

## ABSTRACT

BALZ, EILEEN MARIE. The Establishment of Alfalfa-Grass Mixtures Under Organic and Conventional Management. (Under the direction Dr. Steve Washburn and Dr. Sue Ellen Johnson).

North Carolina livestock producers are interested in high quality hay for milk and grass-fed beef production. Organic producers are particularly interested in forages produced without chemical control of weeds and pests. Thus, this study had two objectives: 1) to determine the impact of organic and conventional management on cumulative alfalfa, forage, and weed production of the establishment year and 2) to compare alfalfa interseeded with prairie grass (PG) to alfalfa not interseeded with prairie grass (NPG) in terms of alfalfa, forage, and weed production in the establishment year. Management differences included defoliation frequency and chemical use. Field 1, at the end of the first season (2010), reached alfalfa weevil threshold in April, 2011. Thus, organic was harvested in April, and conventional was controlled with pesticide (Lorsban®). Cumulative conventional alfalfa production was significantly greater ( $P < 0.05$ ) than cumulative organic alfalfa production ( $4415 \pm 220$  vs.  $3545 \pm 220$  kg/ha, respectively), with the differences primarily in the first and last harvests. However, forage production (alfalfa, prairie grass, ryegrass, and crabgrass) did not differ ( $P = 0.206$ ) between conventional and organic management ( $5695 \pm 208$  vs.  $5282 \pm 208$  kg/ha, respectively). Also, there was no significant difference in weed production between the two systems ( $P = 0.749$ ). However, samples in March revealed that conventional management had significantly more chickweed than organic management ( $P < 0.01$ ). Under conventional management in the establishment year, cumulative alfalfa production in NPG plots was significantly greater ( $P < 0.05$ ) than alfalfa production in PG plots ( $5024 \pm 488$  vs.  $3893 \pm 344$  kg/ha, respectively). However, there was no significant difference ( $P = 0.181$ ) between cumulative forage production in NPG plots and PG plots. Cumulative weed production in NPG plots tended to be greater ( $P < 0.10$ ) than PG plots. Under organic management in the establishment year, cumulative alfalfa production in NPG plots tended to be greater ( $P < 0.10$ ) than PG plots. Cumulative forage production in NPG plots also tended to be greater ( $P < 0.10$ ) than PG plots. Although alfalfa and forage production were successful,

cumulative weed production in NPG plots tended to be greater ( $P < 0.10$ ) than PG plots. Organic alfalfa plant counts were numerically lower, but adequate

Field 1 reached alfalfa weevil threshold in March, 2011. Organic plots were harvested and conventional plots were sprayed with insecticide (Lorsban®). Thus, May 10, 2011 was the second harvest for organic, and the first harvest for conventional plots. Cumulative organic alfalfa production was significantly greater ( $P < 0.05$ ) than conventional alfalfa production. In addition, cumulative organic forage production was significantly greater ( $P < 0.05$ ) than conventional forage production. However, weed production was greater ( $P < 0.05$ ) in organic plots than conventional plots. Under conventional management, alfalfa production, forage production, and weed production did not significantly differ between PG and NPG treatment. Under organic management, cumulative alfalfa production in PG plots was not significantly different ( $P = 0.762$ ) from alfalfa production in NPG plots. Cumulative forage production in PG plots tended to be greater ( $P = 0.101$ ) than NPG plots. Cumulative PG weed production did not differ from NPG weed production.

In conclusion, conventional management produced more alfalfa than organic management. However, alfalfa grass mixtures yielded as much forage without the need chemical control of weeds and insects. Interseeding prairie grass may have more of a role in suppressing weed production than boosting forage production. Potentially less weed pressure could reduce ovipositioning sites of the alfalfa weevil.

Establishment of Alfalfa-Grass Mixtures Under Organic and Conventional Management

by  
Eileen Balz

A thesis submitted to the Graduate Faculty of  
North Carolina State University  
in partial fulfillment of the  
requirements for the Degree of  
Master of Science

Animal Science

Raleigh, North Carolina

2011

APPROVED BY:

---

Dr. Steve Washburn  
Committee Co-Chair

---

Dr. Sue Ellen Johnson  
Committee Co-Chair

---

Dr. Chris Reberg-Horton

---

Dr. Vivek Fellner

## **BIOGRAPHY**

Eileen Balz was born December 6, 1986 in Portsmouth, New Hampshire to Ann and John Balz currently of NH. Her interest in livestock agriculture started at the University of New Hampshire where she worked at the Fairchild Conventional Dairy Farm. However, it was the C.R.E.A.M. (Cooperative Real Education in Agricultural Management) program that educated her about the dairy industry and management requirements including proper handling, reproduction, and nutrition. After graduation, she worked at the UNH Organic Dairy where she discovered the hardy Jersey cow breed and the pasture-based system. The guidance from all the dairy science professors at UNH inspired her to pursue her Master's in agriculture, under the direction of Dr. Steve Washburn and Dr. Sue Ellen Johnson.

## **ACKNOWLEDGMENTS**

I would like to thank my advisors for their guidance over the past two years. I have been able to learn from practical experiences of my own project and also from producers in North Carolina. I am appreciative of the farm visits and pasture walks, and I find that these are some of the most important events for researchers and producers. I understand that this exchange of practical experience is important for continuing agricultural education.

I would like to thank the staff at CEFS, James, Windy, Bryan, Pat, Larry, Rex, and Matt for all their help and advice throughout the project. I could never have done it without them.

I have thoroughly enjoyed the graduate students that I have met during this program and I appreciate all their assistance. I would also like to thank Joe Ellington and Dr. Surry Roberts because they were the first people to make Raleigh feel like home. Lastly, I would like to thank my parents and my sister, Maggie, as they have always been only a phone call away and the most dependable support.

## TABLE OF CONTENTS

List of Tables.....	v
List of Figures.....	vi
<b>Chapter I: Literature Review.....</b>	<b>1</b>
Growth/Temperature/Dormancy.....	2
Declining Stands.....	4
Animal Performance.....	5
Bromegrass.....	6
Grass Mixtures.....	7
Bromegrass Mixtures.....	9
Production.....	10
Cutting/Grazing.....	12
Grazing Alfalfa Mixture.....	14
The Alfalfa Weevil [ <i>Hyperapostica</i> (Gyllenhal)] .....	15
Life Cycle.....	16
Control of Weevil.....	17
Organic Alfalfa Production.....	18
References.....	21
<b>Chapter II.....</b>	<b>31</b>
Introduction.....	34
Materials and Methods.....	35
Results.....	38
Discussion.....	56
Conclusion.....	63
References.....	64
<b>Chapter III.....</b>	<b>94</b>
Introduction.....	96
Materials and Methods.....	97
Results.....	100
Discussion.....	109
Conclusion.....	115
References.....	117

## LIST OF TABLES

### Chapter II

<b>Table 1.</b> Field 1 (planted 2009) Harvests 2010—The effect of management (organic vs. conventional) and treatment (PG: interseeded prairie grass vs. NPG: no interseeded prairie grass) on alfalfa, prairie grass, ryegrass, crabgrass weed production in four harvests of the establishment year.....	56
<b>Table 2.</b> Field 1 (planted 2009) Harvests 2011—The effect of management (organic vs. conventional) on the alfalfa, forage, biomass, and weed production at two harvests for organic management and one harvest for conventional in the second season.....	57
<b>Table 3.</b> Field 1 (planted 2009) Harvests 2011—The effect of <b>conventional</b> alfalfa interseeded prairie grass (PG) or not interseeded with prairie grass (NPG) on alfalfa, forage, biomass, and weed production of March sample and May harvest of the second season.....	58
<b>Table 4.</b> Field 1 (planted 2009) Harvests 2011—The effect of <b>organic</b> alfalfa interseeded prairie grass (PG) or not interseeded with prairie grass (NPG) on alfalfa, forage, biomass, and weed production at two harvests of the second season.....	59
<b>Table 5.</b> Field 1 (planted 2009) Non-destructive Interharvest Samples 2010 and Harvests 2010, Field 2 (planted 2010) Harvest 2011—The effects of alfalfa variety, Arriba (AR) vs. Haygrazer (HG), on alfalfa production.....	60
<b>Table 6.</b> Field 1 (planted 2009) Non-destructive Interharvest Samples 2010 and Harvests 2010, Field 2 (planted 2010) Harvest 2011—The effects of alfalfa variety, Arriba (AR) vs. Haygrazer (HG), on alfalfa production.....	61
<b>Table 7.</b> Field 1 (planted 2009) and Field 2 (planted 2011)—The effects of alfalfa variety on plant count. Arriba alfalfa (AR) and Haygrazer alfalfa (HG) counts.....	62
<b>Table 8.</b> Field 1 (Planted 2009) Cumulative Production 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on cumulative alfalfa, prairie grass (PG), ryegrass (RG), crabgrass (CG), and weed production of the establishment year.....	64
<b>Table 9.</b> Field 1 (Planted 2009) Harvests 2011—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG).....	72
<b>Table 10.</b> Field 2 (Planted 2010) Harvest 2011—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG).....	78

## LIST OF TABLES

### Chapter III

<b>Table 1.</b> Field 1 (planted 2009) Grazing 2010—The effect of management (organic vs. conventional) on the alfalfa, forage, biomass, and weed production at four grazing events.....	113
<b>Table 2.</b> Field 1 (planted 2009) Non-destructive Interharvest Samples — Theeffect of management (organic vs. conventional) on the alfalfa, forage, biomass, and weed production at two samples prior to grazing.....	114
<b>Table 3.</b> Field 1 (planted 2009) Grazing 2011—The effect of management (organic vs. conventional) on the alfalfa, forage, biomass, and weed production at three grazing events.....	115
<b>Table 4.</b> Field 2 (planted 2010) Grazing 2011—The effect of management (organic vs. conventional) on the alfalfa, forage, biomass, and weed production at the first grazing of the establishment year.....	116
<b>Table 5.</b> Field 2 (planted 2010) Grazing 2011—The effect of organic alfalfa interseeded with prairie grass (PG) vs. organic alfalfa not interseeded with prairie grass (NPG) on the alfalfa, forage, biomass, and weed production at the first grazing of the establishment year.....	117
<b>Table 6.</b> Field 1 (planted 2009) Grazing 2010 and Field 2 (planted 2010) Grazing 2011—The effects of management (organic vs. conventional) on alfalfa plant count.....	118

## LIST OF FIGURES

### CHAPTER II

<b>Figure 1.</b> Field 1 (Planted 2009) Harvests 2010—The effect conventional alfalfa with interseeded prairie grass (PG) vs. not interseeded with prairie grass (NPG) on the biomass of three non-destructive interharvest samples.....	62
<b>Figure 2.</b> Field 1 (Planted 2009) Harvests 2010 –The effect of organic alfalfa interseeded prairie grass (PG) vs. not interseeded with prairie grass (NPG) on the biomass of three non-destructive interharvest samples.....	63
<b>Figure 3.</b> Field 1 (Planted 2009) Harvests 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. not interseeded with prairie grass (NPG) on conventional cumulative alfalfa production and organic cumulative alfalfa production of the establishment year.....	65
<b>Figure 4.</b> Field 1 (Planted 2009) Harvests 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. not interseeded with prairie grass (NPG) on conventional cumulative prairie grass production and organic cumulative prairie grass production in the establishment year.....	66
<b>Figure 5.</b> Field 1 (Planted 2009) Harvests 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on conventional cumulative ryegrass production.....	67
<b>Figure 6.</b> Field 1 (Planted 2009) Harvests 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on conventional cumulative crabgrass production.....	68
<b>Figure 7.</b> Field 1 (Planted 2009) Harvests2010—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on conventional cumulative weed production and organic cumulative weed production in the establishment year.....	69
<b>Figure 8.</b> Field 1 (Planted 2009) Harvests2010—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on conventional cumulative forage production and organic cumulative forage production in the establishment year.....	70
<b>Figure 9.</b> Field 1 (Planted 2009) Harvests 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on conventional cumulative biomass and organic cumulative biomass in the establishment year.....	71
<b>Figure 10.</b> Field 1 (Planted 2009) Harvest 2011—Theeffect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on conventional cumulative alfalfa production and organic cumulative alfalfa production of the second season.....	72

