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Seed production of *Urochloa plantaginea* (Link) R. Webster in pure stands and in maize crop

Produção de sementes de *Urochloa plantaginea* (Link) R. Webster em populações exclusivas e na cultura do milho

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ABSTRACT: *Urochloa plantaginea* is an important weed and forage crop in Brazil. To subsidize management strategies for this plant, we studied its seed production in pure stands and infesting maize. The experiments were conducted in Londrina, Brazil, in two growing seasons, on a Red Latosol, under a Cfa climate. Both experiments had a completely randomized design, with four replications. In the experiment of *U. plantaginea* infesting maize treatments had weed-control periods of zero, 20 (control), 40, and 60 days. In the experiment with pure stands treatments had four emergence dates. When infesting maize *U. plantaginea* seed production ranged from 0.5 to 281.0 kg ha^{-1} and was enough to perpetuate weed infestation even when the cereal yield was not affected. This indicates that the preservation of crop yield is not enough as a criterium to measure success in weed control. Seed production of pure *Urochloa* stands ranged from 247.0 and 1905.7 kg ha^{-1} and it was affected by the interaction of year and emergence date and tended to decrease as emergence was delayed. Implications of *U. plantaginea* seed production on its use as a forage crop and its control as a weed are discussed.

KEYWORDS: broad-leaf signal grass, alexander grass, weed seed production, ecological weed control.

RESUMO: O papuã é importante como uma planta invasora e forrageira no Brasil. Para subsidiar estratégias de seu manejo, estudamos sua produção de sementes em populações exclusivas e infestando milho. Os experimentos foram conduzidos em Londrina, Brasil, repetidos por dois anos, em um Latossolo Vermelho, sob clima Cfa. O delineamento foi inteiramente casualizado, com quatro tratamentos e quatro repetições. Infestando milho, os tratamentos foram períodos de zero, 20 (controle), 40, e 60 dias com controle de invasoras. Em população exclusiva, os tratamentos foram quatro datas de emergência. Infestando milho, a produção de sementes variou de 0,5 a 281,0 kg ha^{-1} e foi suficiente para perpetuar a infestação mesmo quando o rendimento do milho não foi afetado. Isso indica que a redução do rendimento da cultura é critério insuficiente para o sucesso no controle de invasoras. Em população exclusiva, a produção de sementes variou de 247,0 a 1905,7 kg ha^{-1}, foi afetada pela interação do ano com a data de emergência e tendeu a decrescer nas emergências mais tardias. São discutidas as implicações da produção de sementes de papuã sobre seu aproveitamento como forragem e seu controle como invasora.

PALAVRAS - CHAVE: produção de sementes de invasoras, controle ecológico de daninhas, capim marmelada, capim-doce.

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Introduction

The African grass *Urochloa plantaginea* (Link) R. Webster formerly named *Brachiaria plantaginea* (Link) Hitchc, is naturalized in several tropical and sub-tropical agroecosystems in the world. It is reported as a noxious weed in the US, Brazil, Paraguay, Argentine and other countries (AGRICULTURAL RESEARCH SERVICE, 2015). In Brazil, it is endemic in most agricultural regions, infesting an array of crops, from grains to vegetables and orchards. In a comprehensive study of the weed flora in the State of Parana, Brazil, Kranz et al. (2009) ranked this plant as the most important weed species for the state as a whole, particularly in maize, edible beans and soybeans.

But *U. plantaginea* is also a forage crop (OLIVEIRA NETO et al., 2013; ELOYET et al., 2014), along with several other species of the same genus. However, while other forage species of *Urochloa* are perennial, *U. plantaginea* has a life cycle of only four to six months. For forage utilization, it may be used either as a full season crop or as a relay crop, after maize is harvested for silage. In the latter case, the cohort *U. plantaginea* emerged under the maize canopy develops abundant forage soon after the cereal plants are removed for silage.

