital letter compose statistically homogeneous group in the row; Scott & Knott; $P > 0.05$.

No interaction was observed in the scarification factor, so just the means were compared by Scott & Knott test ($P < 0.05$; Table 32; row). Acid scarification was not efficient in promoting germination, being in all levels deleterious to the germination in comparison to the control treatment (no Scarification). Seeds immersed for 5 and 10 minutes presented the lowest results, once with this procedure almost no seeds germinated. With 15-minutes scarification, in contrast, some germination was observed, besides it presented just half of the control treatment.

The effects of the acid in the seeds were certainly too intense, reaching the inner tissues and damaging the embryo. Figure 60 presents the aspect of the seed after the scarification, as the cracks in the surface evidence a possible door through which the acid entered the deeper tissues. Yet, higher germination with 15 minutes in relation to the 5 and 10 minutes treatments was not an expected behavior. Stimulation of some unreported trigger could be possible, however, the toxicity observed in intermediate levels are supposed to appear in 15-min as well. Freitas et al (1990) tested scarification with H_2SO_4-100% in Alexander grass until 60 minutes, and reported positive effects. Voll et al. (1996a) also reported positive results. Differences on the initial state of the seed could be a hypothesis on that. Besides the levels of the acid scarification were not clear in this trial, as an overall look it is assured that the treatment as proposed here was negative to the Alexander grass seeds.

It must be noted that, despite the fact that in some cases acid can enhance germination, scarification treatments always involve direct damage on the seed with disruption of the husk *i.e.* the main protective layer (CONTRERAS, 2007a). Regardless the risks of viability reduction, other situation less acute as the production of abnormal seedlings are reported, mirroring physiological toxicity by the acid (ALMEIDA, 2002; GONZALEZ et al, 1994; MACEDO et al., 1994). Precautions should be taken, thus, to minimize damage while maximizing dormancy relief (ALMEIDA, 2002).

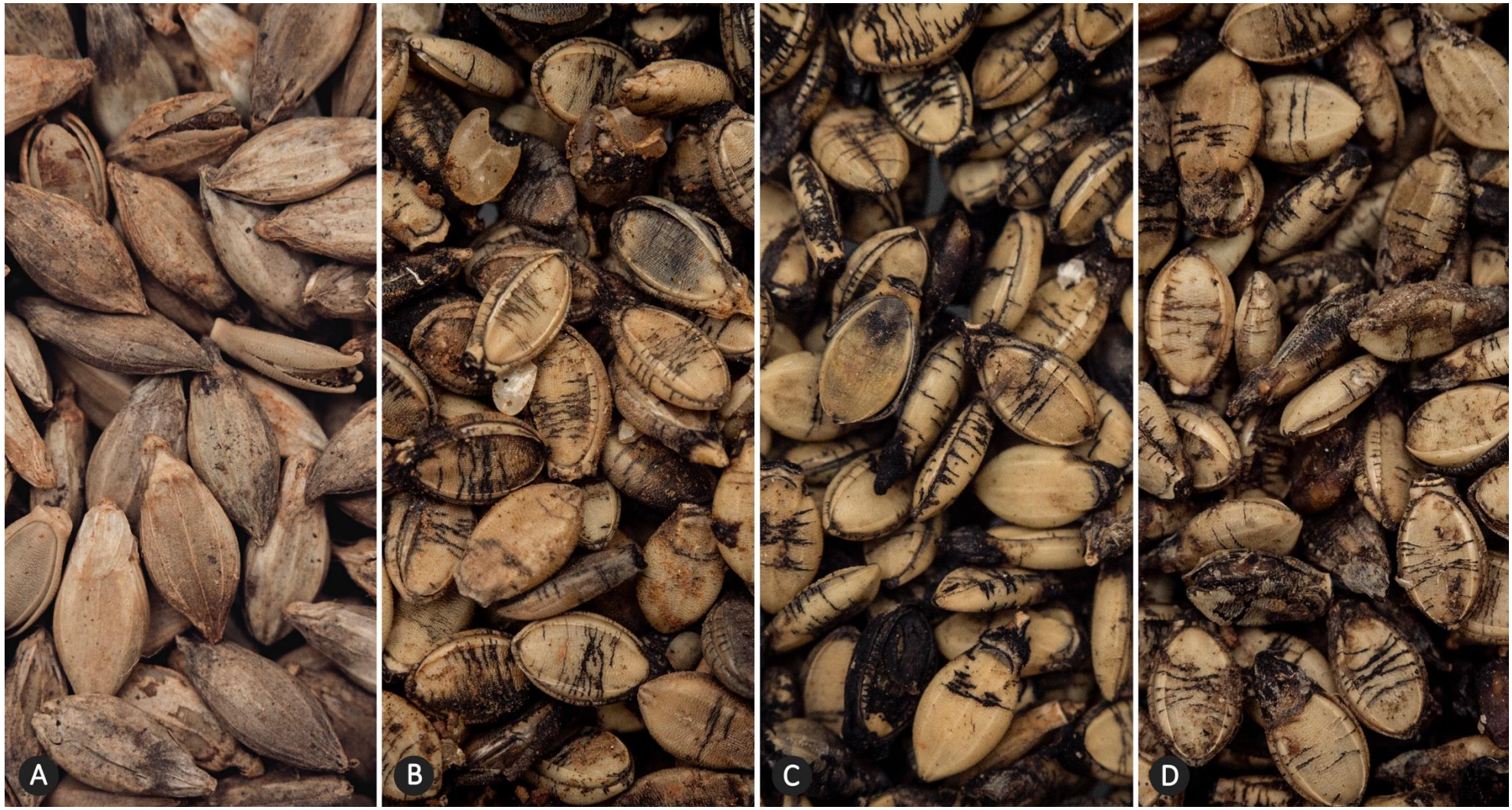

Figure 60. Chemical scarification treatments (H_2SO_4; Figure 56) in Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds, visual aspect after treatment: **(A)** Intact seeds, no treatment; **(B)** 5 minutes imersion; **(C)** 10 minutes immersion; **(D)** 15 minutes immersion (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

Acid scarification is perhaps one of the most controversial issues in the study of *Brachiaria* seeds. The behavior of the germination or the seedling performance widely varies according to factors as aging and seed lot (LIMA & CARDOSO, 1996; MACEDO et al., 1994), and an extreme or other can be related with very similar methodologies. Some of that can be identified as the presented in the Table 33.

Table 33. Reports of H_2SO_4 acid scarification effects in germination of *Brachiaria*.

Species	Positive effects	No effects or negative effects
Palisade grass (*B. brizantha*)	Brites et al. (2011); Santos et al. (2011); Usberti & Martins (2007); Shanmugavalli et al. (2007); Martins e Silva (2003); Custodio & Cardoso (2001); Montorio et al. (1997); Martins & Lago (1996); Castro et al. (1994).	Foloni et al. (2009a); Bonome et al. (2006); Meschede et al. (2004); Martins (1999); Lago & Martins (1997); Previero et al. (1998); Previero et al., (1998); Dias & Toledo (1994); Dias & Toledo (1993).
Signal grass (*B. decumbens*)	Ruiz et al. (1996); Castro (1995); Oliveira & Mastrocola (1984); Goedert (1984); Whiteman & Mendra (1982).	González et al. (1994); Dias & Toledo (1994); Dias & Toledo (1993); Atalla & Toselo (1979); Herrera (1994).
Ruzi grass (*B. ruziziensis*)	Mclean & Grof (1968); Renard & Capelle (1976)	Wisintainer et al. (2010)
Koronivia grass (*B. humidicola*)	Usberti & Martins (2007); Custodio & Cardoso (2001).	Usberti & Martins (2007); Costa et al. (2004); Meschede et al. (2004); Ruiz et al. (1996); Castro et al. (1995); Macedo et al. (1994); Goedert (1984); Atalla & Tosello (1979).

Hare et al. (2008) reported good results with acid scarification, working with *Brachiaria* hybrid cv. Mulato II. On Guinea grass positive effects were observed (MASTROCOLA et al., 1980), or not (GARCIA et al 1998) depending on the research. In Para grass deleterious effects were reported (MCLEAN & GROF, 1968).

Variation in these results was commonly associated to the seed age. Some procedures present good effects in young seeds, and harmful in older ones, or *vice-versa (*LOCH et al., 2004). Still, the acid treatments before storage could be a

tricky option, since in general it tends to lower the shelf life. This situation was confirmed by Herrera (1994) evaluating Signal grass with chemical treatments, where the author observed that KNO_3 interacted positively with storage, but acid treatment before the storage made the germination decrease. Similar situation was reported by Usberti & Martins (2007) in Palisade grass.

Another issue related to H_2SO_4 scarification was the notable effects in the seeds fungal attack during the germination tests, a case observed also by Contreras (2007a). Here it is important to consult details in the annex "Seed borne pathogens associated with Alexander grass seeds". For Alexander grass, thus, according to the conditions of the seed and the procedure used in this trial, acid scarifications is not a recommended treatment to break the dormancy.

Analysis of variance identified differences among the KNO_3 substrate imbibition levels ($P < 0.05$), and mean test detailed the analysis grouping just within the control treatment with no sulfuric acid ($P < 0.05$; Table 32).

The treatments 0.1 and 0.2% presented similar to treatment with pure water, low results were obtained. The use of 0.4% of KNO_3 in the substrate imbibition water, however, promoted increase in Alexander grass seeds germination. The result achieved with this treatment was one of the better germination indexes that Alexander grass seeds presented in this work, reaching 4/5 of the seeds. Still, despite Brazilian official rules for seed testing (BRASIL, 2009) recommend the use of 0.2% KNO_3 for Brachiariagrasses, for Alexander grass it is needed a more concentrated substrate to stimulate the germination.

Voll et al (1996a), evaluating Alexander grass also reported positive effects of KNO_3 in the seeds, however, just when imbibing the seeds before to placing it in the substrate. According to the author, the imbibition of the substrate does not affected germination. Differences in the behavior are possibly a result of the lower doses used by the author in its tests (maximum of 0.2%).

The KNO_3 positive effects in Alexander grass germination are attributed to this substance influence in the penthosis pathway and in the shikimic acid pathway.

These two physiological routes are fundamental to biosynthesis of new compounds to germination: Pentose pathway will synthetize Ribulosis–5-Phosphate used on nucleotides (part of nucleic acids, RNA e DNA) and coenzymes synthesis. Shikimic acid pathway is important to the biosynthesis of some essential amino acids (Tryptophan, phenylalanine and tyrosine) and secondary phenolic compounds (CARDOSO, 2011; CARVALHO & NAKAGAWA, 2000). Other reasons to the action can be the KNO_3 oxidative power, and the work as a source of nitrogen (BONOME et al., 2006). This explanation is widely accepted for most Brachiariagrasses. Still, as the Acid scarification, results on KNO_3 use do not present consensus among the authors. For Signal grass and Koronivia grass, however, there is a substantial predominance of behavior of 'negative or no effects' and 'positive effects', respectively (Table 34).

Table 34. Reports of KNO_3 effects in germination of Brachiariagrasses.

Species	Positive effects	No effects or negative effects
Palisade grass (*B. brizantha*)	Shanmugavalli et al. (2007); Meschede et al. (2004); Amorin (2000); Previero et al. (1998); Garcia & Cicero (1992);	Bonome et al. (2006); Martins & Lago (1996); Cardoso (2011); Lima & Cardoso (1996); Toledo & Carvalho (1990).
Signal grass (*B. decumbens*)	Shanmugavalli et al. (2007); Herrera (1994).	Lima & Cardoso (1996); Martins & Lago (1996); Toledo & Carvalho (1990); Whiteman & Mendra (1982); Atalla & Tosello (1979);
Koronivia grass (*B. humidicola*)	Amorin (2000); Ruiz et al. (1996); Torres & Lenne (1988); Rodriguez et al. (1986); Goedert & Roberts (1986); Atalla & Tosello (1979);	Faria et al. (1996)

*Further Brachiariagrasses, positive results of KNO_3 also reported for Gamba grass cv. Planaltina (EIRA, 1983), and Guinea grass (MARTINS, 1996).

In this experiment, no differences were observed in the KNO_3 levels within the Acid treatment levels (5, 10, 15 minutes). Nonetheless, the use of both treatments concomitantly is occasionally related to promote phytotoxicity. Germination reductions occur as the excessive glumes permeability promoted by the acid make the KNO_3 to reach the embryo in toxic volumes (BONOME et al., 2006; VOLL et al., 1996a). Damages by KNO_3 excess are attributed mainly to unbalances in the

osmotic levels of the cells. In contrast, positive results with the association are also reported in Palisade grass (MARTINS & LAGO, 1996; GARCIA & CICERO,1992) and Signal grass (HERRERA, 1994).

Considerations on the natural heterogeneity of the warm season grasses seed lots are also important. As observed, seeds of Alexander grass present several sizes and weights at maturity (*Chapter 3 – pg.167*), a trait found also in other Brachiariagrasses. The effects of the dormancy breaking could be thus excessive on small seeds (potentially being harmful) and weak in large ones (potentially do not breaking the dormancy) (AMORIN, 2014; FINCH-SAVAGE & LEUBNER-METZGER, 2006; BEWLEY, 1997; MACEDO et al., 1994). In a proper approach, even the level of the dormancy that the seeds were laden in the maturation process is different (FINCH-SAVAGE & LEUBNER-METZGER, 2006). This mean that an efficient processing of the seed in fundamental not just for sowing efficiency, but also for the pretreatment of the seed. Regardless, even for the same species management and/or environment different levels of treatments could be needed depending on the seed classification.

KNO_3 use in the substrate is a simple process, however, practical just to research purposes (MARTINS & SILVA, 1998). This does not take its value, once a concrete response is achieved other methods as the previous imbibition could be designed to be used in commercial production lots. Acid scarification, in contrast, is a more complicated situation – even with industrial methods already developed, inherent and historical problems exists involving the worker's health and the discard of residues (CARDOSO, 2011; SANTOS, 2009; ALMEIDA, 2002; SOUZA, 2001).

Based on these issues, benefit of the methods (particularly acid) is contested. Australia, the world pioneer in the warm season grasses seed production abandoned acid treatments for Signal grass years ago (HOPKINSON et al, 2005), and never used it for Koronivia grass, considering it as unsatisfactory, dangerous, difficult, and unstable in producing improvement in the establishment of the plants (HOPKINSON, 1993). New treatments have been tested. Despite no full solution was achieved with those as well, some reports are presented:

- Lacerda et al. (2010) and Almeida (2002) found hot water a positive treatment to Palisade grass seeds, however the first author documented physiological losses depending on the procedure intensity;
- Hot dry storage is also mentioned as conducive (HILHORST, 1995), being related particularly for Alexander grass as positive for dormancy release in comparison to cold storing (VIEIRA et al., 1998);
- Amorin (2000), evaluating Palisade grass, relates that exogenous gibberellic acid application increased the germination speed, but does not affected the germination percentage; in contrast, Vieira et al (1998) relates germinability increase in the same species; and Cardoso (2011) observed no effects. Dantas et al. (2001) reported positive effects in Alexander grass germination with this treatment, Machado Neto (1983), finally, tested the GA spraying in Alexander grass seedlings and observed no effects;
- According to Dantas et al. (2000) and Lima & Cardoso (1996) KCN (potassium cyanide) were beneficial to germination of Alexander grass and Signal grass;
- Herrera (1994) tested CH_2N_2 (Diazomethane) over Signal grass and observed just deleterious effects;
- Lima e Cardoso (1996) tested H_2O_2 (hydrogen peroxide) and ethanol over Signal grass, reporting positive results for the first and no responses for the second. Eira (1983), in contrast, related damage to the embryo with H_2O_2 in Gamba grass, with consequent germinability reduction;
- Commercial biostimulants (Stimulate® and Organic fish® - CARDOSO, 2011; PASSI& HAGA, 2010) were tested over Signal grass and Palisade grass, but presented no effects.

Even the best results of newer dormancy breaking treatments are not fully efficient. The complex interaction among more than one dormancy mechanism can also confuse the results, since sometimes a treatment is efficient to release one type of dormancy, but germination does not occur by the action of another one. Still, the fact that dormancy can only be measured by germination has often led to misinterpretation (FINCH-SAVAGE & LEUBNER-METZGER, 2006; HILHORST, 1995).

Dormancy breaking treatments are an important matter, which should be assessed to optimize the efficiency of the production. Natural aging however has long been the most widely used, practical, and cost-effective mean to overcome dormancy in commercially traded C_4 grass seed (LOCH et al., 2004). Dormancy is a major issue in Koronivia grass, in which natural release can take up to 24 months (CASTIBLANCO & MENDOZA, 1985). For the other *Brachiaria* species, countries well organized and planed in the production and marketing sector can easily attend the demand of forage seed by mid-term storing the production, allowing the seed to rest and stabilize the dormancy state. In Brazil, actually, treatment is restricted to Koronivia grass, although most export seed of all species still acid treated to meet quarantine requirements of importing countries. For Signal grass and Palisade grass harvest from the ground prevails, such seed is weathered from lying in leaf litter, losing some of the dormancy in the process. Ruzi grass, likewise, is sown untreated in most countries where it is used (HOPKINSON et al., 1996). For Alexander grass, still, rest storage of the seed, possibly with some KNO_3 treatment close the sowing time, or 1-minute sandpaper scarification, are for now the best option to deal with the dormancy issue.

4. CONCLUSIONS

- For seeds recently harvested no physical treatment in the tested range was able to promote germination in Alexander grass seeds;
- After 6-months storage, 1 minute of physic scarification in a rotational machine with sandpaper trigger the germination in Alexander grass seeds. Longer times are deleterious to the seed performance;
- After 6-months storage, the use of naked seeds and seed with incision promoted the germination in Alexander grass seeds. Unfortunately, these treatments are feasible just in small scale, for research purposes;
- Substrate imbibition with KNO_3 at the dose of 0.4% promotes the germination of Alexander grass seeds;
- 6 months storage, in an overall looking, is positive for the dormancy release in Alexander grass seeds.

Soil Seed Banks and the relations with Alexander grass seed and seedling populations dynamic

CHAPTER 5

1. SOIL SEED BANK IMPORTANCE AND CONCEPT

Soil seed banks (SSB) play an important role in the vegetal community securing the maintenance and recurrence of the species according to the seasons. They are defined as the viable seed reservoir in the soil *i.e.* the seeds that despite non germinated are capable of producing new plants after a proper stimulus. This component of the ecosystem is the historical memory of the vegetal succession (ROBERTS, 1981).

There are enormous numbers of seeds in the soil. Although some of the buried readily die, others can remain viable for decades (SKUODIENE et al., 2013). Bigger seed banks are encountered in lowlands, averaging 20,000 seeds m^{-2} (0-10cm), since in some samples this value is estimated until 50,000 seeds m^{-2}. In the sequence there are the cropping systems (~7,000), orchards (~3,500) and finally the pastures (~500) (CARMONA, 1995).

This number directly depends on factors that influence the seed production and viability. Lack of disturbance combined with low fertility make grasslands, for example, a stable environment, proper for the development of a small SSB (CARMONA, 1995). Cultivated soils, on the other hand, are more fertile and frequently disturbed, containing large numbers of seeds (KREMER, 1993), an environment that fits better to Alexander grass, having its classification as a ruderal plant[2].

[2] According to Grime (1979): Ruderal plants are those that develop in disturbed environments, specially when there is anthropic action. These species need a high availability of resources and conditions, making the agricultural fields an interesting option, particularly in conventional tillage. They present short life cycle, being in the majority annual plants, growing quickly and producing lots of propagules. Have vigorous initial growing, predominating the herbaceous growth habit and occupying mostly the early succession phases. This is the world largest group of spontaneous plants, and also the classification of most cultivated forage grasses.

The SSB is also composed both by new seeds, recently shed, and by older ones that persisted along the years, being classified in two general types as persistent and transient (SKUODIENE et al., 2013; MENALED, 2008). A persistent bank is composed of seeds that live further the subsequent germination season. Usually just a small proportion of the seeds display this characteristic, but those cause the continuous emergence over the years, making them the major problems of the weed management (KREMER, 1993). In contrast, a transient seed bank is composed by seeds that do not live until the second germination season following maturation. These seeds live in the soil for some months, during which dormancy can be broken (and so the seed germinates) or preserved until the seed death. Most of these species are adapted to explore open sites as part of a regeneration mechanism, where a population is cyclically eliminated and replaced (*e.g.* cropping fields) (MEDEIROS, 2000).