## LIST OF FIGURES

### CHAPTER III

<b>Figure 1.</b> Field 1 (Planted 2009) Grazing 2010—The effect of management (organic vs. conventional) on alfalfa production of two samples and four grazing events of the establishment year .....	118
<b>Figure 2.</b> Field 1 (Planted 2009) Grazing 2010—The effect of management (organic vs. conventional) on biomass of two samples and four grazing events of the establishment year.....	119
<b>Figure 3.</b> Field 1 (Planted 2009) Grazing 2010—The effect of management (organic vs. conventional) on biomass of two samples and four grazing events of the establishment year.....	120
<b>Figure 4.</b> Field 1 (Planted 2009) Grazing 2011—The effect of conventional alfalfa not interseeded with prairie grass (NPG)vs. organic alfalfa interseeded with prairie grass (PG) on the cumulative alfalfa production of three grazing events in the second season (2011) .....	121
<b>Figure 5.</b> Field 1 (Planted 2009) Grazing 2011—The effect of conventional alfalfa not interseeded with prairie grass (NPG) vs. organic alfalfa interseeded with prairie grass (PG) on the cumulative weed production of three grazing events in the second season (2011) .....	122
<b>Figure 6.</b> Field 1 (Planted 2009) Grazing 2011—The effect of conventional alfalfa not interseeded with prairie grass (NPG) vs. organic alfalfa interseeded with prairie grass (PG) on the cumulative biomass of three grazing events in the second season (2011) .....	123
<b>Figure 7.</b> Field2 (Planted 2010) Grazing 2011—The effect of conventional alfalfa not interseeded with prairie grass (NPG) vs. organic alfalfa interseeded with prairie grass (PG) vs. not interseeded with prairie grass (NPG) on cumulative alfalfa production in first grazing of the establishment year .....	124
<b>Figure 8.</b> Field2 (Planted 2010) Grazing 2011—The effect of conventional alfalfa not interseeded with prairie grass (NPG) vs. organic alfalfa interseeded with prairie grass (PG) vs. not interseeded with prairie grass (NPG) on cumulative biomass in first grazing of the establishment year on May 7, 2011.....	125
<b>Figure 9.</b> Field 1 (planted fall 2009) Grazing 2010 and 2011—counts of alfalfa weevil larvae on a stem of alfalfa under conventional and organic management...	126
<b>Figure 10.</b> Field 2 (planted fall 2010) counts of alfalfa weevil larvae on a stem of alfalfa under conventional and organic management. ....	127

## **CHAPTER 1: Literature Review**

Alfalfa (*Medicago sativa* L.) is known as the “Queen of Forages” from its important role as a nutritive legume in the United States. Originating in Iran and central Asia, alfalfa is a perennial crop that is characterized by its deep tap root and top growth that stems from the crown at the soil surface (Ball, 2007). Alfalfa is valued as a high protein field crop for livestock in the U.S. with an annual hay production of 67.9 million tons in 2010 (USDA, 2011). Alfalfa is also valued for its soil building abilities through nitrogen fixation (Sheaffer, 2009). In 2010, North Carolina production of alfalfa hay was only 16,000 tons (USDA, 2011). In the Southeast Coastal Plains, alfalfa stand persistence has been challenged mostly by acidity, low soil fertility, poor drainage, and the competition of annuals (Haby et al., 1999).

Good establishment of alfalfa is essential for stand productivity and longevity. A firm seedbed and shallow seed placement are recommended for good emergence (Smith, 1981) and herbicide usage has been found to increase first season production of alfalfa (Rogers et al., 1985). The seedling of alfalfa establishes more aggressively than other legumes and grasses (Blaser et al., 1956). Alfalfa requires well-drained soils and a pH above 6.5, as acidic conditions cause shallow root development (Ball, 2007). Problems in subsoil acidity have been associated with excess Aluminum inhibiting root cell division (Adams, 1981). Finely branched feeder roots are restricted to limed layers in acidic soils. The usual fertility amendments also include potassium, phosphorus, sulfur, and boron. Application of N is detrimental, as it inhibits nodulation (Ward and Blaser, 1961).

The deep taproot of alfalfa has allowed it to grow in drought conditions. Studies have shown drought tolerance of alfalfa in animal production systems during the summer months on the Coastal Plains of eastern Texas (Haby et al., 1999). As long as subsoil acidity receives subsoil lime, yields have been comparable to irrigated alfalfa in the Piedmont region of VA (Rechcigl et al., 1985). Under proper management and depending on the location, alfalfa can produce 4-7 cuttings per season (Ball, 2007). Compared to birdsfoot trefoil and ladino clover, alfalfa has been more productive because of the high yield during the second harvest (McCloud, 1953).

### **Growth/Temperature/Dormancy**

Optimal soil temperature for root growth is 20°C (68°F), whereas optimal temperature for shoot growth is 26°C (78°F). This means that energy reserves are directed below the soil surface in early spring growth. Environmental temperature also affects flowering of alfalfa. Understanding the flowering habit is important because hay should be cut at the early bloom stage. Growth stages of alfalfa are shown in the table 1. In a controlled environment study, alfalfa first flowered in 21 days (d) when grown in day/night temperatures of 32/24°C (89/75°F). Alfalfa first flowered in 45d when the same variety was grown in 21/12°C (70/54°F), showing that heat can cause premature flowering (Smith and Struckmeyer, 1974). Alfalfa flowered in 30d, and with greatest growth height, in day/night temperatures 27/18°C (81/64°F) (Greenfield and Smith, 1973). As a cool season plant, alfalfa will reach maturity before warm season plants (Belesky et al., 2002). The spring growth of alfalfa can be useful in a grazing system before the summer growth of popular warm season grasses, such as bermudagrass (Cassida et al., 2006).

When temperatures drop in the winter, alfalfa enters winter dormancy. Alfalfa is able to survive dormancy through specialized energy storage organs in the taproot (Sheaffer, 2009). TNC (total nonstructural carbohydrate) is higher in the crown of plants that are tillering, compared to plants that are nontillering. This supports the hypothesis that the carbohydrate concentration in the crown provides energy required for the initiation and growth processes (Chatterton et al., 1974). Winterkill occurs when plants initiate growth during a temporary mild temperature, which depletes stored energy reserves. For this reason, it is important to grow winter dormant varieties in the Upper South (Ball, 2007). Summer dormancy has also been reported during months of less precipitation (Cassida et al., 2006). Once established, alfalfa swards have been found to cost less to maintain than bermudagrass swards, but expenses can also be greater for alfalfa because of the greater number of hay feeding days from summer dormancy (Cassida et al., 2006).

There are two main types of alfalfa, hay varieties and grazing varieties. Hay type varieties are not recommended for continuous grazing as the depletion of energy in the root reserves will decline the stand. Grazing-type varieties of alfalfa, on the other hand, can be harvested for hay without stand decline (Ball, 2007). When examining persistence of alfalfa cultivars, it was found that mowing alfalfa did not affect persistence across cultivars. In contrast, continuously grazing animals showed a significant difference in persistence among alfalfa cultivars. Thus, traits that contribute to persistence under grazing conditions are different from traits found in mowing systems. Nonpersistent cultivars were found to have significantly more taproot and higher concentrations of TNC (total nonstructural carbohydrates) in the taproot. For these reasons, the selection of grazing tolerant varieties

should be a careful process that does not take away from positive characteristics of the alfalfa plant. (Bouton and Gates, 2003; Counce et al., 1984).

### Declining Stands

Alfalfa crown densities and stem counts declined linearly with time after planting (Cassida et al., 2006). In terms of yield, stands containing 19-108 plants m<sup>-2</sup> demonstrated no difference in yield (Wedin et al., 1965). The economical guideline is to have 20-40 plants m<sup>-2</sup> (Triplett et al., 1977). In a study examining forage quality in a declining stand, crude protein values and acid detergent fiber values were similar when comparing stands of 11 m<sup>-2</sup> to 484 m<sup>-2</sup>. Although production and quality may not be affected, research suggests that once crown density reaches 30-50 crowns/m<sup>2</sup>, action should be taken to prevent invading weeds (Orloff, 2010). Common methods for maintaining desirable forages in a stand include herbicide use or interseeding a grass. Another method of weed control is cultivation of an established stand of alfalfa. With the deep-rooted nature of alfalfa, only the smaller annual weeds are uprooted

<b>Table 1.</b> Developmental stages of alfalfa (Fick, 1989)	
<b>Stage</b>	<b>Description</b>
<b>Vegetative Stage</b>	
Early vegetative	Stem length ≤ 15 cm
Mid-vegetative	Stem length 16-30 cm
Late vegetative	Stem length ≥ 31 cm
<b>Flower bud development: stem with flower bud</b>	
Early bud	1-2 nodes with buds
Late bud	≥3 nodes with open flowers
<b>Flowering phase: stems with open flowers</b>	
Early flower	1 node with 1 open flower
Late flower	≥ 2 nodes with open flowers
<b>Seed production: stems with flowers and seedpods</b>	
Early seedpod	1-3 nodes with green seedpods
Late seedpod	≥ 4 nodes with green seedpods
Ripe seedpod	Nodes with mostly brown mature seedpods

(Welty, 1988).

## **Animal Performance**

Acceptable cattle performance was shown at 10.8 crowns  $\text{m}^{-2}$ . The deep tap root of alfalfa gives the plant an opportunity to be more drought tolerant, which is a common problem of cool-season grasses. Research has shown alfalfa stands that are less than 32 plants/ $\text{m}^2$ , are not optimal in hay production, but grazing alfalfa stands that are at 11 plant/ $\text{m}^2$  have shown excellent gains in beef cattle (Lacefield, 1996). Bloat risk can be reduced with many management techniques including growing a grass with alfalfa, feeding bloat prevention compounds, avoiding turning hungry animals out on a paddock, and waiting to graze cattle at least three days after a killing frost (below  $-2^{\circ}\text{C}$ ) (Lacefield, 1996).

Not all alfalfa has the same nutritive value. For example, Stiles et al. compared alfalfa pasture, alfalfa greenchop, and alfalfa hay in the dairy cow ration (Stiles et al., 1971). In the nine-week study, alfalfa pasture provided a higher milk production compared to alfalfa hay fed ad libitum. Numerically, cows fed greenchop produced less than alfalfa pasture, but more than alfalfa hay. Interestingly, the crude protein of the alfalfa pasture (18%) was lower than the alfalfa hay (23%) due to less rainfall during the study, but resulted in higher milk production. Intake for pasture was slightly lower than intake for hay, showing that higher pasture intake could not have caused the increased production. Reasons for the increased production is speculated to be a result of pasture fed animals selecting the top half of the plant (Stiles et al., 1971).

Harvesting alfalfa at early-bloom, rather than mid-bloom increases the crude protein content (194 to 167  $\text{g kg}^{-1}$ ) and decreases the neutral detergent fiber (388 to 476  $\text{g kg}^{-1}$ ) (Sheaffer, 2009). Throughout the two year trial comparing summer grazing alfalfa and

bermudagrass, alfalfa was higher in crude protein (CP) and lower in neutral detergent fiber (NDF) compared to bermudagrass (Cassida et al., 2006).

Pasture usage has been an economic option to reduce mechanical and feed costs. Feed comprises over 50% of the costs in a dairy production system. Research has shown that cows can walk up to a mile without loss in milk production (Gamroth, 2010).

### **Bromegrass**

Prairie grass varieties have received more attention as palatable forages that are high quality and endophyte-free (Boland et al., 2007). Lakota prairie grass (*Bromus catharticus*) and Matua prairie grass (*Bromus willdenowii*) belong to the genus *Bromus*, and are commonly misidentified due to their similar physical characteristics and growth habits (Rumball, 1974). Matua, also known as 'Grasslands Matua,' was certified in 1974 by Grasslands Division, DSIR, in New Zealand. Matua prairie grass is a short-lived perennial that is drought tolerant and highly productive in the fall months (Jung et al., 1994). Matua has a bunch-type growth habit and produces seed heads at every harvest (Jung et al., 1994). Matua has been a useful forage for extending cool season grazing with its early spring and late fall production (LaCasha et al., 1999). In the third year of a Matua stand, dry matter production can reach 4.0 Mg ha<sup>-1</sup> at 50% head emergence, which is the stage commonly used for hay or silage production (Jung et al., 1994).

Persistence of Matua prairie grass is challenging and not completely understood, but because it readily produces seed, reseeding contributes positively to its persistence. A summer rest period is recommended for optimum production of Matua to allow natural

reseeding. Defoliation frequency was more important than residual height (Bell, 1989). Jung et al. (1994) recommended three specific management practices for winter survival and increased spring yields. First, the initial harvest should be made early in the fall. Spring yields were greater in fields that were clipped in September compared to fields that were delayed until November. Later harvests were speculated to have decreased yields from heavy shading and inhibited tiller production and killing of basal leaves. Second, multiple harvests should be made. Matua plants that were harvested once in late fall, or not at all, recovered very slowly in spring. They also had a lower yield potential compared to plots that were harvested two, three, or four times. Third, leaving 12.5cm high stubble heights resulted in maximum yield (Jung et al., 1994), and a recommended rest period of 30-40 days (Sellars, 1988).

### **Grass Mixtures**

In the 1940s and 1950s it was popular to grow alfalfa in a mixture, but current trends show that alfalfa is grown more as a pure stand in the USA (Hansen, 1988). Areas of the USA that still produce greater quantities of alfalfa mixtures are usually managing less well-drained land (Hansen, 1988).

It has been shown that stand diversity in botanical composition in pastures benefits persistence, yield stability, and productivity (Sanderson et al., 2005). Mixtures of alfalfa with timothy, Kentucky bluegrass, and brome grass were higher in yield than grasses alone (McCloud, 1953). Another advantage of planting a legume-grass mixture is that alfalfa can supply a nitrogen source to the grasses. Grasses have been found with a higher percentage of N when grown with alfalfa compared to pure stands (Van Riper, 1960). As the stand gets

older, alfalfa plant number declines and grasses can invade open sites to keep forage production high and reduce invasion of weeds (Smith, 1981; Triplett et al., 1977). In a study completed on multiple sites in California, interseeding oat (*Avena sativa*) in an established stand of alfalfa (*Medicago sativa*) was comparable to paraquat treatment for weed control. In addition to the control of weeds, the interseeded grass increased the yield of the first harvest (Lanini, 1999). Companion crops can be seeded with a legume, such as alfalfa, to provide erosion control and suppress weed competition (Sheaffer, 2009). Alfalfa-grass mixtures are also used as a management tool for bloat prevention (Jackobs, 1963).

