

Forage Production of Alfalfa Established in Silage Corn vs. Conventional Production Systems

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Abstract

Intercropping of corn silage with interseeded alfalfa is being developed as an alternative method for establishing alfalfa to improve the productivity, profitability, and environmental sustainability of forage production. Our objective was to compare crop growth, yield, and quality of forage produced from four intercropping systems (alfalfa interseeded early at corn planting or late at the VE stage and established with or without the application of prohexadione growth retardant) to four conventional alfalfa systems (spring-seeded alfalfa, corn silage followed by spring-seeded alfalfa, barley followed by summer-seeded alfalfa, and corn silage followed by late-summer-seeded alfalfa). Cropping treatments were replicated four times in a randomized complete block design and initiated during 2020 and 2021 on silt loam soils in Wisconsin and Idaho. Below normal rainfall and application of fungicide plus insecticide in Wisconsin and arid irrigated conditions in Idaho favored growth, foliar health, and good establishment of interseeded alfalfa. Average dry matter yields of intercropped corn silage were 18.8% lower with early interseeding and 6.6% lower with late interseeding compared to solo-seeded corn. Yields of intercropped corn were, however, 2- to 4-fold greater than establishment-year yields of spring-seeded alfalfa or barley grain and straw grown prior to summer-seeded alfalfa. Yields of interseeded alfalfa the following year were similar to or slightly higher than spring-seeded alfalfa if the corn companion crop had been harvested relatively early near the 1st of September. The timing of interseeding and prohexadione application did not substantially influence stand density or yield of alfalfa. Yield of alfalfa summer-seeded after barley or especially after corn were usually lower than spring-seeded alfalfa. Cropping treatments generally had small or insignificant effects on forage quality constituents in corn silage and alfalfa. Overall, the alfalfa-corn intercropping system produced higher total yields and forage of comparable quality compared to conventional production systems for alfalfa.

Introduction

Agricultural statistics indicate alfalfa acreage in the United States has declined by over 50% in the last 30 years to around 15 million acres in 2022. Among other factors, this decline has occurred because corn silage has become the primary source of forage for dairy cattle and other ruminant livestock. One reason for this shift is the relatively low yield of alfalfa compared to corn silage. In the northern USA, establishment-year yields of spring-seeded alfalfa are especially low, often being one-half that of subsequent full-production years. Planting small grain, grass, or legume companion crops can modestly improve yields during alfalfa establishment, but forage quality is often reduced (Undersander et al., 2015).

One way to bypass the low-yielding establishment year of alfalfa and to increase farm profitability would be to interseed alfalfa into corn silage (Berti et al., 2021; Osterholz et al., 2020). In this system, corn silage serves as a high-quality and high-yielding companion crop for alfalfa. During establishment, interseeded alfalfa initially serves as a highly effective cover crop to reduce soil and nutrient loss during and after corn production and then it is brought into full forage production in subsequent years (Grabber, Smith et al., 2021; Osterholz et al., 2019; Osterholz, Ruark et al., 2021a).

While many aspects of this intercropping system have been worked out in recent years (e.g., Grabber, Osterholz et al., 2021; Grabber, Smith et al., 2021; Osterholz, Dias et al., 2021), one longstanding question remains that will greatly affect the adoption of this practice on farms: How does alfalfa establishment and the yield and quality of forage produced from this intercropping system compare with conventional production systems for alfalfa? An experiment designed to answer this question was the primary goal of this USAFRI Alfalfa Checkoff project. This study was carried out in Wisconsin and Idaho, two major northern alfalfa producing states that represent the rainfed eastern region and the irrigated western intermountain region of the United States.

Project Objective

The objective of our study was to compare the establishment of alfalfa and the yield and quality of forage produced from four intercropping systems to four conventional-production systems for alfalfa.

Summary of Results

Studies initiated during 2020 and 2021 in Wisconsin and Idaho indicated alfalfa can be successfully established under a corn silage companion crop to produce higher total dry matter yields and forage of comparable quality compared to conventional production systems for alfalfa.