Saved the modern crops, it is estimated that only 1–9% of the viable seeds produced and dispersed in a given year develop into seedlings and the rest remain dormant or decay (SWANTON al., 2000). Survival strategies of species with short life seeds (transient SSB) will directly depend thus on annual production, dispersal and SSB restocking (BUHLER, 1997). Alexander grass seems to adopt this scheme, which obviously reflects in the behavior of the adult plant as a vigorous seed producer.

Ruderal plants as Alexander grass also avoid other plants previous developed in the sward. They are not very threatening to crops if controlled in the initial stages since the cultivated plant will occupy the ecological niche and overshadow any late developing seedling. In the cases that the proper control is performed before the seed production, the strategy of the plant will breakdown and the emergence pressure will directly decay. If little or no control is done in the previous season, in contrast, plentiful seed will probably be dispersed, the occupation will be quick and aggressive and the overshadowing strategy will invert its players. All these traits fit Alexander grass well (Figure 61; Figure 62).

Figure 61. (A) Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seedlings, emerging from soil seed bank after superficial mowing with rotary hoe. It is remarkable the niche dominance of the grass mainly in the early stages; (B) Just few individuals of other species (Morning glory - *Ipomea purpurea*; Hairy Beggarticks – *Bidens pilosa*) are able to compete to the vigor of Alexander grass (*Picture Source: J.R. Oliveira - OLIVEIRA, 2017*).

Figure 62. (A) Side view of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) vegetative sward, the plant is able to occupy and cover the soil very agressively. Light and physic space limitations block the development of other species. Nutrients and water competitionn could also be a factor in these cases; (B) Closer look of the stem net formed near the ground (*Picture Source: J.R. Oliveira - OLIVEIRA, 2017*).

2. THE RELATION BETWEEN ALEXANDER GRASS EMERGENCE AND SOIL SEED BANK SUPPLY

The determination of SSB behavior is very difficult, demanding a lot of work and usually destructive analysis. The better option is to observe the seedling emergence according to the elapsing of the seasons. A trial was developed, thus, looking to identify this behavior in Alexander grass.

The experiment was established at the Experimental Station of the Federal University of Technology – Paraná – Pato Branco (26°10'40" S; 52°41'18" W; 750 m asl.) from September 2014 to October 2015. Region climate is Cfa transition to Cfb, according to Maak (1968). No soil mobilization was performed, and there was no mulch covering the soil in the first year. A 4 x 5 m plot (20 m^2) was used. The procedure was to count manually the Alexander grass plants and tillers that emerged spontaneously from the soil seed bank, in the late October, and then compare it among the years. A rebar frame of 50 x 50 cm was used (0.25 m^2) to mark the the sampling area. 30 samplings were performed randomly in the plot, avoiding 0.5 meters in the border to prevent external influences. After the first counting (October 2014) the area was kept mowed at 10 cm to the ground to maintain the plants in the vegetative period *i.e.* no seeds were produced or dispersed anymore in the plot. Italian ryegrass seed was broadcasted in the area with no incorporation in early winter. Analysis of variance and Scott & Knott test were performed (both 5% significance). Data was analyzed using 'R' program (R DEVELOPING CORE TEAM, 2011), and graph was generated using Sigmaplot®.

The analysis of variance identified differences among the years for all variables studied ($P < 0.05$; Figure 63). A strong decay on the Alexander grass plant m^{-2} emergence was observed comparing the two years (near 7 times less), a result that support the hypotheses that Alexander grass seeds in the soil seed bank present a transient behavior. Still, the number of tillers m^{-2} followed the same tendency. This is justified firstly because of the tillering potential. Even being affected by the management, this is limited to a short span and, thus, if the number of plants is

reduced, the number of tillers will be as well. Another strong factor in plants m^{-2} in 2015 was the soil cover of the previous winter season – Italian ryegrass developed, but no dense straw was formed, once the sowing was not really efficient (just broadcasting with no incorporation). Soil cover, itself, is possibly one of the major factors in the Alexander grass emergence (*further discussed in this chapter*). Decaying on the emerged plants rates so can be result both seed mortality and limitations by the straw, which balance still open to conjecture.

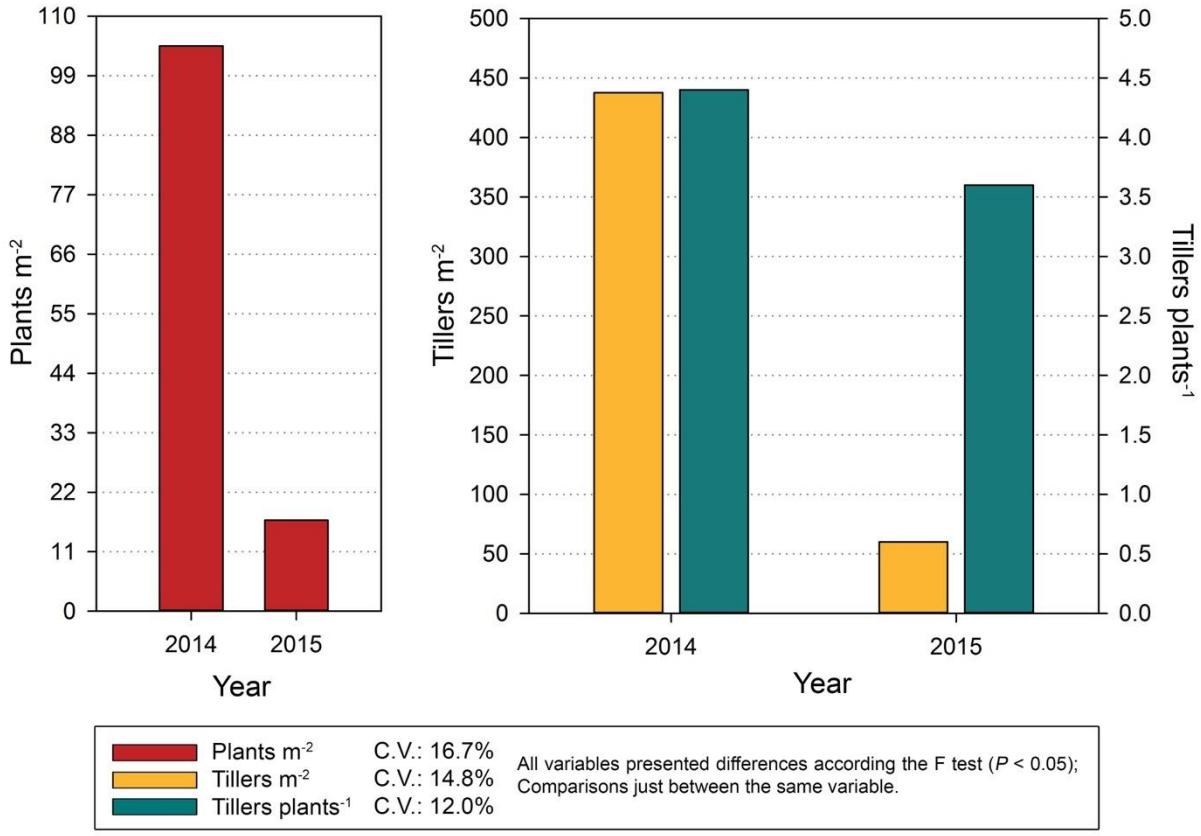

Figure 63. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) natural establishment in 2014 and 2015 spring. The area evaluated did not received seed rain in the period, since the results of 2015 are product of the soil seed bank remanescent from late summer 2014 (*OLIVEIRA, 2017*).

This situation is actually considered a pattern in most soil seed banks. In general, great numbers of seedlings emerge in the first year with a subsequent rapid decline on undisturbed plots when no seed is provided (SCHWERZEL & THOMAS, 1979). Blanco (1994), evaluating several weed species according to soil management,

reported that the absence of seed rain results in a second generation frequently null or close to that. The author indicates that the persistency of the soil seed bank has a small role in the survival of these populations, making the statement also particularly for Alexander grass.

With the constantly mowing of Alexander grass during the trial other species started to emerge. Herbicides were not sprayed once it could influence the Alexander grass behavior, regardless, the low heights of the cut easily controlled it. Another observation is that, in the vast majority, Alexander grass emergence happened just in the beginning of the season (spring – September/October), which is also confirmed by Blanco (1994).

In future works analysis of the emergence dynamic along the season could be helpful to understand better these dynamics. Even tough, it is accepted that the results observed here represents well the behavior of the Alexander grass SSB among the years, once even the further emergences in the mid-season were fainter between the two years, endorsing the transient behavior. Reservations should be kept as some seeds can last for more time even in a transient SSB (Which will be certainly stimulated by the heterogeneity of the Alexander grass seed – *See Chapter 3 – pg.167*), explaining so the emergence in October 2015 of seeds probably shed in March 2014 or earlier.

This experiment was developed in a region where agricultural systems present SSB with large species heterogeneity (Southern Brazil). Same way some dominant species materializes, and usually are those with annual short cycle and high seed production (FAVRETO & MEDEIROS, 2006). Perennial or long cycle plants do not develop well since there is continuous disturbance, explaining why Alexander grass could be frequently found dominating the SSB (FAVRETO, 2004).

The presence of few species in dominance is a normal characteristic of all seed banks. This happens since those that adapt better to the conditions along the seasons will ever and ever highlight, corresponding usually for 70 to 95% of the SSB (AUSKALNIENE & AUSKALNIS 2009; FAVRETO, 2004). Alexander grass itself is reported

as having a great share – estimative of ~18,000 and ~35,000 seeds m^{-2} were presented by Favreto & Medeiros (2006) and Theisen & Vidal (1999), respectively. Despite the high numbers, emergence will depend on several factors and reach just a small part of the bank. This means that most of the seed die in the process or, in the case of Alexander grass, possibly already fall non-viable from the plant (*Chapter 3 – pg.167*).

Average seedling density vary same way, some examples are presented for Alexander grass: 140 plants m^{-2} (PIRES et al., 2000), 312 plants m^{-2} (GALON, 2010), maximum of 780 plants m^{-2} (FLECK et al., 1996), maximum of 1,401 plants m^{-2} (THEISEN et al., 2000) and 1,870 plants m^{-2} (FLECK et al., 2002). Vidal & Theisen (1999) buried Alexander grass seeds, and after 97 days only 4.5% of the seeds emerged from the soil with no cover. With 2.6 and 4.5 T straw cover ha^{-1} just 1.23% and 0.18% of the seeds emerged, respectively. Similar situation is reported for general species: 1-3% (ROBERTS & FEAST, 1973), 4.5% (RADOSEVICH et al., 1997 *apud* THEISEN & VIDAL, 1999), and 1-9% (SWANTON & SHRESTHA, 2013).

3. SOIL MANAGEMENT EFFECTS ON SOIL SEED BANK

There is also a consensus that the land preparation and the crop rotation are the two main agricultural practices that generate impacts on germination and seed decay in soil seed banks (BALL, 1992; TEASDALE et al., 1991). Reports state that in straw covered soils Alexander grass germinate but cannot overcome the litter, giving its small seeds which has few reserves (SALVADOR, 2007). This is also taken as one of the major weed control strategies in several production systems (AUSKALNIENE & AUSKALNIS, 2009; CORREIA & DURIGAN, 2004; FAVRETO, 2004; JAKELAITIS et al, 2003).

Lower number of established plants in soil with higher cover can be related to some factors: *(1)* the straw affects the light availability, reduce thermal ranges and influence the moisture of the soil (CORREIA; DURIGAN, 2004; TAYLORSON & BORTHWICK, 1969); *(2)* it acts as an obstacle to the growth, making the seeding to etiolate or die (THEISEN E VIDAL, 1999; VIDAL, 1995); *(3)* Some straw release allelopathics, which are toxic to other plants development (PUTNAM, 1983), and; *(4)* Predators and parasites as insects and pathogens are stimulated to develop in the straw (JAMHOUR, 2016; THEISEN E VIDAL, 1999). Indeed, according to Theisen & Vidal (1999) soil cover makes Alexander grass seedlings to produce long hypocotyl, becoming feeble to physical damage. The efficiency of the soil cover is accepted and supported by many authors as well:

- The increment of straw level in no-till systems reduces the infestation of Alexander grass (VIDAL et al., 1998).
- With 5 t straw ha^{-1} there was a reduction of 73% in the infestation of Alexander grass (SALVADOR, 2007).
- 5.2 t ha^{-1} of black oat straw reduced Alexander grass emergence in 95%. The higher the straw level, the lower the emergence of Alexander grass. Population expressed in non-covered soil was a hundred times bigger than the observed in the high straw cover (THEISEN & VIDAL, 1999).
- Black oat straw presents clear effect on the suppression of Alexander grass (PEREIRA et al., 2000)
- Alexander grass emergence reduces in the presence soil cover (VOLL et al., 1996b)
- Oat residue soil exponentially reduces the emergence of Alexander grass (THEISEN et al., 2000)
- Reduced development of Alexander grass, Signal grass, Guinea grass and Jamaican Crab grass (*Digitaria horizontalis*) is observed in covered soil (CORREIA & DURIGAN, 2004)

Having these reports, and following Kalsing (2001), Alexander grass plants generally do not represent a problem in no-till proper managed areas. The species has been well controlled in conservative soil systems, where the litter reduces the emergence. In crop livestock integration where Alexander grass fit as a pasture, however, a warier management is needed. Having the grazing, usually the final litter levels are lower than the achieved when cover plants are cropped intending just the straw formation (Besides the total biomass produced during the cycle is higher in grazed plants). Still, in these crop livestock integration systems a guideline is to maintain the soil covered all the year with a minimum of 3 T straw ha^{-1}. This can solve at least partially the situation of the spontaneous plant emergence. Vidal et al. (1998) present that reduction in infestations of Alexander grass was substantial until 6 t ha^{-1}, stabilizing from that. Association with other curative control strategies as herbicide spraying is thus important to reach total control.

Straw, however, endorses the increase of the seed bank size *i.e.* if seeds keep covered and do not germinate the only alternative is to rest until some other factor take its viability. Vidal & Theisen (1999), evaluating Alexander grass, observed that seeds in uncovered soils presented quicker and higher mortality (70 days) than those in soils with presence of straw (200 to 300 days). Yet, the author statement supports the conclusion that Alexander grass seed bank is transient (less than a year). Voll et al. (2001) buried and counted seeds after regular periods, relating that to no-tillage, subsoiling and harrowing managements – seeds of Alexander grass were found in the soil even after 10 years but comments on the viability were not done. It is certain that these reclaimed seeds were already dead.

On the other hand, in no-till uncovered soil if the seeds keep on the surface abiotic effects as temperature and intermittent moisture/drying rapidly kill the seed or break its dormancy – which can happen also in the cases the seed keep suspended on the straw. According to Theisen & Vidal (1999) evaluating seeds in the surface of no-till soil, 45% of the Alexander grass seed decay happened just in 40 days (in average). Observations in pilot experiments of this work helped to support this idea

(away from that of the Figure 63). In the last year of study, an area that received robust seed rain in the previous season was harrowed slightly and superficially with a rotary hoe. The operation moved very little soil but performed a sort of sweeping and grinding of the Italian ryegrass soil cover (which was already faint, at first). This allowed to identify some behaviors of the Alexander grass seeds: as presented in Figure 64 some seeds germinated and some others did not, indicating that those that lasted were possibly dead (result of elapsing all the winter in the soil surface, to the mercy of biotic and abiotic factors).

Complex interactions will be present in these systems but, in a summarized analysis, keeping Alexander grass seeds close to the surface will reduce dormancy, encourage germination and lead to a more efficient curative weed management (It is, kill the plant, and not the seed - SWANTON & SHRESTHA, 2013; VOLL et al., 1995a). Still, ever reinforcing that if a faint plant control takes place, the restocking of the seed bank will be huge.

Another agronomical influent – besides the absence/presence of straw – is the soil tillage. Alexander grass has a sharp and concise response to till, since the emergence is readily triggered with soil moving (Figure 65; Figure 4; OLIVEIRA, 2013; PEREIRA, 2000; VOLL et al., 1995b; BLANCO, 1994; VOLL et al., 1991). According to Rodrigues (2000) in a long-term experiment (five years), the emergence of Alexander grass proved to be higher in tilled systems. This was also supported by the observations of Voll et al. (1995b) who observed 7.8%, 3.7% and 0.18% emergence of the Alexander grass SSB in conventional tillage, harrowing and no-till, respectively. On that, other authors also relate emergence/decaying of the whole SSB with the soil moving (SKUODIENE, 2013; VOLL et al., 2001; TEASDALE et al., 1991; ROBERTS & FEAST, 1973)

Figure 64. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seedlings, emerging from soil seed bank after slightly harrowing with rotary hoe. Rows formed by the blades still observable and, in the detail, some seeds in the soil surface present no germination (*Picture Source: J.R. Oliveira – OLIVERIA, 2017*).

Figure 65. **(A)** On the left, Alexander grass (*Brachiaria syn. Urochloa plantaginea*) emergence from soil seed bank after superficial mowing with rotary hoe and, on the right, no management performed. The germination is notably stimulated by soil disturb resulting in numerous and vigorous seedlings; **(B)** early stage of 'A' left side; **(C)** early stage of 'A' right side; **(D)** After 20 days Alexander grass covered the moved soil. In the no till just few plants were present, with ocurrence of other espontaneous plants and remnants of winter Italian ryegrass (*Picture Source: J.R. Oliveira - OLIVEIRA, 2017*).

In Crop livestock systems, the increased cropping frequency endorses more soil mobilization and, consequently, more emergence and SSB decay (NICOLAI, 2009; BLANCO, 1994). If no-till is strictly adopted, however, this situation is not a problem.

Voll et al., (1995b) also evaluated Alexander grass according to soil managements and herbicide spraying, and presented the following conclusions: *(1)* With post emergence herbicides and no-till there was a substantial reduction of the seed pool, which was sequentially lower in harrowing, and then in plowing; *(2)* With no herbicide treatment re-infestations tended to be higher in no-till, harrowing and plowing, respectively (VOLL et al., 1995b).

It is possible to conclude through the observations of Voll et al. (1995b), thus, that the Alexander grass control in no-till systems with little presence of cover will be achieved just in the cases that the systematic control is adopted as well. In Southern Brazil, theoretically, this is not a limitation, since several herbicides are very efficient in controlling Alexander grass (*See Chapter 1 – pg.104*). Summarizing the overall discussion, effects on Alexander grass are:

(1) Tilled systems, evidently without long-term straw cover, will be always promoting emergence, in one hand reducing the soil seed bank, but in other endorsing the invasion, demanding a more severe control. In addition, at the same time, some seeds will be buried and others will be brought back to the surface in the tillage process. Those buried – at least while not killed by the natural factors or germinated – will avoid the plant or seedling systematic control. In soils as the hypothesized here, several works report the vertical distribution and consequent burying of seeds in the profile (SWANTON & SHRESTHA, 2013; JAKELAITIS et al., 2003; RODRIGUES et al., 2000; CLEMENTS et al., 1996; VOLL et al., 1995b; CARMONA, 1992; BALL, 1992).

(2) Systems with no till and dense soil cover, in contrast, will present a bigger soil seed bank (VOLL et al, 2001). The survival of the seeds will be longer if it places below the straw. If the seed remains over the straw, its life will be shorter since it is also more exposed to environmental factors. If the seed bank is preserved, emergence will be small considering the long-term maintenance of the straw, and so the systematic curative control (as herbicide spraying) could be weaker. Yet, the vast majority of the seeds will be concentrated near the soil surface (SWANTON & SHRESTHA 2013; SKUODIENE, 2013; AUSKALNIENE & AUSKALNIS, 2009; MENALED, 2008; VOLL et al., 1995b; YENISH 1992; CARMONA, 1992; PAREJA, 1984).