When choosing a grass to interseed with alfalfa, characteristics should include palatable species with a similar heading date. Plants with similar growth and maturation habits are most competitive. Density of seeding, soil fertility, along with time and height of defoliation make managing an alfalfa-grass mixture challenging.

Managing aggressive grasses is one of the greatest challenges in sward mixtures. Less desirable grasses for alfalfa mixtures establish and mature at different rates than alfalfa and can wilt by the time the legume is at bud stage (Campbell, 1961). Tall fescue completely shaded the crown buds of alfalfa in early growth stages in North Carolina (Chamblee, 1953). Although it depends on location, research has shown that other incompatible grasses include orchardgrass (*Dactylis glomerata* L.), reed canarygrass (*Phalaris arundinacea*) (Smith, 1981), and perennial ryegrass (Jung et al., 1982). Varieties of switchgrass and needlegrass did not establish well with alfalfa (Berdahl et al., 2001). Environmental conditions can change the composition of a mixed sward. For example, the orchardgrass component of a sward was increased with irrigation (Ward et al., 1966). In addition, alfalfa-bromegrass mixtures under

dry conditions had a lower percentile of alfalfa composition (<25cm annually), while humid conditions favored the alfalfa component (Lorenz et al., 1961).

The development of more persistent alfalfa cultivars has added different requirements in the management practices for these mixtures. Most alfalfa fields are managed under three cuttings a year, but the additional cuttings that are possible with improved varieties are not always favorable for grass persistence.

Companion crops compete for light, water, and plant nutrients (Bula et al., 1954). Alfalfa is proposed to compete well with grasses because roots usually penetrate deeper than grass roots, and can compete effectively for water (Chamblee, 1958). The small, fibrous roots of grasses will occupy the top 20cm of the soil, while alfalfa has the ability to penetrate to a greater depth (Lamba, 1949). Nutrient deficiencies can determine the botanical composition of swards, as potassium deficiencies usually favored the growth and production of grasses in mixtures with alfalfa (Hunt and Wagner, 1963; MacLeod and Bradfield, 1963). Alfalfa roots have been found to have twice as much cation exchange capacity (CEC) as bromegrass (Drake et al., 1951). A higher CEC indicates that legumes favorably compete for divalent cations, such as  $\text{Ca}^{+2}$ , while grasses favorably compete for monovalent cations. Thus, legumes and grasses are competing for different nutrients (Havlin, 2005).

### **Bromegrass Mixtures**

Legumes that are interseeded into an established stand can vary in their compatibility. A study comparing legumes interseeded in an established stand of Matua found that alfalfa was most compatible compared to ladino clover, red clover, and annual lespedeza (Guay,

2007). The mixtures were compared based on digestibility, crude protein, and the reduced percentage of Matua in the stand.

Meadow brome grass (*Bromus riparius*) was found to maintain a balance of botanical composition when mixed with alfalfa (Holt and Jefferson, 1999). Nitrogen fertilization generally increases the grass component in a grass legume mixture (Berdahl et al., 2001; MacLeod, 1965; Wedin et al., 1965; Wolf and Smith, 1964). However, some studies have shown that by the third growing season, smooth brome grass-legume mixtures can yield a lesser grass component as a result of depleted fixed N by legumes (McCloud, 1953). In addition, the composition of alfalfa grass mixtures change throughout the season. In brome grass-alfalfa mixtures, the first cutting of alfalfa contained 45-73% alfalfa, where as the second cutting contained 80-90% alfalfa, with brome grass making up the balance (Kalton, 1952).

### **Production**

Dense seeding of grass with alfalfa may reduce the number of alfalfa plants at establishment (Chamblee, 1953). Seeding rates that were higher than 17 kg ha<sup>-1</sup> reduced total forage yield. In a similar manner, high densities of alfalfa can suppress grass establishment (Chamblee, 1953).

Grass-legume mixture hay fields can be more productive than nitrogen-fertilized monoculture grass hay fields. A study in North Dakota reported that when fertilized at 50 kg N ha<sup>-1</sup> dry matter yields of cool season grass-legume mixtures averaged 8.72 Mg ha<sup>-1</sup>, while dry matter yields of monoculture grass averaged 5.04 Mg ha<sup>-1</sup> (Berdahl et al., 2001). In New Jersey, Sprague (1964) reported that alfalfa-orchardgrass mixtures and alfalfa-brome grass

mixtures did not have a significant difference in total yields, but alfalfa-orchardgrass out yielded alfalfa-bromegrass by 10-15%. Interestingly, the yield of bromegrass was higher in mixtures (legume or another grass) than when bromegrass was grown alone. Because the beneficial effect of companion species was also produced by grasses, legume nitrogen fixation was not a possible advantage (McCloud, 1953).

Production of mixtures is greater compared to grass monocultures, but also compared to legume monocultures. Production average was increased 50-66% with a mixture of alfalfa and smooth bromegrass compared to alfalfa alone (McCloud, 1953). At 8.5 tons/acre, alfalfa-bromegrass mixture had the highest yield compared to other mixtures of alfalfa with other cool season grasses including Kentucky bluegrass, timothy, birdsfoot trefoil, and ladino clover (McCloud, 1953). Bromegrass-alfalfa mixtures demonstrated greater production than pure stands of alfalfa, but alfalfa mixture with another legume did not demonstrate a yield advantage (McCloud, 1953).

Smooth bromegrass has been found to have a greater contribution in the first cutting, compared to the second cutting in binary mixtures with alfalfa (Berdahl et al., 2001). However, in New Zealand a mixture of *Bromus willdenowii* and alfalfa produced from 3% more dry matter in the first year, and 15% more dry matter in the second year (Fraser, 1982). Increased yields can be significant or insignificant depending on the precipitation and location. Some studies have found that inclusion of bromegrass with alfalfa did not increase yield during five years of production compared to pure alfalfa stands (Wilsie, 1949). Similar results were reported in Iowa where the yield of the pure alfalfa was similar to the yield of alfalfa-bromegrass (Carter and Scholl, 1962).

## **Cutting/Grazing**

Grazing removes aged leaves that photosynthesize less efficiently. Forage removal manages leaf age and shading, and the frequency of removal necessary depends on the growth characteristics of plant. Legumes with leaves that grow horizontally, such as white clover, require more frequent forage removal to prevent self-shading. Because alfalfa is an erect-growing legume, more light filtrates through the canopy, allowing more leaf photosynthesis and higher yield (Ball, 2007).

Maturation of alfalfa and grasses can differ significantly across varieties of grass-legume combinations. Studies have indicated higher yields when alfalfa was cut at a more mature stage for alfalfa and alfalfa-mixtures (Dotzenko, 1950). Research found that the yield of bromegrass was unaffected by the cutting treatments, while alfalfa yields greatly differ depending on the maturity stage. Alfalfa annual yield was the greatest when cut at the pod stage (see Table 1: Development stages of alfalfa). Alfalfa yield was least when harvest height was only 5 inches. Frequent and early cuttings did not allow root energy reserves to accumulate (Dotzenko, 1950; Nelson, 1952). It is important not to graze alfalfa at least four weeks before the winter dormancy to allow carbohydrate accumulation in roots (Smith et al., 1989).

Under grazing conditions, most of plant nutrients are returned to the system through manure and urine. However, grazing animals may damage alfalfa crowns during wet and muddy conditions or during new shoot development. To prevent decline of the stand from hoof traffic in wet soil conditions, cattle should be placed in “sacrifice” paddocks (Ball, 2007).

‘AlfaGraze’ was the first variety of grazing alfalfa released. Alfalfa grazing varieties have been selected for their increased tolerance of hoof action and their ability to maintain greater stand density under grazing. Grazing tolerant varieties of alfalfa are also characterized by leaves near the soil surface, and higher root carbohydrate levels (Ball, 2007).

Alfalfa generally does not persist well under continuous grazing, although grazing cultivars persist better than hay-type varieties (Smith et al., 1989). Alfalfa must be intensively grazed, as longer rotations slow alfalfa regrowth and increase weed pressure (Lacefield, 1996). A study in Georgia showed that after three seasons of continuous grazing, 6-9 plants m<sup>-2</sup> persisted in the hay-type varieties, while 40-48 m<sup>-2</sup> plants persisted in the grazing varieties (Smith et al., 1989). In terms of animal production, Savory and Parsons (1980) support the theory that rotational short-duration grazing doubles the carry capacity while maintaining equivalent levels of production per animal compared to the conventional grazing system (Savory and Parsons, 1980).

Alfalfa has a shorter grazing season and more grazing interruptions compared to grazing bermudagrass in Arizona (Cassida et al., 2006). Alfalfa percent composition was lowest in mid-July of the second year at 47%, with the balance consisting of palatable weeds and volunteer warm season grasses (Cassida et al., 2006). In this two year study, alfalfa went dormant both years in August. Although the deep root system was thought to provide an advantage, the leaves dropped and there was no useful stock piled forage. Alfalfa broke summer dormancy with the cooler fall weather, but it did not accumulate enough to graze for the remainder of that season.

## **Grazing Alfalfa Mixture**

Regrowth of grasses and alfalfa differ in that alfalfa must re-grow from new basal buds while grasses elongate cut leaves from meristematic activity at the leaf base (Barnard, 1964). This quality delays the re-growth of alfalfa compared to grasses. Giving alfalfa plants a recovery period will prevent damage to developing shoots. Pure alfalfa stands can be used in grazing, but alfalfa grass pastures can reduce bloat risk, along with filling in open sites of stand. Animals may refuse eating stem to target height in the summer when the plant is less leafy, which causes re-growth from the stem as well as crown buds. This type of re-growth can reduce alfalfa yields (Wolf and Blaser, 1981).

Short-duration intensive grazing encourages more uniform utilization of the pastures (Briske and Stuth, 1982). A pasture that is established with an equal botanical composition of legumes and grasses can change depending on the grazing management. A brome-alfalfa-creeping red fescue pasture that is rotationally grazed can increase its alfalfa composition from 23 to 47% in four years (Walton et al., 1981). Compared to ryegrass, Matua does not persist well under frequent grazing. During periods of growth, the recommended rest period for Matuawas 30-40 days (Sellars, 1988). Alfalfa was more persistent at watering sites than cool season grasses (Campbell, 1961).

Alfalfa is most productive when grazed to 2-5cm, more stubble can decrease stand density (Belesky and Fedders, 1997). Mowing alfalfa after grazing can be an option, but usually animals have trampled stems to the ground (Cassida et al., 2006). In comparison to a *continuously* grazed pasture, a *rotationally* grazed alfalfa-grass mixture can have an overall higher digestibility with higher calcium, magnesium, copper, and crude protein (Walton et

al., 1981). These higher levels are associated with the increased proportion of alfalfa under rotational grazing (Walton et al., 1981). Recommended rotational grazing includes grazing a paddock for one week and resting that pasture for about four weeks. Plants should not be grazed for more than 10-12 days at the risk of damaging the new shoots developing at crown bud. On productive stands, alfalfa can support a stocking rate of 3-5 cows acre<sup>-1</sup>. Stocking density plays an important role in removing forage in this amount of time. The most intensive systems, which remove forage in 1-2 days, require more cattle movement. Alfalfa should be grazed short enough that regrowth occurs from the crown. It is important to give the plants enough time to build reserves in roots before the winter freeze-down. Thus, the last harvest/grazing should occur in mid-September for overwintering. Grazing alfalfa in the late fall should be done carefully, while leaving 8 inches of growth (Ball, 2007).

### **The Alfalfa Weevil [*Hyperapostica* (Gyllenhal)]**

In 1951 the eastern strain of alfalfa weevil was discovered near Baltimore. The alfalfa weevil was accidentally introduced to the USA on three different occasions. The three strains of alfalfa weevil that exist in the USA are almost identical in appearance and research has shown no chromosomal difference (Hsiao, 1984). Like many of the immigrant insects, the weevils escaped its natural enemies when transported to the USA. The alfalfa weevil is the destructive insect of alfalfa and can be controlled by spraying with an insecticide or grazing early (ISU Extension, 1992). Minimizing inputs, while maximizing forage quality and yield, is the goal of both organic and conventional alfalfa producers.

## **Life Cycle**

The adult weevil winters over in weeds and rubbish along ditches and fences, but also under coarse alfalfa crowns or stubble. The alfalfa weevil is a brown, black-striped beetle that causes significant damage on alfalfa across the United States (ISU Extension, 1992). The alfalfa weevil typically has one generation per year, and lay their eggs in the late fall and early spring. The eggs hatch mid to late spring, and the green larvae feed on alfalfa leaves. Weevil larvae cause the most damage and usually reduce yields of the first cutting. Mature larvae form net-like cocoons and then transform into adults that continue to feed on alfalfa, mate, and lay their eggs. The alfalfa weevil migrates to estivation sites on field borders, and then returns in the fall. In Virginia, peak return of weevil migration was in the fall, with few migrations in the winter and spring (Pamanes, 1965). The concentration and location of estivating weevils on the border sites can vary depending on the wind speed at the time of flight, tree height, size of alfalfa field, and ground cover (Zavaleta and Ruesink, 1980). Methods of migration differ depending on the date that alfalfa is harvested. Adult weevils tend to fly to the estivation site in uncut alfalfa, while an early cut alfalfa forces weevils to migrate before complete adult development (Prokopy, 1965).