Materials and Methods

Sites and weather conditions during crop production and alfalfa establishment. Independent experiments were initiated in 2020 and in 2021 on silt-loam soils near Prairie du Sac, Wisconsin and near Kimberly, Idaho. At Prairie du Sac, long-term average temperature is 60.2 degrees F and total precipitation is 29.1 inches during the April through October growing season. Production of companion crops and alfalfa establishment during this period generally occurred under near-normal temperatures, but temperatures were 3.4 degrees below normal in September and October of 2020 and 5.2 degrees above normal in October 2021. Total precipitation from April to October was 5.1 inches below normal during 2020 with dry conditions occurring mainly during spring. During 2021 precipitation was 7.7 inches below normal with lower-than-average rainfall throughout most of the growing season.

At Kimberly, the long-term average temperature is 61.4 degrees F and total precipitation is 5.6 inches during the April through October growing season. Production of companion crops and alfalfa establishment during this period occurred under near-normal temperatures during 2020 and for much of 2021 but in the latter year, temperatures were 7.2 degrees above normal in June and July. Precipitation was below normal throughout most of the 2020 growing season and

totaled only 2.9 inches. During 2021 rainfall was below normal from April through June but total precipitation was 5.1 inches due to above average rainfall in October.

Cropping treatments and management. The following cropping treatments for alfalfa establishment were evaluated in both states.

1. Corn silage interseeded immediately after planting with alfalfa
2. Treatment 1 with prohexadione sprayed onto alfalfa seedlings
3. Corn silage interseeded at the vegetative-emergence (VE) stage with alfalfa
4. Treatment 3 with prohexadione sprayed onto alfalfa seedlings
5. Corn silage followed by spring-seeded alfalfa in year 2
6. Spring-seeded alfalfa
7. Barley grown for grain and straw followed by summer-seeded alfalfa
8. Corn silage followed by late-summer-seeded alfalfa

Treatments were assigned to plots according to a randomized complete block design with four replications. Plot size was 10 by 30 ft in Wisconsin and 40 by 40 ft in Idaho to match the spacing of the sprinkler irrigation system. Prior to planting, fertilizer and other soil amendments were applied based on soil tests and Extension Service recommendations.

Glyphosate-resistant corn hybrids were planted in 2020 and 2021 between 28 April and 5 May in plots and experimental borders using a 30-inch row spacing to obtain final populations near 34,000 plants per acre in Wisconsin and 38,000 plants per acre in Idaho. In Wisconsin, a 106-day hybrid was grown for treatments 1-5, while an 88- or 89-day hybrid was grown prior to treatment 8; the 88-day hybrid used in 2020 proved to be susceptible to lodging, so a different 89-day hybrid was used in 2021. In Idaho, a single 91-day hybrid was grown both years for treatments 1-5 and 8.

Glyphosate-resistant alfalfa was drilled at a 6-inch row spacing at rate of 16 lb of live seed per acre. Interseeded alfalfa was sown immediately after corn planting or 10- to 15-days later at the VE stage of corn in treatments 1-4. For conventional treatments 6-8, seeding dates for Wisconsin in 2020 and 2021 were respectively 2 May and 29 April for spring-seeded alfalfa, 12 August and 28 July for summer-seeded alfalfa after barley, and 26 August and 25 August for late-summer-seeded alfalfa after corn silage. In Idaho, seeding dates for conventional treatments 6-8 in 2020 and 2021 were respectively 28 April and 6 May for spring-seeded alfalfa, 20 August and 16 August for summer-seeded alfalfa after barley, and 25 September and 21 September for late-summer-seeded alfalfa after corn silage. Alfalfa in treatment 5 was spring seeded in year 2 on 26 April 2021 and 20 April 2022 in Wisconsin and on 8 May 2021 and 29 April 2022 in Idaho.

Weeds were controlled by applying glyphosate and encapsulated acetochlor. The growth-retardant prohexadione was sprayed at 0- or 4-oz a.i. per acre onto interseeded alfalfa in mid-June. In Wisconsin, Priaxor-Xeminum fungicide (2-oz a.i. per acre fluxapyroxad + pyraclostrobin) and Warrior-II insecticide (2-oz a.i. per acre lambda-cyhalothrin) were applied to spring-seeded and interseeded alfalfa near 1 July to suppress foliar disease and insect pests. Plots in Idaho were irrigated within a few days of planting corn to ensure good germination. Irrigation was scheduled based on crop water use data from a local AgriMet weather station.