(3) In the case of no-till systems with deficient soil cover both emergence and soil seed bank growth will be favored. It will make high invasion occur, particularly if no curative treatment as spraying of herbicides is performed (or faintly performed), and the adult plant is allowed to seasonally supply the soil seed bank. This is perhaps the worst management thinking in controlling the plant and maybe the main reasons that Alexander grass keeps as a weed of crops in the Southern Brazil. In the region, no-till systems are widespread, especially on soybean and corn crops. Regardless, Soil cover (supposed to be one of the prerequisites of no-till) is usually weak. This situation is a result from overgrazing in the winter pastures and repeated soybean production in the summer, a crop that produces poor biomass with high rates of decomposition (*Dr. Tangriani Simioni Assmann, UTFPR, unpublished data*).

As already stated, Alexander grass was a weed in conventional systems of the past, when just few chemicals were available. In no-till, with proper straw cover, it will certainly not be a problem. For these systems, other species (*i.e. Conyza spp., Amaranthus spp., Euphorbia spp., Digitaria spp.,* etc.) will take place as 'key species' and will so determine a management that easily eliminates Alexander grass (FAVRETO & MEDEIROS, 2006; FAVRETO, 2004; *Chapter 1 – pg.104*). Changes in the floristic composition according to changes in the management of the production system are also broadly reported in the literature (CORREIA & DURIGAN, 2004; FAVRETO, 2004; JAKELAITIS et al., 2003; PEREIRA, 2000; FELDMAN et al., 1997; CLEMENTS et al., 1996).

4. OTHER FACTORS AFFECTING SOIL SEED BANK DYNAMIC

The dynamic *i.e.* the composition and the size of soil seed bank through time is dependent on the balance of inputs and outputs of seeds. The first is determined essentially by the seed rain, mostly by seeds produced in the local community, being possible also some external contribution (VIVIAN et al., 2008). External inputs however are more frequently observed in feathery seeds that travel in the wind; for Alexander grass, in contrast, the main ways of dispersal are water runoff, animals and human activity (not so prone to external contaminations). Outputs, on the other hand, will be determined by germination, re-dispersion, predation and deterioration (VIVIAN et al., 2008).

Occurrence of these events will depend on the relation of many environmental factors (*e.g.* light, temperature, moisture, gas levels, light, soil chemicals, etc.) to the intrinsic characteristic and the state of the seed (MENALED, 2008; FAVRETO, 2004; THEISEN & VIDAL, 1999; CARMONA, 1992). Still, the proximity of the seed to the soil surface dictates the intensity that all these interactions occur (CARMONA, 1992).

Higher outputs in the soil seed bank happen in the most favorable periods to germination (VOLL et al., 1995b), which are often seasonal (FINCH-SAVAGE & LEUBNER-METZGER, 2006), and slightly variable among the years (VOLL et al., 1991). For Alexander grass, as the vast majority of C_4 grasses, soil seed banks manifest seedling recruitment vigorously in early warmer season (NICOLAI et al., 2010; NICOLAI, 2009; RODRIGUES et al., 2000), supported by the presence of proper humidity (NICOLAI, 2009).

Several of these species also germinate when exposed to light, especially those which have small seeds and consequently few reserves, such as the forage grasses (SOUZA et al, 2013). This strategy to increase the survival is the dormancy (CONTRERAS, 2007b; LOCH et al., 2004), a response to situations where the seed is

buried, covered by straw or shadowed by a dense canopy of vegetation (BRAINARD, 2013; SALVADOR, 2007; FAVRETO, 2004). Seeds germination deep in the soil will highly reduce the chance of survival, once the hypocotyl can burn all the seed reserves before the shoot becomes autotrophic. This response develops since the seed is able to sense the quantity and the quality (wavelength) of the light, and then trigger or not the germination (*See Chapter 1 – pg. 75*).

Alexander grass seeds were broadly accepted as photoblastic positive *i.e.* that needs light to start the germination. This conclusion was supported by the behavior of the seed when soil is moved, emerging in very high densities in comparison to unmanaged soil (Figure 4; Figure 65); and findings as those of Theisen et al. (2000), where higher infestations of Alexander grass occur in the crops sowing row (410 plants m^{-2}) than in the inter-rows (25 plants m^{-2}).

Some authors have been defending, in turn, that this grass do not need light to germinate (SALVADOR, 2007; FREITAS et al., 1990), presenting lab results with root protrusion even in light absence. Nonetheless, Alexander grass is a pioneer specie and do not tolerate shadow, which is easily observed on the plant field behavior. Studies conducted under artificial conditions actually do not promote the same kind of light stimulus found in the environment, neither the interactions among the germination triggering factors. Several species that require light to germinate do not express sensitivity just after the harvest, expressing it after some external influences, particularly when the seed is buried (CARVALHO & NAKAGAWA, 2000; BEWLEY & BLACK, 1982) *i.e.* in this cases light dormancy can be classified as a non-innate dormancy type. It is hypothesized that the Alexander grass sensibility to light can be established just after the seed burying.

Following, Baskin et al. (2001) propose that seeds of many species germinate only at specific times of the season, independently if stimulus (*e.g.* light) is given during constant intervals of the year. This indicates to some extent that the plant could depend of the interaction of light and a second fixed factor to germinate, for example, temperature.

A simpler approach in Alexander grass could be the breaking of one type of dormancy (*e.g.* light) with no germination, making the seed to keep waiting a second signal (*e.g.* warmer environment). In this case the timing of the emergence flushes will be determined by the temperature (FINCH-SAVAGE & LEUBNER-METZGER, 2006), explaining the development in undisturbed soil at early summer. Yet, the opposite could be also valid, once dormancy could be terminated by the temperature previously, and the second trigger is the light reaching the seed, which explains thus the germination that occurs readily after the soil mobilization in the warm season.

Another line, more interactive, is that in the process of light dormancy release the phytochrome receptors synthesis is performed in the cellular membrane. When temperature became favorable to germination, the membrane consistency is changed, allowing the flux of receptors to the surface, where they are activated by nitrates. Active receptors, then, combine with the phytochrome that is enabled after light is perceived. There is gibberellic acid synthesis, which joins to their receptor, and triggers the germination (HILHORST, 1995).

Nicolai (2009) reported increases of Alexander grass emergence from the soil seed bank with temperature changing from 17 to 25^{o}C. Regardless, soil temperature is accepted as one of the main factors to these seeds germination. Soil surface also receive more solar radiation and is closer to the air temperature fluctuations, which is gradually altered with the depth (GASPARIM et al., 2005; PAREJA, 1984). A common and more refined theory is the triggering of germination not just by a fix temperature, but by variations on that (SALVADOR, 2007; CARMONA, 1992; THOMPSOM et al., 1977). According to Theisen & Vidal (1999), there are strong evidences that most emerged Alexander grass seedlings are product of seeds placed near the soil surface where the great thermal range occurs.

This important statement evidencing that perhaps the temperature level is not the direct cause of Alexander grass seeds germination, but the thermal range that the seeds are exposed. Some arguments on that are presented:

- Alexander grass germinates just in the layers close to the soil surface (THEISEN & VIDAL, 1999). As the depth of the soil increase the temperature range decreases (Figure 66; Figure 67), which makes the plant sense an unfavorable environment to germination. The sum of the daily difference from the maximum and the minimum temperatures (July 2014 to May 2015; Figure 66; Figure 67) evidence the changes in the temperature range according to the soil depth. Close to the surface, the sum of the temperature fluctuation increases hugely: 100cm – 17°C; 40cm – 90°C; 20 cm - 689°C; 10cm – 1,919°C; 5cm – 2,976°C; 2cm – 4,133°C;

- The vast majority of Alexander grass germination in Southern Brazil occurs in the early spring *i.e.* late September early October months, with weaker re-infestation in the next months (BLANCO, 1994). At this period nights still cold, and minimum temperatures are lower than in the early summer (December; Figure 24), besides day temperatures are already high. Thus, it could be compared to the temperatures presented in the Figure 24 and the scheme in the Table 35: higher temperature ranges will be observed always in the month of October, independently of the variable, which will progressively decrease until January (Table 35; Figure 24). Still, the soil temperatures – even at 2 cm, the most superficial data available – fluctuate far less than the air, confirming the trait that soil conducts less heat (Figure 66; Figure 67; PAREJA, 1984), and explaining why Alexander grass seeds germinate just when they are very close to the surface (THEISEN & VIDAL, 1999).

- Also, litter over can influence germination of Alexander grass and literature broadly report less temperature fluctuation when the soil is covered (FURLANI et al., 2008; FAVRETO, 2004; BORTOLUZI et al., 2000; SALTON & MIELNICZUK 1995). This effect is reproduced also when vegetation is developed in the sward before the Alexander grass seed germination (in a crop-shadowed sub-sward, for example). This is perhaps the explanation why the grass do not germinate

under crop shadow or under the straw (Figure 65; OLIVEIRA, 2013; PEREIRA, 2000; VOLL et al., 1995b; BLANCO, 1994; VOLL et al., 1991).

- In tropical regions, near the equator, temperature fluctuation is lower in comparison to subtropical regions, along the year and along the day, a possible factor on the fact that Alexander grass is concisely present in higher latitudes.

Table 35. Soil and air temperature range in Pato Branco – PR – Brazil, in late 2014 and early 2015 (*OLIVEIRA, 2017*).

Month	Temperature (°C)		Range
	Air Maximum absolute	Air Minimum absolute	
September 2014	30.6	9.0	21.6
October 2014	35.6	11.2	24.4
November 2014	30.6	12.2	18.4
December 2014	31.2	14.0	17.2
January 2015	32.0	17.4	14.6
	Air Average maximum	Air Average minimum	
September 2014	23.9	14.3	9.6
October 2014	29.2	16.2	12.9
November 2014	27.9	17.0	10.9
December 2014	27.7	18.2	9.5
January 2015	29.3	19.1	10.2
	Soil maximum (2 cm)	Soil minimum (2cm)	
September 2014	39.0	11.6	27.4
October 2014	45.0	14.0	31.0
November 2014	47.0	17.0	30.0
December 2014	46.0	18.0	28.0
January 2015	49.0	19.8	29.2

*Data source: Instituto Agronômico do Paraná - IAPAR, Meteorological Station of Pato Branco PR, Brazil.

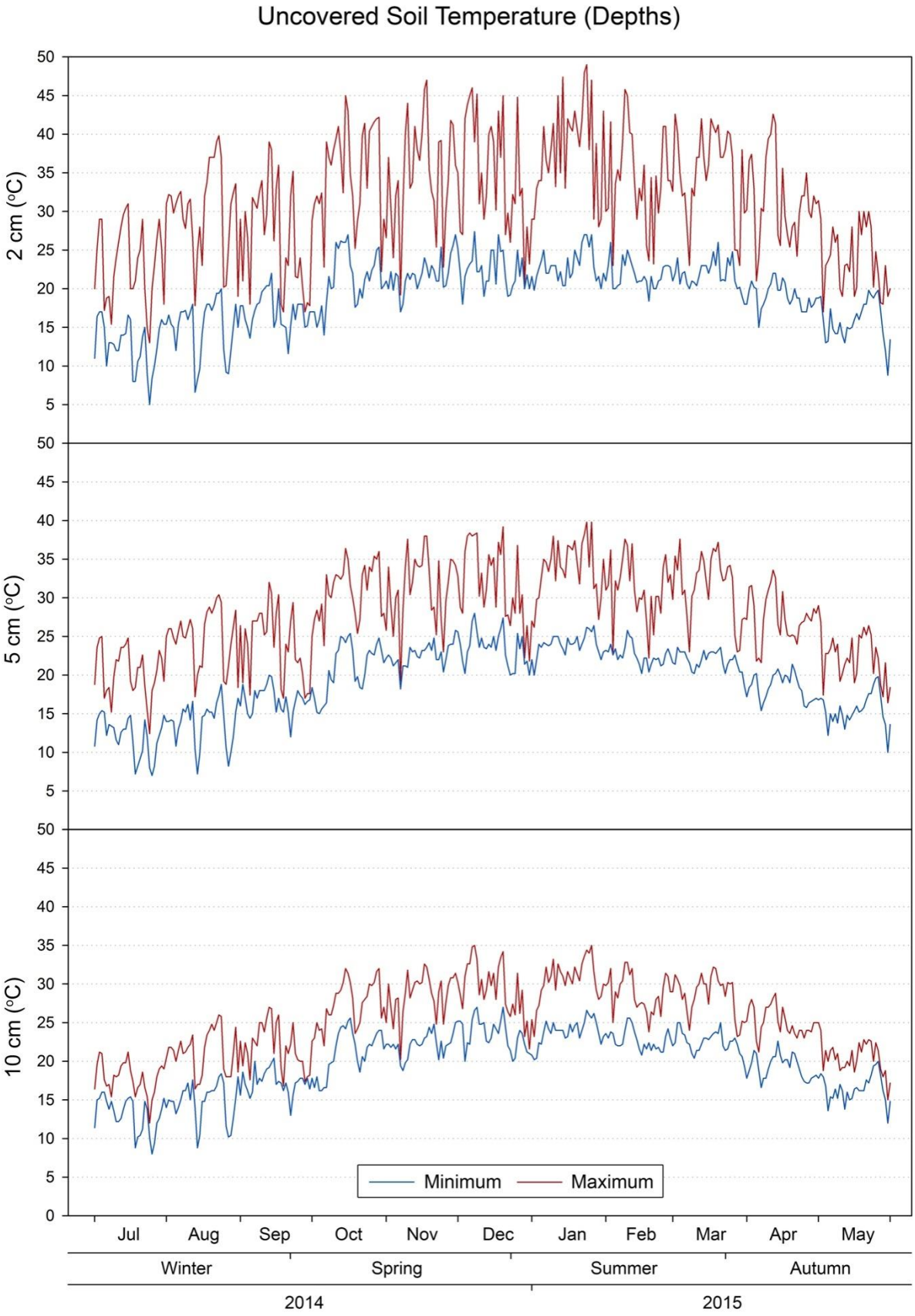

Figure 66. Maximum and minimum uncovered soil temperature in depths of 2, 5 and 10 cm from the surface (1/2) (*Data source: Instituto Agronômico do Paraná – IAPAR, Meteorological Station of Pato Branco- PR, Brazil*).

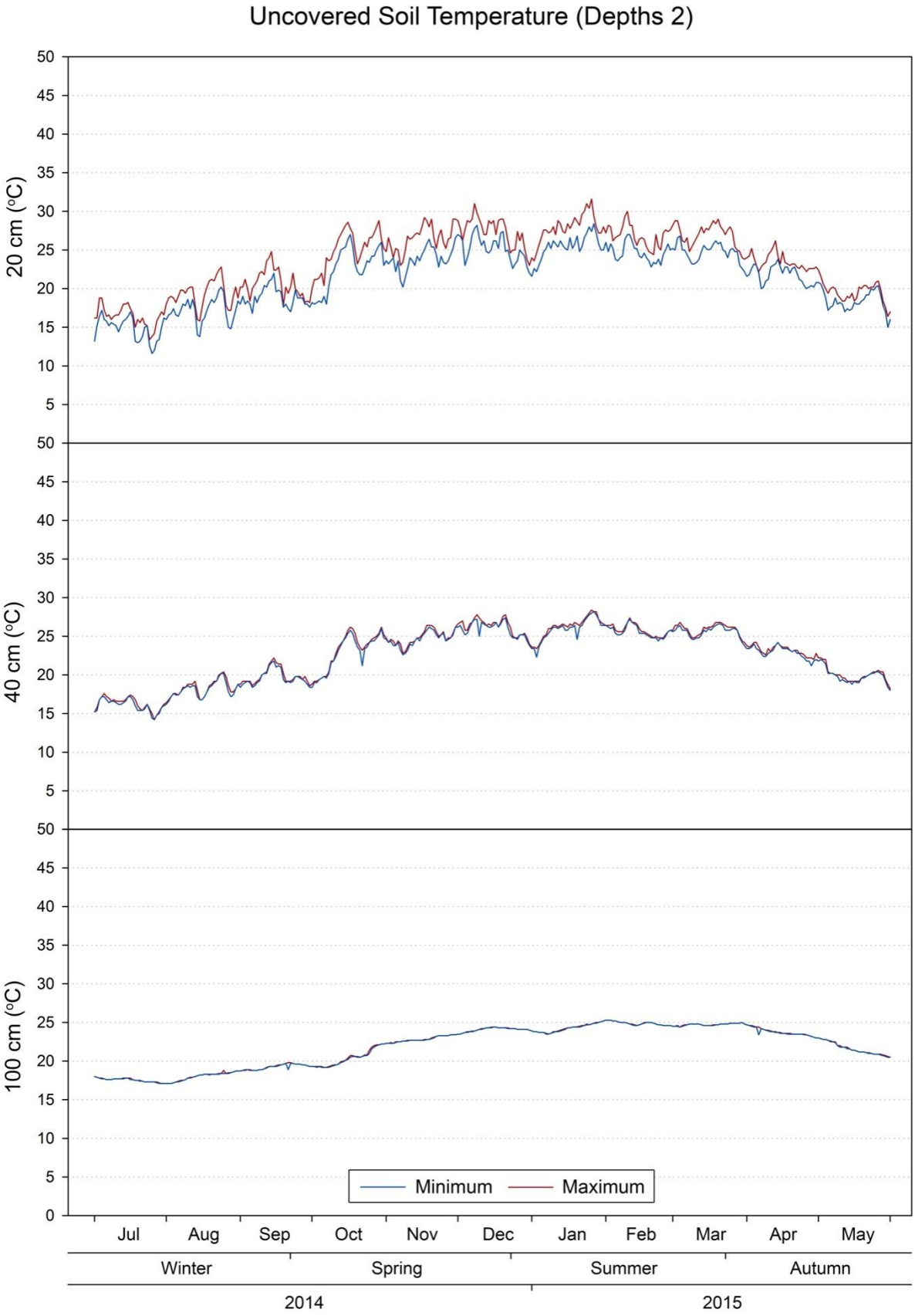

Figure 67. Maximum and minimum uncovered soil temperature in depths of 20, 40 and 100 cm from the surface (2/2). (*Data source: Instituto Agronômico do Paraná – IAPAR, Meteorological Station of Pato Branco- PR, Brazil*).

This theory on the effects of temperature in Alexander grass germination does not eliminate the possible influence of the light, once the two factors are not opposite. In a gross analysis the higher the light reaching the seed (*i.e.* solar radiation, reflected or not), the higher the heat it will receive. Future detailed experimentation could help to clarify these issues and separate the influence of each factor.

Beyond that, Alexander grass seed germination – as all seeds – will be directly dependent on soil humidity (KISSMAN & GROTH, 1997). It is accepted that, besides the elemental moisture needed to trigger germination, water availability could be involved in the dormancy release. If dormancy is imposed mechanically, by a thick seed husk, drought can increase its thickness, thereby contributing to reduce germinability. On the other hand, drought typically diminishes seed dormancy when it is imposed biochemically, possibly interfering in the dynamic of synthesis, degradation and leaching of inhibitors and promoters (CONTREARAS, 2007; SIMPSON, 1990).

According to Hopkinson (1993), brief periods of seed tissue hydration promote the repair of subcellular aging damages, prolonging the seed life. Intermittent hydration followed by drying, with no shoot protrusion, however, can degrade the protective tissues, and so increase vulnerability. The early expansion of the plumule and coleorhiza can press the husk and create little cracks in the surface of the seed, making it more permeable, and the balance of all these processes are potential factors to change the seed sensibility to other dormancy release factors. Yet, soil mobilization and cover will also directly influence in the humidity of the soil along the season (JAKELAITIS et al., 2003).

Excess of water, in contrast, can also generate problems for the seed germination. It is related essentially to the 'drowning' of the seed and the reduction in the availability of air oxygen, fundamental to the germination process (*Chapter 1 – pg.71*). Most species, however, do not need high concentrations of this gas to germinate, since the demands are low in comparison to the levels in the atmosphere. Still, lack of it could appear in two main situations: extreme presence of water and deep burying (CARVALHO & NAKAGAWA, 2000). Into the soil, the reduction of O_2 will

be directly accompanied by increases in CO_2 (PAREJA, 1984), which is known to discourage germination.

