INCREASING VALUE OF CORN SILAGE IN CORN–TRITICALE SYSTEM BY INTERCROPPING WITH FORAGE SOYBEAN

Background

Intercropping is an old and commonly used agricultural practice of cultivating two or more crops in the same space at the same time. Double cropping is when two crops are planted sequentially in one year. Double cropping corn–triticale rotation for silage (Figure 1) is a common practice in the Columbia Basin and in the Treasure Valley of Idaho and Oregon as it increases the amount of feed that can be grown for dairy cows (Brown and Griggs 2009). Double cropping corn–triticale also results in increased phosphorus removal, which is desirable for dairy farms as they typically have high phosphorus levels. Double cropping provides protection of the soil from wind and water erosion during the winter months and additional organic matter to the soil via root degradation. Double cropping will also enhance intercropping of corn and soybean as the later planting will increase soybean competition in the intercrop mixture with corn.

In 2019, 80,000 acres corn silage was harvested in Washington State (USDA NASS 2020). Silage corn makes excellent feed for dairy cattle because of its high dry matter yield, energy content, and palatability, especially when mixed with other feeds. Numerous corn hybrid varieties, such as conventional, leafy, brown midrib, and waxy hybrids, are available for silage. When selecting hybrids for silage, one should consider:

1. Avoiding hybrids based on grain yields exclusively.
2. The variation in the nutrient content for dairy cattle.
3. Evaluating hybrids on the basis of protein, net energy for lactation (NEL), amylase neutral detergent fiber (aNDF), and fiber fill on a per-acre basis, using the current value of these nutrients (St-Pierre and Weiss 2011).

The most common advantage of intercropping is the greater yield on a given piece of land by making efficient use of the available resources. Moreover, intercropping with legumes improves soil fertility through biological nitrogen fixation, increases soil conservation, and provides better lodging resistance for crops susceptible to lodging. Intercropping often improves forage quality by increasing crude protein (CP) of forage (Titterton and Maasdrop 1997). Intercropping provides financial stability, especially during extreme weather conditions such as drought, and makes the system particularly suitable for labor-intensive small farms. In addition, intercropping minimizes agriculture's environmental influences and reduces fertilizer and pesticide application requirements. However, there are some disadvantages with intercropping, such as the selection of the appropriate crop species, sowing densities, crop management, and harvest.

Figure 1. Corn–soybean intercropping with soybean maturity group 7 (MG 7) planted at 76,000 seeds per acre and corn at 38,000 seeds per acre. Intercropping corn with soybean yielded 2.3 tons per acre more than corn at 67% moisture. Intercropping also decreased amylase treated neutral detergent fiber (aNDF), which increased value per ton and per acre. Photo was taken at the Irrigated Research and Extension Center located near Prosser, WA, in September 2012. Photo credit: Don Llewellyn.

Grass–legume intercropping combinations are often used for forage and cover crops. Intercropping corn–legumes often produces higher dry matter yield and better-quality silage than monocrop corn (Geren et al. 2008; Putnam et al. 1986). Barley or oat with peas intercropping enhances forage yield and quality (Carr et al. 2004). Similarly, crude protein, dry matter yield, and ash content of corn forage increase by intercropping with legumes compared with monocrop corn (Javanmard et al. 2009). It is evident from the above studies that corn–legume intercropping can substantially increase forage quantity and quality compared with corn monocrop (Javanmard et al. 2009).

Why Consider Intercropping Corn with Soybean

Ultimately, the reasons for intercropping corn–soybean include increasing yields and increasing protein content and dry matter intake by dairy cows due to the lower fiber content in soybeans which will increase value and decrease costs to a dairy farmer. Feed prices for dairy feedstock have increased dramatically in recent years so intercropping was a method successfully researched to decrease costs of producing feed as well as increase milk production to meet demand.

