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Relay Intercropping with Cover Crops Improved Autumn Forage Potential of Sweet Maize Stover

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Abstract: Maize (*Zea mays* L.) stover is used globally as winter feed for livestock but the nutritive value is low, requiring supplementation. A 2-year randomized complete block study with three replicates at New Mexico State University's Alcalde Sustainable Agriculture Science Center compared sweet maize (*Zea mays* var. *rugosa*; maize-alone) with sweet maize relay intercropped with oat (*Avena sativa* L.; maize-oat) or turnip (*Brassica rapa* L.; maize-turnip). Relay intercropping had no effect ($p > 0.05$) on sweet maize stover dry matter (DM) yield and there was no difference in aboveground biomass DM yield of the intercropped species. Turnip aboveground biomass had greater crude protein concentration and 48-h in vitro dry matter disappearance (IVDMD) than oat aboveground biomass. Relay intercropping with turnip improved sweet maize stover IVDMD (443, 439, and 515 g IVDMD kg^{-1} for maize-alone, maize-oat, and maize-turnip, respectively, $p < 0.0001$). Intercropping increased animal gains compared to maize-alone (0.36, 0.52, and 0.59 kg/day for maize-alone, maize-oat, and maize-turnip, respectively, $p < 0.02$), likely due to provision of additional crude protein. Relay intercropping oat or turnip into sweet maize is viable for improving sweet maize stover for fall forage. In addition turnip, specifically, had a positive effect on stover nutritive value.

Keywords: forage; sweet maize; oat; brassica; relay intercropping; grazing; nutritive value; crude protein; in vitro dry matter disappearance

1. Introduction

Improved productivity of available land resources is a global concern [1]. Moreover, farmers seek options to sustain their livelihood in the face of increased input costs while protecting soils and other natural resources [2]. Crop residues, such as maize stover, help to protect the soil, but also have been used as an economical winter feed source for livestock in many parts of the world, either grazed in situ [1–4] or as stored feed ex situ [2,5,6]. Grazing is probably the best use of maize stover although energy and/or protein may be limiting, except possibly for non-lactating cows or calves, especially in irrigated fields [4,7].

Cover cropping is another management option to conserve water and soil and to reduce the cost of applied inorganic fertilizer. Legumes are used to acquire and store atmospheric nitrogen and non-leguminous cover crops can be used to recover and store applied nutrients [8]. Grazing cover crops has the potential to produce both cash returns and soil quality improvements [8]. Consequently, interest is increasing in grazing cover crops or harvesting them as stored feed.

Although they are not without their limitations, integrated crop-livestock enterprises, including grazing cover crops and crop residues, provide significant production and environmental benefits [8]. Others [9] found no difference between grazing and mowing for termination of cover crops in regard to their ecological effects on weed or carabid beetle communities [9] and grazing did not have a negative effect on soil organic carbon or total soil nitrogen to a 150 cm soil depth [10]. However, grazing cover crops in a soybean (*Glycine max* L.) production system improved soil phosphorus status and utilization through beef production compared to the ungrazed treatment [11].

Intercropping and sequential cropping describe multiple cropping options commonly used in warmer climates to increase productivity per unit of land [12–14]. Relay intercropping is a form of multiple cropping in which a sequential crop is planted when the first crop has reached its reproductive stage [12]. This reduces competition between the primary (generally the higher value crop and planted first without competition) and secondary crop as opposed to planting the secondary crop earlier [1]. Relay intercropping is suitable in some cropping scenarios, but not others. For example, peanut (*Arachis hypogaea* L.) relay intercropped into winter wheat (*Triticum aestivum* L.) to evaluate earlier planting options for peanut reduced wheat grain yields due to traffic damage during peanut planting and reduced peanut yields that were attributed to the lack of tillage prior to peanut planting [15]. On the other hand, when the primary crops were not stressed, relay intercropping forage kale (*B. oleracea* L.), rape (*B. napus* L.), and turnip into standing sweet maize and chile peppers (*Capsicum annuum* L.) to increase the available autumn forage generally led to no reduction in primary crop yield [16,17]. Generally, turnip had greater aboveground biomass dry matter (DM) yields than the other brassicas with the added benefit that the root also can be utilized by grazing livestock [16,17]. In another study, turnip had greater regrowth potential and crude protein (CP) concentration that is more sustained across regrowth periods compared to kale and rape in a multiple-cut system, which should be of value under grazing where regrowth potential is important [18].