Besides gases, about the chemicals in the soil, nitrate is perhaps the only inorganic ion in the soil solution that affects germination in a wide range of species (VIVIAN et al., 2008; FAVRETO, 2004; CARMONA, 1992). This influences in Alexander grass seeds were observed in the artificial tests discussed in the Chapter 4 – *pg.233*. In the soil, concentrations are generally higher near the surface – also, where most Alexander grass seeds are located – since there are great levels of organic matter in decomposition and consequently more microbial activity. Favreto (2004) speculated also that the increase of the emergence in the sowing row (Figure 4), could be influenced by the N fertilizer distributed in the same operation.

Despite the effects observed in laboratory experiments, the influence of these substances in the field could be guided by different factors. The soil pH, for example, is an important topic to be considered when thinking in the action of chemicals (CARMONA, 1992). According to Voll et al. (1995b), after limestone incorporation Alexander grass seed bank reduced 50%. Despite the author reports the promotion of a better environment for microorganism development – which is valid – pH and nitrate interaction could be involved.

Other substances such as artificial chemicals will probably affect the seeds as well. Schweizer & Zimdahl (1984) reduced the seed bank in 98% after the application of atrazine in a cornfield, during six years. Particularly for herbicides with soil action (as atrazine), selectivity is achieved by crops by differential location of the roots, as the deeper layers are the less affected (BUHLER & MESTER, 1991). In addition, most seeds are placed close the surface where the herbicide is more active.

Organic fraction is another matter of consideration. Amorin (2014), evaluating Palisade grass found humic acid to promote the germination of the seeds. The composition of the SSB is related to the levels of organic matter (FAVRETO & MEDEIROS, 2006; FAVRETO, 2004) directly by chemical interaction or indirectly by the endorsement of biotic development.

Some studies suggested that the substances accumulated in the soil surface layer in long-term no-till fields create a unique environment, with high in biological activity, ideal for proliferation of seed predators as insects, mollusks and microbiological parasites (MENALED, 2008; VARGAS & SCHOLLES, 2000; VIDAL & THEISEN, 1999; PAREJA, 1984). Several of these organisms have an important role in dormancy breaking, deterioration and loss of viability of the seeds in the soil (MENALED, 2008; KREMER, 1993), acting in the weakening or breaking the seed husk (FOWLER & BIANCHETTI 2000; VOLL et al., 1995b), or even by the exudation of compounds toxic to the seed (CARMONA, 1992).

The interaction of both meso and micro fauna boosts even more this relation. According to Kremer (1993), insect attack promoted microbial infection of 98%, in comparison to 8% in insect-free seeds. Hare et al. (2007c), evaluating *Brachiaria* hybrids, also related intense ant activity. According to the author observations in Stylo (*Stylosanthes guianensis*) seeds evidence that ants were not able to break the seed, taking it entire to the nest, once it was already hard in the maturation. In contrast*, Brachiaria* seeds were relatively soft just after they shatter, which favored the damages by the insect. Lund (1977), observed carabide damage in weeds seeds in Indian cornfields. These situations can be even intensified by the use of Crop Livestock systems, where the development of meso-fauna as dung beetles is promoted (JAMHOUR, 2016).

Birds as sparrows and canaries can also consume seeds, a question already discussed for Alexander grass. Beyond the seed bank, consumption of stand seed by herbivores during grazing is evident, and changes in the seed state due to the passage through the animal digestive tract will probably happen (ADKINS et al., 2002). Lisboa (2009) recovered South African lovegrass (*Eragrostis plana*) seeds from cattle feces, and evaluated its viability. Some of the seed came back to the environment viable, but those that stayed in the digestive tract for more than a day lost the germination capacity. This kind of assessment could be convenient for Alexander grass.

Besides all these external factors, the intrinsic characteristics of the seed will be the major determinant on the intensity of the effects. Husk is often the only protective barrier between the embryo and the external environment, but it will act in several ways depending on the species. It could be composed by outer and inner cuticle, occasionally impregnated with fatty and waxy substances, and one or more layers of thick-walled, protective cells. Mechanical reinforcement through the synthesis of secondary cell walls, impregnated with impermeable fats/waxes or lignin can occur, as well as the production of polyphenolics as protectants from insects. Layers of crystal-containing cells occur in the seed coats of many species, which may play a protective role, dissuading insect predation too. Coats may contain pectin-rich cell walls that erupt upon contact with water, releasing the pectin as mucilage, providing a water retaining barrier around the seeds. The hydrophilic mucilage also aids the passage of the seed though the digestive system of dispersing birds and other animals (BEWLEY, 2013). Long-term seed survival in soil, thus, will be directly influenced by the state of the seed husk and its proper formation during maturation. Their damage could promote germination but increases vulnerability. In general, only physically perfect seeds with intact protective structures have any prospect of long-term survival (HOPKINSON, 1993).

Finally, modern approaches are not looking anymore for the total elimination of the soil seed bank. Evidences suggest that a management that allows to keep some seeds in the banks with no harm for cultivated crops will be the better option for both ecological and production management (FORCELLA et al., 1996 *apud* FAVRETO, 2004). Avoiding the problems of spontaneous plant in crops in these cases is just a matter of concentrating the seeds at a position in the soil profile from which they cannot easily emerge (BRAINARD, 2013), like under the straw in no-till systems, for example. The pool of dormant seeds could be present in the soil, but it is only after seed germination, seedling emergence and sward establishment that the problem materializes. It should be remembered that more Individuals mortality occurs during the seed stage than in any other period of the plant life (YENISH et al., 1992)

Several studies discussed here illustrated that seed bank abundance declines relatively rapidly when no seed rain is allowed to restock the soil (MENALED, 2008; VIVIAN, 2008). In Alexander grass, after some years of control the soil seed bank became almost nonexistent, however, with one year of production the bank can recover to half of its original value (VOLL, 1995b). For Alexander grass, thus, a widely known logic takes place: the depletion of the soil seed bank in the long term depends equal to the seed production and to the emergence of the seeds from the soil seed bank.

Seed sowing, harvesting and processing guidelines for Alexander grass seeds smallholder and initial production

CHAPTER 6

1. SOWING

A successful pasture establishment is achieved when the seeds are allowed to germinate, initiate shoots, develop into seedling, tiller and form a dense sward (OBASI, 2014; LOCH & FERGUSSON, 1999; OBEID et al., 1994). Proper sowing is a key point that determines the speed and intensity of all these processes, being affected by several factors as the cultural value, sowing method, depth and seeding rate (OBEID et al., 1994).

In tropical grasses, this procedure should be particularly observed. As the seed of most species are small and present limited endosperm reserves it is more sensitive to management mistakes (LOCH & FERGUSSON, 1999). In suitable temperature, enough moisture and absence of dormancy however these plants are very responsive, and the shoot protrusion occurs promptly in 2 or 3 days (FAVRETO, 2004; LOCH & FERGUSSON, 1999).

Choosing the correct sowing method thus could be the first determinant to obtain a good pasture. In Brazil, a common procedure is to broadcast the seed using tractor mounted centrifugal spreaders or airplanes (particularly in the case of high purity lots). Limestone broadcasters are used as well, but in this case the seed needs to present lower purity since, even with the proper adjustments, these implements discard lots of material (they were firstly developed to spread tons per hectare, and not Kg; SOUZA, 2003).

Modern systems however prefer direct seeders, a method that normally promotes better results (ANDRADE et al., 2015; FOLONI et al., 2009). These implements furrow, dose, deposit and cover in the same operation, placing the seed in in a more uniform distribution and suitable location in the soil. It also allows delivering the fertilizer, endorsing a better plant nutrition.

The row planting promoted by these seeders is also interesting in the case of seed crops. It *(1)* eases weed management, rouging and legal field inspections; *(2)* allows to sow a bigger area with the same amount of seeds; *(3)* favors the plant

nutrition; *(4)* improves light penetration in the sward; *(5)* reduces the soil rugosity – in comparison to the systems which broadcast the seed and further perform harrowing, helping the ground sweeping harvest (SOUZA, 2001), and; *(5)* permits to precisely adjust the distribution of the plants in the field *i.e.* setting the inter-row spacing and the seeds per meter different arrangements appear.

A good start to decide for the sowing method is to think in the harvest. For ground sweeping a wider inter-row is interesting to facilitate the seed recovery. For manual harvest, the values are more flexible: in Thailand, for example, seedlings are planted in rows 80–90 cm apart and seed spacing of 50–60 cm within the row, while in Laos the farmers plant at a wider spacing of 1–1.25 m (HARE et al., 2014). As general rule, the farer the plants, the harder the weed management and easier the other operations during the cycle. For Alexander grass the use of the general recommendation for Brachiariagrasses (~1m) can fit for most situations.

Unfortunately, the Brazilian machinery technology stills poor for sowing these grasses. The seeders are usually designed for crops such as corn and soybean, and the adjustment for smaller seeds can be tricky. It is usually done using the cycles of the mechanism or/and the type and the size of the collector disk. Alexander grass presents narrower and longer seeds, not fitting well to the circular holes of the regular disks. If the slots are too small the seeds do not enter and are not dosed, if the holes are larger more than one seed can pass through (Figure 68). In this last case, the sowing occurs anyway but a better option could be the use of small seed boxes adapted to the machine. This parts are, however not available for all models, usually expensive and difficult to buy. The disk mechanism is successfully used for Sorghum, since its seeds are rounder than those of Alexander grass. Other Brachiariagrasses (*e.g.* Palisade grass, Signal grass, Ruzi grass, Koronivia grass, etc.) are sowed by this method and – until no better technology – at least a reasonable result could be attained for Alexander grass as well.

Figure 68. Alexander grass *(Brachiaria syn. Urochloa plantaginea)* seeds in a 4 mm slot horizontal seeder disk. Several seeds fits into a single hole, however, smaller ones could make the seed to stay out of the holes (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

A different mechanism that uses worm screws to dose the seeds is used in Southern Brazil for winter crops as Oat, Italian ryegrass and Wheat. This could be an interesting method for *Brachiaria* as well, particularly to deal with the form of the seed of Alexander grass. Another option, commonly used in the intercropped systems of *Brachiaria* and corn, is the mixture of the pasture seed with the fertilizer (distributed in the same operation). In these cases, caution should be taken since some reports state that the hygroscopicy of the fertilizer can be prejudicial to the physiology of the seed (REZENDE et al., 2012; MOTA, 2008; CARVALHO & NAKAGAWA, 2000; SADER et al., 1991). Beyond those, a vast array of domestic improvised machines is locally used, particularly on small-mid scale farms. Some future test on that can probably bring to light innovative mechanisms that can also be used for Alexander grass.

The next step on the sowing process will be to set a proper seeding rate. This index depends on the germination and the purity of the seed. In the case of forage seeds the cultural value is settled to be called as PGS (Pure Germinable Seeds – *e.g.* a lot with 48% cultural value have 480 PGS). Still, attention should be given to another index, the PLS (Pure live seeds), also common in the regular market. The difference between PLS and PGS is that the first is guided by the tetrazolium test and the second by the germination test. This means that PLS represents the amount of alive seeds but does not guarantee that it germinates, for example, when dormancy mechanisms are present (LOCH et al., 2004; SANTOS FILHO, 1996; CIAT, 1982).

A standard planting rate for Brachiariagrasses is near 400 PLS ha^{-1} (SANTOS FILHO, 1996) or 4 Kg of pure viable seed ha^{-1}. Considering a thousand seed weight averaging 5 g (average popular Brachiariagrasses), a Kg of seed will have 200,000 seeds and 4 Kg will sow around 800,000 seeds ha^{-1} or 80 seeds m^2. Keeping the same math, and assuming a lot of Alexander grass seed classified to deliver a thousand seed weight of 4 g, to sow 80 seeds m^2 it will be needed 3.2 Kg of viable seeds ha^{-1}. Hypothesizing the same seed lot presenting 60% viability and 80% purity, 6.6 Kg of seed could be used to establish 1 ha of Alexander grass pasture.

Caution should be placed on dormancy issues. Dormant seeds besides potentially germinating in the future are a source of uncertainty. According to Hopkinson (1993) the contribution of that in the final sward is negligible. High performance propagative material should be used, promoting germination and emergence as rapid as possible, endorsing active competition to spontaneous plants and reducing the period to the grazing beginning.

In Brazil, sowing rates are a point of debate among seed producers and cattle raisers (ANDRADE, 2001). According to MILES et al., (2004), in general terms for Brachiariagrasses it should assure the establishment of 15 to 20 seedlings m^{-2}. Particularly for Alexander grass, studies already evaluated the development of the sward according to the number of plants per area. According to Velho (2012), the plant strictly follows the law of final constant mass. In a range of 5 to 90 plants m^{-2}, the

final sward presented the same final forage amount. There was high plant mortality in high densities (90 plants m^{-2}), and high tillering in low densities. A negative relation was reported also between number of plants per area and final plant mass. Besides valuable for the understanding of Alexander grass behavior, it is a common pattern for most grasses.

Finally, a major issue that influences the results of the sowing is the seed depth in the soil (NEGRISOLI et al., 2011; OBEID et al., 1994). The variation in depth will change conditions as moisture and temperature, affecting also the likelihood of the seedling to reach the surface (MCDONALD & COPELAND, 1997). As already stated, this is even more crucial for small seeds as those of Alexander grass. According to McDonald & Copeland (1997), the depth of one to one-half the seed's diameter is usually the ideal for most plants, which make recommendation for Brachiariagrasses very shallow. To understand this issues a trial was developed.

1.1 Sowing depth and water availability on the Alexander grass emergence

1.1.1 Materials and Methods

The major aim of this trial was to identify the Alexander grass emergence according to depths of sowing and levels of water in the substrate. The seed harvest phase of the experiment was carried out at the experimental station of the Federal University of Technology – Paraná – Pato Branco (26°10'40" S; 52°41'18" W; 750 m asl.). Region climate is Cfa transition to Cfb, according to Maak (1968) classification. At early September 2014, soil samples were collected and chemical analysis performed (Table 5). No soil mobilization was performed and there was no mulch covering the soil. Two uniformization cuts at 20 cm were done when the plant reached 40 cm, using a back bushcutter equipped with a metal blade. 200 Kg N ha^{-1} were broadcasted using urea 45%, in the occasion of the first uniformization cut. In mid-October (2014) Metsulfuron-methyl was sprayed at the dose of 5 g a.i. ha^{-1}, using Ally ® (Du Pont) to

control spontaneous broadleaf species that grew together with Alexander grass. The seeds were harvested by manual ground sweeping and processed at late March 2015, being blown and sieved to separate the gross impurities. To refine the cleaning a Laboratory seed blower model South Dakota was used, composing a final seed bulk with thousand seed weight of 5.23 grams (Figure 54).

Emergence was evaluated in transparent plastic boxes (Gerbox; 11 x 11 cm wide x 3 cm depth), which were previously washed with dish soap, intensively rinsed, sprayed (sterilized) with alcohol 70%, and then dried with paper towels. 200 g of substrate presenting density of 0.42 g cm^{-3} and chemical levels according to the Table 36, were added in each box. The amount of substrate was enough to fill the box with no compacting.

Table 36. Substrate chemical levels, used for Alexander grass (*Brachiaria syn. Urochloa plantaginea*) sowing depth experiment.

Index	Value[1]	Unit
Organic matter	10.5	%
P	243	mg dm^{-3}
K	1.9	$cmol_c$ dm^{-3}
Al^{+3}	0	$cmol_c$ dm^{-3}
$H + Al^{+3}$	3.84	$cmol_c$ dm^{-3}
Ca	16.7	$cmol_c$ dm^{-3}
Mg	5.2	$cmol_c$ dm^{-3}
Bases sum	23.8	$cmol_c$ dm^{-3}
V	86.1	%
Aluminum saturation	0	%
pH	5.9	$CaCl_2$
CTC	27.6	

[1] Analysis developed at the Soil Laboratory of Federal University of Technology – Paraná – *Câmpus* Pato Branco. 2014.

Four replications were developed for each treatment. The first factor was composed by levels of water in the substrate, being full and half of its holding capacity (80 ml and 40 ml of water for each box). This parameter was established according to a pilot experiment – substrate was moistened until saturation in a recipient with a grille bottom that allowed the passage of the water but no the passage of the substrate particles. The substrate and the recipient were weighted just before the saturation, moistened, weighed again and left for two days in cold environment, letting the free water run through the grille. Then, a new weighing was

performed, presenting the values of the water retention according to a rule of thumbs among all the obtained values. Four replications were performed for the pilot trial, and potential losses by evaporation were not considered assuming that the cold environment made it negligible. Final values of water retention after 2 days presented as 40% of the substrate weight.

Second treatment factor was the sowing depths of 0.75; 1.50; 2.25 and 3.00 cm, plus a control treatment where the seed was placed on the surface. To establish the treatments, part of the substrate was leveled into the box, letting an empty space that exactly matches the sowing depth of the treatment. Fifty seeds were uniformly distributed in each box using tweezers, and then the rest of the substrate was placed over the seeds uniformly. All the process was performed above a scale of 0.1 g precision to guarantee the conformity of the methodology and the uniformity of the substrate amount among the boxes. No compaction was done in the substrate.

After the mounting boxes were placed into a BOD incubator, set to provide an environment with 11 hours of dark and 13 hours of light, simulating a daylength close to the seasonal Alexander grass emergence period in Southern Brazil. Temperature was set to 20^{o}C (dark) and 30^{o}C (light), according to Brazilian seed testing rules general recommendation for warm season grass species (BRASIL, 2009) and some other authors that evaluated Brachiariagrasses (CARNEIRO et al., 2007; SALVADOR, 2007; GARCIA et al., 1998; VOLL et al., 1997). Emergence count was performed at 7, 14 and 21 days after incubation. On that, any shoot that appeared in the surface were counted as emerged, independently of its size. For the surface treatment, any seed that emitted shoot were counted as emerged.

In the occasion of each counting small amounts of water were added to match the methodology. The boxes were placed on a scale (0.1 g precision) and moistened until reaching the initial weight. Differences by the weight of the seedlings were considered negligible. Data was catalogued and Statistical analysis developed using 'R' program (R DEVELOPING CORE TEAM, 2011). Analysis of variance and Scott & Knott test were performed considering a significance level of 5% probability.

1.1.2 Results and discussion

No interaction among the factors and no differences for the water levels were identified for the seedling emergence by the analysis of variance ($P > 0.05$). For the sowing depth, differences were found, and grouping was done by the mean test as presented in Table 37 ($P < 0.05$).

Table 37. Alexander grass (*Brachiaria syn. Urochloa plantaginea)* seedling emergence (%) according to sowing depths[1] (OLIVEIRA, 2017).

Depth	Emergence
Surface	61 a
0.75 cm	53 a
1.50 cm	57 a
2.25 cm	55 a
3.00 cm	22 b
Mean	49
C.V.: 18.3%	

[1]Means followed by the same letter compose statistically homogeneous group; Scott & Knott; *P* >0,05.

The deeper sowing (3 cm) was the only treatment that presented lower emergence among the studied range. From the surface control to the 2.25 cm treatment similarity was observed, presenting an average of 57 % of emergence, a good value considering the particularities of tropical grass seeds (Considering that it was not just the germination, but also the emergence of the seedling). With 3 cm, however, emergence decreased more than two and a half times, being probably the mark from which Alexander grass seedlings start to have problems to emerge.

The final counting (21 days of incubation) was followed by the dismantling of the boxes. In the occasion, non-germinated seeds where searched in the substrate looking for particularities. This observation evidenced – especially in the deeper sowings – seeds that germinated, emitted shoot, but were unable to emerge (Figure 69), a phenomenon widely reported for small seeds placed too deep in the soil.