Soybeans grow well in the Pacific Northwest (PNW) and have excellent potential for addressing need in the Columbia Basin for oil, seed, and forage under irrigation. Soybeans are grown extensively in the midwestern and southeastern parts of the United States where soybean varieties and agronomic information is abundant for seed production. The soybean maturity group (MG) is a measure of how long it takes a particular soybean varietal to produce seed, ranging from 000 to 9 planted in northern and southern zones, respectively (Norberg et al. 2010). These MG can be further categorized into relative maturity groups by adding a decimal. For instance, relative maturity groups from 0.5 to 1.4 are best adapted to the Lower Columbia Basin for grain production (Kesoju and Woodward, 2017, unpublished results). However, these maturity groups may not be ideal for silage production as they increase fat content which can create problems in rations, and early maturing soybeans tend to be less competitive when intercropped with corn than later ones. Significant visual height differences exist between maturity groups of soybeans (Figure 2).

Limited data on varieties or agronomics are available to PNW growers and most of it is for grain production. Soybean grain variety trials in the PNW have been conducted in Idaho and Oregon by Norberg et al. (2010) and in Washington by Woodward (2018, personal communication). It is possible to produce irrigated soybean grain yields as high as those observed in the Midwest, which may reach up to 80 bushels per acre of grain (Kesoju and Woodward, 2017, unpublished results). Washington State University variety trials at Patterson, WA, and Columbia Basin College at Pasco, WA, reported yields of about 65 bushels per acre.

Figure 2. In Washington State, MG 7 soybeans (left side) produce no seeds, have more vegetative growth, and are taller, while MG 1 (right side) produce seed, have less vegetative growth, and are shorter, making MG 7 a better choice when intercropping for forage. Photo was taken in September 2012 at the Irrigated Research and Extension Center located near Prosser, WA. Photo credit: Don Llewellyn.

Soybeans intercropped with corn have been demonstrated to increase silage protein and produce a more balanced feedstuff to use for total mixed rations (TMR), thereby significantly decreasing the cost of dairy production by reducing the need for protein supplements. Recently, efforts to breed forage types of soybeans have resulted in newer varieties with greater forage yield potential and competitiveness with silage corn (Blount et al. 2011; Blount et al. 2017).

Since soybeans contain twice as much protein as corn, intercropping will reduce the amount of high protein feed needed to be purchased in order to formulate a TMR. Other advantages include the incorporation of a legume into the rotation to help break up continuous corn in the corn-and-triticale rotation and decreased insect and disease pressures in the field. Also, drilling soybean in conjunction with corn will close the canopy quicker (Figure 3).

Figure 3. Soybeans emerging with corn will close the canopy faster. Notice soybean drill rows are perpendicular to corn rows to reduce competition. Some soybeans are circled for identification purposes. Photo taken on June 2012 on a farm near Othello, WA. Photo credit: Steve Norberg.

Challenges to Consider When Intercropping

When intercropping, work with your seed dealer and purchase only registered seed treatments for feeding soybeans. In the PNW, purchase seed with insecticide that controls seed corn maggot which is the worst pest for soybean and may decrease stand. At the time of this publication, Cruiser Maxx Insecticide with Fungicides and Cruiser Maxx Advanced Insecticide with Fungicides have shown to be effective at improving stands and are labeled for forage use. Both labels have Thiamethoxam, Mefenoxam, and Fludioxonil as the active ingredients.

Intercropping corn with soybeans greatly reduces herbicide options; however, drilling soybean in conjunction with corn will close the canopy quicker, which will help with weed control (Figure 4 and Figure 5). Corn–soybean intercropping restricts herbicide options compared to monoculture corn. When considering weed control options, the label is the law. Using the same herbicide-resistance for both corn and soybeans makes weed control possible when intercropping corn and soybeans. Roundup Ready corn and soybeans allow for good weed control. It is important that you use herbicides that both crops can tolerate and all crop protection chemicals allow for forage harvest and feeding. Labels vary as to the grazing interval or harvest interval before feeding to animals.

Center pivot irrigation systems typically apply less irrigation water than what is lost due to evapotranspiration in mid-summer and could cause yield reductions if soil moisture content gets below critical levels. Intercropping will cause the canopy to develop faster, thereby increasing irrigation needs earlier in the season. To prevent yield-reducing situations, keep your center pivot well maintained so breakdowns do not occur.