Winter cereal forages also are used widely in the irrigated western USA and other semiarid regions of the world for supplemental autumn and winter forage and are especially beneficial to provide pasture high in nutritive value for recently weaned calves [19,20]. As with the brassicas evaluated by others [16,17], earlier planting increased autumn forage yield of winter cereals compared to later planting [20].

The sweet maize-brassica relay intercropping system previously described [16] was not evaluated for its forage nutritive value and others have stated that intercropping forages into annual cash crops requires more information [1]. Therefore, the objectives of this research were to determine how relay intercropping oat or turnip might have an effect on sweet maize stover component and overseeded forage (oat or turnip) biomass and nutritive value.

2. Materials and Methods

2.1. Experimental Site Description

Trials with the same relay intercropping treatments (sweet maize only (maize-alone), sweet maize overseeded with oats (maize-oat), and sweet maize overseeded with turnips (maize-turnip)) were conducted in two years at New Mexico State University's Alcalde Sustainable Agriculture Science Center (36.08° N, 106.05° W, elev. 1745 m). Soil type was Alcalde clay (fine, mixed (calcareous), mesic Vertic Torriorthent).

2.2. Weather

The climate in the region is continental semiarid steppe with warm, moist summers and cool, dry winters. Weather data were collected from an on-site station within 0.5 km of the study area. The average temperature during the years of this study was just above the long-term average, but there was variation between years (Table 1). The average annual precipitation during the study period was below the long-term average for Year 1 and above the long-term average for Year 2 (Table 1). Differences between years can be partially explained by a nearly 46 mm difference in October precipitation, although, there also were considerable differences between years in precipitation amount and distribution for other months (Table 1).

Table 1. Monthly mean air temperatures and total precipitation at Alcalde, New Mexico, USA, from each year of the study period and the long-term (1953–2016) means.

Month	Temperature, °C			Precipitation, mm		
	Year 1	Year 2	Long-Term Mean	Year 1	Year 2	Long-Term Mean
January	−1.6	0.0	−0.9	3	2	10
February	4.5	1.3	2.1	15	11	9
March	5.4	5.1	5.8	4	22	13
April	12.0	8.7	10.2	0	6	15
May	19.3	15.0	14.8	0	0	19
June	21.1	18.7	19.6	54	7	20
July	22.2	22.8	22.4	20	57	35
August	21.4	21.8	21.2	42	58	48
September	15.6	19.4	17	21	16	32
October	9.4	11.0	10.9	58	104	26
November	4.2	5.7	4.4	4	19	16
December	−1.5	1.9	−0.5	10	0	12
Mean	11.0	11.0	10.6	232	300	254

2.3. Crop Establishment and Management

The same field was used for both years of the study; however, the tests (Year 1 and Year 2) reported here were separated by a fallow year for weed management. During the fallow year before the first test and between tests, the field was cultivated by disking multiple times for weed control. Additionally, glyphosate (isopropylamine salt of *N*-(phosphonomethyl)glycine; 1.96 kg ha^{-1}) was broadcast once in the fall and again immediately pre-planting and 2,4-D (Dimethylamine salt of 2,4-Dichloro-phenoxyacetic acid; 1.12 kg ha^{-1}) was applied in the spring of the intervening year. Before planting, beds were shaped with a rolling cultivator on 0.91 m centers for furrow irrigation. No pre-emergent herbicides were used.

Sweet maize ('Bodacious'; 75 days to maturity) was planted at a seeding rate of 8.5 kg ha^{-1} on 7 and 8 May of Years 1 & 2, respectively, with a two-row planter to achieve a population density of 63,292 plants ha^{-1}. Each test was furrow-irrigated after planting and throughout the growing season to supplement precipitation and prevent moisture stress.