The biological reasons for the ubiquity of *U. plantaginea* in Brazilian agroecosystems lay on a set of traits. It uses the C4 photosynthetic pathway and has high phenological plasticity: depending on environmental conditions, a single plant can reproduce at the height of few centimeters, with a few narrow leaves, or grow taller than a meter and cover more than a square meter. It achieves its maximum vigor under the hot and wet season of typical tropical climates. In such conditions, it develops a high suppressive effect on other weed species, tending to acquire complete dominance in the weed flora (VOLL et al., 1995). In addition, it produces seeds abundantly and the seeds can remain dormant for more than a decade (VOLL et al., 2001). In a long term study conducted by Skora Neto (2001), there still was a population of 2000 seedlings emerging per hectare, after 10 years of complete prevention of seed production.

However, in agroecosystems where *U. plantaginea* is used as forage, too intensive grazing is avoided so that enough seeds may be produced to replenish the soil seed bank. A low seed bank results in a delay in the use of the grass cover as pasture. Looking at this same aspect of rapid soil covering, Kranz (2014) opines that in the absence of *U. plantaginea*, the problem of soil erosion in the hilly agricultural landscapes of Southern Brazil would be worsened. Considering the necessity of reducing soil losses, *U. plantaginea* may be regarded as a beneficial cover crop species in the long run, even when it imposes an immediate and heavy toll to commercial crops as a noxious weed.

But either as a weed or as a beneficial plant, seed production of *U. plantaginea* is a critical management factor, be it to reduce or increase the population of this ubiquitous plant in Brazilian agroecosystems. Despite the crucial importance of seed production, there is no single report on it in the scientific literature worldwide. In order to fill this gap, we carried out a series of experiments to quantify seed production of *U. plantaginea* in the most usual agricultural conditions in which its growth takes place. In this paper, we report the quantification of seed production both as a sole crop emerging at different times in the summer crop growing season and as a weed infesting maize, and its consequences to agroecosystem management.

Materials and Methods

We conducted two experiments to assess the development and seed production of *U. plantaginea*. Experiment 1 was focused on the plant as a weed infesting a maize stand, and Experiment 2 addressed it as a pure stand simulating fallow land. Both experiments were repeated in the 2001-2002 and the 2002-2003 seasons.

Experiment 1 was arranged in a completely randomized design with four treatments and four replications. The treatments comprised four weed-control periods (0, 20, 40, and 60 days, counted from maize planting date), during which all weed plants were eliminated. After these periods weeds grew freely. Each plot measured 7.2 m x 4.0 m (eight 4 m long rows of maize, spaced 0.9 m). The experimental area for maize was the central 2 m segment of the two central rows (1.8 m x 2 m = 3.6 m^2). The inter-row space between the maize experimental rows (0.9 m x 2 m = 1.8 m^2) was the experimental area for *U. plantaginea*.

Experiment 2 was also arranged in a completely randomized design with four treatments and four replications, treatments being different emerging dates, simultaneous with the cohort infesting maize after each weed-free period. In order to achieve simultaneous emergence, weeds were controlled in Experiment 2 on the same dates as the corresponding maize plot in Experiment 1. Thus, there were four emergence dates spaced at 20-day intervals in the pure stands of *U. plantaginea*. Plot size and experimental area were the same as in Experiment 1.

Although the experiments were statistically independent, they were installed in adjacent fields, so as to permit an estimation of the order of magnitude of the effect of maize on *U. plantaginea* for each emerging date.

The experiments were conducted in two areas, one for each cropping season, both at the experimental farm of the Instituto Agronômico do Paraná (IAPAR) in Londrina, Brazil (23°21' 31" S, 51°09' 36" W, 585 m above sea level). The local soil is an Acrortox, classified as a dystroferric Red Latossol (EMPRESA BRASILEIRA DE PESQUISA AGROPECUARIA, 2006). The local climate is classified as "Cfa, with hot summers and mild winters and no defined dry season" (INSTITUTO AGRONOMICO DO PARANA, 2000).