Figure 69. Alexander grass *(Brachiaria syn. Urochloa plantaginea)* seeds germinated but non emerged as a result of too deep sowing (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Some literature on C_4 grasses present that sowing close to the surface is the method that presents the better results. This usually keep on the range from 1 to 5 cm depth: for 16 cultivars of warm season forages Townsend (2014) recommend shallow sowing, bypassing 3 cm just for Palisade grass and Setaria. According to Rezende et al. (2007) Palisade grass emergence do not differed until 5 cm of sowing depth, and Paulino et al. (2004) observed for the same specie better performance until 4 cm. Zimmer et al. (1994) reports better results with 2 and 4 cm sowing for Palisade grass and Signal grass, respectively. Foloni et al (2009a) reported problems in emergence of Palisade grass under 5 cm, with better emergence at 2.5 cm, as the same was reported for Signal grass and Alexander grass by Facco et al. (2010). Obeid et al. (1994) observed the best emergence rates in the range around 3 to 4.5 cm for Koronivia grass, Palisade grass and Guinea grass. Reports are also found on better performance for Alexander grass with 3 cm depth (SCHREN et al., 2013), and for Negrisoli et al. (2011) negative effects were observed under 4 cm for the species. Finally, according to Mota (2008), evaluating Signal grass and Palisade grass, the sowing depths affect not just the emergence but also the mass of canopy and root produced by the seedlings. Better performance was observed by this author in the range 0-3 cm, with substantial reductions under 6 cm. Despite, when soil temperature in the surface is too high as in Brazilian Cerrado (near 50^{o}C) a deeper incorporation could be convenient.

A second observation on the dismantling of the boxes is the length of the hypocotyl of the seedlings. Evidently, the deeper the seed the longer the hypocotyl has to be to reach the surface and emerge. This is also directly proportional to the amount of reserves the seed has to burn. Before the emergence the seedling is rely completely on the reserves of a seed that weighs around 0.004 grams (Counted also the tegument and the embryo axis). To develop both a 3 cm hypocotyl and a root in the opposite direction is so a notable challenge for an Alexander grass seed (Figure 70).

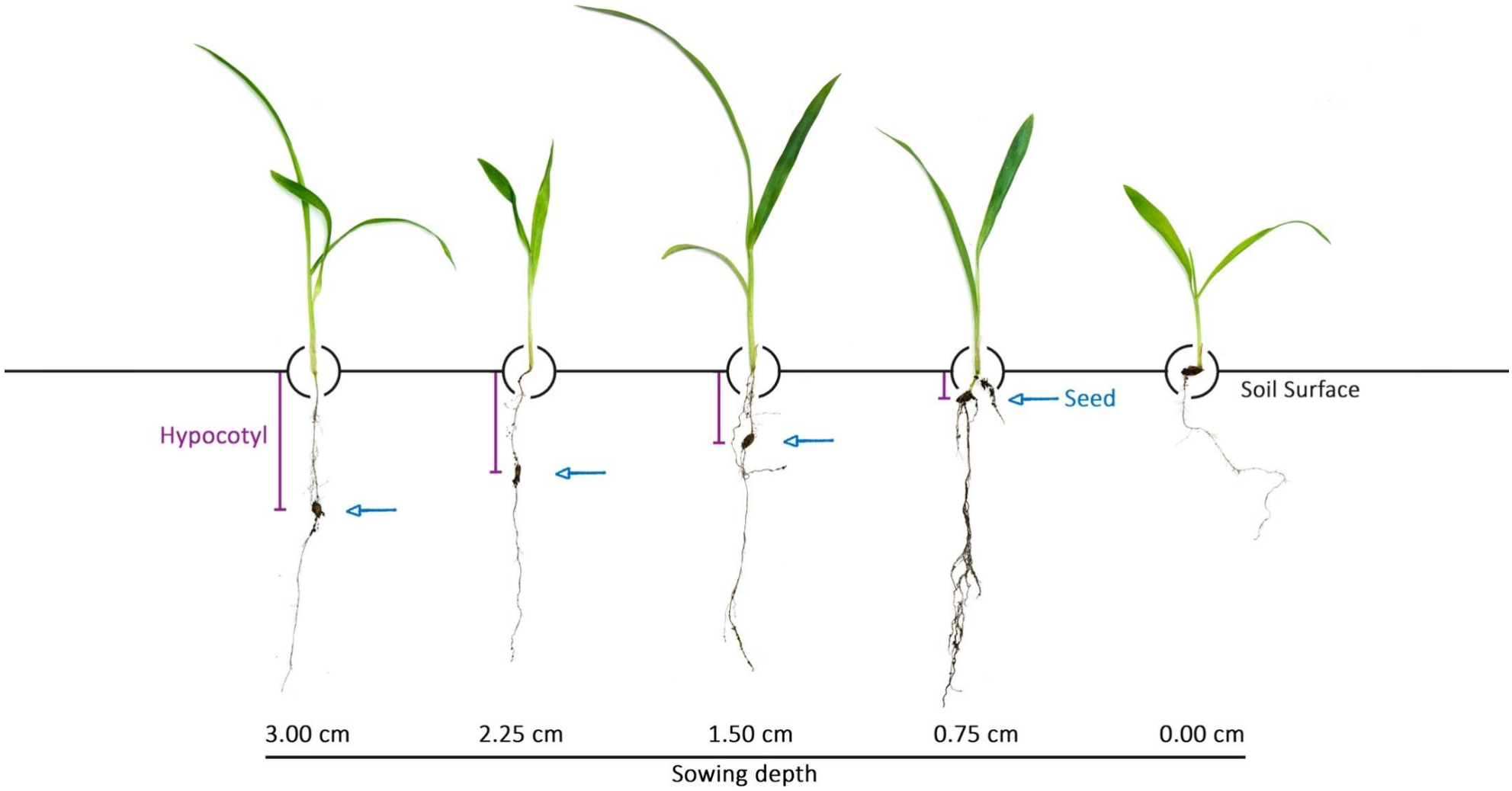

Figure 70. Samples of Alexander grass *(Brachiaria syn. Urochloa plantaginea)* seedlings in 5 depths of sowing. The lower the seed depht, the longer the hypocotyl (*Picture source: J.R.Oliveira – OLIVEIRA, 2017*).

Superficial sowing, in contrast, placed in the better performance group. This matches the findings of Alcantara (1977) that evaluated Signal grass and Guinea grass and related that the shallower the sowing, the higher the emergence. Foloni et al. (2009a) also found good performance of the seed on the surface, however, the author also related evidences that the superficial sowing is not the best method to choose (FOLONI et al., 2009b).

An issue involving this treatment, away from the emergence rates, is that the superficial sowing can pose some problems on the seedling anchoring in the soil. It was common to observe the root lifting the seed from the ground in this experiment, letting it exposed and prone to bend and brake (Figure 71). It happened since the pressure developed by the seed to pierce the soil was far superior than that needed to move the small seed, an opposite situation to a normal hypogeal germination.

Occasionally the primary root also developed in parallel to the soil when the seed was placed in the surface. In these cases hairy roots were developed, perhaps as a mechanism to improve the superficial area to absorb water and nutrients (Figure 72 BC). A comparison to a treatment that bury the seed is useful to observe the difference on the growing direction of the seedlings: with 2.25 cm depths, the plants point straightly up and no roots are seen above the substrate (Figure 72 A). It is important to point that the substrate used to grow these seedlings presents a lower density than most soils, which can even compound this phenomenon in the field. In the Figure 73 (*pilot experiment, unpublished data*) it was noticeable that the root is capable even to lift small soil clods depending on the position it was placed.

Figure 71. Alexander grass *(Brachiaria syn. Urochloa plantaginea)* seedlings after superficial sowing in nutritive substrate. With this management it was common to observe the root shoot to lift the seed from the ground, exposing it to a bend and brake (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*)

Figure 72. (A) Alexander grass *(Brachiaria syn. Urochloa plantaginea)* seedlings in 2.25 cm depht sowing. No roots were observed above the soil and the canopy grew straight up. **(B;C)** Alexander grass seedlings in superficial sowing - roots grew above the soil and have to bend downward looking for an anchor point. These seeds also developed hairy roots as a strategy to increase absorption capacity. As presented in Figure 66, soil temperatures in the surface can reach high values posing a risk to the root to dry (*Picture source: J.R.Oliveira – OLIVEIRA, 2017*)

Figure 73. Alexander grass *(Brachiaria syn. Urochloa plantaginea)* seedlings after superficial sowing in soil (*pilot experiment, unpublished data*). The pressure performed by the root to pierce the soil can lift even small clods. See also Figure 71 (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*)

Sowing in the soil at scale farming using large machines will obviously do not provide the same precision of this trial. In these cases, variations are expected, since even a well regulated machine, to put seeds at 2 cm deep (*e.g.*), will place some seeds at 1 cm and others at 3 cm. This happens once the mechanisms of tillage, seed deposition, burying and compacting have to deal with soil clods, sites of different moisture, rocks, straw, vegetation mass, etc. A good guideline to sow Alexander grass seed thus is to put it around 1.5 cm depth. Assuming that in a well-adjusted seeder some seeds will be placed at 0.5 and 2.5 cm, it is on the range to avoid most problems of surface sowing or deep burying.

In intercropped systems, when the seed is mixed with the fertilizer, (not the best option, but still possible), probably the seeder will place it deeper in the soil. This is done most of the time to delay intentionally the emergence of the pasture in relation to the grain crop. Caution should be taken so to avoid the emergence of a poor stand. Studies of Pacheco et al. (2010) suggest that a coefficient of correction should be adopted in these cases, presenting the numbers of 270%, 220% and 660% of the standard reference for Palisade grass, Signal grass and Ruzi grass, respectively. No strict value is available for Alexander grass, yet, an increasing is recommended.

No differences were observed for the water factor in this trial ($P > 0.05$). In an overall analysis, it is possible to say that both treatments supplied plenty of water in the substrate and did not limit the seed germination and seedling emergence. Seeds typically possess extremely low water potential and are very efficient in absorbing water (MARCOS FILHO, 2007d; MCDONALD, 2007b), which is even enriched in small seeds that present a great ratio between surface area and volume (MCDONALD, 2007b). C_4 grass seeds, particularly, tolerate widely fluctuating environmental conditions in natural environments, such extremes of temperature and erratic water supply. Often, these seeds possess specialized structures and water uptake patterns to make the most of narrow windows for successful germination (LOCH et al., 2004).

The amount of water taken up by a seed to trigger the germination is very small, not exceeding two to three times the seed dry weight (BENNET, 2007b; DESAI, 2004). If considering fifty Alexander grass seeds weighing 0.0053 grams each (Figure 54), for all the seeds placed in the box 0.26 grams (or ml) of water would be enough to trigger the germination. Still, in 200 g of substrate with 40 ml water – figuring uniform distribution and ignoring seed spacing – each gram of substrate would present 0.2 ml of water, and so, 1.3 cm^3 of substrate would have enough water to trigger the germination of all the seeds. Major conclusion on this factor is that the treatments should be far more severe to reach differences.

2. WEED MANAGEMENT IN ALEXANDER GRASS FIELDS

After the Alexander grass establishment an important point to consider is the maintenance of a sward clean from other species contamination. Weeds are a major problem especially during the establishment phase when it can compete with the grass and reduce forage and seed yields (ANDRADE, 2001), or contaminate seed lots in the case of seed production.

Still, weed free production fields are important to avoid problems and losses during seed cleaning (ANDRADE, 2001). For example, it is very hard to distinguish *Brachiaria* seeds and even worst to separate it in the processing. In several cases, Brazilian seed lots of Palisade grass carry together seeds of Signal grass. Having no proper solution to separate them, it is very important thus to make the seed to come from the field with a good purity level (NERY et al, 2012).

In all the experiments developed in this work no major problems were encountered in managing weeds, firstly due the Alexander grass aggressive space occupation (*See Chapter 5 – pg.243*). The only plant that appeared occasionally in the sward matching the development of Alexander grass was the Jamaican Crab grass (Figure 74). In higher infestations, it could be a problem given the fact that the vast majority of herbicides that kill that plant are also toxic to Alexander grass. Areas with historical contamination should be avoided.

Figure 74. Jamaican Crab grass (*Digitaria horizontalis*) inflorescence in Alexander grass field (*Brachiaria syn. Urochloa plantaginea*). In this work, Jamaican Crab grass was the main weed observed in pastures and seed crops of Alexander grass (*Picture source: J.R. Oliveira – OLIVEIRA, 2007*).

Broadleaves, however, are easy controlled in forage swards, using herbicides as 2,4-D (ANDRADE, 2001; SOUZA, 2001; CIAT, 1982) or Metsulfuron methyl (PEREIRA et al., 2000). According to Hawton (1980), Brachiariagrasses are included among the species that readily detoxify Atrazine too. Oliveira (2013), however, observed toxicity in young Alexander grass seedlings, despite symptoms disappeared in some days and the plants kept developing. Having that the Atrazine acts just in the soil, and the selectivity is achieved by differential location of the roots; it is assumed that this compound will cause no harm for adult plants. Martins et al. (2007) and Rassini (2002) reported atrazine controlling weeds in Palisade grass and Signal grass with no effects over the pastures.

Rasini (2002) also reported alternatives as imazaquin, imazethapyr + ametryne, and diuron as useful in the control of Palisade grass weeds. Martins et al. (2007) recommends (for Signal grass) the use of imazethapyr, chlorimuron-ethyl, bentazon, despite some toxicity in the pasture that disappeared in 20 to 30 days. These authors also reported the use of nicosulfuron, besides it presented high dry mass reduction. With Alexander grass Oliveira (2013) observed that the spraying of nicosulfuron was fatal for young seedlings. Actually, all these reports on Palisade grass and Signal grass are just potential options for Alexander grass, which should be tested before to establishing some management.

During this work a case of intoxication was observed in Alexander grass with the spraying of metsulfuron-methyl, particularly because of the concomitant application of nitrogen fertilizer (Urea) and the herbicide spraying. It is assumed that the two managements interacted and boosted the action of the chemical, making the plant not able to handle the detoxification processes as in a regular situation (Figure 75). Luckily, application was just in spots of the sward where some seedlings of Hairy beggarticks were developing, and the symptoms disappeared in about two weeks. Management as this, however, should not be used in Alexander grass.

Figure 75. (A) Comparison between sprayed Metsulfuron and non treated tiller of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) and the redish symptoms of toxicity; (B) Metsulfuron intoxicated tiller of Alexander grass on a healthy sward; (C) Metsulfuron intoxicated tussock after spraying of Metsulfuron. The symptoms were a result of an interaction of nitrogen fertilization applied at the same time of the herbicide spraying (*Picture source: J.R.Oliveira – OLIVEIRA, 2017*).

3. HARVEST

Harvest is one of the main sources of concern in the management of warm season forage grasses. The characteristics of these plants make the decisions complex, especially about the starting moment. In most species, an early single destructive harvest will recover a large share of under-ripe seeds, and a late one can result in low productivity by the effects of the shattering (SOUZA, 2001).

Alexander grass itself strongly adapts to this characteristic. The heterogeneity of the plant maturation – among the panicles and within the panicle – summed to the readily shattering after the seed development, make the combine harvest a challenging technique (*See chapter 1 – pg.120*). Still, even if harvesting from the panicle was possible, the quality of these seeds will be the worst encountered in the field, as the fully mature seeds are ever in the bulk of shed seeds on the ground (*See chapter – pg.167;* Figure 76). It is accepted thus that the proper recommendation for the Alexander grass seed harvest is to proceed according to the ground sweeping method, following the general procedures for popular Brachiariagrasses used in Brazil (*Chapter 1 – pg.81*).

Initial production of seed, however, could depend on manual or semi mechanized methods. On that, the techniques used in the trials could be convenient, as it presented relative good efficiency and feasibility:

Alexander grass was established by the soil seed bank, which makes the plant to develop randomly distributed in the area. If some seed is available and sowing is possible, the row planting is a better option to favor the harvesting process and the overall management. The use of seedlings is efficient as well, since Alexander grass is easily transplanted in the presence of good moisture. It is probable that plants will not develop the tussocks strictly in the row as it easily root in the nodes contacting the soil (Figure 5), same way, advantages of this management are kept.

Figure 76. On the left: Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds harvested from the ground. On the right: Alexander grass seeds threshed from the panicle (*Picture source: J.R Olivaira - OLIVEIRA, 2017*).

In the end of the cycle, the sward should be chopped as close as possible to the ground. Closer cuts will ease the recovery of the seed near the tussocks crown, which is the toughest place (Figure 77). Implements that mow the forage using horizontal blades are more desirable than those that use rotational blades, since those do not grind the forage so intensively, facilitating the raking process and providing a better purity in the collected material.

Figure 77. Ground aspect after Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seed recovery (Figure 78). The eficiency of the process depends on the capacity to mow the grass close to the ground, once the machine used was not able the recover the seeds too close to the tussocks crown (*Picture source: J.R. Oliveria - OLIVEIRA, 2017*).

After the cut the biomass should be left to dry for nearly five days, period which will directly depend on the climatic conditions. Sunny days are preferred; if forecast indicates rain events, the period should be avoided. High temperatures will help detach seeds that remained linked to the panicles and reduce the moisture of the overall seed bulk. If proper weather is achieved, artificial drying could be even overlooked.

The mass should be then manually raked and piled away from the seeds that will be recovered (Figure 78A). To collect the seeds manual sweeping could be used, however an electric garden vacuum is a good and relatively cheap option to increase the feasibility of the process (~R$ 500.00, in Brazil). These machines create an air column that collects the seeds, and deposit it into a bag, which is further detached to unload (Figure 78B). In cases where the seed field are far from an electricity point the use of a combustion generator is also a cheap and practical option (Figure 78 C). In Southern Brazil, there are companies that rent these machines for a day at the costs around R$ 50.00 each. The resulting material could be placed into bags and preceded to processing.

With the harvest method established, it is important to decide the moment to start it. In Brachiariagrasses it is a hard task once in the most cases there is no consistent morphological changes to identify the maturation stage (SOUZA, 2001). Even though, one of the objectives of future studies on the seed development of these plants should be on the phenological differences that can guide practical parameters to determine the best time for the harvest.