Fertilizer (133-25-0 kg N-P-K ha^{-1} in Year 1 and 25 kg P ha^{-1} in Year 2) was applied preplanting. Sidedressings of 90 kg N ha^{-1} were made on 3 July in Year 1 and on 2 and 22 June in Year 2. These fertilizer rates were based on local recommendations for sweet maize production and urea (46-0-0) and triple superphosphate (0-46-0) were always used as the sources. Maize earworm (*Helicoverpa zea* L.) was controlled with applications of Dipel (*Bacillus thuringiensis* L.) on 20 June and 6 July of Year 1 and with MVP (*B. thuringiensis*) on 3 and 10 August of Year 2. On each date, 0.56 kg ha^{-1} of product was applied.

Each year, test areas were divided into 76 m × 20 m plots for the relay intercropping treatments and annual forages were broadcast into the sweet maize on 12 and 15 July of Years 1 & 2, respectively, at the V7–9 maturity stage (7–9 leaves) [21] and plants were approximately 0.5 m tall. A tractormounted broadcast spreader was used and a ground crew carried a tarp between plots to prevent cross-contamination. After overseeding, a final light pass with the rolling cultivator was used to incorporate the seed. Unhusked market-ready maize ears were hand-harvested from the entire test area on 9 and 13 August of Years 1 & 2, respectively.

2.4. Forage Sample Collection

After the first killing frost had occurred, forage samples were collected (11 and 3 November of Years 1 & 2, respectively) from four 3 m x 1.8 m locations within each plot in Year 1 and three locations in Year 2. At sampling time, the maize stover was senesced; the oats had fully headed and completely senesced; and, while the turnips had frost damage, the leaves were still green and succulent. Whole maize plants were cut with a machete 5–10 cm above the soil surface, counted and weighed fresh in the field after which leaves and ears that had not been previously market ready were stripped and weighed separately. Stalk yield was determined by the difference. While leaf sheaths may or may not have been stripped with the leaves, it was assumed that stripping the leaves in this way would simulate removal by grazing livestock [22] as opposed to harvesting only leaf blades. Whole plant sweet maize biomass DM was calculated as the sum of the component DM biomasses.

Overseeded oat aboveground biomass was then harvested to ground level with hand-held shears and weighed fresh in the field. Whole turnip plants were pulled by hand and separated into roots and tops (aboveground biomass) using the shears. Forage samples also were taken after grazing was terminated near the locations previously sampled to determine post-grazing DM yield and disappearance calculated as the proportion of forage that had disappeared during the grazing occupation [4]. A subsample of each sweet maize stover component (ears, leaves, and stalks) and overseeded forage component (tops and roots) collected from each harvested area before and after grazing was dried in a forced-air oven at 65 °C for 48 h for moisture determination and biomass DM yield calculations. Subsamples were ground to pass a 1-mm screen. Laboratory analyses were conducted to determine crude protein (CP) concentration by Kjeldahl [23] and 48-h in vitro DM disappearance (48-h IVDMD) [24]. Whole plant sweet maize CP and IVDMD concentrations were calculated as a weighted average of the component CP and IVDMD concentrations. Sweet maize whole plant CP and 48-h IVDMD were calculated as the weighted mean of the ear, leaf, and stalk components.

2.5. Grazing Management

Newly weaned beef heifers (predominantly British x continental cross) (188 ± 8 kg BW (body weight) and 200 ± 7 kg BW in Years 1 & 2, respectively) grazed the intercropping treatment paddocks. Prior to grazing, all animals were acclimated using a combination of dormant alfalfa (*Medicago sativa* L.) pasture in Year 1 or maize stover in Year 2, both supplemented with alfalfa hay. Each paddock was fenced separately and grazed by 2 heifers. Single strand electric fence was used to limit graze within each plot. The grazing allotment was increased every three to five days with free access to previously grazed areas and their water source. Animals were removed when the forage in the entire plot had been effectively utilized, four to five weeks after the onset of grazing in Year 1; however, higher yields of the maize-turnip treatment in Year 2 permitted 9.5 weeks of grazing.

2.6. Cattle Measurements

Prior to the onset of grazing and when grazing was terminated, the heifers were shrunk overnight and weighed the following morning and afternoon. The average weight for that day was used for each heifer to calculate average daily gain (ADG).