The experimental areas had a history of high infestation with *U. plantaginea* and were left in fallow in the preceding summer to guarantee abundant seed in the soil seed bank for the experimental season. In both years, black oat (*Avena strigosa*) was planted in the winter preceding experimentation. Mulch levels at the time of maize planting were 4.2 Mg ha^{-1} in 2001-2002 and 4.6 Mg ha^{-1} in 2002-2003. In early October, the mature oat stand was rolled down. Open-pollinated maize IPR 114 was no-till planted on 9 November 2001 and on 8 November 2002, and fertilized with 300 kg ha^{-1} of 8-28-16 formulation (N-P_2O_5-K_2O). Weeds were controlled manually every five to ten days, the last operation on the last day of the corresponding treatment. In both seasons, the climate during the maize cycle was normal, totaling 896 mm of precipitation and averaging 24.0 °C of mean daily temperature in 2001-2002, and 808 mm and 24.2 °C in 2002-2003.

In Experiment 1, biomass and seed production of both maize and *U. plantaginea* were measured at maize harvest time on 5 April 2002, and on 31 March 2003. In Experiment 2, *U. plantaginea* biomass and seed production were determined when the plants were mature, which varied from simultaneous with maize in the earliest emerging treatments, up to 40 days later for the latest emergence dates. Biomass of both maize and *U. plantaginea* were assessed by cutting standing plants at the soil level, and drying the material to constant weight at 60 ºC.

Seed production of *U. plantaginea* was determined by brushing the seeds from the soil surface and cutting panicles from standing plants. The seeds were passed through an air-screen seed cleaner and subjected to manual selection, until samples reached at least 99% purity in weight. To assess the seed viability, 5 g of cleaned seeds of each treatment were used to make a composite seed sample, which was stored at 22 ºC for two months. Germination test was carried out in an alternating regime of 16 h at 20 ºC without light, and 8 h at 30 ºC with light. Seeds were considered viable if they germinated or remained firm when pressed with tweezers.

All data were subjected to ANOVA, using the general linear procedure in SAS (SAS INSTITUTE INC., 2006), and Tukey's Studentized Range (HSD) Test at P = 0.05. Regression analyses were conducted to explore the relationship between weed-control periods and *U. plantaginea* seed production.

Results and Discussion

As the most usual focus on *U. plantaginea* is like a weed it was first explored the results in these terms, and then in terms of its seed production as a forage crop. In both experiments *U. plantaginea* emerged from 8 to 12 days after the last control operation. Therefore, while interpreting the results, weed-free periods were around ten days longer than weed-control periods.

Effect of the weed-control period on maize and *U. plantaginea* biomass production and on maize grain yield - *U. plantaginea* experiment in the maize stands showed results of the two seasons very similar in terms of maize biomass and yield and weed biomass, with no interactions between years and treatments. In the treatment without any weed control after maize planting, maize biomass was substantially lower ($p< 0.0001$) than in those where weeds were controlled (Fig. 1). However, there was no difference between weed-control periods of 20, 40, and 60 days on biomass production of either maize or *U. plantaginea*. The effect on maize grain yield was similar to that on maize biomass (Fig. 1) and yield levels were within the usual range for maize without side-dressed N in the region.

The weed flora was dominated by *U. plantaginea*, which accounted for at least 98.6% of the weed biomass, followed by *Commelina benghalensis* L.. Biomass production of *U. plantaginea* was reduced as the weed-free period increased (Fig. 1), but the striking reduction of 84% occurred from 0 to 20 day weed-control periods. This abrupt reduction was attributed to the competitive edge gained by weed-free maize seedlings over later emerging weeds, a phenomenon that is commonly observed in studies of competition dynamics between annual crops and annual weeds (MOHLER, 2001).