The damage of alfalfa weevil will depend on spring weather, since cold springs tend to delay the growth of alfalfa weevil more than alfalfa. Conversely, if the spring is especially warm, the weevil can grow faster than the alfalfa crop, resulting in extensive plant damage (Metcalf and Luckmann, 1982).

## **Control of Weevil**

The damage caused by alfalfa weevil is mostly in the first cutting, but can also reduce yield in subsequent cuttings (Long, 2009). Alfalfa populations are monitored through stem collection and larvae count or through the use of a sweep net. When weevil counts reach three larvae per stem, or 15 larvae per sweep net, action is recommended (Long, 2009). Organic pesticides that are certified by OMRI (Organic Materials Review Institute) are allowed, however they are costly and not as effective as other pesticides offered conventionally (Long, 2009). It is important to note that pest control is difficult to manage under conventional conditions after accounting for the withdrawal periods (Cassida et al., 2006). Alternate feed sources are needed during these withdrawal periods.

If alfalfa is in a grazing system, an option is to graze it over the winter when plants are dormant. This allows for the weevil eggs to be ingested or trampled by the animals. If making hay, a management option is to harvest the stand early to avoid the greatest larvae destruction of alfalfa. Another available, but uncommon, practice is flaming the field with propane to give a similar effect of grazing off, but it is not currently an economically viable option.

Overseeding an established stand of alfalfa with grasses or legumes that are unpalatable to the weevil, can increase the production of the stand (Canevari, 2000), but can change the market value if investing in hay. Natural enemies of pests can be attracted with hedgerows of flowering plants. The beneficial insects can migrate through the field to help control pests (Long, 2009). Beneficial parasites have saved East Coast alfalfa producers millions of dollars each year and reduce insecticide use. The USDA has imported and

released parasitic wasps to reduce alfalfa weevil population in the United States. Parasites of the alfalfa weevil were brought from Italy in 1911 in response to a growing alfalfa weevil problem in Utah (USDA, 1911; USDA, 1912; USDA, 1913). Wasps lay their eggs inside the host alfalfa weevil. After hatching from the egg, the developing parasite fed on the insect (1992). There are more than a dozen parasitic species that are known to attack the alfalfa weevil, including *Bathyplectes anurus*, which is a small black wasp (1/8-inch long). The adult female wasps lay their eggs into alfalfa weevil larvae and the developing parasite kills the weevil as it completes its cocoon.

Developing a completely weevil resistant variety of alfalfa may not be necessary, according to some researchers (Zavaleta and Ruesink, 1980). Using computerized models of alfalfa crop and the alfalfa weevil, 20%, 40%, 60%, and 100% mortality levels were evaluated. A plant with 100% mortality represents a truly resistant plant. Although 100% larval mortality would produce the greatest yield and least pesticide use, 60% larval mortality was computed to be effective enough to disregard the need for pesticide application. In addition, 40% larval mortality would require some insecticide use, but at application rates 85% less than those at the time. Zavaleta and Ruesink (1980) demonstrate that although 100% larval mortality is desired, partial resistance can still decrease the use of pesticides and increase crop yield.

### **Organic Alfalfa Production**

The high cost of organic feed makes alfalfa an attractive crop for some organic milk and beef production systems. Alfalfa is valued not only for its value as feed, but also because of its agronomic advantages. It adds nitrogen to the soil and, since it is a perennial, it creates

a favorable habitat for beneficial arthropods, including pollinators and natural enemies of pests. The two challenges in the production of organic alfalfa are weed and insect control, as chemical management is prohibited. Concepts of organic management can be used in conventional management, but organic has limited approved methods for successful production so it is imperative that they are completely utilized. Soil fertility, for example, determines the optimal for alfalfa, and not for the weeds. Lime and fertility amendments, along with appropriate variety, will determine the success of an organic alfalfa stand.

Protecting beneficial insects and allowing them to reproduce is part of the organic production philosophy. The identification of alfalfa pests and their natural enemies are the first steps to successful management. Some researchers have found that harvesting alfalfa in alternate strips can dramatically increased the number of beneficial pests (Anon, 1993). Cutting alfalfa late in the season prevented adult weevils from finding a place to lay their eggs. However, there is a risk of depleting root reserves if alfalfa is cut too late in the season (Metcalf and Luckmann, 1982). Other agronomists determined that grazing spring growth of alfalfa in late vegetative and early bud stage allows nearly allows the livestock to demonstrate weevil control (Gerrish, 1997).

Other beneficial insects that will attack alfalfa weevil include damsel bugs, assassin bugs, spiders, and lacewing larvae. These species can be unintentionally reduced under pesticide control (Kalaskar and Evans, 2001). There are other weevil egg predators, such as *Peridesmia discus*, that have been identified in North Carolina (Dystart, 1988). Upon the introduction of beneficial parasites, it can take three years to get pests under control. Sugar sprays have been found to attract some parasites for the alfalfa weevil (Jacob and Evans,

1998). Organic sprays for alfalfa weevil usually include neem and prevent growth of weevil, although applications must be frequent (Orouchi and Lorra, 1993).

Non-herbicidal weed control usually involves the interseeding alfalfa with an annual or perennial grass. Although grasses are valuable in the control of weed production, it should be noted that there is some value lost in alfalfa-mixture hay production compared to pure alfalfa hay. Bowman (1992) reported that alfalfa-grass mixtures can reduce larvae and weevils in some areas. These management techniques for alfalfa weevil and weeds are so successful that they are also used in conventional production systems (Anon, 1999). Thus, research in organic methods of weed control and pest management is beneficial for both organic and conventional production systems.

## REFERENCES

- 26th Natl. Alfalfa Symp. (ed.) 1996. East Lansing, MI. 4-5 Mar. 1996. Certified Alfalfa Seed Council, Davis, CA.
- Anon. 1999. Early spring grazing as a component of alfalfa integrated pest management. Midwest Biological Control News. April p. 6.
- Anon, 1993. Burning helps control alfalfa weevils. Hay and Forage Grower. May P. 22.
- Adams, F. 1981. Nutritional imbalances and constraints to plant growth on acid soils. Journal of Plant Nutrition 4:81 - 87.
- Ball, D.M., Hoveland, C.S., Lacefield, G.D. 2007. Southern Forages. 4th Edition ed. International Plant Nutrition Institute, Norcross, GA.
- Barnard, C. 1964. Grasses and Grasslands. Soil Science 98:349.
- Beardmore, R.A., and Linscott, D.L. 1988. Postemergence Herbicide Suppression of Wheat, *Triticum aestivum*, Growing with Alfalfa, *Medicago sativa*. Weed Science 36:636-641.
- Belesky, D.P., and Fedders, J.M. 1997. Residue height influences stand dynamics of alfalfa grown on a shallow soil. Agron. J. 89:975-980.
- Belesky, D.P., Fedders, J.M., Ruckle, J.M., and Turner, K.E. 2002. Bermudagrass-white clover-bluegrass sward production and botanical dynamics. Agron. J. 94:575-584.
- Bell, C.C., Ritchie, I.M. 1989. The effect of frequency and height of defoliation on the production and persistence of 'Grassland Matua' prairie grass. Grass Forage Science 44:245-248.

- Berdahl, J.D., Karn, J.F., and J.R., Hendrickson. 2001. Dry matter yields of cool-season grass monocultures and grass-alfalfa binary mixtures. *Agron. J.* 93:463-467.
- Blaser, R.E., Griffeth, W.L., and Taylor, T.H. 1956. Seedling competition in establishing forage plants. *Agron. J.* 48:1-6.
- Boland, H.T., Scaglia, G., Fontenot, J.P., Abaye, A.O., Stewart, R.L., and Smith, S.R. 2007. Case Study: grazing behavior of beef steers consuming different tall fescue types and lakota prairie grass *The Professional Animal Scientist* 23:721-727.
- Bouton, J.H., and Gates, R.N. 2003. grazing-tolerant alfalfa cultivars perform well under rotational stocking and hay management. *Agron. J.* 95:1461-1464.
- Bowman, Greg. 1992. Grass in alfalfa baffles bugs. *New Farm Magazine* May-June. p. 22-23, 28-29.
- Briske, D.D., and Stuth, J.W. 1982. Tiller defoliation in a moderate and heavy grazing regime. *Journal of Range Management* 35:511-514.
- Bula, R.J., Smith, D., and Miller, E.E. 1954. Measurements of light beneath a small-grain companion crop as related to legume establishment. *Botanical Gazette* 115:271-278.
- Campbell, J.B. 1961. Continuous versus repeated-seasonal grazing of grass-alfalfa mixtures at swift current, Saskatchewan. *Journal of Range Management* 14:72-77.
- Canevari, W., Putnam, D., Lanini, W. 2000. Overseeding and companion cropping in alfalfa UC ANR Publication number 21594.
- Carter, L.P., and Scholl, J.M. 1962. Effectiveness of inorganic nitrogen as a replacement for legumes grown in association with forage grasses. I. dry matter production and botanical composition. *Agron. J.* 54:161-163.

- Cassida, K.A., Stewart, C.B., Haby, V.A., and Gunter, S.A. 2006. Alfalfa as an alternative to bermudagrass for pastured stocker cattle systems in the southern USA. *Agron. J.* 98:705-713.
- Chamblee, D.S. 1958. The relative removal of soil moisture by alfalfa and orchardgrass. *Agron. J.* 50:587-589.
- Chamblee, D.S., Lovvorn, R.L. 1953. The effect of rate and method of seeding on the yield and botanical composition of alfalfa-orchardgrass and alfalfa-tall fescue. *Agronomy Journal* 45:192-196.
- Chatterton, N.J., Carlson, G.E., Hart, R.H., and Hungerford, W.E. 1974. Tillering, nonstructural carbohydrates, and survival relationships in alfalfa. *Crop Sci.* 14:783-787.
- Counce, P.A., Bouton, J.H., and Brown, R.H. 1984. Screening and characterizing alfalfa for persistence under mowing and continuous grazing. *Crop Sci.* 24:282-285.
- Dotzenko, A., and Ahlgren, G.H. 1950. Response of alfalfa in an alfalfa-bromegrass mixture to various cutting treatments. *Agron J.* 42:246-247.
- Drake, M., Vengris, J., and Colby, W.G. 1951. Cation-exchange capacity of plant roots. *Soil Science* 72:139-148.
- Dystart, R.J. 1988. Establishment in the United States of *Peridesmia discus* (Hymenoptera Pteromalidae), an egg predator of the alfalfa weevil (Coleoptera, Curculionidae). Eleventh North American Prairie Conference. (ed.) 1989.
- Fick, G.W., and Mueller, S.C. 1989. Alfalfa quality, maturity, and mean stage of development. Cornell University Cooperative Extension, Ithaca, NY.

- Fraser, T.J. 1982. Evaluation of 'grassland matua' prairie grass and 'grassland maru' *Phalaris* eith and without lucerne in Canterbury. N.Z. J. Exp. Agric. Sci. 64:351-359.
- Gerrish, Jim. 1997. Grazing alfalfa successfully. Forage System Update. October. p. 2-4.
- Gamroth, M . 2010. Energy Requirements of Grazing Activity. North Carolina State Cooperative Extension.
- Greenfield, P.L., and Smith, D. 1973. Influence of temperature change at bud on composition of alfalfa at first flower. Agron. J. 65:871-874.
- Guay, J.F. 2007. Compatibility, yield, and nutritive value of matua prairie grass with interseeded legumes. Plant Management Network.
- Haby, V.A., Davis, J.V., and Leonard, A.T. 1999. Response of overseeded alfalfa and bermudagrass to alfalfa row spacing and nitrogen rate. Agron. J. 91:902-910.
- Hansen, A.A., Barnes, D.K., Hill, R.R. 1988. Alfalfa and alfalfa improvement American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, Wisconsin.
- Havlin, J.L., Beaton, J.D., Tisdale, S.L., Nelson, W.L. 2005. Soil fertility and fertilizers Pearson Education, Upper Saddle River, NJ.
- Holt, N.W., and Jefferson, P.G. 1999. Productivity and sustainability of four grazed grass-alfalfa mixtures. Canadian Journal of Animal Science 79:83-89.
- Hsiao, C., and Hsiao, T.H. 1984. Cytogenetic studies of alfalfa weevil (*Hypera postica*) strains (Coleoptera: Curculionidea). Can. J. Genet. Cytol. 26:244-246.
- Hunt, O.J., and Wagner, R.E. 1963. Effects of phosphorus and potassium fertilizers on legume composition of seven grass-legume mixtures. Agron. J. 55:16-19.

- Iowa State University Extension. 1992. Extension Bulletin: Biological Control of the Alfalfa Weevil.
- Jackobs, J.A. 1963. A measurement of the contributions of ten species to pasture mixtures. *Agron. J.* 55:127-131.
- Jacob, H.S. and E.W. Evans. 1998. Effects of sugar spray and aphid honeydew of field populations of parasitoid *Bathyplectes curculionis* (Hymenoptera: Ichneumonidae). *Environment Entomology*. Vol 27, No. 6. p. 1563-1568.
- Jung, G.A., Shaffer, J.A., and Everhart, J.R. 1994. Fall management effects on 'grasslands matua' prairie grass production and sward characteristics. *Agron. J.* 86:1032-1039.
- Jung, G.A., Wilson, L.L., LeVan, P.J., Kocher, R.E., and Todd, R.F. 1982. Herbage and beef production from ryegrass-alfalfa and orchardgrass-alfalfa pastures. *Agron. J.* 74:937-942.
- Kalaskar, A., and E. W. Evans. 2001. Larval responses of aphid-eating lady beetles to weevil larvae vs. aphids as prey. *Annal of the Entomological Society of America*. Vol 94, No. 1. p. 76-81.
- Kalton, R.R., Wilsie, C.P. 1952. Effect of bromegrass variety on yield and composition of a brome-alfalfa mixture. *Agron J.* 45:308-311.
- LaCasha, P.A., Brady, H.A., Allen, V.G., Richardson, C.R., and Pond, K.R. 1999. Voluntary intake, digestibility, and subsequent selection of matua bromegrass, coastal bermudagrass, and alfalfa hays by yearling horses. *J. Anim Sci.* 77:2766-2773.