During establishment spring-seeded alfalfa was harvested three times in Wisconsin and two times in Idaho whereas interseeded alfalfa was not harvested or clipped during intercropping with corn. Barley grain and straw were harvested in both states between late July and early

August. In Wisconsin dry conditions accelerated dry down of corn especially the 106-day hybrid, so corn silage was harvested both years at a moisture content between 60-65% near 24 August for treatment 8 and near 1 September for treatments 1-5. In Idaho the 91-day corn hybrid was harvested for corn silage from treatments 1-5 and 8 at 55-65% moisture content on 16 September 2020 and 2 September 2021; relatively warm temperatures in June and July contributed to the earlier harvest in 2021. Following establishment, alfalfa was harvested four times in Wisconsin and three times in Idaho at the bud/early flowering stage. Harvests of all crops were made using self-propelled plot harvesters equipped with weigh bins and load cells.

Data collection and statistical analyses. Subsamples of harvested crops were oven dried at 140 °F to determine dry matter content. Yields for each harvest were calculated from fresh crop weights and dry matter estimates. Dried subsamples of whole-plant corn and alfalfa were Udy milled through a 1-mm screen and scanned by near-infrared-reflectance spectroscopy (NIRS) to estimate crude protein (CP), neutral-detergent fiber (NDF), 48-h in-vitro true dry matter digestibility (IVTDMD), 48-h in-vitro NDF digestibility (IVNDFD), and starch (corn silage only). Calibrations developed by the NIRS Consortium were used to estimate forage quality constituents and selected samples were analyzed by wet chemistry to validate NIRS results.

Soil moisture to a 6-inch depth was monitored with a time domain reflectometry probe or by measuring moisture loss from soil cores following oven drying at 220 °F. A ceptometer was used to estimate the leaf area index of corn just prior to silage harvest. Dry biomass of corn and alfalfa clipped to ground level in quadrates was determined at the V5, V10, R1, and silage stages of corn. Nitrogen content of milled biomass was determined by combustion analysis. Dry biomass and plant height of alfalfa was also determined in late October. Alfalfa stand density was estimated by stem counts or by removing soil along seeded rows and counting plants.

Data were analyzed within states by a generalized linear mixed-model analysis of variance. In several cases, data were transformed or analyzed by heterogenous variance models to normalize variances. Treatments were compared by the pdiff method and contrast statements. Treatment differences described in the Results and Discussion were significant at $P \leq 0.05$.

Results and Discussion

Crop growth and yields during alfalfa establishment. Spring-seeded and interseeded alfalfa had excellent initial establishment with stand densities in June averaging 37 plants per square foot in Wisconsin and 50 plants per square foot in Idaho. Application of prohexadione primarily reduced dry mass of interseeded alfalfa sampled at the V10 or R1 stages of corn, but it did not affect nitrogen uptake by alfalfa. Nitrogen uptake by interseeded alfalfa peaked at the V10 stage of corn in both states and averaged 66.6 lb per acre for early-interseeded alfalfa and 38.1 lb per acre for late-interseeded alfalfa. Nitrogen content of interseeded alfalfa then declined 50% before corn harvest.

Alfalfa interseeding had inconsistent effects on the development of corn at the V5 stage, but interseeding reduced corn dry mass by 14 to 50% at the V10 stage and by 8 to 30% at the R1 stage relative to corn grown alone. Reductions in corn mass were two-fold greater with early- than with late-interseeded alfalfa. Leaf area index of corn prior to harvest averaged 3.8 in Wisconsin and 3.2 in Idaho and was not affected by interseeding.

Final yield of harvested biomass in Wisconsin and Idaho was influenced by a seeding year by cropping treatment interaction. The interaction in Wisconsin was largely driven by substantial differences between seeding years in the yield of the short-season corn hybrid grown prior to late-summer-seeded alfalfa. In Idaho, the interaction primarily occurred because yields of corn silage grown with early-interseeded alfalfa and of barley grain and straw grown prior to summer-seeded alfalfa were greater in 2020 than in 2021.