The effects on both maize and the weed confirm the established knowledge in the region that, from the perspective of maize production, weeds have to be

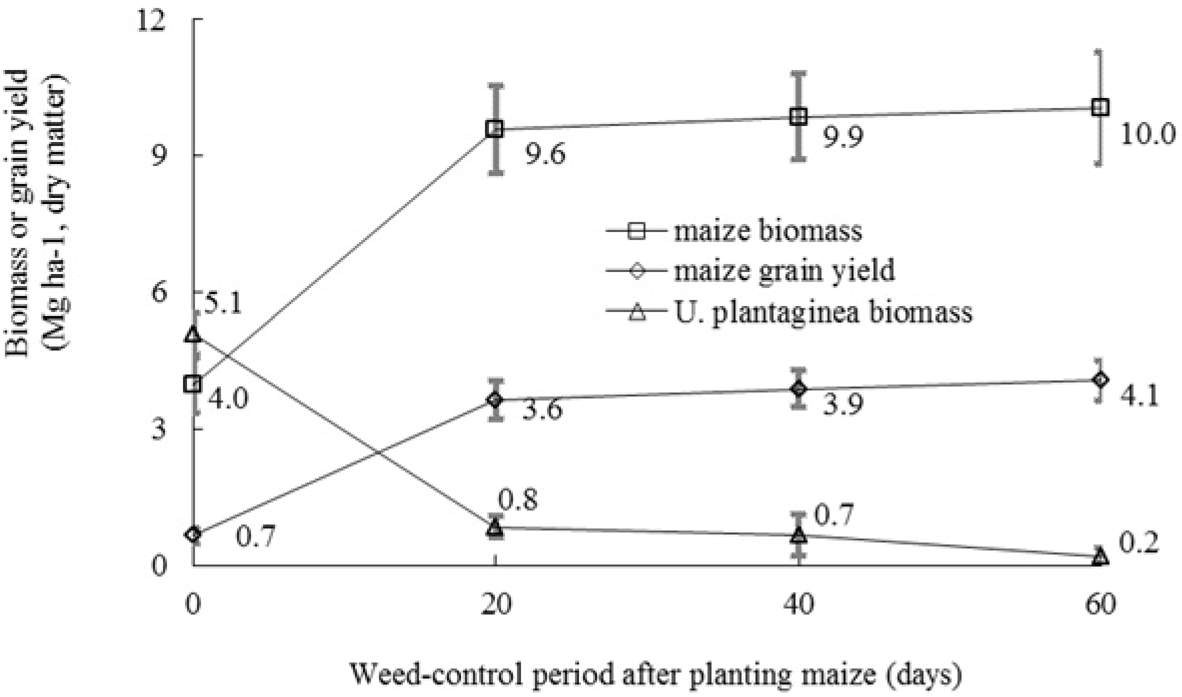

Figure 1. Effect of the weed-control period on maize biomass and grain yield, and on biomass of *U. plantaginea* as a weed. Londrina, 2001-2002 and 2002-2003 seasons. Points are means of eight experimental units. Tukey's Studentized LSD values at p= 5% are 1.2 for maize biomass, 0.6 for maize yield and 0.6 for *U. plantaginea* biomass.

effectively suppressed during at least the first month of the crop cycle. In the more specific condition of no-till maize planted in black oat mulch, the impact of non-controlled *U. plantaginea* on crop yield in our experiments was very similar to that obtained by Spader & Vidal (2000) in Eldorado do Sul, Brazil. In our experiment, maize yield was reduced by 82% when weeds were not controlled at all, while Spader & Vidal observed reductions of around 80% with *U. plantaginea* densities at or above 100 seedlings m^{-2}.