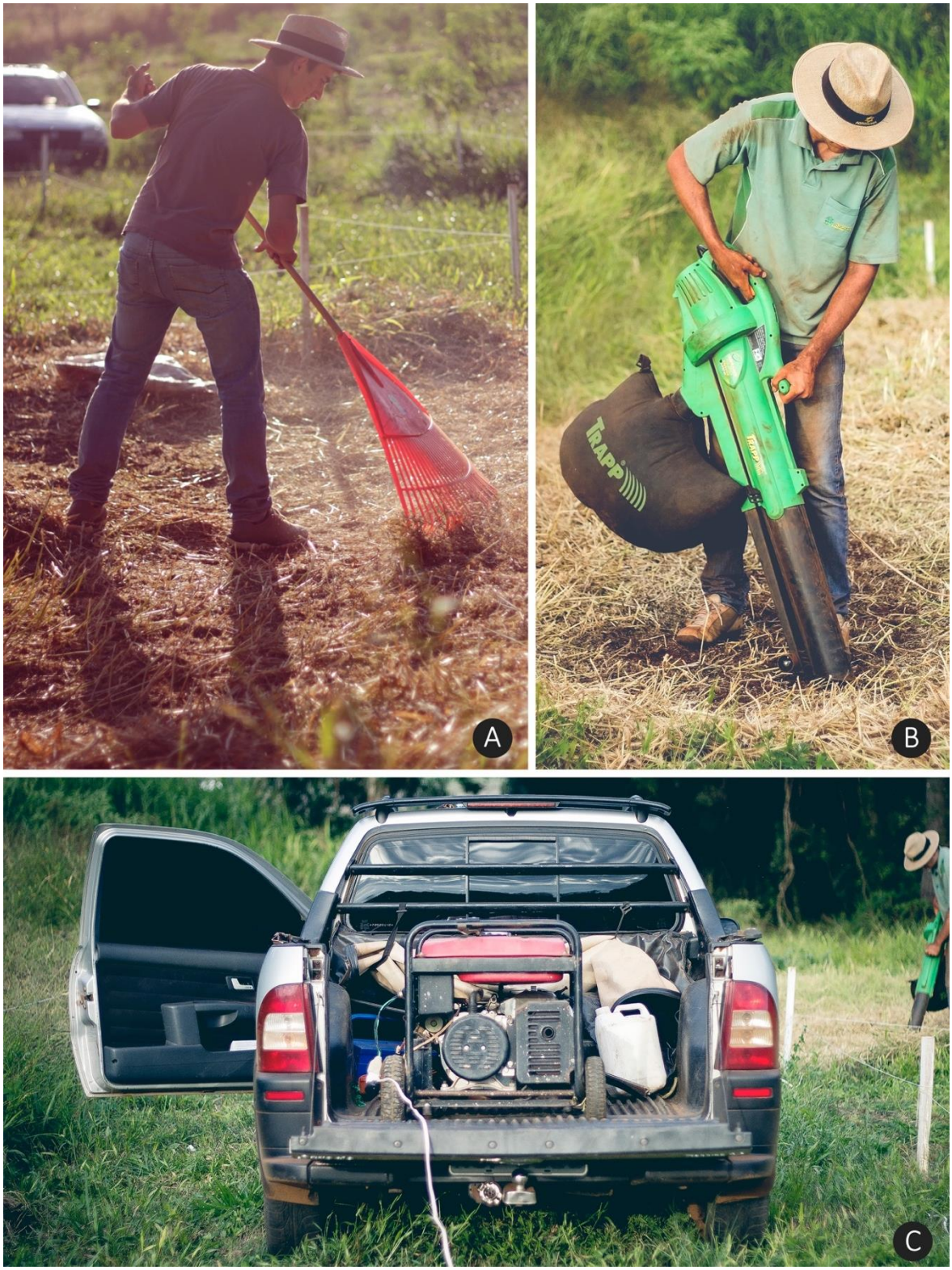

Figure 78. Partially mechanized ground sweeeping method system used to harvest Alexander grass (*Brachiaria syn. Urochloa plantaginea*) in the Southern Brazil. The sward is mowed at the end of summer (April), straw naturally dried in nearly 5 days (considering a sunny wheater). (A) The excess of biomass was swept (B) opening space to recover the seed using a electrical garden vacuum (C) An alternative for areas where electricity is not closely available is the use of a combustion generator (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

It is important to consider that the seed should be harvested after the physiological maturity, when most seed is available. For the harvest from the ground, it can be simplified to the moment which most of the seed is already produced and shed. For Alexander grass it was observed that physiological maturity is reached within the panicle (ignoring the intrinsic heterogeneity) around 20 days after the panicle emergence (*Chapter 3 – pg.167*), but having the indeterminate appearance of panicles (*Chapter 2 – pg.120*), knowing the value for individual inflorescences is just a partial solution. The proper parameter will be achieved thus crossing the data on the physiological maturity to the appearance of most panicles in the sward. According to the results, peak in panicle emergence occurs 54 days after the beginning of the panicle emergence (Figure 21), which summed to 20 days to reach the physiological maturation, plus 5 days as a coefficient to respect the heterogeneity within the panicle, will give a proper harvest by ground sweeping 79 days after the emergence of the first panicles. Yet, if considered that the 54th day after panicle emergence occurred at mid-February, Alexander grass seed harvest in the Southern Brazil will be recommended for the first fortnight of March. If ground harvest is delayed until a month, probably there will be no problem. Advances, in contrast, could result in lower viability.

Days after panicle emergence are perhaps the most commonly used parameter to decide on the harvest for the popular warm forage grasses (NERY et al., 2012; LOCH et al., 2004; ANDRADE et al., 1999). Despite in these cases it is used to define the period for combine harvest, the range of some reports are presented to comparison (for all data, days after inflorescence emergence): Palisade grass, 32 (BENTEO et al., 2016); Signal grass, 30 to 38 (ZHANG, 2014; QUADROS et al., 1994; CONDE & GARCIA, 1985); Guinea grass, 28 to 38 (ITALIANO, 2000; CONDE & GARCIA, 1988b); Gamba grass, 20 to 25 (ITALIANO, 2000; CONDE & GARCIA, 1988b); Setaria, 32 to 44 (CONDE & GARCIA, 1990; ITALIANO, 2000); Molasses grass, 38 to 48 (CONDE & GARCIA, 1988; ANDRADE, 1983); Jaragua grass, 44 (CONDE & GARCIA, 1986).

Combine harvest is commonly performed just after the peak of panicle emergence (54 days, in the case of Alexander grass). Thus, it is conclusive that the period from the beginning of the flowering to the maximum flowering in Alexander grass is larger than for most species (Figure 21). If considered the cutting management this value can be reduced (*See chapter 2 – pg.*130).

This, however, is not a strict recommendation, but a valuable guideline that indicates when harvesting is likely to occur that allows preparing in advance the infrastructure and machinery necessary for the harvest procedure (ANDRADE et al., 1999). Growers normally base their final decision in a series of morphological indicators such as shattering, color change, and seed hardness, which, besides complex, will be interesting to define for Alexander grass as well. In the field this intuitive indexes are important to regulate the harvest date according to the year environmental variations that influence processes as flower induction and seed maturation.

A good auxiliary parameter to define the harvest is the shattering *i.e.* the evolution of the relation among seeds detached and seeds attached in the inflorescence, composing the shattering percentage (Table 14; Table 15; ESGPIP, 2010; ANDRADE, 2001; SOUZA, 2001). Considering that most of C_4 forages present indeterminate inflorescence emergency this data have to be used just as a support, particularly in the case of Alexander grass where the panicle emerge period is very long (3 months - Figure 21). Some reports for combine harvest are presented: For Guinea grass, harvest should be performed when 1/3 of the upper panicles shattered the seeds (MASCHIETO & NOVEMBRE, 2007); for Signal grass, harvest should occur at the beginning of the shattering (CONDE & GARCIA, 1988b; CANI, 1980); for Koronivia grass, 10% of shattering (CIAT, 1982), and; for Palisade grass, when 10% of the seeds are shattered in 50% of the inflorescences (NOVEMBRE, 2007).

The consistency of the caryopsis is reported as a possible indicator as well (NERY et al., 2012; ESGPIP et al., 2010; SOUZA, 2001; LOCH & FREGUSSON, 1999), being well related to the dry mass percentage of the seed. It is assumed that in the state that the seed present 'cheesy' consistency it is very close to the maximum seed feeling, which mean also physiological maturation (CARVALHO & NAKAGAWA, 2000). This indicator, however, is again helpful just for the stand seed, and not for seed shed to the ground.

Finally, for some grasses, observation of the changes in the seed color is a maturity indicator. It is one of the easiest methods to use in the field, as there is no need for specific analysis or tools. Seeds of Molasses grass, for example, change from purplish to brownish coloration around 24 days after anthesis (ANDRADE, 1983). According to Nery et al. (2012), seeds of *Brachiaria* present greenish color when immature and brown-sugar color when mature. Wongsuwan (1999) reports the same pattern in Ruzi grass. For other authors, in contrast, Brachiariagrasses do not have any noticeable color change, as the seed stay green until the full maturity (ESGPIP, 2010; LOCH & FERGUSSON, 1999). The case of Alexander grass fits better on this last report, since the seed do not make any perceptive change in the color when attached to the plant, keeping during all the development a green color. Curiously, just after the shedding the seed readily change its color to a brown-sugar color, which so matches with the first reports. The clear limitation is that this coloring process occurs strictly just after the shedding, which make the parameter useless to the identification of the Alexander grass stand seed (Figure 79). This observation also endorse the statements on the maturation process of this species seeds, which is probably ended just after the shedding (See Chapter 3 – *pg.*167).

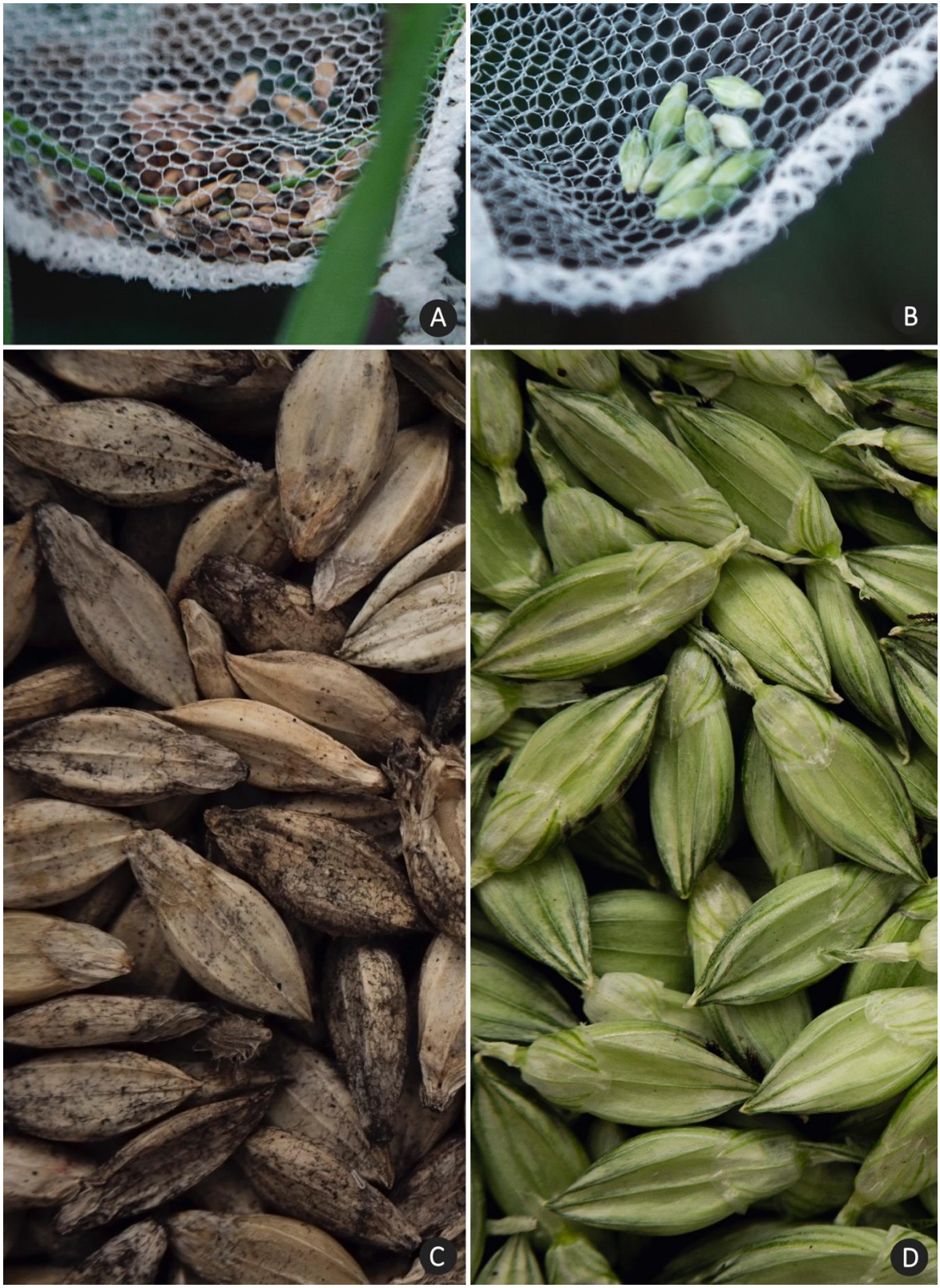

Figure 79. Alexander grass (*Brachiaria syn. Urochloa plantaginea*); (A;C) seed color around a week after shattering; (B;D) Seeds just after shattering. Besides the notable difference the seed just turns from a greenish to a brownish collor after the shattering, taking the opportunity to use this criteria as a maturity indicator in the panicle (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*).

Aiming to better characterize these issues, pictures of the seed bulk threshed from the panicle were registered and transformed into a single color. For that, six base images were taken in a dark room, with controlled light, using a bounced Canon 430 ex II Speedlight (1/1), as source. White balance was determined by the white card technique, being fixed in 5,200-Kelvin color temperature for all pictures. A 50mm 1.8 stm Canon lenses mounted reversed in a Canon 60D body was used. Same focal distance for all pictures was ever kept as well. Camera was set in 1/40 shutter speed, ISO 1,000, and lens *f* stop to 7.1. Each image was generated with 18-megapixel resolution (5,184 x 3,456 pixels), and reduced then to 1000 x 667 pixels for image processing. The reduced images were submitted to filter Median (500*px.* radius) and the mixed as 1/6 opacity in a single image. Color homogenization was completed reducing the image to 1x1 pixel side, and then resizing it to 500x500 pixels. For each color, it was obtained the universal HEX color code, and result is presented in Figure 80. As observable, no difference enough is presented in the color of the seed bulk according to the panicle ages, which make unfeasible the use of this parameter in the field.

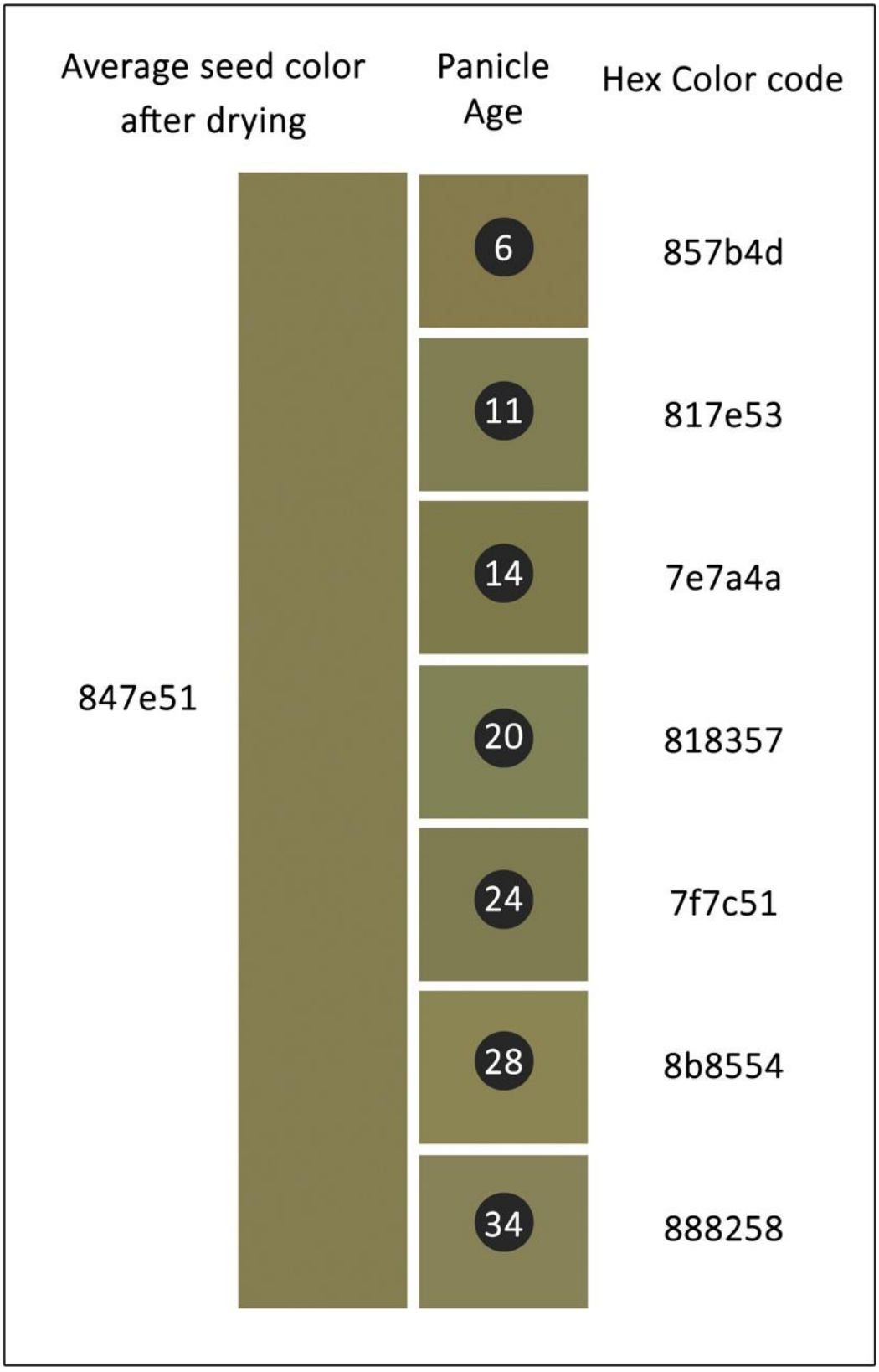

Figure 80. Alexander grass (*Brachiaria syn. Urochloa plantaginea*) dry seed color in relation to panicle age (days after panicle emergence). Native colors can be picked with respective code at <http://www.color-hex.com/>.

4. PROCESSING

Presenting a pure and clean propagative material is fundamental for the attendance of quality parameters and the support of the seed marketing. Especially for international market, consumers can demand purity up to 95% (PREVIERO et al., 1998), making the cleaning procedure vital for the delivering of a suitable product. In Brazil, unfortunately, these issues are not evenly taken as primary in the choosing of a forage seed – Almeida et al. (2007) reports that until 60% of the lots do not attend the minimum quality rates of official regulamentation.

Above that, cleaning is possible and efficient when used. Conventional machinery used to clean grains has been adapted to clean *Brachiaria* seed and present good results (SANTOS FILHO, 1996). It naturally creates some seed lost, which however is compensated by gains in the product price and in the better performance in sowing and establishment of the pasture.

For a ground swept seed lot (As the assumed for Alexander grass), pre cleaning can be performed using a sieve machine which, is in some cases, is mobile and can be taken to the field. It helps to separate most of gross impurities facilitating the transport and the further fine cleaning in the processing unit. Still, in the case of initial or smallholder production manual sieving and blowing in natural wind can be used with good results as well (Figure 81). A set of sieves with different sizes can separate most impurities, presenting so a seed lot just with little clods and pieces of dry leaves and stems.

Fine cleaning, however, will be more dependent on machinery. This began with the passage of the seed in more precise equipment with fan and sieves in the processing unit. Other auxiliary mechanisms as those that shred clods are valuable. Finally, separation is achieved with the use of gravity separators, a machine that blows an air column upward the seed in a shaking table, making the impurities and different seed classes fell into gutters. In the case of forage crops, gravity separators usually need more maintenance than for grain crops, since with

the high amount of dust that comes from the field, more damages in mechanisms as bearings can occur (ANDRADE, 2001). For research purposes as in this work a Laboratory blower will deliver very acceptable cleaning, allowing also separating the seed according to the TSW (Figure 82).

Figure 81. (A) Sieving of gross material provenient from the ground recover of Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds (Figure 78); **(B)** Detail of the bigger portion of the material as dry leaves and sections of stem retained in the sieve, smaller parts as the seed and clod passed through (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*)


A


B


C

Figure 82. Alexander grass seeds (*Brachiaria syn. Urochloa plantaginea*) **(A;D)** Gross material, provenient from ground recovery containing seeds, dry leaves, stems, roots and clods; **(B)** Same material after pre-cleaning, with sieving and fan blowing (Figure 81) **(C;E)** Material after cleaning in Laboratory South Dakota blower (*Picture source: J.R. Oliveira – OLIVEIRA, 2017*)

The use of ground sweeping in most cases dispense the drying of the seed, since the period that the seed is kept on the ground diminishes the water content to safe levels (LOCH & FERGUSSON, 1999; HOPKINSON et al., 1996). If it is chosen the combine harvest, however, drying is necessary. Koronivia grass in Brazil, for example, is harvested at the peak of the wet season, and with large areas to be harvested in a short time producers tend to dry the seed quickly or let it on truck body or piles covered from the rain. This summed to the high natural temperatures of the tropics often results in disastrous effects (LOCH et al., 2004; HOPKINSON et al., 1996).

For large amount of seeds industrial driers can be used – the major attention should be given to keeping temperatures around 35 to 40°C or less, avoiding overheating and loss of viability (HOPKINSON & ENGLISH, 1985). For smallholder or initial production, a good option could be the canvas drying, which consists essentially to spread the seed in a small layer over a clean surface and let the natural ventilation and heat to reduce the moisture content. In these cases, the major points of success are to mobilize the bulk recurrently and avoid canvas as tarmac or plastic that can promote overheating (NERY et al., 2012; ESGPIP, 2010; SOUZA, 2001; LOCH & FERGUSSON, 1999).