During harvest, potential issues such as feeding into the header may occur, but a corn header on the combine has been demonstrated to be successful.

Figure 4. The left photo shows a corn-only plot where grassy weeds are present in the understory and sunlight reaches the ground in many places. The right photo shows a corn plot, intercropped with soybeans, which provides additional high protein forage and captures all sunlight, thereby minimizing weed pressure. Both photos were taken in September at the Irrigated Research and Extension Center located near Prosser, WA. Photo credits: Steve Norberg.

How to Intercrop Corn with Soybeans

Intercropping in a corn–triticale relay cropping system works best if planting is delayed to late May or early June, which reduces problems with staggered emergence (soybean emergence is slower than corn in cold soils). Drill the soybean seed in six-inch spacing crossways or perpendicular to future corn rows (Figure 3). This planting arrangement will decrease within-row competition, allowing both crops to rapidly grow and is preferred in the seedling stage, thereby resulting in better stands. It is wise to start planning early when intercropping soybeans with corn, since soybeans are not traditionally grown, and soybean seed and inoculants are not typically sold in the PNW. In addition, selecting soybean and purchasing the seed early may reduce transportation costs since the seed can be shipped with corn seed. Also soybean needs a different strain of rhizobium inoculant (*Bradyrhizobium japonicum*) compared to other legumes grown in the PNW and will likely require ordering from the Midwest. Keep the inoculant in a cool environment but do not allow it to freeze, and keep it out of direct sunlight. Purchase the inoculant every year to ensure living and active *Rhizobium*. Since most of Washington producers have not grown soybeans, it is better to double-apply the recommended rate of *Bradyrhizobium japonicum* inoculant on the seed. Inoculant is relatively inexpensive compared to other input costs and will help reduce the nitrogen requirements for the intercrop mix.

Corn and Soybean Intercropping Research

Field research conducted at the Washington State University Irrigated Agriculture Research and Extension Center near Prosser, Washington, in 2012 and 2013 evaluated intercropped soybean seeding rates and soybean content in the corn–soybean intercrop mix (Norberg et al. 2021). Results show that selecting a very late MG 7 increased return by $90 per acre compared with MG 1 soybean. Late-maturing soybeans are more aggressive in competing with corn and will not produce seed that could shatter to the ground, which prevents soybean from becoming a potential weed. Early-maturing soybeans (MG 1) produce viable seed, which may affect the fat content of milk but negatively affect the TMR. When soybeans are planted at 76,000 seeds per acre and corn at 38,000 seeds per acre, MG 1 soybean had a concentration of 3.3% of the intercrop silage mix while MG 7 had 5.2% (Figure 5).

Plant Soybeans First

Corn will comprise the majority of the crop mixture when intercropped with soybean. To help overcome this, plant the soybeans first. Also, drilling the soybeans prior to planting corn is an ideal option since it eliminates driving over planted corn which comprises most of the silage yield. Ideally, the farmer

Figure 5. Corn–soybean intercropping with soybean MG 7 planted at 76,000 seeds per acre and corn at 38,000 seeds per acre on August 26, 2013, at the Irrigated Research and Extension Center located near Prosser, WA. Photo credit: Steve Norberg.

would have an extra tractor, a drill, and one extra person so corn planting is not slowed down. Follow soybean planting with corn just as you would for monoculture corn silage.

Soybean Seeding Rate

Do not plant soybeans simply by pounds per acre as seed size among varieties can vary as much as 50%. Check the soybean seed bag for the number of seeds per pound and adjust the drill accordingly. Planting soybeans at about 75,000 seeds per acre, or about twice the corn-planting rate, has been shown to maximize silage nutrient value (Norberg et al. 2021). When producers sold strictly by tonnage, a soybean seeding rate of 117,000 seeds per acre was found to be optimum (Figure 6).