- Lamba, P.S., Ahlgren, H.L., Muckenhirn, R.J. 1949. Root growth of alfalfa, medium red clover, brome grass, and timothy under various soil conditions. *Agronomy Journal* 41:451-458.
- Lanini, W.T., Orloff, S. B., Bendixen, W. E., Canevari, W. M., Schmierer, J. L., Vargas, R. N. 1999. Influence of oat (*avena sativa*) interseeding on weed suppression in the final year of an alfalfa (*medicago sativa*) stand. *Weed Technology* 13:399-403.
- Lorenz, R.J., C.W. Carlson, G.A. Rogler, and H. Holmen. 1961. Brome grass and brome grass-alfalfa yields as influenced by moisture level, fertilizer rates, and harvest frequency. *Agron. J.* 53:49-52.
- MacLeod, L.B. 1965. Effect of nitrogen and potassium fertilization on the yield, regrowth, and carbohydrate content of the storage organs of alfalfa and grasses. *Agron. J.* 57:345-350.
- MacLeod, L.B., and R. Bradfield. 1963. Effect of liming and potassium fertilization on the yield and composition of an alfalfa-orchardgrass association. *Agron. J.* 55:435-439.
- McCloud, D.E., and G.O. Mott. 1953. Influence of association upon the forage yield of legume-grass mixtures. *Agron. J.* 45:61-65.
- Metcalf, R. L., and W. H. Luckmann. 1982. *Introduction to Insect Pest Management*. 2<sup>nd</sup> ed. John Wiley & Sons. New York, NY p. 446, 449-450, 453.
- (ed.) 1991. *Amer. Forage and Grassl. Coun.*, Columbia, MO. April 4-9.
- Nelson, N.T. 1952. The effects of frequent cutting on the production, root reserves, and behavior of alfalfa. *Jour. Amer. Soc. Agron.* 17:100-113.

- Norris, R.F.K.M. 2000. Interactions between weeds, arthropod pests, and their natural enemies in managed ecosystems. *Weed Science* 48:94-158.
- Pamanes, A.G., and R. L. Pienkowski. 1965. Dispersal of the alfalfa weevil in virginia. *Annals of the Entomological Society of America* 58:230-233.
- Prather, T.S.L., W.T.; Vargas, R.; Orloff, S.; Canevari, W.M.; Mueller S. 2000. Interplanting grasses into alfalfa controls weeds in older stands. University of California, California Agriculture 54:37-41.
- Prokopy, R.J., and G. G. Gyrisco. 1965. Diel flight activity of migrating alfalfa weevils, *hypera postica* (Coleoptera: Curculionidae). *Annals of the Entomological Society of America* 58:642-647.
- Rechcigl, J.E., Reneau, R.B., and Starner, D.E. 1985. Effect of subsurface amendments and irrigation on alfalfa growth. *Agron. J.* 77:72-75.
- Rhodes, N.G., Breeden, G. K., Bates, G., McElroy. Hay Crop and Pasture Weed Management. University of Tennessee Extension:1-23.
- Rogers, D.D., D.S. Chamblee, J.P. Mueller, and W.V. Campbell. 1985. Fall no-till seeding of alfalfa into tall fescue as influenced by time of seeding and grass and insect suppression. *Agron. J.* 77:150-157.
- Rumball, W. 1974. Grasslands 'Matua' prairie grass (*Bromus catharticus*). *N.Z. J. Exp. Agric.* 2:1-5.
- Sanderson, M.A., K.J. Soder, L.D. Muller, K.D. Klement, R.H. Skinner, and S.C. Goslee. 2005. Forage mixture productivity and botanical composition in pastures grazed by dairy cattle. *Agron. J.* 97:1465-1471.

- Savory, A., and S.D. Parsons. 1980. The savory grazing method. *Rangelands* 2:234-237.
- Sellars, M.D. 1988. Manawatu dairy farmers experiences with matua prairie grass. *Proc. N.Z. Grassl. Assoc.* 49:185-186.
- Sheaffer, C., Moncada, K. 2009. *Introduction to agronomy food, crop, and environment*  
Delmar Cengage Learning, Clifton Park, NY.
- Smith, D. 1981. *Seeding establishment of legumes and grasses* Kendall/Hunt, Dubuque, IA.
- Smith, D., and B.E. Struckmeyer. 1974. Gross morphology and starch accumulation in leaves of alfalfa plants grown at high and low temperatures. *Crop Sci.* 14:433-436.
- Smith, S.R., J.H. Bouton, and C.S. Hoveland. 1989. Alfalfa persistence and regrowth potential under continuous grazing. *Agronomy Journal* 81:960-965.
- Stiles, D.A., E.E. Bartley, G.L. Kilgore, F.W. Boren, and H.B. Perry. 1971. Comparative value of alfalfa pasture, alfalfa greenchop, or alfalfa hay for lactating dairy cows. *Journal of dairy science* 54:65-70.
- Sulc, R.M., and K.A. Albrecht. 1996. Alfalfa establishment with diverse annual ryegrass cultivars. *Agron. J.* 88:442-447.
- Tesar, M.B. 1976. Sod seeding birdsfoot trefoil and alfalfa. *Mich. Coop. Ext. Serv.:*E-956.
- Triplett, G.B., R.W.V. Keuren, and J.D. Walker. 1977. Influence of 2,4-D, pronamide, and simazine on dry matter production and botanical composition of an alfalfa-grass sward. *Crop Sci.* 17:61-65.
- USDA, 1911. *United States Department of Agriculture Year Book.*
- USDA, 1912. *United States Department of Agriculture Year Book.*
- USDA, 1913. *United States Department of Agriculture Year Book.*

- USDA, N.A.S.S. 2011. Crop production 2010 summary 1057-7823.
- University of California. 2008. Extension Bulletin: Integrated Pest Management. Statewide IPM Program.
- University of California, Extension. 2009. western alfalfa and forage conference, Reno, NV.
- University of California. 2010. Extension Bulletin: Alfalfa & forage symposium and corn/cereal silage mini-symposium, Visalia, CA.
- Van Riper, G.E. 1960. Protein difference among varieties of alfalfa and red clover and grass combinations. *Agronomy Journal* 52:549-550.
- Walton, P.D., Martinez, R., and Bailey, A.W. 1981. A comparison of continuous and rotational grazing. *Journal of Range Management* 34:19-21.
- Ward, C.Y., and R.E. Blaser. 1961. Effect of nitrogen fertilizer on emergence and seedling growth of forage plants and subsequent production. *Agron. J.* 53:115-120.
- Ward, C.Y., J.N. Jones, J.H. Lillard, J.E. Moody, R.H. Brown, and R.E. Blaser. 1966. Effects of irrigation and cutting management on yield and botanical composition of selected legume-grass mixtures. *Agron. J.* 58:181-184.
- Wedin, W.F., J.D. Donker, and G.C. Marten. 1965. An evaluation of nitrogen fertilization in legume-grass and all-grass pasture. *Agron. J.* 57:185-188.
- Welty, L.E., Ditterline, R.L., Hall, J.A., Prestbye, L.S. 1988. Effect of tillage for renovation of established alfalfa. *Appl. Agric. Res.* 3:123-127.
- Wilsie, C.P. 1949. Evaluation of grass-legume associations with emphasis on the yields of bromegrass varieties. *Agronomy Journal* 41:412-420.

Wolf, D.D., and D. Smith. 1964. Yield and persistence of several legume-grass mixtures as affected by cutting frequency and nitrogen fertilization. *Agron. J.* 56:130-133.

Wolf, D.D., and R.E. Blaser. 1981. Flexible alfalfa management: early spring utilization. *Crop Sci.* 21:90-93.

Zavaleta, L.R., and W.G. Ruesink. 1980. Expected benefits from nonchemical methods of alfalfa weevil control. *American Journal of Agricultural Economics* 62:801-805.

**CHAPTER II:**  
**The establishment of organic and conventional alfalfa-grass mixtures in hay systems**

## ABSTRACT

North Carolina livestock producers are interested in high quality hay for milk and grass-fed beef production. Organic producers are particularly interested in forages produced without chemical control of weeds and pests. Thus, this study had two objectives: 1) to determine the impact of organic and conventional management on cumulative alfalfa, forage, and weed production of the establishment year and 2) to compare alfalfa interseeded with prairie grass (PG) to alfalfa not interseeded with prairie grass (NPG) in terms of alfalfa, forage, and weed production in the establishment year. Management differences included defoliation frequency and chemical use. Field 1, at the end of the first season (2010), reached alfalfa weevil threshold in April, 2011. Thus, organic was harvested in April, and conventional was controlled with pesticide (Lorsban®). Cumulative conventional alfalfa production was significantly greater ( $P < 0.05$ ) than cumulative organic alfalfa production ( $4415 \pm 220$  vs.  $3545 \pm 220$  kg/ha, respectively), with the differences primarily in the first and last harvests. However, forage production (alfalfa, prairie grass, ryegrass, and crabgrass) did not differ ( $P = 0.206$ ) between conventional and organic management ( $5695 \pm 208$  vs.  $5282 \pm 208$  kg/ha, respectively). Also, there was no significant difference in weed production between the two systems ( $P = 0.749$ ). However, samples in March revealed that conventional management had significantly more chickweed than organic management ( $P < 0.01$ ). Under conventional management in the establishment year, cumulative alfalfa production in NPG plots was significantly greater ( $P < 0.05$ ) than alfalfa production in PG plots ( $5024 \pm 488$  vs.  $3893 \pm 344$  kg/ha, respectively). However, there was no significant difference ( $P = 0.181$ ) between cumulative forage production in NPG plots and PG plots. Cumulative weed

production in NPG plots tended to be greater ( $P < 0.10$ ) than PG plots. Under organic management in the establishment year, cumulative alfalfa production in NPG plots tended to be greater ( $P < 0.10$ ) than PG plots. Cumulative forage production in NPG plots also tended to be greater ( $P < 0.10$ ) than PG plots. Although alfalfa and forage production were successful, cumulative weed production in NPG plots tended to be greater ( $P < 0.10$ ) than PG plots. Organic alfalfa plant counts were numerically lower, but adequate

Field 1 reached alfalfa weevil threshold in March, 2011. Organic plots were harvested and conventional plots were sprayed with insecticide (Lorsban®). Thus, May 10, 2011 was the second harvest for organic, and the first harvest for conventional plots. Cumulative organic alfalfa production was significantly greater ( $P < 0.05$ ) than conventional alfalfa production. In addition, cumulative organic forage production was significantly greater ( $P < 0.05$ ) than conventional forage production. However, weed production was greater ( $P < 0.05$ ) in organic plots than conventional plots. Under conventional management, alfalfa production, forage production, and weed production did not significantly differ between PG and NPG treatment. Under organic management, cumulative alfalfa production in PG plots was not significantly different ( $P = 0.762$ ) from alfalfa production in NPG plots. Cumulative forage production in PG plots tended to be greater ( $P = 0.101$ ) than NPG plots. Cumulative PG weed production did not differ from NPG weed production.

Field 2 did not reach alfalfa weevil threshold in the establishment year. At May 11, 2011 (the first season), management did not significantly affect alfalfa production or forage production. Under conventional management, alfalfa production in NPG plots was significantly lower ( $P < 0.05$ ) than PG plots. Under organic management, organic alfalfa in

NPG plots was similar ( $P=0.359$ ) to alfalfa production in PG plots. Organic alfalfa plant counts were lower than conventional plant counts ( $P<0.05$ ).

In conclusion, conventional management produced more alfalfa than organic management. However, alfalfa grass mixtures yielded as much forage without the need chemical control of weeds and insects. Interseeding prairie grass may have more of a role in suppressing weed production than boosting forage production. Potentially less weed pressure could reduce ovipositioning sites of the alfalfa weevil.

## **Introduction**

The high cost of organic feed makes alfalfa an attractive crop for some organic milk and beef production systems. Last year (2010), North Carolina was one of the bottom 10 states in their production of alfalfa (Progressive, 2011). Soil acidity and fertility are challenges of the persistence of alfalfa in the Southeast Coastal Plains, but its deep tap root could allow growth during drought conditions in this area (Haby et al., 1999). Alfalfa has soil building properties through its nitrogen-fixation, and eliminates the need for manufactured nitrogen fertilizers. In addition, alfalfa is a nutritive forage high that has been compared with soybean portion of the livestock ration (Lehnert, 1998). The two obstacles in the production of organic alfalfa are typically weed control and pest management. Under conventional management, alfalfa growers can chemically overcome these challenges. However, other solutions are necessary for organic management.