However, maize grain yields in Spader & Vidal's (2000) study ranged from 2 to 10 Mg ha^{-1}, while it was harvested from 0.8 to 4.5 Mg ha^{-1}, on a 12% moisture basis. Although the hybrid maize cultivar may have contributed to higher yields in their study, we believe that the differences were mostly due to the higher fertilization rates they used, which amount was 600 kg ha^{-1}of 5-20-20 (N-P_2O_5-K_2O), plus 250 kg ha^{-1} of side-dressed N, compared with only 300 kg ha^{-1} of 8-28-16 (N-P_2O_5-K_2O) in our study.

Effect of the emergence date on *U. plantaginea* biomass production in pure stands - *U. plantaginea* dominated the flora emerging in pure weed stands, accounting for at least 98.3% of the total biomass. Such dominance was probably due to factors such as competitiveness, allelopathy and seed production and survival in the soil, as discussed by Voll et al. (1995), which contribute to the elimination of other species on areas colonized by *U. plantaginea*. The remaining 1.7% or less came from *Commelina benghalensis* L.

Biomass production of *U. plantaginea* (Fig. 2) was affected by the interaction of emergence date and season (p 0.0023). In the 2001-2002 season no consistent trend between emergence date and plant biomass was observed (Fig. 2). In the 2002-2003 season, however, *U. plantaginea* biomass production decreased linearly at a rate of 0.15 Mg ha^{-1} day^{-1} (r^2 = 0.95, p = 0.016) as the emergence was delayed from November 19th to January 18th.

Our initial expectation was that later emergence would reduce total biomass production, due to shorter vegetative periods. This indeed occurred in 2002-2003 season. However, in 2001-2002, the maximum biomass production of 9.6 Mg ha^{-1} was that of latest emergence date, January 17th. We attributed this unexpected behavior to more favorable rainfall experimented by that *U. plantaginea* cohort.

Seed production of *U. plantaginea* infesting maize - Seed production of *U. plantaginea* infesting maize (Table 1) was affected by the interaction of weed-free period

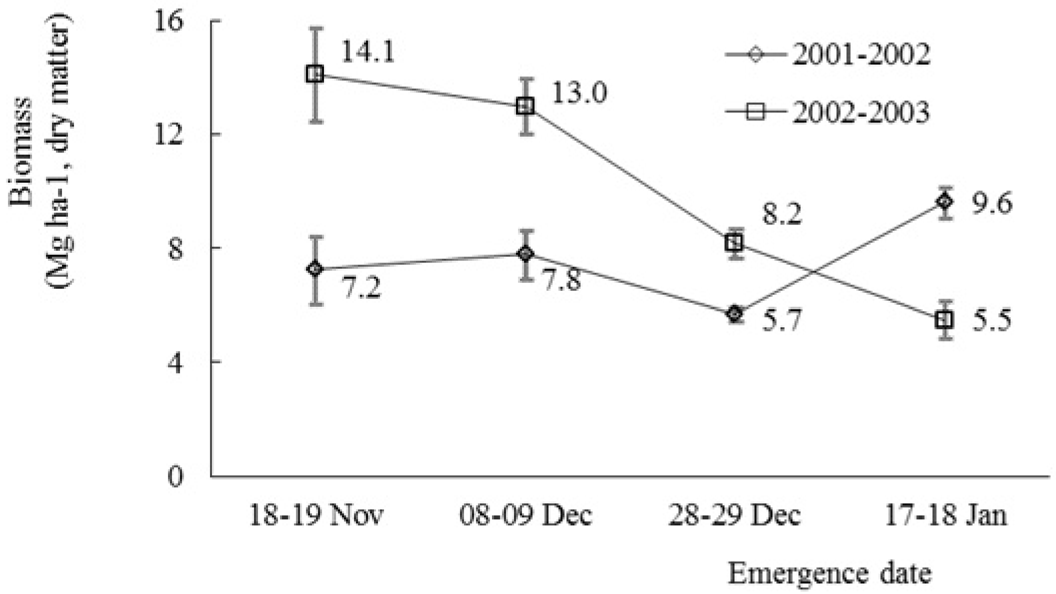

Figure 2. Emergence date of U. Plantaginea and its biomass production. Londrina, seasons 2001-2002 and 2002-2003. Points are means of four experimental units. Tukey's Studentized LSD values at p= 5% are 1.7 for 2001-2002, and 2.1 for 2002-2003.