Yields of corn silage grown with interseeded alfalfa were often statistically or numerically lower than corn grown alone prior to late-summer-seeded or spring-seeded alfalfa (Figure 1). In most cases, delaying interseeding of alfalfa until the VE stage improved yields of corn silage, but

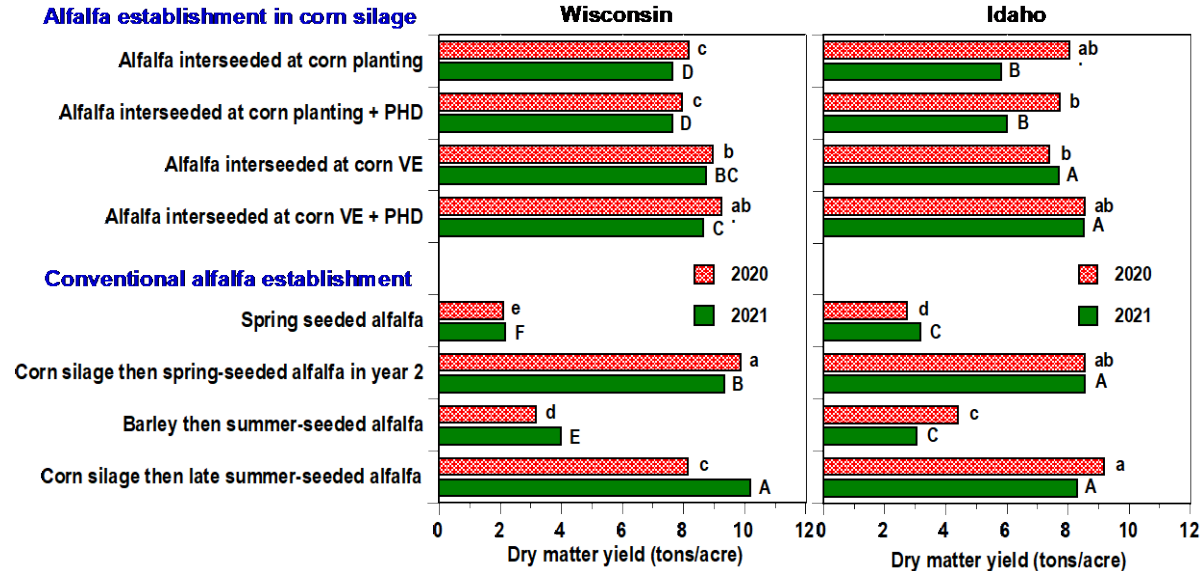


Figure 1. Dry matter yields of corn silage, barley grain plus straw, or spring seeded alfalfa during alfalfa establishment in year 1. Least square means with no common lower-case letter (2020) or upper-case letter (2021) are significantly different at $P = 0.05$.

yields were not influenced by prohexadione application on interseeded alfalfa. Yields of corn silage interseeded with alfalfa were, however, approximately 2- to 4-fold greater than spring-seeded alfalfa or barley grain and straw grown prior to summer-seeded alfalfa.

In most cases, interseeding of alfalfa had no effect on nitrogen concentration in corn. The exception was corn grown with early-interseeded alfalfa in Wisconsin, which had a lower concentration of nitrogen relative to corn grown alone at the V10 stage (2.6 vs. 3.1%). This depression in nitrogen concentration corresponded to the period of maximal nitrogen uptake by interseeded alfalfa. Alfalfa interseeding primarily influenced volumetric soil water content at the V5 stage of corn. Relative to corn grown alone, corn with early-interseeded alfalfa reduced volumetric soil water content in Wisconsin by 8.1% following prolonged dry conditions during the spring of 2020. In Idaho, early-interseeded alfalfa reduced volumetric soil water by average of 17.8% following relatively dry spring conditions in 2020 and 2021 that preceded regular irrigation. These results indicate early season uptake of soil nitrogen and water during dry conditions by early-interseeded alfalfa may have contributed to reduced growth and yield of the corn silage in Wisconsin and Idaho.

Overall, our results indicate early interseeding of alfalfa will reduce corn silage yields but delaying interseeding until the VE stage can be used as a management technique to reduce yield

drag on corn silage. Concurrent work in Wisconsin, however, indicated further delays in interseeding can result in alfalfa stand failure if competition from corn and disease pressure are especially high during the growing season (Grabber et al, unpublished results).

Fall growth and stand density of alfalfa prior to forage production. Dry mass and height of alfalfa in late October was influenced by a seeding year by cropping treatment interaction in both states. Overall, dry mass and height was relatively high for spring-seeded alfalfa, moderate to high for interseeded alfalfa, low to moderate for summer-seeded alfalfa after barley, and extremely low for late-summer-seeded alfalfa after corn (e.g. Figure 2).