After the raw processing, other techniques of enhancement can be performed. *Brachiaria* seed coating, for example, has been common in several companies of central Brazil. This practice incrusts the seed with layers of chemicals as insecticides, fungicides, fertilizers, etc. to improve the performance (FERREIRA et al., 2015; BENNET, 2007a). Still, it gives the seed a rounder form and smooth finishing, helping in the physics of the sowing by the better flowing in the mechanical seeders (SANTOS, 2009). This could be a solution to the problem of Alexander grass seeds not fitting properly in the sowing disks (Figure 68). Yet, considering that the seed coating increases the seed size and weight it is very important to adjust sowing rates, as the values often reach double of untreated seeds (ARGEL, 2007). Further the potentialities this technique have to be careful

designed, since with the wide range of possible substances some authors report reductions in the seed performance by limitations mainly in the seed water intake capacity (FERREIRA et al., 2015; SANTOS et al., 2010).

As a last step, attention should be given to the storage. *Brachiaria* seeds are orthodox: their rates of deterioration rise with increases in storage temperature and moisture content. Usually they are grown, used, and stored in warm, humid climates and readily regain moisture from the atmosphere, making these seeds prone to rapid loses in physiological quality (HARE & HORNE, 2004; HOPKINSON et al., 1996). Techniques can be used to mitigate this. While details depend on the practicalities of a given system, attention must first be paid to moisture content, even before temperature, as it is the more critical of the two variables over the normal range of variation, and the cheaper to control (HOPKINSON et al., 1996). However, if opted for the sweeping harvest, shelf life of the seed will be already longer (SANTOS FILHO, 1996). Option for cold or environment temperature storage depend on the time that the seed is intended to be used (*See Chapter 3 – pg.*167).

New packaging could also be considered. In Brazil seeds are usually sold in bags of 20 Kg of seeds, which is a great amount assuming the size and the weight of the pasture seeds. Experiences as the presented in Kenya for smallholder production where bags of 1 Kg of seed were available (CIAT, 1982), could be a good strategy to promote the initial spreading of the Alexander grass as a pasture until the farmer know its advantages and look for the establishment of bigger areas.

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ANNEX

Seed borne pathogens associated with Alexander grass seeds

The concerns on pests attacking warm forage grasses appeared after the 80s, when these plants started a booming expansion through the tropical world. With the great populations of spittlebugs that decimated Brazilian Signal grass pastures (VALERIO et al., 1996) however, the major search from solutions got focused just in the insects, and diseases were forgotten in the early years.

The constant tissue renovation of grazed pastures makes colonization a hard task for the fungi. Nonetheless, extensive monocultures can threaten the environment balance, endorsing the appearance of diseases (VECHIATO et al., 2010; VERZGNASSI & FERNANDES, 2001). In seed crops, fungal diseases potentially reduce quality and commercial value of the seeds, being able to kill it even before the germination (MARCHI et al., 2010a; LASCA et al., 2004). Still, seeds are an important vehicle of pathogens dissemination, supporting the spreading of fungal species that are potentially harmful to the adult plant (LOCH & FERGUSSON, 1999).

According to the CIAT (1982), in Caribbean's early 80s diseases control already was one of the main factors of success in Signal grass crops. At the same time, Pearl millet and Bermuda grass have been suffering tough fungal attacks in the east Africa (Kenya) and *Fusarium, Sphacelotheca* and *Tilletia* caused serious damage to seed crops of Rhodes grass (LOCH & FERGUSSON, 1999). In Mato Grosso (central Brazil state), the preference for forage seed harvest by ground sweeping occasionally endorse nematodes dissemination. As these seed lots usually contains a good fraction of inert material – including clods, dust and small rocks – microorganisms or fungi spores, can be easily taken with the seed (MARCHI et al., 2010b).

From the ecologic point of view, these agents are thus divided into two main groups: the phytopathogenic and the storage microorganisms. Fungi comprise the largest number of species associated, followed by bacteria, viruses and nematodes (SANTOS et al., 2014). Also, grasses that are vegetative propagated or present apomictic reproduction as several Brachiariagrasses usually present a very narrow genotypic range, which can make the incidence of the diseases increase easily in the population (CIAT, 1982). In the case of Alexander grass the sexual behavior can help to improve the richness of variability of the population, regardless as a cleistogamic plant the local variability will be narrow as well (*See Chapter 1 – pg.94*).

Data on causative agents are poor. Despite, fungal attack is particularly noticeable in the seed testing of most species (GOBIOUS et al., 2001). In the case of the trials developed in this work, it was also a common situation, and so, some associated pathogens with Alexander grass seeds were identified. Fractions of the pathogens mycelia, collected directly from the germination test, after the 21-days incubation, were multiplied using PDA culture medium in petri dishes, in a growing chamber set to promote a 25°C environment. The resulting culture was then observed in stereomicroscopic looking to identify the species. Some are presented:

- ***Rhizopus spp.*** (Figure 83) – According to Marchi et al. (2010ab) this is one of the commonest storage species encountered in *Brachiaria* and *Panicum*, being present until in 95% of the seed lots. In Alexander grass seeds it seems to be not so aggressive since, besides the spreading in the paper substrate, the contaminated seedlings developed well (storage fungi usually are less harmful to the canopy of the plant);

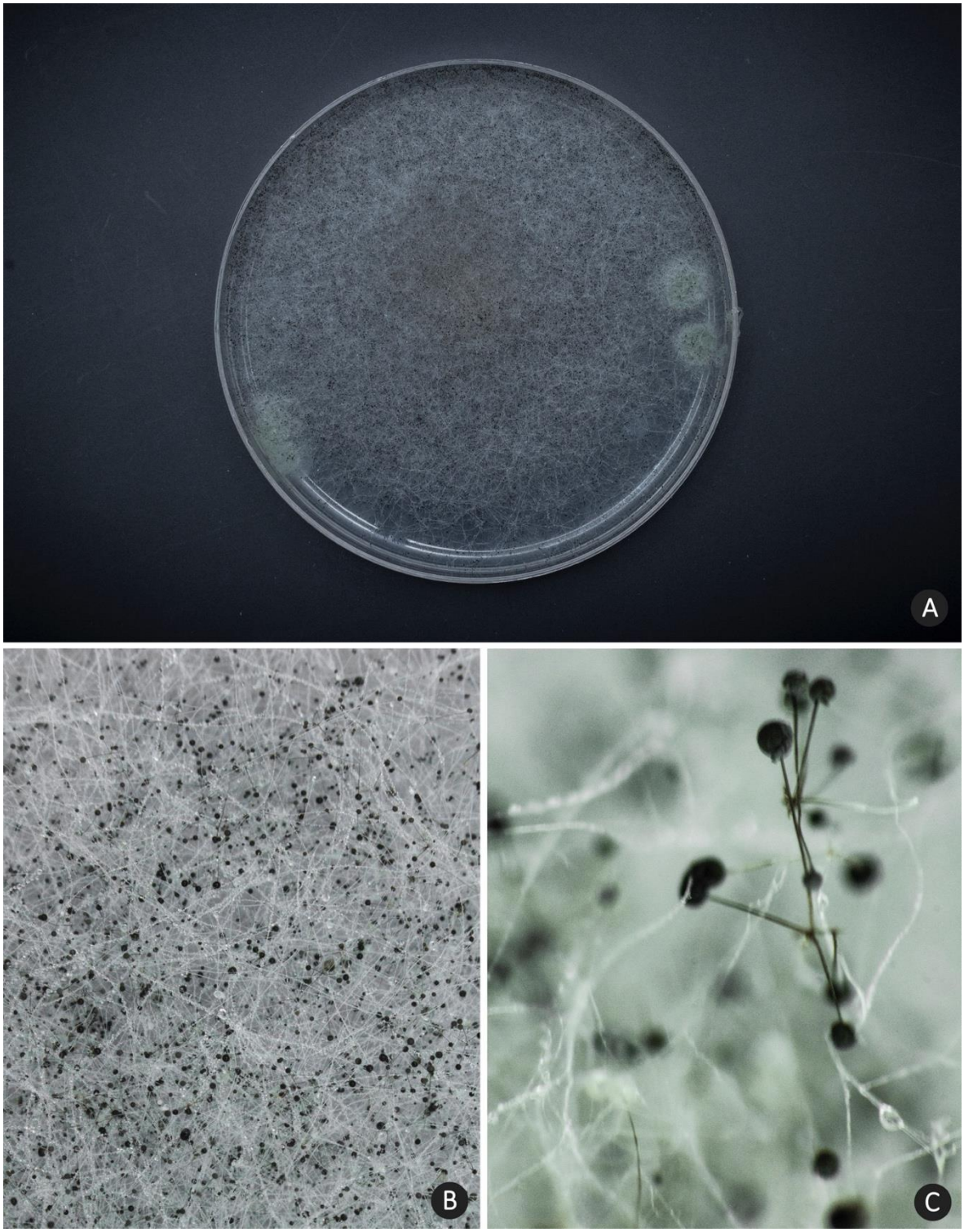

Figure 83. *Rhizopus* spp. from Alexander grass seeds (*Brachiaria syn. Urochloa plantaginea*). (A) Petry dish with colony; (B) Macro picture of Spores, and (C) Steromicroscopical image of *Rhizopus* spp. spores (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

- ***Aspergillus*** **spp.** (Figure 84) – Found just in non-germinated seeds, especially in those which present faint filling. This statement matches with the saprophytic habit of the fungus (MARCHI et al., 2010). Kremer (1993) suggest that microorganisms may prefer seeds already dead. Besides there are no studies that strictly distinguish attack before or after the death, it is possible that microorganisms prefer to colonize decayed seeds due the increased nutrient exudation from damaged membranes and the reduced antibiotic or enzymatic activity (HARMAN & STASZ, 1986). *Aspergillus spp.* was reported by LOCH et al. (2004) as present in warm season grasses seeds especially in high humidity environments. It is reported by Marchi et al. (2010a) also as one of the commonest pathogens in *Brachiaria*, and found in *Panicum* and *Stylosantes* too.

- ***Penicillium*** **spp.** (Figure 85) – Present in the Alexander grass seeds with behavior very similar to *Aspergillus.* It was also reported by Marchi (2011) in *Brachiaria* seeds and Loch et al. (2004) in humid environments. Low aggressiveness was observed both for *Penicillium* and *Aspergillus*, which accords to the exposed by Bahry (2007), that saprophytic fungi as those can cause no harm to the seeds, depending on the levels it is present. Actually, the presence of this fungus in germinated seeds was not observed.

- ***Curvularia*** **spp.** (Figure 86) – It was the pathogen most frequently found in Alexander grass seeds, and reported as one of the major fungus of *Brachiaria* and *Panicum* seeds (MALLMAN et al., 2013; MARCHI et al., 2011; LASCA et al., 2004; TORRES & LENNE, 1998), presenting a phytopathogenic behavior (MARCHI et al., 2010a) and being very aggressive in the colonization. The rapid development made it quickly spread in the germination paper, contaminating even the closer seedling in the treatments that favored its development. According to Santos et al (2014), it can be transmitted to the plant, but for Alexander grass no symptoms were observed in the canopy.

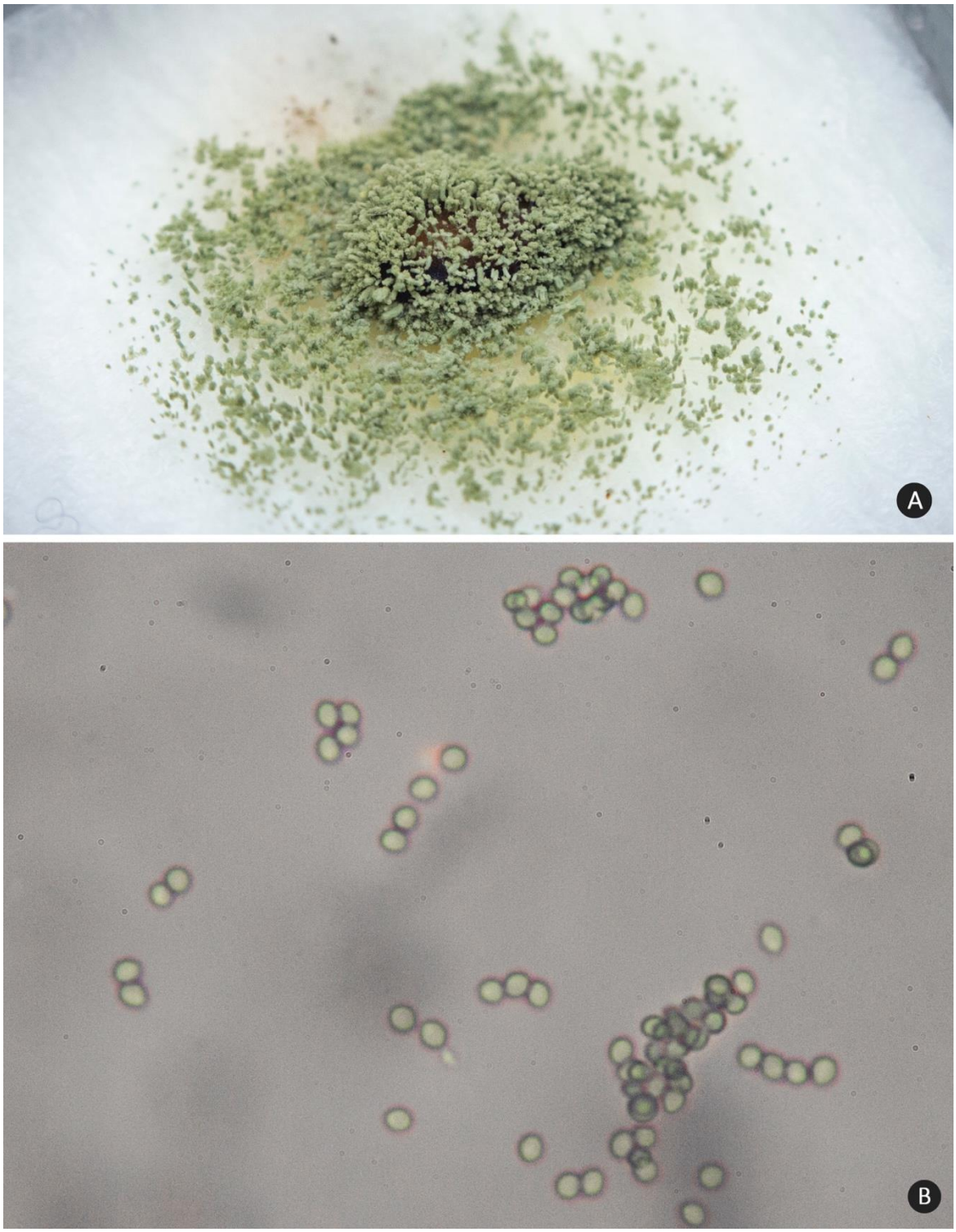

Figure 84. *Aspergillus* spp. from Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds. **(A)** Micelial development in Alexander grass seeds incubated in paper substrate, and; **(B)** Steromicroscopical picture of spores (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

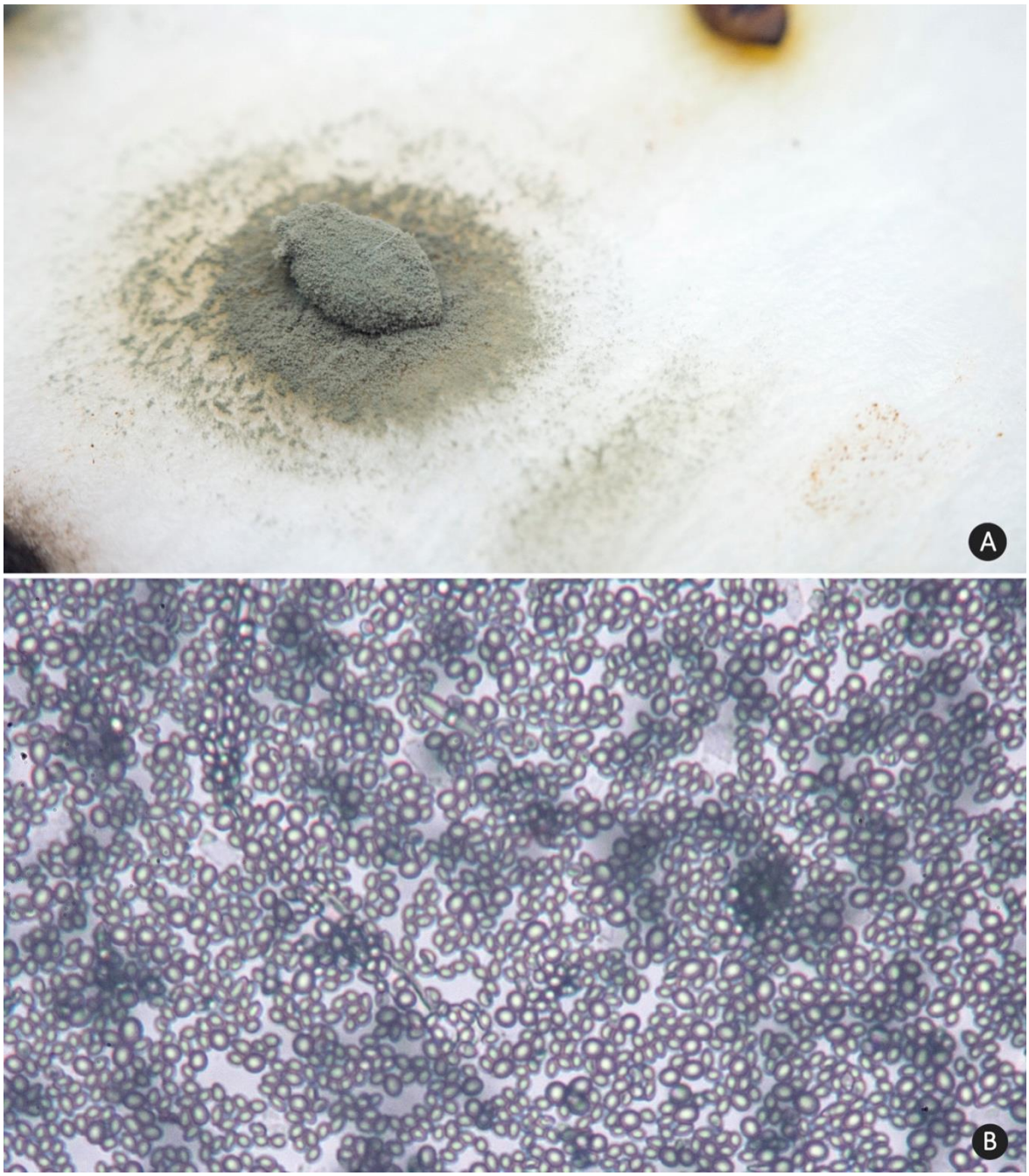

Figure 85. *Penicillium* spp. from Alexander grass (*Brachiaria plantaginea* sn. *Urochloa*) seeds. **(A)** Micelial development in Alexander grass seeds incubated on paper substrate, and; **(B)** Steromicroscopical picture of spores (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