Table 1. Seed production of the *U. plantaginea* emerging at different dates, either infesting maize or in a pure stand. Londrina, 2001-2002 and 2002-2003 seasons. In each column and for each season, values not followed by the same letter are different by Tukey Studentized test, at p=5%.

Growing season	**Emergence date**	**Seedproduction (kg ha^{-1})**		**Seedproduction (1000 seeds m^{-2})**	
		infestingmaize	**pure stand**	**infestingmaize**	**pure stand**
2001-02	Nov 19 2001	281.0 a	513.4 a	6.94 a	12.68 a
	Dec 09 2001	14.7 b	548.2 a	0.36 b	13.54 a
	Dec 29 2001	2.0 c	185.2 b	0.05 c	4.57 b
	Jan 18 2002	0.5 c	247.0 b	0.01 c	6.10 b
2002-03	Nov 18 2002	12.9 A	1905.7 A	0.32 A	47.05 A
	Dec 08 2002	2.0 B	595.7 B	0.05 B	14.71 B
	Dec 28 2002	1.7 B	663.3 B	0.04 B	16.38 B
	Jan 17 2003	1.2 B	359.7 C	0.03 B	8.88 C

and season (p 0.0023). Although in both seasons seed production decreased as the weed-control period increased, the actual quantities of seeds were higher in 2001-2002 (Table 1). The difference between seasons was especially great in the treatment without any weed control, seed production in 2001-2002 being 281 kg ha^{-1}, 23 times greater than the 12,9 kg ha^{-1} in 2002-2003. The difference between seasons decreased as the weed-control period increased (Table 1). In both seasons, maize-infesting *U. plantaginea* cohorts that emerged after the 40-day weed-control period produced quantities of seeds smaller than 2 kg ha^{-1}, or less than 50 seeds m^{-2}.

Seed production of *U. plantaginea* emerging at different dates in pure stands - Seed production of *U. plantaginea* in pure stands emerging from mid-November to mid-January (Table 1) was affected by the interaction of emergence date and season (p=0.0045). In both years seed production decreased as emergence date was delayed from mid-November to mid-January, but the rate of decrease and maximum production varied (Table 1). Seed production of *U. plantaginea* in pure stands ranged from 185 to 513 kg ha^{-1}, dry matter, which means 4.6 to 13.5 thousand seeds m^{-2} in 2001-2002, and from 360 to 1906 kg ha^{-1}, dry matter, or 8.9 to 47.1 thousand seeds m^{-2}) in 2002-2003. In commercial farm operations virtually pure *U. plantaginea* stands do occur in fallow or neglected plots, so seed production of this order of magnitude is likely to occur.

No study on *U. plantaginea* seed production is reported in the literature, so we had to resort to studies on perennial *Urochloa* species used for forage, mainly *U. decumbens*, *U. brizantha* and *U. humidicola*. In most studies, the order of magnitude of seed production is in the range of 50 to a few hundred kg ha^{-1} (DEMINICIS et al., 2010; PERES et al., 2010; QUADROS et al., 2010). Inherent problems of such studies are the long time span of seed maturation and natural dehiscence, so that this range reflects rather harvest efficiency than seed production itself.

Nevertheless, pure stands of *U. plantaginea* yielded from a few hundred kg to almost 2 Mg ha^{-1}, far above the figures reported to perennial *Urochloa* species. We did expect *U. plantaginea* to produce more seeds than related perennial species, because annual species do not have to divert photosynthates to the maintenance of live structures. However, we don't have elements to estimate to which extent higher seed production of *U. plantaginea* is due to its annual character and/or to the underestimation of seed production in perennial *Urochloa* species.