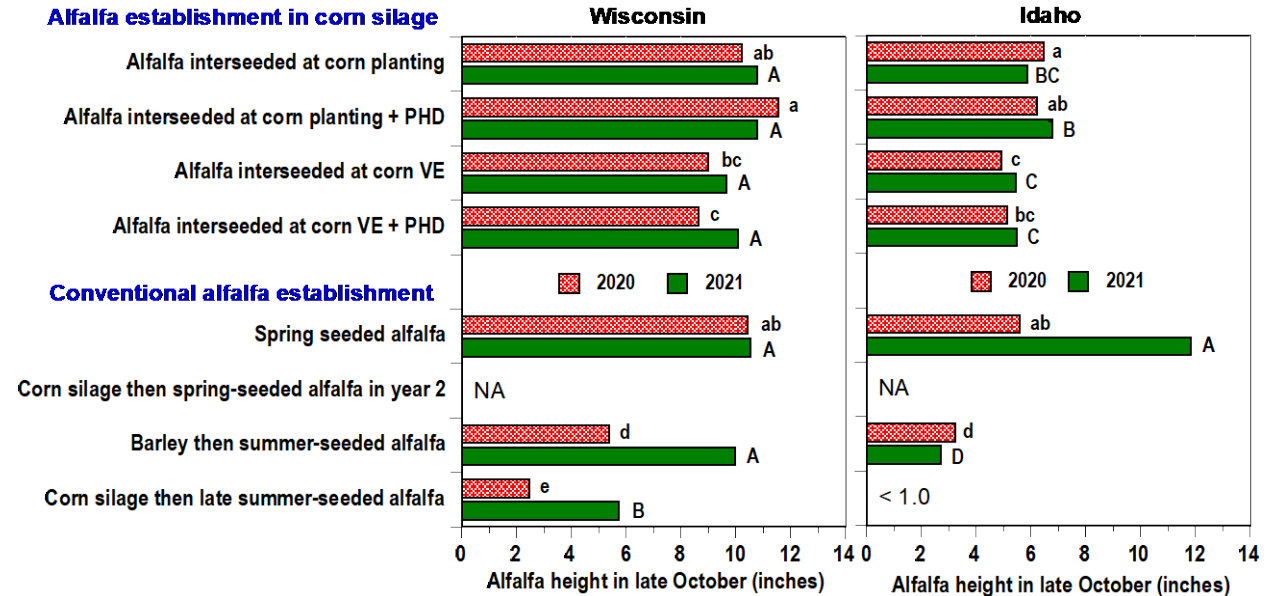


Figure 2 Alfalfa height in late October following establishment in year 1. NA = not applicable. Least square means with no common lower-case letter (2020) or upper-case letter (2021) are significantly different at $P = 0.05$.

Stand density of alfalfa following establishment in both states was also influenced by a seeding year by cropping treatment interaction. The interaction was mainly due to a narrower range in stand density among treatments following establishment in 2020 than in 2021. In Wisconsin stand density was determined by plant counts made in late October and late April. Averaged across sampling dates and seeding years, plant density per square foot in Wisconsin was greatest for late-summer-seeded alfalfa following corn (40.1), intermediate for summer-seeded alfalfa following barley (30.8) and spring-seeded alfalfa (26.4), and lowest for interseeded alfalfa treatments (19.8). In Idaho, preliminary counts after establishment indicated all cropping treatments had high plant densities (>30 plants per square foot) so stand density was primarily assessed by taking stem counts in late April. Averaged across seeding years, stem density per square foot in Idaho was greatest for spring-seeded alfalfa (138), intermediate for interseeded alfalfa treatments (110) and lowest for alfalfa summer-seeded after barley (63). Late-summer-seeded alfalfa following corn in Idaho had insufficient plant development in late April for estimating stem counts. In Wisconsin the relatively high plant density of late-summer-seeded alfalfa after corn could be attributed to the younger age of the stands, while the relatively low plant density of interseeded alfalfa could be attributed to stands being older and subjected to

competition from corn during establishment. Neither the timing of interseeding after corn planting nor the application of prohexadione influenced alfalfa stand density in either state.