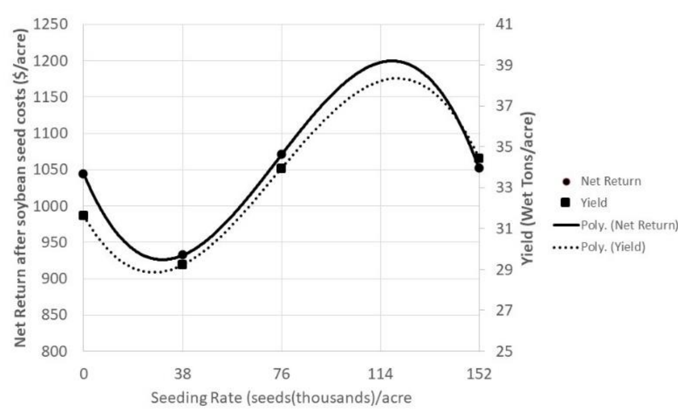

Figure 6. Net return and yield of intercropped corn and soybean after seed costs as influenced by soybean seeding rate in 2012. Regression shows an optimum of 117,000 seeds per acre and assumes $15 per acre drilling cost, $92 per bag soybeans (140,000 seeds), and silage valued at $33 per ton at 66% moisture (Norberg et al. 2021).

Fertilization

Apply nitrogen and other nutrients to corn just as if soybean were not there. Our most current recommendations for corn fertilization can be found in *Nutrient Management for Field Corn Silage and Grain in the Inland Pacific Northwest* (Brown et al. 2010). Soybeans require similar soil nutrient levels to corn, other than nitrogen, since seed inoculation with Rhizobia will fulfill the nitrogen needs of soybean.

Quality and Ensiling Considerations

PNW dairy producers rely on corn silage as a component of TMR. Intercropping MG 7 soybean into corn influences the feed quality and ensiling characteristics of the crop. When comparing corn and soybean monocultures, with corn planted at a normal rate of 38,000 seeds per acre and soybean at 76,000 seeds per acre, several forage quality parameters were affected (Table 1). Soybeans have twice the protein content of corn and 16% lower aNDF content, which allows dairy cows to eat more feed. However, monoculture corn has much higher starch and energy content and lower ash content than soybeans. To determine the treatment value of nutrients for a dairy cow, we followed the method by St-Pierre and Weiss (2011). When intercropped together at a soybean seeding rate of 76,000 seeds per acre, the nutrient value of the resulting silage was increased $23 per ton over monoculture corn (Table 2). Seeding at these rates resulted in intercropped silage composed of 4.3% soybeans and 95.7% corn and increased nutrient value to dairy cows by $288 per acre, primarily due to increased feed intake (i.e., decreased aNDF (Table 3; Figure 7). Quite interestingly, addition of soybean to corn did not significantly reduce the starch content of the silage, which is a major attribute of corn silage and provides significant amounts of energy in the feed (Table 1).

Table 1. Averaged over years, results for MG 7 soybean quality parameters, including crude protein, net energy for lactation (NEL), acid detergent fiber (ADF), ash free neutral detergent fiber (aNDF), fat, ash, starch, and moisture content as influenced by cropping system and intercropped soybean seeding rate.

Treatment	Soybean Seeding Rate	Crude Protein[1]	NEL[1]	ADF[1]	aNDF[1]	Fat[1]	Ash[1]	Starch[1]	Moisture[1]
	seeds per acre	%	MCal/lb	%	%	%	%	%	%
Monocrop Corn	0	8.2b	0.60a	35.1b	52.1b	1.42	13.1a	15.7b	66.1
Intercrop MG 7	38,000	8.9b	0.57a	32.4ab	47.8b	1.45	16.4a	15.4b	67.0
Intercrop MG 7	76,000	8.7b	0.58a	30.9ab	46.9b	1.70	15.5a	18.1a	66.9
Intercrop MG 7	152,000	9.3b	0.59a	35.5b	51.1b	1.37	14.3a	13.7b	63.5
Monocrop Soybean	38,000	15.8a	0.39c	29.4a	33.5a	1.49	29.8b	1.4c	67.7
Monocrop Soybean	76,000	14.7a	0.42c	31.2a	36.8a	1.43	27.4b	2.1c	66.0
Monocrop Soybean	152,000	15.1a	0.45b	32.9a	39.3a	1.60a	24.8b	2.7c	66.0
P Value		0.0001	0.0001	0.0366	0.0001	NS	0.0001	0.0001	NS

[1] Different letters within a column are significantly different at $p \leq 0.05$.