<u>Seed production of *U. plantaginea* cohorts emerging at the same date either infesting maize or in pure stands</u> - For the ease of experimentation our study comprised two independent experiments. This independence set limits to statistic comparison of seed production for the same emergence in each experiment. However, the experiments were purposely installed in adjacent areas so as to permit some biological comparative assessment. For any emergence date, maize imposed a strong reduction in *U. plantaginea* seed production (Table 1), but the reduction was higher for later emerging cohorts, which had to compete with previously established maize plants. The comparative seed production under these contrasting growth conditions reveals the strong competitive pressure imposed by maize and the astonishing phenotypical plasticity of *U. plantaginea*.

After two-month storage period, the viability of seeds produced by maize-infesting *U. plantaginea* plants was 90.3% (87.1% germinated plus 3.2% hard) in 2001-2002, and 92.0% (63.1% germinated plus 28.9% hard) in 2002-2003. For pure stands and the same storage period, seed viability was 89.3% (86.0% germinated plus 3.3% hard) in 2001-2002, and 91.7% (53.4% germinated plus 38.3% hard) in 2002-2003. The values were very similar regardless the season and growing condition.

Seed viability of perennial *Urochloa* species (DEMINICIS et al., 2010; PARIZ et al., 2010) is usually much lower than those from our experiments. We don´t have elements to estimate to which extent this difference is due to harvest procedures or to intrinsic specific characters.

<u>What do the figures of seed production contribute to the design of agroecosystem management strategies?</u> - Humans manage agroecosystems to achieve human goals, so the management of *U. plantaginea* may be geared toward two contrasting objectives, to reduce its population density in crop production fields or to guarantee high enough population density where its forage use is desired.

The prevalent idea in current weed control strategies is to focus on the critical period of competition with the crop, which typically results in the attempt to guarantee a weed-free environment in the first third of the crop cycle. The most widespread efficiency indicator in use is the crop yield in that season. However, this indicator does not take into account the potential seed production of the residual weed population that develops after the critical competition period.

In our experiment, a 20-day weed control period was enough to prevent losses in maize yield. However, the residual *U. plantaginea* cohorts that emerged after the 20-day control period in 2001 and 2002 produced 50 and 360 seeds m^{-2}, respectively, while cohorts emerging after the 40-day or 60-day periods produced 11 to 50 seeds m^{-2} (Table 1).

To assess the importance of seed production of the no-yield-impact *U. plantaginea* populations, we made resort to the seed rates recommended to install perennial *Urochloa* species, namely *U. decumbens*, *U. brizantha*, *U. ruziziensis* and *U. humidicola*. For these species, usual seed rates range from 5 to 10 kg ha^{-1}, approximately 60 to 300 seeds m^{-2}. This showed up that the residual *U. plantaginea* population after a 20-day control period produces the equivalent to a full seed rate to install a pasture. Therefore, the focus on crop yield affection in the season is a guarantee to perpetuate *U. plantaginea* infestation!

As for the lower rates of 11 to 50 seeds m^{-2} produced after control periods of 40 and 60 days, they certainly also contribute to the permanence of *U. plantaginea* in production fields. However, their impact is likely to be much lower, because these rates suffer further reductions by predation, metabolic decay, pathogens and germination. In a five-year study on a crop sequence soybean – wheat (summer – winter), Voll et al. (1995) observed *U. plantaginea* seed longevities of 5.2 years for no-till, and 11.5 to 12.2 years for conventional tillage systems. Higher longevity in conventional tillage is likely to be associated with lower temperatures experienced by deeply buried seeds, and its protection from predators.

These longevity figures converge with empirical observations of organic soybean producers in southwestern Parana – Brazil. Some of these farmers pursue a strategy of total weed-seed-prevention, which consists of eliminating all weed plants the entire year before they produce seeds, combined with minimum tillage, with the ultimate goal of depleting the soil seed bank. With this strategy, strong reductions in weed infestation occur from the fourth year onwards.