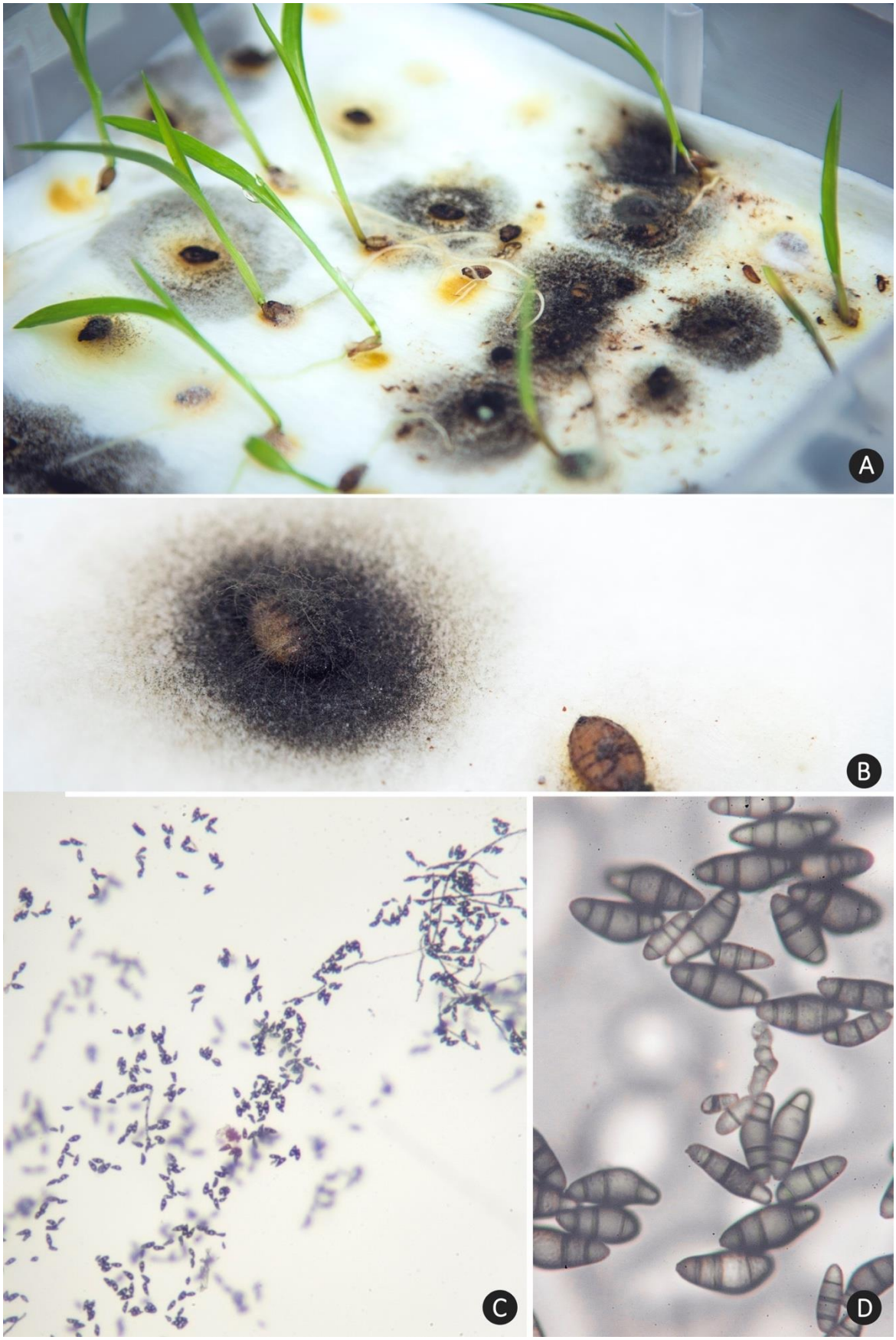
A
B
C
D

Figure 86. *Curvularia* spp. from Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds. This fungus species was the most frequently encountered in this grass seeds. **(A)** Micelial development in Alexander grass seeds incubated in paper substrate; **(B)** Detail of micelial development in a seed; **(C;D)** Steromicroscopical picture of spores, and; **(E)** *Curvularia* spp. micelia spreading from an Alexander grass seedling (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

- ***Bipolaris*** **spp.** (Figure 87) – One of the less frequent fungi that attacked Alexander grass seeds, nonetheless, it was perhaps the most aggressive, presenting in this case damages even in the canopy of the seedling. Early protruded shoots could even be killed by its attack. Known by the post of major fungus in Guinea grass pastures it is the causative agent of leaf spot. Further *Panicum*, is broadly reported in Brachiariagrasses (MALLMAN et al., 2013; MARCHI et al., 2011; MARCHI et al., 2010a; VECHIATO, 2010; MACERO & BARRETO, 2006), found in association with Signal grass in coffee inter-rows (NECHET et al., 2012) and observed in 88% of Palisade grass cv. Xaraés seed lots by Marchi et al. (2010a). The species *Bipolaris cynodontis,* in particular, was found attacking Bermuda grass (MENDES *et al.*, 1998 *apud* MACEDO & BARRETO, 2006). For this trial the species was not determined, but Manamgoda et al. (2014) reports Alexander grass as a host of *Bipolaris sorokiniana* (Despite this species is commonly found in wheat, a winter grass).

- ***Fusarium*** **spp.** (Figure 88) – As the related for *Bipolaris*, *Fusarim* was rarely observed but very aggressive. In this trial no seed contaminated with *Fusarium* expressed development, which possibly means that the fungus is fatal for the grass. As no canopy developed, it was not possible to state if symptoms occur or not in the seedling. The pathogen is broadly reported in Brachiariagrasses and Guinea grass (NERY et al., 2012; MARCHI et al., 2011; MARCHI et al., 2010a; LASCA et al 2004; QUADROS et al., 1994; TORRES & LENNE, 1988). Kremer (1993), studying soil seed banks, generally observed that *Fusarium* interacts with the occurrence of insect attacks, as with both pests weed seeds viability reduces to less than 2%.


A
B
C

Figure 87. *Bipolaris* spp. from Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds. **(A)** Micelial development in Alexander grass seeds incubated in paper substrate; **(B)** Detail of micelial development in a Alexander grass seed; **(C)** In the left, Micelial development in Alexander grass seeds incubated in paper substrate. The fungus presented an waterish aspect in comparison to *Curvularia* spp.; **(D)** Petry Dish with *Bipolaris* colony, and; **(E)** Stereomicroscopical image of *Bipolaris spp.* spores (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*)

Figure 88. *Fusarium* spp. from Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds. **(A)** Petry dish F*usarium* spp. colony; **(B;C)** Detail of micelial development in a Alexander grass seed, and; **(D)** *Fusarium spp.* and *Penicillium* spp. incidence in Alexander grass seed (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

One of the major problems involving phytopathology of Brachiariagrasses in Brazil is the ergot *Claviceps sulcata,* which is the most popular disease of warm forage seed production. The pathogen colonizes the flower ovary and causes the symptom known as “honey-dew”, in which sticky golden drops with further development of a hyaline mycelium appear (NERY et al., 2012; LIMA, 2012; SOUZA, 2001; HOPKINSON et al, 1996). As the infection evolves, it takes all the panicle making the harvest impracticable (VERZIGNASSI& FERNANDES, 2001). Neither symptoms in the panicle, nor presence in the seeds were observed in Alexander grass, it is possible that the pathogen develops just in regions close the equator. Other pathogens also frequently reported in association with Brachiariagrasses as *Ustilago operta* (NERY et al., 2012) and *Phoma* (MALLAMAN et al., 2013; MARCHI et al 2011; LASCA et al., 2004; TORRES & LENNE, 1988) were not found in Alexander grass.

According to the proposed by Kremer (1993) in a nonspecific approach, the hypotheses on the acquiring of the pathogens in Alexander grass seed guides to the infection prior the dispersal. It is supported and better explained if the seed formation is considered – the sequence of development is embryo, endosperm and lastly the coat (which is the protective structure). In addition, partially formed seeds are more prone to develop fungus. As the seed is filled in the maturation, the endosperm will make internal pressure within the spikelet, a determinant process to make the socketing of the palea and the lemma, overlapping its parts and, consequently, sealing the seed. In immature or faintly filled seeds this pressure is not enough to promote the tight enclosure, leaving so some doors to the microorganism entrance (GOBIOUS et al., 2001; HOPKINSON et al., 1996). The fungus settles inside the glumes and manifest then in the presence of humidity (GARCIA & PINEDA, 2000).

Other influent that was closely related to the occurrence of fungus in the Alexander grass germination tests was acid scarification (Figure 89). Besides sometimes efficient in raising germination, acid scarification degrades the seed wrap which strongly favors fungal invasion (BRITES et al., 2011; CONTRERAS, 2007; GARCIA & CICERO, 1992). Voll et al (1996a), evaluating Alexander grass, also observed this situation, and reported a compensatory effect in which an increase in germination promoted by the acid was counterpoised by physiologic degeneration and fungal development. Eira et al. (1983), evaluating Gamba grass, reports that the treatment with hydrogen peroxide, further deleterious to the physiologic state of the seed, also endorsed strong fungal attack, since in some cases the mycelia take all the gerbox bottom surface.

Usually the authors that evaluate the acid treatment in forage seeds assess just the germination in artificial conditions, and consider as a better result simply the increases in protrusion of the seedling shoot. Stills, importance should be given to the performance of these treated seeds in the field, as losses in the integrity and the fungal endorsement can easily constrain the pasture establishment.

Controversially, according to Santos Filho (1996), Brazilian external market usually demands acid scarification as treatment looking particularly to free the product of quarantine in some destination countries. Considering yet that the seed will have to be freighted and possibly stored, this treatment can reduce the shelf life and support even stronger physiological degradation. This is, thus, an obsolete approach as nowadays a vast range fungicide and chemical products are available, with a less invasive action. These treatments protect the seed from fungus and improve its overall performance as seedling in the early development stages.

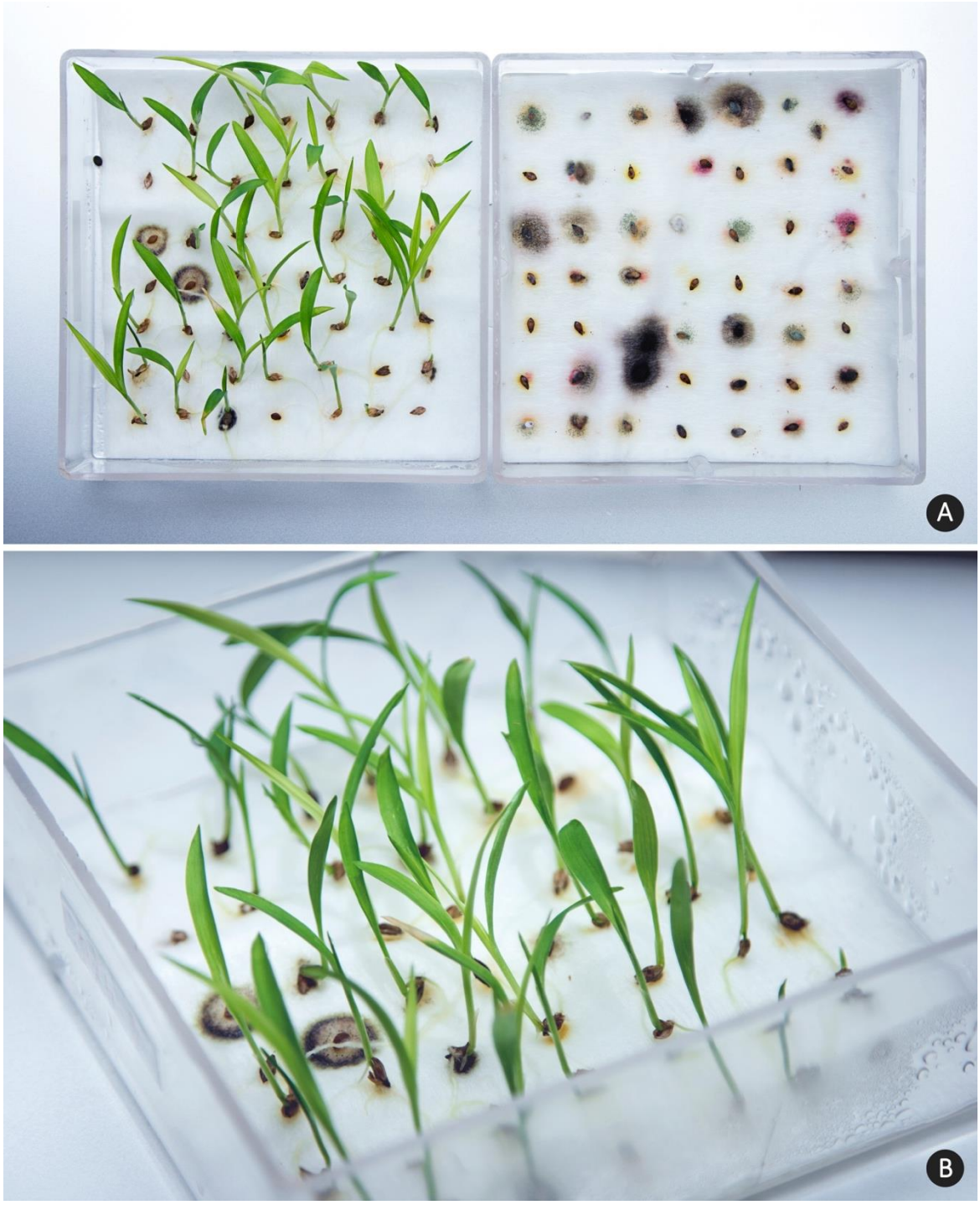

Figure 89. **(A)** Comparison of Germination after 14 days incubation, with 6 months stored Alexander grass (*Brachiaria syn. Urochloa plantaginea*) seeds harvested from the ground, on the left intact seed with no chemical treatment, and on the right 10 minutes H_2SO_4 scarification. Besides the occurrence of *Bipolaris* spp. in two seeds and *Curvularia* spp. in other, generally the left gerbox is clean from fungal atack. Still, in the treatment with chemical scarification fungus of various species atacked the non germinated seeds; **(B)** Detail of treatment with intact seeds, vigorous seedling growing, and sanity of the seedling leaves (*Picture Source: J.R. Oliveira – OLIVEIRA, 2017*).

Lasca et al (2004) evaluated seed treating with fungicides over Signal grass and Palisade grass seeds (*i.e.* carboxin, thiran, thiabendazole, quintozene, captan, difenoconazole) and obtained expressively reductions in the fungus incidence with several associations. Dias & Toledo (1993), evaluating Signal grass, also found positive effects of fungicides (*i.e.* captan, thiram, thiabendazole and iprodione), and its associations. Santos et al. (2010) also reports the same results evaluating Palisade grass. Fungicides for sward spraying (Tebuconazole, Triadimenol, Pyraclostrobin + Epoxiconazole, Trifloxistrobina + ciproconazole, azoxistrobin + ciproconazole), presented partial control of the fungus in forage seeds, being possible to be used as an auxiliary treatment (FERNANDES et al., 2010). These treatments, thus, are good guidelines to the the Alexander grass seeds looking to control the seed borne pathogens.

Besides the viability of the curative treatments, the overall management of the seed can strongly interact with the action of the pathogens in the seed lot. One of the main points is the proper cleaning, since impurities can be a rich host for pathogens depending on the causative agent species (LIMA, 2012). Storage conditions and proper drying itself can reduce the inoculum (SANTOS, 2009; LOCH et al., 2004). On the field, avoiding managements that can induce the plant to lodge are worthy to reduce the humidity in the sward, and so the fungal development (ANDRADE et al., 1983)

Beyond the lack of scientific information, Brazil lacks also official regulamentation on forage seed sanity. The Normative Instruction n. 9 of the Ministry of Agriculture Livestock and Supply (06/2005), approves rules for the production, commercialization and use of these seeds, however, it does not include sanity regulations (SANTOS et al., 2014). In the end, the delivery of a good seed quality – not just for sanity, but also for the overall indexes – is promoted by a conscious seed production sector, concerned in deliver a reliable and effective input to the consumer.

APPENDIX

Daylength requirements for flowering of some C_4 grasses – determined in controlled environmental studies or inferred from field behavior

Species		Cultivars	Daylength response	Sources
Common name	Scientific name			
Gambagrass	*Andropogon gayanus* Kunth		(SD)	Tompsett (1976)
Narrowleaf carpetgrass	*Axonopus fissifolius* (Raddi) Kuhlm. (syn. *Axonopus affinis* Chase)		(LD)	Knight and Bennett (1953)
Broadleaf carpetgrass	*Axonopus compressus* (Sw.) P. Beauv.		MD	Nada (1980)
Forest bluestem	*Bothriochloa bladhii* (Retz.) S.T. Blake	Swann	SD	Loch et al. (1999)†
Creeping bluestem	*Bothriochloa insculpta* (Hochst. *ex* A. Rich.) A. Camus	Bisset, Hatch	SD	Loch (1980)†
Indian bluestem	*Bothriochloa pertusa* (L.) A. Camus	Dawson, Emerald Downs, Keppel, Medway	SD	Loch et al. (1999)†
		Bowen	I	Loch (unpublished data, 1989–1991)†
Paragrass	*Brachiaria mutica* (Forssk.) Stapf in Prain		SD	Wang (1961), Dirven et al. (1979), Nada (1980)
Ruzigrass	*Brachiaria ruziziensis* Germain. & Evrard		(SD)	Dirven et al. (1979)
Rhodesgrass	*Chloris gayana* Kunth	Callide, Masaba (tetraploids)	(SD)	Dirven et al. (1979), Loch (1983)
		Katambora, Pioneer (diploids)	I	Nada (1980), Loch (1983)
		Unspecified	I	Wang (1961)
Bermudagrass	*Cynodon dactylon* (L.) Pers.		LD	Mes (1958)
			(LD)	Nada (1980)
Angleton bluestem	*Dichanthium aristatum* (Poir.) C.E. Hubb.	South African ecotype	SD?	Knox and Heslop-Harrison (1963)
		Alabang X	I	Wang (1961)
			SD	Nada (1980)
Digitgrass	*Digitaria eriantha* Steud.		I	Mes (1956)
Weeping lovegrass	*Eragrostis curvula* (Schrad.) Nees	Ermelo	I	Leigh (1960)
		Unspecified	SD	Tainton (1969)
Coolataigrass	*Hyparrhenia hirta* (L.) Stapf		I, (SD)	McWilliam et al. (1970)
Jaraguagrass	*Hyparrhenia rufa* (Nees) Stapf		SD	Agreda and Cuany (1962), Nada (1980)
Molassesgrass	*Melinis minutiflora* P. Beauv.		SD	Loch (1980), Ison and Hopkinson (1985)†‡
Blue panic	*Panicum antidotale* Retz.		(SD)	Wang (1961)
Kleingrass/makarikarigrass	*Panicum coloratum* L.	Burnett	(LD)?	Pritchard and De Lacy (1974)
		Solai	I	Nada (1980)
Guineagrass/panic	*Panicum maximum* Jacq.	Unspecified	SD	Wang (1961)
		Colonião	SD	Felippe (1978)
		Gatton	(SD)	Nada (1980)
Dallisgrass	*Paspalum dilatatum* Poir.		LD	Knight and Bennett (1953); Knight (1955); Tainton (1969)
			I	Tainton (1969); Nada (1980)
Brunswickgrass	*Paspalum nicorae* Parodi		LD	Loch et al. (1999)†
Bahiagrass	*Paspalum notatum* Flügge	Argentine, Pensacola	LD	Knight and Bennett (1953); Nada (1980)
Plicatulum	*Paspalum plicatulum* Michx.	Rodds Bay	SD	Chadhokar and Humphreys (1974)
		Bryan, Hartley	SD	Loch (1980)†
		Unspecified	SD	Nada (1980)
Buffelgrass	*Pennisetum ciliare* (L.) Link (syn. *Cenchrus ciliaris* L.)		MD	Evers et al. (1969), Nada (1980)
Kikuyugrass	*Pennisetum clandestinum* Hochst. *ex* Chiov.		I	Nada (1980)
Setaria	*Setaria sphacelata* (Schumach.) Stapf & C.E. Hubb. *ex* Chipp.	Nandi	(LD)	Boyce and Silsbury (1969), Boyce (1970), Nada (1980)
Sabigrass	*Urochloa mosambicensis* (Hack.) Dandy		I?	Nada (1980)

† Inferred from field behavior.
‡ cf. no response by *Melinis minutiflora* to daylength in controlled environment studies by Wang (1961) and Nada (1980).

Categories: SD – qualitative short-day; (SD) – quantitative short day; MD – intermediate day; I – Insensitive to experimental daylengths; LD qualitative long day, and; (LD) quantitative long day; (?) indicates responses not conclusively demonstrated.

Main Source:

MOSER, L.E.; BURSON, B.; SOLLENBERGER, L.E. Warm-Season (C_4) Grass Overview. In: MOSER, L.E.; BURSON, B.L.; SOLLENBERGER, L.E. (Org.). **Warm season (C_4) grasses.** Madison: ASA, CSSA and SSSA Publishers, 2004, p. 1-14.

References within the table found in main source.