Table 2. Value in dollars per ton of metabolizable protein, energy, fiber, adjustment for dairy feed intake, total value of dry forage, and amylase treated nutrient detergent fiber percent averaged over years for maturity group seven soybean treatments. Different letters are significantly different across treatments ($p \leq 0.05$) (Norberg et al. 2021).

Treatment	aNDF	Value of Metabolizable Protein[1]	Value of Energy (from NEL)[1]	Value of Fiber (aNDF)[1]	Adj. for Feed Intake[2]	Total Value of Dry Forage[3]
	%	------------------------------$ per Ton----------------------------------				
Corn Only Control	52.07d	11.21b	46.56a	15.22a	-40.33d	32.34b
Intercropped 38,000 Seeds per Acre	47.78bc	12.08b	43.83a	13.97a	-18.92bc	50.62b
Intercropped 76,000 Seeds per Acre	46.93b	11.78b	44.70a	13.72a	-14.65b	55.20b
Intercropped 152,000 Seeds per Acre	51.05cd	12.65b	45.27a	14.92a	-35.25c	37.23b

Treatment	aNDF	Value of Metabolizable Protein[1]	Value of Energy (from NEL)[1]	Value of Fiber (aNDF)[1]	Adj. for Feed Intake[2]	Total Value of Dry Forage[3]
	%	------------------------------$ per Ton----------------------------------				
Soybean Only 150,000 Seeds per Acre	39.29a	20.50a	34.53b	11.49b	23.53a	89.46a

[1] Calculated at $0.35 per lb of metabolizable protein (corn at 60%, soybean 55% of C. Protein); $0.11 per lb of MCal of energy (from net energy of lactation) NEL; $0.07 lb of effective aNDF; negative $0.08 lb for ineffective fiber (assuming aNDF is 81% effective and 19% ineffective fiber).
[2] Adjustment for fiber impact on milk production due to cows eating more or less ration due to fiber; $5.00 increase or decrease of value of hay for every percentage point below or above and aNDF 44%, respectively.
[3] Total value of forage per ton (sum of protein, energy, fiber, and fiber adjustment).

Table 3. Value in dollars per acre of metabolizable protein, energy, fiber, adjustment for dairy feed intake, total value of dry hay, and total dry matter produced years for MG 7 soybean treatments averaged over years. Different letters are significantly different across treatments ($p \leq 0.05$) (Norberg et al. 2021).

Treatment	Value of Metabolizable Protein[1]	Value of Energy (NEL)[1]	Value of Fiber (aNDF)[1]	Adj. for Feed Intake[2]	Total Value of Forage[3]	Difference in Value from Corn Control
	--$ per Acre--					
Corn Only Control	121.91a	474.66a	150.80a	-379.80c	367.57b	0
Intercrop 38,000 Seeds per Acre	128.87a	449.31a	140.30a	-199.69bc	518.79ab	151.22
Intercrop 76,000 Seeds per Acre	136.16a	485.97a	145.05a	-112.04b	655.13a	287.56
Intercrop 152,000 Seeds per Acre	139.96a	484.58a	156.89a	-373.13c	408.30b	40.73
Soybean Only 152,000 Seeds per Acre	126.39a	215.67b	70.34b	166.99a	579.39ab	211.82

[1] Calculated at $0.35/lb of Metabolizable Protein (corn at 60%, soybean 55% of C. Protein); $0.11/lb of MCal of energy (from net energy of lactation) NEL; $0.07 lb of effective aNDF; and $-0.08 lb for ineffective fiber (assuming aNDF is 81% effective and 19% ineffective fiber).
[2] Adjustment for fiber impact of milk production due to cows eating more or less ration due to fiber; $5.00 increase or decrease of value of hay for every point below or above and aNDF 44%, respectively.
[3] Total value of hay per acre (sum of protein, energy, fiber & fiber adjustment).