In the case of pure *U. plantaginea* plots, they do occur in commercial operations, especially in large scale agricultural practice, in areas occasionally neglected or left in fallow. In such situations, we expect them to behave similarly to our *U. plantaginea* pure stands, in terms of both biomass and seed production. In this case, seed production (Table 1) varied from around 25 to 254 times the average seed rate recommendation of 7.5 kg ha^{-1} used for perennial *Urochloa* species! This tremendous addition to the soil seed bank is expected to keep high infestation rates for several years, even if a total seed prevention strategy is pursued afterwards.

To explore the magnitude of *U. plantaginea* plant densities in subsequent seasons, we used the equations that SkoraNeto (2001) obtained in a 10-year experiment with total weed seed prevention, in no-till and conventional tillage management. Weed density decreased exponentially over time, and was always higher in conventional tillage than in no-till.

For the purpose of exploring how long a single year of replenishment in the soil seed bank may affect *U. plantaginea* emergence in subsequent years, we arbitrarily adopted the threshold density of 10 plants m^{-2}, which permits a relatively comfortable control for maize (SPADER e VIDAL, 2000).

After a single cycle with our minimum pure-weed-stand seed production (4.6 thousand seeds m-2), it would take three years with no-till and six years with conventional tillage to achieve the threshold density. For our maximum weed seed production, 47 thousand seeds m^{-2}, it would require complete prevention of seed production for 10 years of with no-till and 18 years with conventional tillage to come down to 10 plants m^{-2}.

These long survival periods contribute to explain why *U. plantaginea* is so well naturalized in Brazil. In several agricultural areas, particularly where no-till herbicide-anchored systems predominate, there is a wrong idea that this species is no longer important. In such areas, herbicide use has promoted the increase of ecologically specialist weed floras, whose specialization is the tolerance or resistance to the herbicides applied, like the recent outbreak of *Conyza* spp. in Brazil (LAZAROTO et al., 2008).

However, an opportunistic species like *U. plantaginea* is very well naturalized and is likely to remain in the area, deeply and safely protected in the soil seed bank.

The most important outcome from our maize – *U. plantaginea* experiment was that seed production may be substantial even when the weed does not affect maize production. Seed production can be enough to perpetuate infestation. Unfortunately, most studies to manage *U. plantaginea* in the last decade, like those of Marchesan et al. (2013) and Galon et al. (2010) continue to focus on chemical control during the critical competition period. Such an approach produces indeed an immediate relief, but, in our opinion, does not address the critical issue, which is seed production and the need to deplete the soil seed bank.

From our study on *U. plantaginea* seed production as emergence date was delayed in the season, we learned that its seed production is severely reduced when emergence occurs under a previously established maize stand. However, in pure *U. plantaginea* stands, late emerged cohorts still produced several thousand seeds m^{-2} even at the latest emergence date. In addition, seed production of pure *U. plantaginea* stands from a single period of fallow or neglect can be enough to cause infestation problems for more than a decade.

In the long run, there seems to be no practical success in the control of *U. plantaginea* unless its seed production is prevented. On the other hand, for the use as a forage crop after silage maize, the elimination of *Urochloa* should be limited to the first month of the cereal cycle, to guarantee enough seeds for a rapid forage sword to develop.

Conclusions

Urochloa plantaginea seed production was affected by the interaction of year and the emergence date along the season.

As a weed in maize stands, seed production ranged from 0.5 to 281.0 kg ha^{-1}, and was enough to perpetuate weed infestation, even when crop biomass and yield were not affected. This entails that the concept of critical period of competition is inadequate to reduce weed pressure in the following seasons.

Seed production of *U. plantaginea* in pure stands ranged from 185.2 to 1905.7 kg ha^{-1}, with a tendency to decrease as emergence was delayed.

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