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Evaluation of annual companion crops for the establishment of perennial forage crops in eastern Canada

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Key words: Alfalfa; lucerne; timothy; establishment; seeding

Abstract
The use of companion crops when establishing perennial forages is desirable as it often reduces weed growth and increases forage biomass in the seeding year. In eastern Canada, oat (*Avena sativa* L.) is the main species used as companion crop; although other species are used, they have not been systematically evaluated. A field study was established in 2019 at three sites in Québec, Canada, to contrast the use of six annual species as companion crops for the establishment of lucerne (*Medicago sativa* L.)-timothy (*Phleum pratense* L.) mixtures. Species evaluated include berseem clover (*Trifolium alexandrinum* L.), annual ryegrass (*Lolium multiflorum* Lamarck), forage pea (*Pisum sativum* L.), forage oat, Japanese millet [*Echinochloa esculenta* (A. Braun) H. Scholz], and sudangrass [*Sorghum* × *drummondii* (Nees ex. Steud.) Millsp. & Chase]. The control treatment consisted of the perennial species seeded without companion crop. Treatments were seeded at three dates (mid-May to early-June, mid-June to early-July, and early August) and evaluated during the seeding year based on biomass production and botanical composition. Overall, across sites, for the first two seeding dates, highest annual forage yields were observed with sudangrass, Japanese millet, and oat as companion crops. The use of these species increased yields by 1.8 to 2.5 Mg ha^{-1} on a dry matter basis (DM) compared to the control which yielded an average of 3.7 Mg DM ha^{-1}. For the early August seeding, response varied significantly across sites. Annual yields were the highest with the use of oat at two sites (avg. of 2.4 Mg DM ha^{-1}), whereas no differences between treatments were observed at the other site. Companion crop species which maximized total forage yields in the seeding year often reduced weed biomass, but also that of perennial species. The impact of treatments on the survival of perennial forages and their production during the first post-seeding year will be presented in a later publication.

Introduction
In eastern Canada, timothy and lucerne are among the most widely cultivated perennial forage species. Since perennial forages generally establish slowly, low yields and weed encroachment can occur during the seeding year. To reduce weed competition, perennial forages can be direct seeded combined with the use of herbicides. However, perennial forages are usually established in mixtures of grasses and legumes in eastern Canada, limiting herbicide selection. Another approach is to use annual companion crops to establish perennial forages which can offer weed control and can also increase forage yields in the seeding year (Hoy et al. 2002; Sheaffer et al. 2014). Oat is the most commonly used companion crop in the province of Québec (CRAAQ 2005). Other annual species can be used to establish perennial forages, but there have not been evaluated across multiple sites in the province of Québec. Therefore, the main objective of the study was to compare the effect of different annual companion crops used to establish a mixture of lucerne-timothy on forage yield, botanical composition, and weed control during the seeding year. The various companion crop treatments were seeded at three different dates during the growing season (mid-May to early June, mid-June to early July, and early August) to determine the best seeding period for each of the species evaluated. Finally, the experiment was conducted at three contrasting sites with different pedoclimatic conditions to determine their suitability among regions.

Methods and Study Sites

Experimental plots were seeded in 2019 at three contrasting sites in Québec, Canada: Sainte-Anne-de-Bellevue (2136 growing degree days on a 5°C basis [GDD5]; 45° 25' N lat., 73° 55' W long.), Saint-Augustin-de-Desmaures (1821 GDD5; 46° 43' N lat., 71° 31' W long.), and La Pocatière (1506 GDD5; 47° 21' N lat., 70° 1' W long.). Experimental units were monitored for two consecutive years (i.e., the seeding and post-seeding year) but only results of the seeding year are presented here because of space limitations. There were three blocks per site, resulting in a total of 63 experimental units at each site. These units were assigned to a randomized complete block design with split-plot restriction. The main experimental units corresponded to the seeding dates while the sub-units corresponded to the companion crop treatments. A total of six different annual companion crops with a mixture of lucerne and timothy were seeded, in addition to a control of lucerne-timothy (at rates of 9 and 7 kg ha^{-1}, respectively) established without a companion crop. The six annual companion crops evaluated consist in: berseem clover, forage pea, annual ryegrass, forage oat, Japanese millet, and sudangrass, seeded at rates of 5, 60, 6, 60, 20, and 20 kg ha^{-1} on a pure live seed basis, respectively, based on local recommendations or previous studies. Each of these treatments were seeded at three different dates, depending on the location (from mid-May to early-June, mid-June to early-July, and early-August). Depending on the site and the seeding date, 1 to 3 harvests were taken during the seeding year. The first harvest was done at the optimal stage of development of the companion crops, based on local recommendations or previous research. Subsequent harvests were done when lucerne reached the early flower stage of development.