Based on published stand density recommendations (Grabber, Smith et al., 2021; Undersander et al., 2015), all cropping treatments in Wisconsin appeared to have sufficient plant density to support high yields of alfalfa. In Idaho stem counts indicated stands of spring-seeded, interseeded, and summer-seeded alfalfa following barley would be sufficient to support high yields. The relatively poor growth of late-summer-seeded alfalfa after corn, especially in Idaho, indicated this treatment would have a lower forage production potential. Good establishment of interseeded alfalfa without the use of prohexadione could be attributed to below normal rainfall in Wisconsin and to arid irrigated conditions in Idaho during 2020 and 2021 that favored survival of alfalfa under corn.

Forage yield of alfalfa during the first full production year. Following establishment, alfalfa dry matter yields in Wisconsin and Idaho were influenced by a seeding year by cropping treatment interaction (Figure 3). In both states, yields of established stands of interseeded and spring-seeded alfalfa ranged from 5.5 to 6.7 tons per acre. By comparison, establishment year yields of

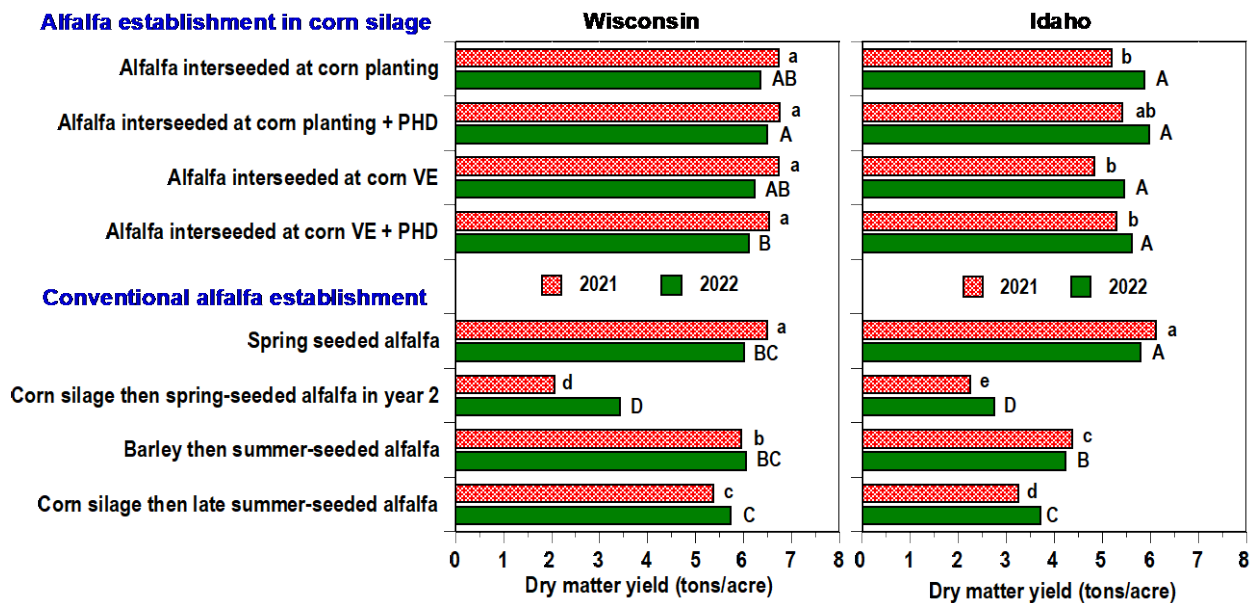


Figure 3. Dry matter yields of alfalfa in year 2. Least square means with no common lower-case letter (2021) or upper-case letter (2022) are significantly different at $P = 0.05$.

spring-seeded alfalfa were much lower, ranging from 2.1 to 3.4 tons per acre. Yields of interseeded alfalfa were similar to or slightly higher than spring-seeded alfalfa when established during 2020 and 2021 in Wisconsin and during 2021 in Idaho; in these trials corn was harvested near the 1st of September. Yields of interseeded alfalfa established in Idaho during 2020 were, however, 0.5 to 1.3 tons per acre lower than spring-seeded alfalfa and, in this case, corn was harvested in mid-September. A companion harvest timing study in Wisconsin also found that shifting corn harvest from the 1st to the 15th of September reduced fall growth of interseeded alfalfa and its yield the following year by up to 0.74 tons per acre (Grabber et al, unpublished results). Contrasts indicated interseeding immediately after corn planting rather than at the VE stage slightly increased ($P = 0.06$) full production yields of alfalfa in both states but application of prohexadione during establishment did not impact subsequent forage yield. Full production

year yields of alfalfa seeded after barley or especially after corn were usually lower than spring-seeded or interseeded alfalfa, but greater than spring-seeded alfalfa harvested during establishment. First harvest yields were impacted the most, and growth stage assessments indicated late-summer-seeded alfalfa planted after corn had delayed development prior to the first harvest. Multiple linear regression indicated first harvest yield was influenced by seeding year and positively related to October plant height in Wisconsin ($R^2 = 0.78$) and to spring stem counts in Idaho ($R^2 = 0.78$). Overall, our results indicate first production year yields can be maximized by spring-seeding or interseeding of alfalfa.