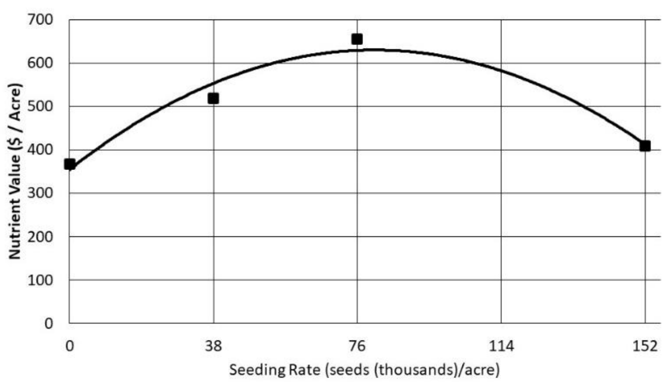

Figure 7. Averaged over years, the nutrient value to a dairy animal (protein, energy, fiber, and fiber fill adjustment) per acre of MG 7 soybeans as influenced by seeding rate (thousands per acre). The predicted optimum soybean seeding rate was 81,000 seeds per acre and was consistent between years (Norberg et al. 2021).

The addition of MG 7 soybean into corn did not significantly affect the pH or the forage after ensiling, with pH near 4.0 in most cases. The loss of NH3 (an indicator of protein breakdown during ensiling) was not appreciably affected as well. Lactic acid (an indicator of homofermentation) was higher for the monoculture corn in the first year of observations, while no such observations were noticed in the second year. Dry matter recovery was not different for monoculture corn or the corn and soybean mixture. Intercropping corn with soybean had no detrimental effect on dry matter 24 and 48 hour *in situ* (in the animal testing) digestibility either pre- or post-ensiling when compared with corn only. Likewise, 24 and 48 hour *in situ* neutral detergent fiber digestibility (NDFD) was not affected either pre- or post-ensiling. Finally, monocultures of soybean were compared with monoculture corn and the corn and soybean mixtures and noted significantly higher CP and lower NDF content in the soybean. However, soybean alone is not a significant source of starch. Monocultures of soybean appear to ensile acceptably but have slightly higher pH upon ensiling. Losses of NH3 are greater for monoculture soybeans, likely because of the greater CP content, but still within acceptable levels. Dry matter recovery of soybean monoculture silage was very good, 94.3% and 98.9%, for the first and second years, respectively. *In situ* 24- and 48-hour dry matter digestibility and neutral detergent fiber digestibility of monoculture soybean was acceptable, but varied in comparison (sometimes higher and sometimes lower) than the monoculture corn or soybean intercropped with corn. Taken together, forage quality, fermentation characteristics, and *in situ* digestion characteristics all show that monoculture corn, corn intercropped with soybean, and monoculture soybean are all potential components for TMRs.

Summary

Intercropping corn with soybeans makes economic sense. On a tonnage basis, the yield increase alone was 2.2 tons per acre at 67% moisture (assuming $33 per wet ton). Intercropping would result in an additional $74 per acre gross income. Soybean seed and drilling cost are estimated at $69 per acre, leaving $24 per acre in profit by intercropping with MG 7 soybeans at 76,000 seeds per acre, which, in our experiment, was twice the corn population. On a nutrient value to dairy cow basis, intercropping increased the gross value by $55 per ton and $288 per acre, and, after expenses, netted an increase of $219 per acre. Forage soybeans are about two times as high in protein as corn silage, so intercropping increases protein with the proportion of soybean in the resulting forage. Amylase treated NDF in corn typically tests near 51%, whereas optimally intercropping with soybean forage runs near 47%, showing that adding soybeans decreases fiber content, allowing increases in feed intake by high-producing dairy cows and thereby increasing milk production.

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