Alfalfa weevil [*Hyperapostica* (Gyllenhal)] is one of most infamous pest in alfalfa production. Weevil damage reduces the first, and sometimes second, harvest yield. Integrated

Pest Management uses a combination of methods to control a problem. Management options that are accepted by organic regulations include the release of beneficial wasps that parasitize the weevil larvae. In addition, an early harvest can remove many of the weevil eggs and larvae in the stem of the alfalfa. Some results have found that alfalfa interseeded with a grass experiences reduced weevil pressure. However, interseeding a grass into alfalfa is associated with weed control, more than anything else. It should be noted that the value of alfalfa-grass mixture hay can be less than pure alfalfa hay, since alfalfa production can be suppressed from interseeding a grass at establishment.

The growth habit and season of the interseeded grass should complement alfalfa. When making hay, the forage needs to mature at a similar time, or nutritive potential is lost. Prairie grass is a short-lived, naturally reseeding perennial that is drought tolerant. It is a palatable forage that has a bunch-type growth habit and produces a seedhead at every harvest. Prairie grass responds to high nutrients and colonizes open spots in alfalfa sward and competes with weed production.

These management techniques for control of alfalfa weevil and weeds are so successful that they are also used in conventional production systems (Anon, 1999). Thus, research in organic methods of weed control and pest management is beneficial for both organic and conventional production systems.

## **Materials and Methods**

This study started in October 2009 at Cherry Research Farm at the Center for Environmental Farming Systems in Goldsboro, NC (35° 22' 55" N, 77° 58' 41" W) on loamy sand soils (Kenansville loamy sand and Lakeland sand). Plots had history of annual ryegrass

(*Lolium multiflorum*) and sorghum (*sorghum bicolor*) under grazing management, with historical pigweed (*Amaranthus spinosus*) weed pressure. Soil samples were taken in August 2009 and again in August 2010. In August 2009, calcitic lime ( $\text{CaCO}_3$ ) was applied at  $1.5 \text{ t ha}^{-1}$ . Plots were disked twice in August to disrupt cool season grass establishment, and then disked a third time after a second lime application ( $1.3 \text{ t ha}^{-1}$ ) on September 3, 2009. Boron was applied at  $34.8 \text{ kg ha}^{-1}$  and potash ( $\text{K}_2\text{SO}_4$ ) was applied at  $247 \text{ kg ha}^{-1}$  according to soil test recommendations. In October 2010, lime ( $3.4 \text{ t ha}^{-1}$ ), potash ( $112 \text{ kg ha}^{-1}$ ), and boron ( $2.2 \text{ kg ha}^{-1}$ ) were applied according to soil test recommendations.

#### Field 1: Planting 2009

On October 9, 2009, Alfalfa (*Medicago sativa*) was planted with a Brillion cultipacker-seeder on a prepared seedbed. Seeding rates were based on seed purity and germination rate. Two varieties of alfalfa were planted, Arriba alfalfa (with a fungicide seed coat) and Haygrazer alfalfa. Arriba (America's Alfalfa®) alfalfa was planted at  $22.5 \text{ kg ha}^{-1}$  and Haygrazer (Cimarron USA®) alfalfa was planted at  $29.0 \text{ kg ha}^{-1}$  and inoculated with *Rhizobium meliloti* (Nitragrin AB®). Observational composition data was collected approximately every 5 weeks. Plant counts were collected in the fall, spring, and summer. Botanical composition samples were sorted according to species and dried for 48 hrs at  $57^\circ\text{C}$ . Alfalfa weevil (*Hyperapostica* Gyllenhal) scouting started in February and continued through April in 2009 and again in 2010. Conventional alfalfa could be sprayed with chlorpyrifos (Lorsban-4E®) if economic threshold (3 weevil larvae per stem) was reached. Precipitation data was retrieved for both experiments from the State Climate Office of North Carolina.

#### Experiment 1 2009 Hay Study

Two varieties of alfalfa were planted under organic or conventional management (12m x 18m plots) in a split-block design with embedded subplots of prairie grass mixtures. Alfalfa mixtures were planted with Matua prairie grass (Barenbrug®) or Lakota prairie grass at two different seeding dates (fall or spring). Fall planted prairie grass was broadcasted at 16.8 kg ha<sup>-1</sup>. Conventional plots without prairie grass were sprayed with sethoxydim (Poast Plus®) at 1.75 liters ha<sup>-1</sup> for ryegrass control on December 9, 2009. Biomass and botanical composition samples were taken in January 2010 and March 2010 using samples cut with a 1.0ft<sup>2</sup> frame. Spring planted prairie grass was broadcasted (16.8 kg ha<sup>-1</sup>) in February 2010. Organic plots were harvested early if weevil larvae reached economic threshold of 3 larvae per stem. Organic plots were harvested in early April, mid-June, late July and late August. Unless managing for alfalfa weevil, plots were cut when alfalfa maturity reached 1/10<sup>th</sup> bloom in plots. Conventional plots were harvested mid-May, mid-June, late July and late August. Yield and botanical composition were estimated before each harvest. Yield was measured with lawn mower (Husquvarna®) and strips were measured after cutting to accurately estimate yield. Following hand separation, samples were dried in a forced air oven at 60°C for 48h and weighed to determine the percent of each fraction in the sward on a DM basis. Plots were harvested with a 10cm stubble height. In spring 2011, organic plots were cut in late April and May 10<sup>th</sup>. Conventional plots were sprayed with chlorpyrifos (Lorsban-4E®) at 1.2 l/ha for alfalfa weevil control. Conventional plots were harvested May 10th 2011.

## Field 2: Planting 2010

Two varieties of alfalfa were planted under organic or conventional management (12m x 18m plots) in a split-block design with embedded subplots of prairie grass mixtures. Before planting alfalfa, Eptam® (EPTC, s-ethyl dipropylthiocarbamat) was incorporated at 4.1 l kg ha<sup>-1</sup> into conventional plots without prairie grass. Alfalfa mixtures were planted with Matua prairie grass (Barenbrug®) or Lakota prairie grass at two different seeding dates (fall or spring). Fall planted prairie grass was broadcasted at 16.8 kg ha<sup>-1</sup>. Spring planted prairie grass was broadcasted (16.8 kg ha<sup>-1</sup>) in February 2010. Yield and botanical composition was collected before each harvest. Organic and conventional plots were harvested in early May 2011.

*Statistical Analysis.* Data were analyzed using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Fixed effects of individual harvests included management (organic vs. conventional) and prairie grass treatment (alfalfa interseeded with prairie grass vs. alfalfa not interseeded with prairie grass). Random effects included rep effect. Cumulative production was analyzed using repeated measures. Degrees of freedom, least squared means and standard errors were calculated applying the correction method of Kenward and Rogers (SAS Institute, 2006). Effects were evaluated in orthogonal contrasts.

## Results

*Alfalfa Varieties.* Differences in alfalfa varieties are summarized in Table 13. In the January 18, 2010 sample, Arriba alfalfa production was significantly greater ( $P < 0.01$ ) than Haygrazer alfalfa production ( $545 \pm 30$  vs.  $340 \pm 30$  kg/ha, respectively). There were no varietal differences in alfalfa production for the March sample ( $P = 0.478$ ). However,

Haygrazer alfalfa production tended to be greater than Arriba in the June, 2010 sample ( $P < 0.10$ ). Varietal differences were not consistent throughout the establishment year, but the cumulative production Haygrazer alfalfa tended to be greater ( $P < 0.10$ ) than Arriba alfalfa production ( $909 \pm 54$  vs.  $1080 \pm 54$  kg/ha, respectively). In spring 2011, Haygrazer was performing better in the beginning of the second season ( $P < 0.05$ ). Unlike Field 1, Field 2 had no varietal difference in alfalfa production in the beginning of the establishment year ( $2423 \pm 136$  vs.  $2561 \pm 136$  kg/ha, respectively). Table 15 reports the values of alfalfa plant counts for each variety of alfalfa. There was no difference in plant counts of Arriba and Haygrazer alfalfa in field 1 or field 2.

*Plant Counts.* Table 14 shows that alfalfa plant counts in Field 1 were not affected by management in October or June of 2010, or March 2011. In Field 2, conventional plant counts were greater than organic plant counts in December 2010 and May 2011.

Results for production are reported in production of alfalfa, forage (alfalfa, prairie grass, ryegrass, and crabgrass), weed (henbit, chickweed, pigweed), and above-ground biomass (forage and weed production). Results are reported as the effect of management (organic vs. conventional), the effect of alfalfa interseeded with prairie grass (interseeded prairie grass vs. no interseeded prairie grass), and the interaction of the two treatments.

### ***Field 1(Planted 2009)***

*Alfalfa Weevil.* In spring 2010, Field 1 had no difference in the number of weevils (larvae/stem) between organic and conventional management. Economic threshold of three larvae per was reached by April 6, 2010. In 2011, the second season of production, Field 1

had no difference in the number of weevils (larvae/stem) between organic and conventional management. Economic threshold was reached by March 29, 2011. Field 2 never reached the economic threshold.

## ***Management***

### *Non-Destructive Interharvest Samples—2010*

The production values describing the non-destructive interharvest samples of 2010 are presented in table 4. Grasses present were prairie grass and ryegrass. Weed specie was henbit. On January 18, 2010, conventional alfalfa production was not significantly different ( $P=0.286$ ) from organic alfalfa production ( $465 \pm 56$  vs.  $420 \pm 56$ kg/ha). Conventional forage production was not significantly different ( $P=0.279$ ) from organic forage production ( $705 \pm 50$  vs.  $646 \pm 50$  kg/ha, respectively). In addition, management did not significantly affect above-ground biomass ( $P= 0.664$ ) or weed production ( $P=0.254$ ).

On March 16, 2010, grasses were prairie grass and ryegrass. The weed specie was common chickweed. Conventional alfalfa production was greater ( $P<0.01$ ) than organic alfalfa production ( $934 \pm 60$  vs.  $485 \pm 60$  kg/ha, respectively). Conventional forage production was greater ( $P<0.05$ ) than organic forage production ( $1176 \pm 78$  vs.  $712 \pm 78$  kg/ha, respectively). Furthermore, conventional management significantly increased ( $P<0.01$ ) the above-ground biomass ( $1034 \pm 60$  vs.  $579 \pm 60$  kg/ha) and weed production ( $P<0.01$ ).

On June 1, 2010, was after the first harvest and the grasses were prairie grass and ryegrass. There was no weed production June 1. Conventional alfalfa production tended to be greater ( $P=0.064$ ) than organic alfalfa production ( $612 \pm 53$  vs.  $828 \pm 53$  kg/ha, respectively).

However, management did not significantly affect forage ( $P=0.196$ ) or above-ground biomass production ( $P=0.196$ ).

#### *Harvests 2010*

*Harvest 1.* Management effects on production of each of the four harvests are shown in Table 1. The first conventional harvest (May 5, 2010) was 27 days later than the organic harvest (April 8, 2010) because of different managements for alfalfa weevil control in conventional and organic treatments. For both management systems, grass species were prairie grass and ryegrass. The weed specie was common chickweed. As expected, conventional alfalfa production was significantly greater ( $P<0.001$ ) than organic alfalfa production ( $1345 \pm 91$  vs.  $549 \pm 91$  kg/ha, respectively). Conventional forage production was greater ( $P<0.01$ ) than organic forage production ( $1518 \pm 112$  vs.  $905 \pm 112$  kg/ha, respectively). Conventional above-ground biomass was greater ( $P<0.01$ ) than organic above-ground biomass ( $1592 \pm 108$  vs.  $923 \pm 108$  kg/ha, respectively), along with weed production ( $P<0.01$ ).

*Harvest 2.* Organic plots (regrowth: 68 days) and conventional plots (regrowth: 41 days) were both harvested for the second time on June 15, 2010. The second harvest had the greatest amount of production under both organic and conventional management. Grasses present were prairie grass and crabgrass. Weed specie was pigweed. There was no significant difference ( $P=0.648$ ) between conventional and organic alfalfa production ( $1834 \pm 116$  vs.  $1755 \pm 116$  kg/ha, respectively). There was also no significant difference ( $P=0.778$ ) between conventional and organic forage production ( $1982 \pm 132$  vs.  $2036 \pm 132$  kg/ha, respectively).

Management did not affect above-ground biomass ( $P=0.767$ ) or weed production ( $P=0.762$ ) in the second harvest.

*Harvest 3.* The third harvest was July 23, 2010 and included organic and conventional plots (regrowth: 38 days). Grass species were prairie grass and ryegrass. Weed type was pigweed. Conventional alfalfa production did not differ ( $P=0.183$ ) from organic alfalfa production ( $692 \pm 84$  vs.  $848 \pm 84$  kg/ha, respectively). In addition, there was no difference ( $P=0.698$ ) between conventional and organic forage production ( $1439 \pm 83$  vs.  $1480 \pm 83$  kg/ha, respectively). Lastly, management did not affect the above-ground biomass ( $P=0.356$ ) or weed production ( $P=0.589$ ).

*Harvest 4.* The final harvest of organic and conventional plots for the establishment year was August 19, 2010 (regrowth: 22 days). Conventional alfalfa production was significantly greater ( $P<0.05$ ) than organic alfalfa production ( $544 \pm 42$  vs.  $393 \pm 42$  kg/ha, respectively). Unlike the production of alfalfa, there was no difference in forage production ( $P=0.266$ ) between organic and conventional management ( $756 \pm 76$  vs.  $861 \pm 76$  kg/ha, respectively). Management did not affect above-ground biomass ( $P=0.222$ ) or weed production ( $P=0.491$ ).