Overall, yields of alfalfa during the first full production year were relatively high for spring-seeded or interseeded alfalfa. Yields were, however, often adversely affected by insufficient fall development following late-summer seeding of alfalfa or by delayed harvest of corn silage grown with interseeded alfalfa. Reductions in first year yield of alfalfa planted after barley or corn in Wisconsin or after barley in Idaho occurred even though seedings were carried out prior to the cutoff date of September 1st for Wisconsin and Idaho recommended in Extension publications (Undersander et al., 2015; Shewmaker, 2005). Although winters are relatively mild with lower risk of winterkill in Idaho, seeding alfalfa during late September after corn substantially reduced alfalfa forage production the following year. Other studies in Wisconsin indicate delaying harvest of high yielding corn silage companion crops until late September can result in stand failure of interseeded alfalfa, especially if conditions are wet during the growing season (Grabber et al, unpublished results). Therefore, corn silage companion crops should be harvested in late August or early September in order to maximize stand establishment and forage yields of interseeded alfalfa.

Total yield and forage quality of corn silage and alfalfa. Total biomass yield in Wisconsin from the establishment year and the first-full production year of alfalfa ranged from 14.4 to 15.3 tons per acre for intercropping systems and from 8.4 to 14.7 tons per acre for conventional production systems. In Idaho total biomass yields from this two-year period ranged from 12.5 to 14.0 tons per acre for intercropping systems and from 8.0 to 12.2 tons per acre for conventional production systems. Interestingly, the only conventional system having yields comparable to intercropping was corn followed by late summer-seeded alfalfa, but this system provided high yield of corn silage at the expense of alfalfa establishment and production the following year. We will continue to monitor alfalfa yields from the cropping treatments through the 3rd production year.

Cropping treatments generally had minor or insignificant effects on forage quality of corn silage and alfalfa. Averaged across cropping treatments, corn silage grown in Wisconsin and Idaho respectively contained an average of 6.4% and 6.0% CP, 41.5% and 44.4% NDF, and 31.0% and 28.3% starch, with 48-h IVTDMD values of 83.6% and 85.1% and 48-h IVNDFD values of 63.8 and 70.7%. During the first-full production year, spring-seeded and interseeded alfalfa grown in Wisconsin and Idaho respectively contained an average of 24.0% and 20.8% CP and 36.9% and 38.1% NDF, with 48-h IVTDMD values of 81.0% and 80.6% and 48-h IVNDFD values of 45.7 and 47.1%. Comparable forage quality values were observed in Wisconsin for alfalfa established by summer seeding after barley or late-summer seeding after corn, but these cropping treatments in Idaho produced forage with slightly higher quality than alfalfa established by spring seeding or interseeding.

In conclusion, intercropping systems gave good establishment of alfalfa and produced higher total 2-year yields of forage that had comparable forage quality compared to conventional production systems for alfalfa. We will continue to monitor alfalfa yields from this experiment

and continue other work aimed at further improving the establishment of interseeded alfalfa under less favorable growing conditions (Grabber et al., 2023) and enhancing the nitrogen use efficiency and yield of corn silage companion crop (Osterholz, Ruark et al. 2021).

Acknowledgements

Funding for this study was provided by the U.S. Alfalfa Farmer Research Initiative of the National Alfalfa & Forage Alliance and by the USDA Agricultural Research Service. The authors are grateful to Matthew Volenec, Swetabh Patel, Claire Muerdter, Joy Barsotti, and Lauren Vitko for excellent technical assistance. Mention of trade names or commercial products does not imply recommendation or endorsement by the USDA. The USDA is an equal opportunity provider and employer.

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Keywords: Intercropping, establishment, alfalfa, corn silage, forage, yield, quality