2.7. Statistical Analyses

Each test was a randomized complete block with three replications. Subsample and cattle data within each plot were averaged to represent that plot. Pre-grazing biomass and pre-grazing CP concentration and 48-h IVDMD and post-grazing biomass and disappearance of sweet maize stover ear, leaf, and stalk component data were analyzed with the mixed procedure of SAS [25]. Tested effects included year, sweet maize stover component (ear, leaf, and stalk), relay intercropping treatment (maize-alone, maize-oat, and maize-turnip), and all possible interactions. Pre-grazing whole plant nutritive value, pre- and post-grazing whole plant biomass and disappearance of sweet maize stover; pre-grazing nutritive value and pre- and post-grazing biomass and disappearance of overseeded forage components; initial cattle weights; and cattle ADG were analyzed with the Mixed procedure of SAS [25]. Tested effects included relay intercropping treatment and year and their interaction. Rep × year and residual mean squares were considered random and used as denominators for tests of significance [26]. All differences reported are significant at $p \leq 0.05$. When a main effect or interaction was significant, protected ($p \leq 0.05$) least significant differences were used to determine where differences occurred among treatment means using the PDMIX800 SAS macro (Arnold M. Saxton, University of Tennessee, Knoxville, TN, USA, 2000).

3. Results and Discussion

3.1. Sweet Maize Stover Biomass

Sweet maize stover components were all different from each other in biomass yield (0.43, 0.73, and 1.61 Mg DM ha^{-1} for the ear, leaf, and stalk components, respectively; standard error of the mean (SEM) = 0.06, $p < 0.0001$). Lesser ear biomass yield also was anticipated because, although the grain component of maize generally comprises about 50% of the total biomass [6,7], the market-ready ears had been previously harvested. There was no relay intercropping treatment effect or interaction for sweet maize stover total DM biomass (Table 2). Relay intercropping with brassicas also had no negative effect on yield of market ears, even when the overseeding took place during the V7–V9 (7 to 9 leaves) sweet maize vegetative stages [16,21]. The competitive ability of maize has been reported as possibly a combination of time of intercrop planting, soil fertility, and water availability, among other factors [1]. Total sweet maize stover yields in this study (Table 2) were considerably less than that reported by others for maize stover [4,27]. These differences may be due in part to genotype [28], such that sweet maize was used in the present study and maize developed for grain and/or forage was used by the others mentioned. Seeding rates, environmental conditions, and management factors also likely had an effect.

Table 2. Relay intercropping treatment main effect means of pre-grazing aboveground biomass dry matter (DM) yield, crude protein concentration, and 48-h in vitro dry matter disappearance (48-h IVDMD) of sweet maize stover alone or intercropped with oat or turnip and the overseeded forage species over two years at Alcalde, NM, USA [1].

Intercropping Treatment Effect (I)	Aboveground Biomass, mg DM ha^{-1}		Aboveground Crude Protein, g kg^{-1}		Aboveground 48-h IVDMD, g kg^{-1}	
	Whole Plant Sweet Maize Stover	Over-Seeded Forage	Whole Plant Sweet Maize Stover	Over-Seeded Forage	Whole Plant Sweet Maize Stover	Over-Seeded Forage
Maize alone	3.06	-	122	-	466 [b]	-
Maize-oat	2.58	1.99	115	119 [2,b]	474 [b]	422 [b]
Maize-turnip	2.68	2.89	122	186 [a]	541 [a]	623 [a]
SEM [3]	0.20	0.39	4	5	15	17
			p-Values			
Year (Y)	0.7844	0.0119	0.0266	0.1455	0.0763	0.2092
I	0.2332	0.1408	0.4248	0.0006	0.0012	0.0001
Y × I	0.6121	0.2069	0.8355	0.3218	0.4167	0.5874

[1] Values in the table are the lsmeans of three replicates for each component of the year × intercropping treatment (Y × I) interaction. [2] Lsmeans in the same column followed by the same letter are not significantly different at the 5% alpha level for the intercropping treatment effect. [3] Standard error of the mean.