*Field 1 (planted 2009) Cumulative Harvests 2010 (establishment year).* Cumulative conventional alfalfa production of all four harvests was significantly greater ( $P<0.05$ ) than cumulative organic alfalfa production ( $4415 \pm 220$  vs.  $3545 \pm 220$  kg/ha, respectively). However, the cumulative conventional forage production was not different ( $P=0.206$ ) from the cumulative organic forage production ( $5695 \pm 208$  vs.  $5282 \pm 208$  kg/ha, respectively). Management did not affect above-ground biomass ( $P=0.254$ ) or weed production ( $P=0.749$ ).

## ***Prairie Grass Treatments***

*Varietal Performance.* There were no production differences between varieties of prairie grass at any time. There were no differences in cumulative ryegrass production between alfalfa interseeded with prairie grass (PG plots) and alfalfa not interseeded with prairie grass (NPG plots) at any harvest/non-destructive sample. The spring seeding of prairie grass was unsuccessful, thus only fall-planted prairie grass was used in comparisons of prairie grass treatment.

### *Conventional Prairie Grass Treatment*

#### *PG Treatment: Non-Destructive Interharvest Samples*

The effect of alfalfa interseeded with prairie grass in conventional alfalfa is summarized in Table 5. The botanical composition of each sample and harvest is shown in figure 1.

On January 18, 2010, grasses present were prairie grass and ryegrass. Weed species was henbit. Alfalfa production of NPG plots tended to be greater ( $P=0.67$ ) than alfalfa production in PG plots ( $483 \pm 68$  vs.  $379 \pm 60$  kg/ha, respectively). Forage production in PG plots was significantly greater ( $P<0.05$ ) than forage production in NPG plots ( $557 \pm 81$  vs.  $771 \pm 65$  kg/ha, respectively). Above-ground biomass in PG plots was significantly greater ( $P<0.05$ ) than in NPG plots ( $956 \pm 68$  vs.  $656 \pm 93$  kg/ha, respectively). There was no significant difference ( $P=0.368$ ) in weed production between NPG and PG plots ( $139 \pm 45$  vs.  $184 \pm 34$  kg/ha, respectively). Alfalfa in PG plots and NPG plots was the greatest portion of the botanical composition (76%, 82%), compared to forage (7%, 2%) and weed production (17%, 16%).

On March 16, 2010, grasses present were prairie grass and ryegrass. Weed specie was common chickweed. Alfalfa production in NPG plots was not significantly different ( $P=0.238$ ) from alfalfa production in PG plots ( $959 \pm 91$  vs.  $833 \pm 71$  kg/ha, respectively). In addition, forage production in NPG plots was not significantly different ( $P=0.128$ ) from PG plots ( $1033 \pm 112$  vs.  $1232 \pm 92$  kg/ha, respectively). Lastly, PG treatment did not significantly affect above-ground biomass ( $P=0.202$ ) or weed production ( $P=0.379$ ). For PG plots and NPG plots, weeds (48%, 46%) and alfalfa (36%, 48%) were the greatest portion of the botanical composition, compared to grass production (16%, 4%).

On June 1, 2010, grasses present were prairie grass and ryegrass. Weed specie was common chickweed. Alfalfa production in NPG plots was significantly greater ( $P<0.05$ ) than PG plots ( $907 \pm 76$  vs.  $669 \pm 59$  kg/ha, respectively). Forage production in NPG plots tended to be greater ( $P<0.10$ ) than PG plots ( $927 \pm 83$  vs.  $742 \pm 63$  kg/ha, respectively). There was no weed pressure in the June 1, 2010 sample. Alfalfa was the greatest portion of the botanical composition (94%, 98%), compared to grasses (6%, 2%).

*PG Treatment: Harvests 2010 (Conventional)*

The effect of alfalfa interseeded with prairie grass is summarized in Table 2. The changes in botanical composition are shown in figure 1.

*Harvest 1.* On May 5, 2010, the grasses present were prairie grass and ryegrass. The weed specie was common chickweed. There was no significant difference ( $P=0.205$ ) between alfalfa production in PG plots compared to NPG plots ( $1237 \pm 115$  vs.  $1429 \pm 141$  kg/ha, respectively). Forage production in PG plots was not different ( $P=0.132$ ) from NPG plots ( $1596 \pm 115$  vs.  $1429 \pm 131$  kg/ha, respectively). Similarly, above-ground biomass in PG

plots was not significantly different ( $P=0.126$ ) in NPG plots ( $1654 \pm 115$  vs.  $1517 \pm 126$  kg/ha, respectively). The only difference in the first harvest was in weed production, where PG plots produced significantly less ( $P<0.01$ ) weeds than NPG plots ( $88 \pm 14$  vs.  $58 \pm 11$  kg/ha, respectively). In PG and NPG plots, alfalfa was the greatest portion of the botanical composition (75%, 94%), compared to grass (22%, 0%) and weed production (3%, 6%).

*Harvest 2.* On June 15, grasses present were prairie grass and crabgrass. Weed type was pigweed. Alfalfa production in NPG plots was significantly greater ( $P<0.01$ ) than alfalfa production in PG plots ( $2336 \pm 217$  vs.  $1496 \pm 196$  kg/ha, respectively). Forage production in NPG plots was also greater ( $P<0.01$ ) than forage production in PG plots ( $2399 \pm 215$  vs.  $1766 \pm 197$  kg/ha, respectively). In addition, above-ground biomass in NPG plots was significantly greater ( $P<0.01$ ) than PG plots ( $2444 \pm 221$  vs.  $1786 \pm 202$  kg/ha, respectively). PG treatment did not affect weed production in the second harvest ( $P=0.609$ ). In PG and NPG plots, alfalfa production was the greatest portion of the botanical composition (84%, 96%), compared to grasses (15%, 2%) and weed production (1%, 2%).

*Harvest 3.* In the July harvest, crabgrass was the only grass specie and pigweed was primary weed. Alfalfa production in PG plots was not significantly different from alfalfa production NPG ( $P=0.136$ ). In addition, PG treatment did not affect forage production ( $P=0.841$ ), above-ground biomass ( $P=0.218$ ), or weed production ( $P=0.225$ ). For PG plots, alfalfa (40%) and grass (40%) made up a majority of the botanical composition. For NPG plots, crabgrass (50%) and weeds (30%) made up a majority of the botanical composition.

*Harvest 4.* In the August harvest, alfalfa production in NPG plots was significantly greater ( $P<0.001$ ) than PG alfalfa production ( $803 \pm 83$  vs.  $418 \pm 61$  kg/ha, respectively).

Interestingly, forage production in NPG plots was not significantly different ( $P=0.522$ ) than PG plots ( $815 \pm 128$  vs.  $720 \pm 111$  kg/ha, respectively). In NPG plots, above-ground biomass tended to greater ( $P=0.086$ ) than PG plots ( $943 \pm 115$  vs.  $1208 \pm 133$  kg/ha, respectively). Lastly, weed production in NPG was significantly greater ( $P<0.05$ ) than PG plots ( $97 \pm 223 \pm 89$  kg/ha, respectively). In PG and NPG plots, alfalfa production was the greatest portion of the botanical composition (44%, 66%), compared to crabgrass (32%, 1%) and weed production (24%, 33%).

*Field 1 (planted 2009) Cumulative Harvests 2010 (establishment year).* In the cumulative production, alfalfa production in NPG plots was significantly greater ( $P<0.05$ ) than alfalfa production in PG plots ( $5024 \pm 488$  vs.  $3893 \pm 344$  kg/ha, respectively). However, the cumulative forage production in NPG plots was not different ( $P=0.181$ ) from PG cumulative forage production ( $6170 \pm 476$  vs.  $5571 \pm 336$  kg/ha, respectively). Cumulative above-ground biomass was significantly greater ( $P<0.05$ ) in the NPG treatment, compared to the PG treatment ( $7329 \pm 472$  vs.  $6256 \pm 332$  kg/ha, respectively). Cumulative weed production in NPG plots tended to be greater ( $P=0.100$ ) than PG plots ( $1159 \pm 256$  vs.  $685 \pm 204$  kg/ha, respectively). In PG and NPG plots, alfalfa was the greatest portion of the botanical composition (62%, 69%) compared to grass (27%, 16%) and weed production (11%, 15%).

### *Organic Prairie Grass treatment*

#### *PG Treatment: Non-Destructive Interharvest Samples*

The effect of alfalfa interseeded with prairie grass in the non-destructive interharvest samples is summarized Table 6. The botanical composition of each sample and harvest is shown in Figure 2.

On January 18, 2010, grasses were prairie grass and ryegrass. Weed specie was henbit. Alfalfa production in PG plots did not significantly differ ( $P=0.952$ ) from alfalfa production in NPG plots ( $370 \pm 60$  vs.  $366 \pm 68$ kg/ha, respectively). However, forage production in PG plots was significantly greater ( $P<0.01$ ) than NPG plots ( $725 \pm 65$  vs.  $475 \pm 82$ kg/ha, respectively). Above-ground biomass in PG plots tended to be greater ( $P=0.074$ ) than NPG plots ( $905 \pm 68$  vs.  $699 \pm 93$ kg/ha, respectively). PG treatment did not affect weed production ( $P=0.376$ ). In PG and NPG plots, alfalfa was the greatest portion of the botanical composition (41%, 52%) compared to grasses (39%, 16%) and weeds (20%, 32%).

On March 16, 2010, grasses present were prairie grass and ryegrass. The weed specie was common chickweed. Prairie grass treatment did not affect alfalfa production ( $P=0.602$ ). Forage production in PG plots was greater than forage production in NPG plots ( $857 \pm 92$  vs.  $552 \pm 112$  kg/ha, respectively). In addition, above-ground biomass ( $P<0.05$ ) and weed production in PG plots ( $P<0.05$ ) were significantly greater than NPG treatment. In PG and NPG plots, Alfalfa (31%, 45%) and weed production (46%, 45%) were the majority of the botanical composition grass (23%, 10%).

On June 1, 2010, the grasses present were prairie grass and ryegrass. The weed specie was common chickweed. Prairie grass treatment did not affect alfalfa production ( $P=0.952$ )

in PG and NPG plots ( $511 \pm 59$  vs.  $559 \pm 76$  kg/ha, respectively). However, the forage production in PG plots was significantly greater ( $P < 0.01$ ) than forage production in NPG plots ( $830 \pm 63$  vs.  $594 \pm 83$  kg/ha, respectively). There was no weed pressure in the June 1, 2010 sample. In PG and NPG plots, alfalfa was the greatest portion of the botanical composition (62%, 94%), compared to grasses and weeds (38%, 6%).

*PG Treatment: Harvest 2010 (Organic)*

The effect of interseeding prairie grass in organic alfalfa is summarized in Table 3. Botanical composition of each harvest is shown in Figure 2.

*Harvest 1.* In the first harvest of April 8, 2010, grasses present were prairie grass and ryegrass. The weed species was common chickweed. There was no difference ( $P = 0.973$ ) between alfalfa production of NPG plots and PG plots ( $575 \pm 141$  vs.  $571 \pm 115$  kg/ha, respectively). There was also no significant difference between the NPG and PG forage production ( $P = 0.661$ ) and above-ground biomass ( $P = 0.950$ ). However, NPG weed production was greater ( $P < 0.01$ ) than PG weed production ( $51 \pm 14$  vs.  $10 \pm 2$  kg/ha, respectively). In PG and NPG plots, alfalfa was the greatest portion of the botanical composition (61%, 61%) compared to grass (38%, 33%) and weed production (1%, 5%).

*Harvest 2.* For the June harvest, the grasses present were prairie grass and crabgrass. Weed species was pigweed. Alfalfa production in NPG plots was significantly greater ( $P = 0.01$ ) than PG plots ( $2107 \pm 216$  vs.  $1486 \pm 197$  kg/ha, respectively). In addition forage production in NPG plots tended to be greater ( $P < 0.10$ ) than PG plots ( $2316 \pm 215$  vs.  $1959 \pm 198$  kg/ha, respectively). However, prairie grass treatment did not affect biomass ( $P = 0.064$ ) or weed production ( $P = 0.689$ ). For PG and NPG plots, alfalfa was the majority of the

botanical composition (74%, 90%), compared to grass (24%, 9%) or weed production (1%, 1%).

*Harvest 3.* On July 23, 2010, the grass species was crabgrass and the weed species was pigweed. Alfalfa production of NPG plots was not significantly different ( $P=0.427$ ) than PG plots ( $702 \pm 153$  vs.  $852 \pm 108$  kg/ha, respectively). In addition, prairie grass treatment did not change ( $P=0.704$ ) forage production. However, above-ground biomass in NPG plots tended to be greater ( $P<0.10$ ) than PG plots ( $2267 \pm 187$  vs.  $1820 \pm 132$  kg/ha, respectively). NPG weed production also tended to be greater ( $P=0.071$ ). In PG and NPG plots, botanical composition was split between alfalfa (47%, 31%), weed (19%, 32%), and crabgrass (34%, 37%).