Harvests were done using an experimental flail mower and the weight of the harvested material in each experimental unit was recorded to determine forage yields. A 500-g sample of fresh material was taken at each harvest and dried to determine yields on a DM basis. Another biomass sample was also taken from each experimental unit to determine the botanical composition. Weight of each species was recorded on a DM basis and their contribution to yield were then determined. Data were analysed separately for each site: a two-way analysis of variance (ANOVA) was done using PROC GLM of the SAS software (SAS Institute 2014). Using the least square means difference and Scheffé's adjustment for multiple comparisons, differences between means were determined and considered significant at $P \leq 0.05$ level.

Results

Seeding date and companion crop treatment effects were significant at each site ($P < 0.001$) but a seeding date × companion crop interaction was observed at each site, illustrating that companion crop performance differed depending on the seeding date ($P \leq 0.05$). Overall, at Sainte-Anne-de-Bellevue and Saint-Augustin-de-Desmaures, annual forage yields were similar for the first two seeding dates and they were significantly higher than the yields for the August seeding. At La Pocatière, the total yields for the first seeding date were significantly higher than the one for the second seeding which was also significantly higher than the one for the third seeding. At Sainte-Anne-de-Bellevue, sudangrass treatment resulted in significantly higher total forage yields for the first two seeding dates compared to the control seeded without companion crop and all other treatments (Figure 1). Oat and Japanese millet also resulted in significantly higher total forage yields compared to the control and all other companion crop treatments, except sudangrass for the first two seeding dates. Weed biomass as well as lucerne annual yields were reduced by oat, Japanese millet, and sudangrass. Timothy yield was marginal and no difference among treatments was observed. Total forage yields were significantly higher with oat and Japanese millet treatments compared to all other treatments for the third seeding date. No difference among treatments was observed for weed biomass, and lucerne and timothy yields for this seeding date. At Saint-Augustin-de-Desmaures, for the first two seeding dates, the highest yielding treatment was oat, followed by Japanese millet and sudangrass. For the second seeding date, Japanese millet and sudangrass reduced weeds, but also lucerne and timothy yields compared to all other treatments. For the last seeding date, there was no difference among treatments in terms of forage yields. However, oat and Japanese millet contributed to yields and further reduced weeds compared to all other treatments. They also reduced lucerne yields compared to the other companion crops while no difference was observed among treatments for timothy yields. At La Pocatière, sudangrass and oat produced the highest yield, followed by Japanese millet compared to the other treatments for the first seeding date. However, with these companion crop treatments, lucerne yields were lower compared to other treatments while no difference was observed among treatments for timothy yield. For the second seeding date, total forage yields of oat, sudangrass, and Japanese millet treatments did not differ, but were higher when compared to the other treatments. With these companion crops, weeds were reduced, and no difference was observed for lucerne and timothy yields. For the third seeding, oat resulted in the highest yields compared to all other treatments.