3.2. Overseeded Forage Biomass

A difference existed between years for overseeded forage aboveground biomass (1.55 and 3.33 Mg DM ha^{-1} for Years 1 and 2, respectively; SEM = 0.39, $p < 0.0119$), likely because of precipitation differences in October (Table 1). Between-year and between-site variability in the benefits of intercropping have been attributed to environmental conditions, with greater benefits observed in semiarid environments [14]. At 2 Mg DM ha^{-1}, aboveground biomass yield of oat sown in late summer and harvested in the autumn in this study (Table 2) was somewhat less than that reported by others for late summer sown oat [19,20,29]. The mid-summer-sown oat in the present study was headed when harvested. Aboveground biomass yield of turnip in this study (Table 2) was similar to that reported for monocrops [18], as well as under relay intercropping [16] at the same location of the present study. Turnip root biomass did not differ across years at 1.01 Mg DM ha^{-1}. The proportion of total DM in the turnip roots (26%, calculated from yield reported in text and Table 2) was less than that for turnip planted in late June to mid-July [16] early August [16,17] at the same location of the present study.

Although oat and turnip were not significantly different in aboveground biomass yield (Table 2), competition with the sweet maize in the present study may have limited growth of the oat because, although sweet maize and oat have some dissimilarities in their root system architecture, they are both hydrotropic and explore a similar horizon of the root zone regulated by soil factors that cause them to follow paths of least impediment and avoid dry soil [14,30] and the maize roots were established first [1]. Nevertheless, oat is the species of choice among winter cereals for autumn forage because it is more productive than winter wheat during that period [19]. Brassica root architecture is different enough from the grasses, being more taprooted, and can break through soil impedances more readily to access soil moisture and nutrients in deeper horizons [14,27,31]. Although the sweet maize root system was established first [1], brassica roots in the present study could have pushed through that competition to find nutrients and water to promote growth [27]. Brassicas use hydraulic lift to improve P and K uptake in dry soils [31].

The choice of forage species and time of planting were important factors in determining the productivity of the primary crop when palisadegrass (*Urochloa brizantha* (Hochst. ex A. Rich.) R. Webster syn. *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf) and guineagrass (*Megathyrsus maximus* (Jacq.) B. K. Simon & S. W. L. Jacobs syn. *Panicum maximum* Jacq.) were intercropped into a maize grain production system at two planting times [1]. By comparing results of the present study with those of others [1,16,17], it would appear from the present study that choice of primary and overseeded forage may both have an effect on the production potential of the overseeded forage without having any effect on the primary crop when it has not been stressed. Others [14] have suggested that more distantly related species (e.g., sweet maize and turnip as opposed to sweet maize and oat) might have greater complementarity effects due to less of an overlap in their niche [13].

3.3. Sweet Maize Stover CP Concentration

Whole plant sweet maize stover component CP concentration differed between years (110 and 130 g kg^{-1} CP for Years 1 and 2, respectively; SEM = 4, $p < 0.0266$). Climatic conditions from September through the end of the growing season may have been a factor in the year effect as temperatures were 1.5 to nearly 4 °C warmer in Year 2 than Year 1 (Table 1). Precipitation was likely not a factor during the sweet maize growing period in the present study because irrigations were applied to prevent moisture stress.

Differences among relay intercropping treatments did not exist and there were no interactions (Table 2); however, there were differences in CP concentration among sweet maize stover components (123, 89, and 134 g kg^{-1} for the ear, leaf, and stalk components, respectively; SEM = 3, $p < 0.0001$). Lesser leaf concentrations could be due to mobilization of N to the ears [5] or greater weathering after senescence compared to ears and stalks [4]. Nonetheless, lesser ear CP concentration than stalk CP concentration is contrary to the findings of others [4]. Maize stalk CP concentration is also directly associated with soil N status [5,6]; however, sufficient N was applied in the present study pre-planting or at sidedress to meet the sweet maize requirement and it was consistent across years. One study [5] reported no differences in total N accumulation at N rates above 140 kg ha^{-1} and that once the maize became reproductive differences in ear-leaf N observed during the vegetative stages disappeared. The applied N in the present study totaled about 180–223 kg ha^{-1} and the CP concentration of sweet maize components measured in this study was about one and a half to two-fold that measured by others, who applied various rates from 0 to 244 kg ha^{-1} [4,6,27]. Genetics can have an effect on maize stalk CP concentration in addition to environmental conditions and N fertility [6] and sweet maize is genotypically different from maize grown for grain [28]. Little information about sweet maize stover nutritive value was found in the literature. Sweet maize stover (stalks, leaves, and remnant ears) CP concentration of 96 g kg^{-1} have been reported [32], which is slightly less than the whole plant stover CP concentration measured for maize-alone in the present study (Table 2). Additionally, others have reported that sweet maize residues (husks, cobs, cull ears, and part kernels after processing for canning, but somewhat similar to the ear component of the present study) contained about 108 g CP kg^{-1} before ensiling [33] and sweet maize residue silage CP concentrations of 71 g kg^{-1} [34]. Both of these values are less than those of the present study, possibly due to the inclusion of cobs with no grain and ensiling done in one of the cases [34].

3.4. Overseeded Forage CP Concentration

Neither the year nor the year × relay intercropping treatment interaction had an effect on overseeded forage aboveground biomass CP concentration; however, there was a difference for the main effect of relay intercropping treatment because turnip aboveground biomass had greater CP concentration than oat aboveground biomass (Table 2). This, again, may have been related to root system architecture and greater competition between the grass species (oat and sweet maize) than between sweet maize and turnip because brassicas can utilize nutrients at a deeper level in the soil profile [27,31]. Spatial complementarity in exploring the root zone can occur by species with contrasting root architecture [13], such as maize and turnip. Additionally, that the oat had reached maturity and was senesced in the present study would have reduced oat CP concentration (Table 2) [29]. Oat CP concentration in the present study was slightly less than the 150 g kg^{-1} average of five cultivars measured by others [19], but consistent to that measured for more mature oat [29]. Turnip aboveground CP concentration measured in this study was consistent to that measured for turnip planted in August [18] and for three species of brassica (*Brassica campestris* L. x *napus* L., *B. rapa* L., and *Raphanus sativus* L.) [27]. Turnip root CP concentration in this study was 162 g kg^{-1} and did not differ across years.

3.5. Sweet Maize Stover 48-h IVDMD

Similar to the difference among components in CP concentration, the 48-h IVDMD of sweet maize stalks was greater than ears and leaves, which also were different from each other (487, 349, and 561 g kg^{-1} for the ear, leaf, and stalk components, respectively; SEM = 16, $p < 0.0001$). This was consistent to the report by others [4]. Husks have been reported to be the most digestible component of grain maize stover [7] as well as sweet maize residue (husks, cobs, cull ears, and part kernels), which, as a whole, would have about 650 g kg^{-1} total digestible nutrients (TDN) [33]. The ear component in the present study had somewhat lesser 48-h IVDMD at 487 g kg^{-1}. Sweet maize residue and sweet maize by-product silage acid detergent fiber (ADF) has been reported at 374 [33] and 413 [34] g kg^{-1}, respectively, which equates to digestible dry matter [35] of 598 [33] and 567 [34] g kg^{-1}, respectively. In another study [7], stem nutritive value of less mature maize was greater due to greater sugar content.

There also was difference among relay intercropping treatments because whole plant stover of sweet maize overseeded with turnip (maize-turnip) had significantly greater 48-h IVDMD than maize alone or maize-oat (Table 2). While the cause of this is not well understood, several factors could be involved. First, both P and water availability can have an effect on ADF, which, in turn, can have an effect on digestibility [36,37]. Canola (also *B. napus* L.) increases the length and density of root hairs to increase P absorption aside from hydraulic lifting [31]. Additionally, P content in maize shoots was increased by 44.6% when grown with turnip [13] and P fertilization increased plant P content and reduced forage fiber components in narbon vetch (*Vicia narbonensis* L.) [38]. No mechanism was provided for increased P uptake by maize-turnip other than species complementarity and facilitation in resource use [13]. A difference between their study and the present study was the timing of planting. In one study [13] maize was planted after planting turnip while the reverse was the case in the present study. Nonetheless, enhanced P uptake could have been a factor in increased 48-h IVDMD of the sweet maize stover through reduced fiber. The release of water from hydraulic lifting by brassicas could potentially have increased P uptake by the sweet maize [31]. Maize also uses hydraulic lift as determined by drought-tolerant genetics, but brassica hydraulic lift continued for 28-d after drought was imposed [31]. Both maize and turnip acidify the rhizosphere of calcareous and alkaline soils and increase the availability of several nutrients, including P by secreting organic acids and phosphatases [14], although turnip had greater phosphatase activity than maize [13].