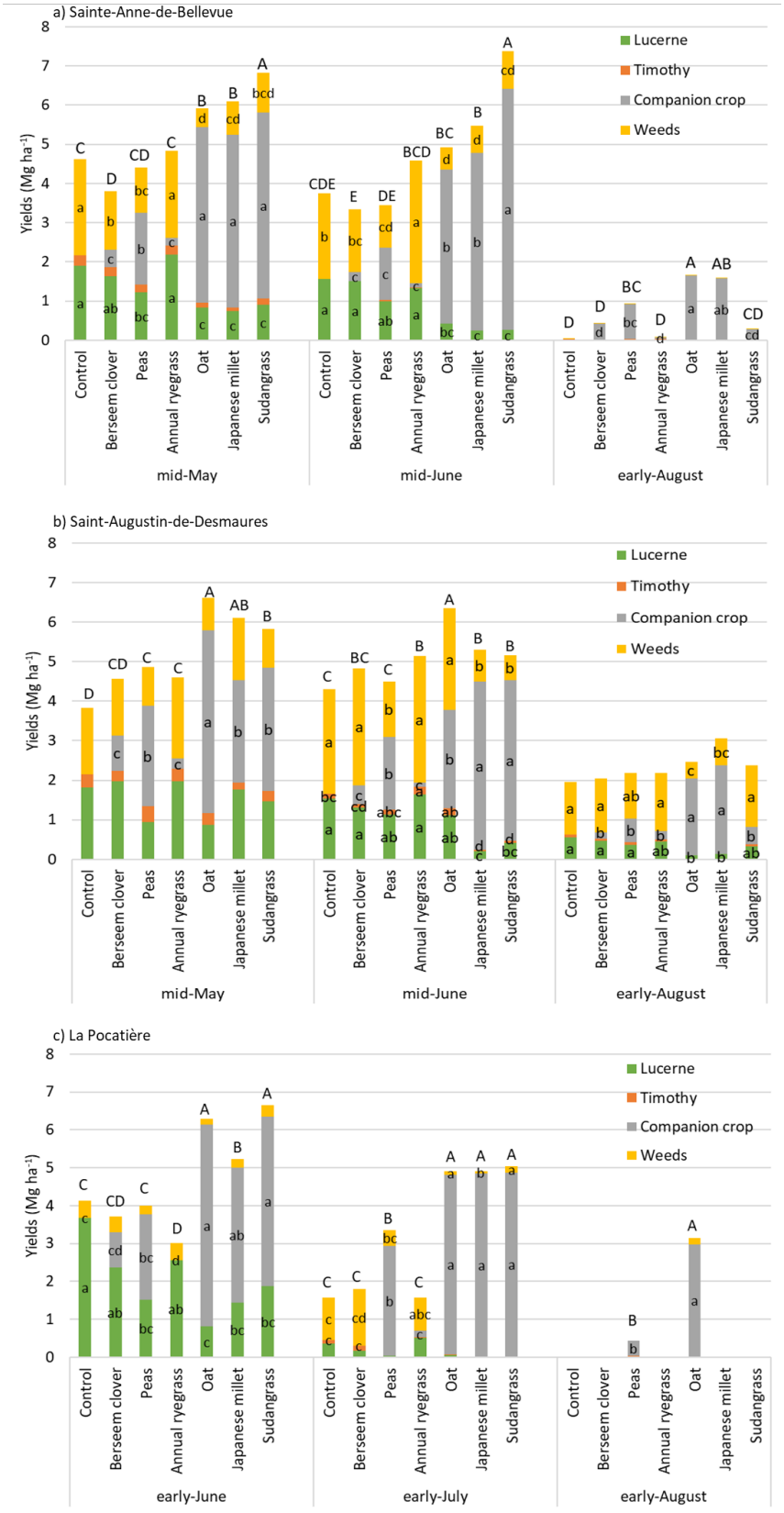

Figure 1. Seeding year forage dry matter yield and botanical composition of a lucerne-timothy mixture seeded with six companion crops at three different dates and three sites in Québec, Canada**.**

Conclusions/Implications

These preliminary results demonstrate that, although there are differences among sites, oat, Japanese millet, and sudangrass are suited to a wide range of pedoclimatic conditions. During the seeding year, sudangrass performed best when seeded later in the summer while oat yielded more when seeded in the spring. When seeded in May or June, and at all sites, these three crops increased total annual forage yields compared to other companion crop treatments and the control. When seeded in August, and at all sites, total annual forage yield of the mixture was the highest when the companion crop was oat. Oat, Japanese millet, and sudangrass, as annual companion crop species, also significantly reduced weeds when compared to the control for most seeding dates at all sites. However, they also significantly reduced lucerne and timothy yields at some of the seeding dates and sites. Therefore, they could have a negative impact on the establishment of the perennial species which will be further assessed in the post-seeding year. In conclusion, the use of oat, Japanese millet, and sudangrass as companion crop for the establishment of a lucerne-timothy mixture increase total annual forage yields in the seeding year, however, they could negatively impact their establishment and their productivity in post-seeding years.

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