Another factor that can have an effect on IVDMD of maize is N fertility [5,6]. Brassicas are known to scavenge N from deeper soil horizons [27] and in the present study, turnip could have competed for available soil N in the upper horizon, although, similarly to the case already made for lesser oat CP concentration in the present study (Table 2), the sweet maize roots were already utilizing the N in that part of the root zone. Additionally, low N tends to increase fiber and reduce IVDMD [6], which is considered a better predictor of digestibility than ADF alone [5].

3.6. Overseeded Forage 48-h IVDMD

Relay intercropping had an effect on overseeded forage aboveground biomass 48-h IVDMD because 48-h IVDMD of turnip aboveground biomass was greater than that of oat aboveground biomass (Table 2). This was to be expected due to the leafy nature of turnip aboveground biomass and that the oat had headed and senesced, which leads to a reduction in (TDN) [19]. Lesser fiber and greater digestibility of less mature summer-sown oat has been reported [29]. Turnip root 48-h IVDMD was high and consistent across years at 742 g kg^{-1}.

In the present study, both the sweet maize stover and the turnip aboveground biomass of the maize-turnip relay intercropping treatment had greater 48-h IVDMD compared to the sweet maize stover of either the maize-alone or maize-oat relay intercropping treatments (Table 2). Relay intercropping turnip with sweet maize may have led to a beneficial neighbor interaction that allowed for greater exploitation of resources [13] by the sweet maize resulting in improved nutritive value of the stover [13]. Maize stover nutritive value varies genetically [7] and hydraulic lift [31] and root system architecture [30] both vary between plant species and possibly within plant species. Maize digestibility is a major objective of breeding programs [13] and it has been suggested that breeding to improve stover nutritive value of maize grain grown for human food would be a good venture [2]. It also has been suggested that breeding programs should consider traits that would benefit mixed cropping as a means to increase resource-use efficiency [14].

3.7. Post-Grazing Sweet Maize Stover Biomass and % Disappearance

While post-grazing sweet maize biomass and disappearance did not differ among relay intercropping treatments (Table 3), post-grazing biomass did differ among stover components because ear post-grazing biomass was less than that of leaf and stalk (0.03, 0.18, and 0.13 Mg DM ha^{-1} for the ear, leaf, and stalk components, respectively; SEM = 0.03, $p < 0.0033$). Percentage disappearance also differed among sweet maize stover components because disappearance of leaf was less than the disappearance of the other two components (89, 74, and 92% disappearance for the ear, leaf, and stalk components, respectively; SEM = 5, $p < 0.0116$). Post-grazing ear yield could be lower in this study because of higher nutritive value than weathered leaves (4) and accessibility, being still attached to the standing stalk. Others [4,7] have reported that grain and husks disappeared more rapidly than leaf components most of the time, especially if not covered with snow. They [4,7] also reported that cattle grazing maize stover will select higher quality plant components first, in this case, the ear and stalk components.

Table 3. Relay intercropping treatment main effect means of post-grazing aboveground biomass dry matter (DM) yield and percent disappearance of sweet maize stover alone or intercropped with oat or turnip and the intercropping forage species over two years at Alcalde, NM [1].

Intercropping Treatment (I)	Whole Plant Sweet Maize Stover		Overseeded Forage	
	Aboveground Biomass, Mg DM ha^{-1}	Disappearance, %	Aboveground Biomass, Mg DM ha^{-1}	Disappearance, %
Maize alone	0.25	92	-	-
Maize-oat	0.23	90	0.42	78
Maize-turnip	0.55	81	0.40	92
SEM	0.011	4	0.22	5
		p-Values		
Year (Y)	0.9108	0.7864	0.1381	0.2188
I	0.0713	0.0735	0.9600	0.0716
Y × I	0.3025	0.2628	0.4148	0.3432

[1] Values in the table are the lsmeans of three replicates for each component of the year × intercropping treatment (Y × I) effect.

At >70%, sweet maize stover disappearance in the present study (Table 3) was greater than the 20–30% previously reported for stover of maize grown for grain [7], possibly because of the limit grazing, which should maximize utilization, as well as lower initial DM yield in the present study (Table 2) compared to other reports [7]. Additionally, there could be a greater loss to trampling of leaves that had fallen from the plant into the furrows when furrow-irrigated maize stover was grazed [4]. This may not have been much of a problem in the present study, which was furrow-irrigated, for the sweet maize stover because mechanical harvesting had not been used that would detach leaves.

3.8. Post-Grazing Overseeded Forage Biomass and % Disappearance

There was no difference in post-grazing overseeded forage aboveground biomass due to relay intercropping treatments (Table 3), likely due to the equal pre-grazing aboveground biomass and utilization to a level at which availability would become limited [39]. Turnip root yield and disappearance after grazing (0.17 Mg DM ha^{-1} and 85%, respectively) were not different between years. Trampling also may not have been a problem for the turnip and, possibly, the oat because most of the turnip stand established on the sides of the beds where trampling would be less likely as has been reported in other research [16,17]. Although not compared in the present study, cattle also will select the higher quality plant species first in mixed pastures [40] (e.g., turnip vs. maize in the maize-turnip treatment, Table 2).

3.9. Animal Performance

There was no difference among years or relay intercropping treatments and no interaction for initial BW of the heifers used in the study, although the heifers tended to be lighter in Year 1 as mentioned in the methods section. The relay intercropping treatment effect was significant because ADG of heifers grazing the maize-alone was lower than ADG of heifers grazing either the maize-oat or maize-turnip treatments (0.36, 0.52, and 0.59 kg/day for the maize-alone, maize-oat, and maize-turnip relay intercropping treatments, respectively; SEM = 0.05, $p < 0.0153$). Maize residue is sufficient for maintenance of non-lactating beef cattle and is commonly grazed during late fall and winter, which is the most efficient harvest method [4]. Newly weaned calves also can gain 0.2 to 0.6 kg/day [4], which is consistent to the ADG in this study. It has been stated [7] that maize stover feeding systems should be designed to achieve gains of >0.5 kg/day and that gains <0.5 kg/day, as was the case for the maize-alone treatment, suggest that protein was limiting in the diet and the animals were converting body fat to use as energy for protein synthesis. The higher gains by maize-oat and maize-turnip may have been due to the additional CP available in the overseeded forage despite oat having lower CP than turnip (Table 2). This study demonstrated the feasibility of relay intercropping oat or turnip into sweet maize as a nutritional management scheme for grazing beef calves after weaning. The ADG in the present study is less than that measured by others [39,41] for steers grazing winter wheat with unlimited availability, but higher than that measured by those authors for steers grazing either dormant native warm-season grasses with a protein supplement or winter wheat with limited availability. Both of those studies [39,41] found that low ADG when weanling growth was restricted in the winter grazing period led to greater feed efficiency in the next feeding period (summer grazing or finishing) compared to animals fed for unrestricted growth during winter.

4. Conclusions

Turnip and oat aboveground biomass yield were not different when relay intercropped with sweet maize. However, CP concentration and 48-h IVDMD of turnip aboveground biomass was greater than oat aboveground biomass. Relay intercropping turnip with sweet maize improved the 48-h IVDMD of the sweet maize whole plant stover. Relay intercropping with oat or turnip increased ADG by >0.15 kg/day over grazing sweet maize stover alone and demonstrated an alternative nutritional management for weaned calves while adding value to sweet maize stover. Maize-turnip or other brassica relay intercropping should be included in breeding efforts to improve digestibility of maize silage. Additional research is needed to determine if the same effect of improvement in 48-h IVDMD by relay intercropping with turnip in sweet maize is reflected in total digestibility and can occur with maize grown for silage or grain or other annual grass forage species using turnip or other brassica species.

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