*Harvest 4.* For the August harvest, the grass and weed species were crabgrass and common chickweed, respectively. Alfalfa production in NPG plots was significantly greater ( $P<0.01$ ) than PG plots ( $674 \pm 83$  vs.  $329 \pm 62$  kg/ha, respectively). Forage production in NPG plots was significantly greater ( $P<0.01$ ) than PG plots ( $1260 \pm 128$  vs.  $797 \pm 112$  kg/ha, respectively). In addition, above-ground biomass production of NPG plots was significantly greater ( $P<0.001$ ) than PG plots ( $1661 \pm 133$  vs.  $1019 \pm 116$  kg/ha, respectively). Prairie grass treatment did not affect weed production ( $P=0.069$ ). In PG and NPG plots, botanical composition was split between alfalfa (32%, 41%), weed (22%, 24%), and crabgrass (46%, 35%).

*Field 1 (planted 2009) Cumulative Harvests 2010 (establishment year).* In terms of 2010 cumulative organic production, alfalfa production in NPG plots tended to be greater ( $P=0.089$ ) than PG plots ( $4260 \pm 488$  vs.  $3238 \pm 344$  kg/ha). Conversely, forage production

in NPG plots tended to be greater ( $P=0.062$ ) than forage production in PG plots ( $6012 \pm 476$  vs.  $5164 \pm 340$  kg/ha). Above-ground biomass in NPG plots was significantly greater ( $P<0.01$ ) than PG plots ( $7209 \pm 472$  vs.  $5788 \pm 332$  kg/ha), but NPG weed production was also greater ( $P=0.085$ ).

Table 16 reports the botanical composition production values of the cumulative production of the establishment year. For conventional alfalfa in PG plots 62% was alfalfa, 4% was prairie grass, 4% was ryegrass, 19% was crabgrass, and 11% was weed production. For conventional alfalfa in NPG plots total biomass was 69% was alfalfa, 0% was prairie grass or ryegrass, 16% was crabgrass, and 15% was weed production.

#### *Management and Prairie Grass Treatment Interaction*

Figure 3 shows that there was no interaction between prairie grass treatment and management. The greatest ( $P<0.10$ ) cumulative alfalfa production was achieved under conventional and organic NPG plots ( $5024 \pm 488$  and  $4058 \pm 488$  kg/ha, respectively). There was less alfalfa production in PG plots under conventional and organic management ( $3893 \pm 344$  and  $3238 \pm 344$  kg/ha, respectively). Figure 4 shows that there was greater ( $P<0.05$ ) cumulative prairie grass production under conventional compared to organic management ( $249 \pm 68$  vs.  $451 \pm 68$  kg/ha). Figure 5 shows that there was no difference in ryegrass production among conventional PG plots, organic PG plots, and organic NPG plots ( $236 \pm 64$ ,  $245 \pm 64$ , and  $309 \pm 92$  kg/ha, respectively). Conventional NPG plots had no ryegrass production from herbicide control. Figure 6 shows the values for cumulative crabgrass production and they did not change under either management or either prairie grass treatment. Interestingly, Figure 7 shows that weed production was lower ( $P<0.10$ ) in

conventional and organic PG plots ( $670 \pm 204$  and  $622 \pm 204$ kg/ha) compared to conventional and organic NPG plots ( $1155 \pm 256$  and  $1199 \pm 256$ , respectively).

In terms of total forage production, Figure 8 shows that interseeding prairie grass has slightly different effects under conventional and organic management. In conventional management, interseeding a prairie grass did not affect forage production. However, organic NPG plots produced greater forage production ( $P < 0.10$ ). Figure 9 shows that there was no interaction between prairie grass treatment and management. Both conventional and organic NPG plots produced more biomass ( $P < 0.10$ ) than conventional and organic PG plots.

#### ***Small Plots Field 1 (Planted 2009): Harvests 2011***

*Alfalfa Weevil.* In spring 2010, Field 1 had no difference in the number of weevils (larvae/stem) between organic and conventional management. Economic threshold (three larvae/stem) was reached by April 6, 2010. In 2011, Field 1 had no difference in the number of weevils (larvae/stem) between organic and conventional management. Economic threshold was reached by March 29, 2011.

#### ***Management***

Table 7 summarizes the conventional and organic production values.

*Harvest 1.* Organic plots were harvested early on March 25, 2011 after plots reached economic threshold of three weevils per stem. May 10, 2011 was the first conventional harvest and the second organic harvest. On March 25, 2011, organic plots were harvested and conventional plots were treated with pesticide (Lorsban®) application. Conventional alfalfa

production was significantly greater ( $P < 0.01$ ) than organic alfalfa production ( $842 \pm 62$  vs.  $569 \pm 62$  kg/ha, respectively). Conventional forage production was significantly greater ( $P < 0.01$ ) than organic forage production ( $876 \pm 69$  vs.  $590 \pm 69$  kg/ha, respectively). Conventional above-ground biomass was significantly greater ( $P < 0.01$ ) than ( $1057 \pm 76$  vs.  $711 \pm 76$ , respectively). Conventional weed production was tended to be greater ( $P = 0.067$ ) than organic weed production ( $181 \pm 27$  vs.  $121 \pm 27$  kg/ha, respectively).

*Harvest 2.* On May 10, 2011 (the first conventional harvest, and the second organic harvest) there was no significant difference ( $P = 0.679$ ) between conventional and organic alfalfa production ( $2033 \pm 155$  vs.  $1964 \pm 155$  kg/ha, respectively). In addition, there was no significant difference between conventional and organic forage production ( $2487 \pm 131$  vs.  $2525 \pm 131$  kg/ha, respectively). Conventional above-ground biomass was not significantly different ( $P = 0.484$ ) from organic ( $2598 \pm 116$  vs.  $2720 \pm 116$  kg/ha, respectively). Conventional weed production was not significantly different ( $P = 0.342$ ) from organic weed production ( $112 \pm 56$  vs.  $193 \pm 56$  kg/ha, respectively).

*Cumulative Production of Harvests at Beginning of 2011.* There was no significant difference between the measures under conventional (one harvest) and organic (two harvests) management. Conventional alfalfa production was not significantly different ( $P = 0.212$ ) from organic alfalfa production ( $1447 \pm 95$  vs.  $2526 \pm 190$ , respectively). Conventional forage production was not significantly different ( $P = 0.424$ ) from organic forage production ( $1694 \pm 119$  vs.  $3102 \pm 238$  kg/ha, respectively). Lastly, management did not significantly affect above-ground biomass or weed production ( $P = 0.457$  and  $P = 0.342$ , respectively).

### ***PG treatment***

#### *PG Treatment: Harvests 2011(Conventional)*

The effect of interseeding prairie grass in conventional alfalfa is summarized in Table 8.

*March Sample.* On March 25, 2011 (sample of production, but no harvest) PG alfalfa production was not significantly different ( $P=0.854$ ) from NPG alfalfa production ( $832 \pm 80$  vs.  $851 \pm 97$  kg/ha, respectively). PG forage production was not significantly different ( $P=0.711$ ) from NPG forage production ( $910 \pm 86$  vs.  $870 \pm 104$  kg/ha, respectively). PG treatment also did not significantly change above-ground biomass or weed production ( $P=0.650$  and  $P=0.716$ , respectively). In PG and NPG plots, alfalfa production was the greatest portion of the botanical composition (78%, 82%). Weed production (16%, 16%) and grasses (6%, 2%) were secondary.

*Harvest 2.* On May 10, 2011 (the first conventional harvest) PG alfalfa production was not significantly different ( $P=0.614$ ) from NPG alfalfa production ( $2044 \pm 227$  vs.  $1912 \pm 272$  kg/ha, respectively). PG forage production was not significantly different ( $P=0.127$ ) from NPG forage production ( $2797 \pm 243$  vs.  $2332 \pm 293$  kg/ha, respectively). PG above-ground biomass was not significantly different ( $P=0.121$ ) from NPG above-ground biomass ( $2902 \pm 216$  vs.  $2450 \pm 263$  kg/ha, respectively). PG weed production was not significantly different ( $P=0.758$ ) from NPG weed production ( $105 \pm 47$  vs.  $118 \pm 53$  kg/ha, respectively).

#### *PG Treatment: Harvest 2011 (Organic)*

The effect of interseeding prairie grass in organic alfalfa production is summarized in Table 9.

*Harvest 1.* On March 25, 2011 PG alfalfa production was not significantly greater ( $P=0.495$ ) than NPG alfalfa production ( $548 \pm 79$  vs.  $634 \pm 97$  kg/ha, respectively). PG forage production was not significantly different ( $P=0.845$ ) from NPG forage production ( $583 \pm 85$  vs.  $653 \pm 104$  kg/ha, respectively). PG above-ground biomass was not significantly different ( $P=0.739$ ) from NPG above-ground biomass ( $746 \pm 90$  vs.  $736 \pm 105$  kg/ha, respectively). PG weed production was not significantly different from NPG weed production ( $164 \pm 39$  vs.  $83 \pm 45$  kg/ha, respectively).

*Harvest 2.* On May 10, 2011 (the second organic harvest) there was no significant difference ( $P=0.774$ ) between PG alfalfa production and NPG alfalfa production ( $2053 \pm 234$  vs.  $2078 \pm 272$  kg/ha, respectively). However, under organic management, PG forage production was significantly greater ( $P<0.05$ ) than NPG forage production ( $3049 \pm 239$  vs.  $2474 \pm 281$  kg/ha, respectively). PG above-ground biomass was significantly greater ( $P<0.05$ ) than NPG above-ground biomass ( $3152 \pm 223$  vs.  $2668 \pm 263$  kg/ha, respectively). Interestingly NPG weed production was significantly greater ( $P=0.107$ ) than PG weed production ( $108 \pm 48$  vs.  $194 \pm 53$  kg/ha, respectively).

*Cumulative Organic Harvests 2011.* In terms of cumulative organic production of the two harvests of spring 2011, there was no significant difference ( $P=0.762$ ) between cumulative PG alfalfa production and NPG alfalfa production ( $2601 \pm 234$  vs.  $2712 \pm 278$  kg/ha, respectively). Cumulative PG forage production tended to be greater ( $P=0.101$ ) than cumulative NPG forage production ( $3632 \pm 245$  vs.  $3127 \pm 246$  kg/ha, respectively). PG above-ground biomass production tended to be greater ( $P=0.094$ ) than NPG above-ground biomass ( $3898 \pm 235$  vs.  $3404 \pm 281$  kg/ha, respectively). There was no significant difference

( $P=0.993$ ) between cumulative PG weed production and NPG weed production ( $272 \pm 58$  vs.  $277 \pm 74$  kg/ha, respectively).

### ***Small Plots Field 2 (Planted 2010): Harvest 2011***

Weevil checks from February through May determined that Field 2 never reached the economic threshold.

### ***Management***

Table 10 summarizes the harvest of field 2 on May 11, 2011. Conventional alfalfa production was not significantly different ( $P=0.837$ ) from organic alfalfa production ( $2534 \pm 192$  vs.  $2476 \pm 192$  kg/ha, respectively). Conventional forage production was not significantly different ( $P=0.993$ ) from organic forage production ( $3104 \pm 215$  vs.  $3107 \pm 215$  kg/ha, respectively).

### ***PG treatment***

#### *PG Treatment: Harvests 2011 (Conventional)*

The effect of interseeding prairie grass in conventional alfalfa is summarized in Table 11. NPG alfalfa production was significantly greater ( $P<0.01$ ) than PG alfalfa production ( $3038 \pm 280$  vs.  $2099 \pm 215$  kg/ha, respectively). However, there was no significant difference ( $P=0.282$ ) between NPG forage production and PG forage production ( $3428 \pm 303$  vs.  $3019 \pm 215$  kg/ha, respectively). There was no weed production in this harvest.

#### *PG treatment: Harvests 2011 (Organic)*

The effect in interseeding prairie grass in organic alfalfa is summarized in Table 12. There was no difference ( $P=0.359$ ) between NPG production of alfalfa and PG production of

alfalfa ( $2635 \pm 280$  vs.  $2345 \pm 216$  kg/ha, respectively). There was also no significant difference between NPG forage production and PG forage production ( $2984 \pm 303$  vs.  $3069 \pm 215$  kg/ha, respectively).

## **Discussion**

Organic and conventional alfalfa had a total a four cuttings in the first season, which is in the normal range according to current research (Ball, 2007).

### *Field 1 (planted 2009) harvests 2010*

*Conventional Alfalfa Production.* Prairie grass may play more of a role in suppressing weeds than boosting forage production under conventional management since cumulative PG forage production was not significantly greater than cumulative NPG forage production.

Previous research has reported that interseeding a grass suppresses weed production (Prather, 2000). However, research has mixed results for the interseeding of grass in boosting forage production, with bromegrass increasing yield (McCloud, 1953) or not changing yield (Wilsie, 1949), depending on the location and yearly precipitation. It is important to note conventional PG plots also contained annual ryegrass which could have also contributed to the cool season suppression of alfalfa and weed production.

PG plots had weed production that was different in May, which was the only harvest when prairie grass was part of the botanical composition. Thus, when prairie grass was present, it suppressed weed production. However, at the May harvest, the weed type was common chickweed (*Stellaria media*) which is considered a forage by some agronomists (Lawrence, 1989). So this weed suppression is not usually as much of a concern compared to other weed species.

Conventional NPG was treated with an herbicide for ryegrass control, however the exclusion of this voluntary grass did not increase alfalfa production in the first harvest.

In the month of June, a biomass sample was taken June 1 and then another at harvest on June 15. The second harvest had the greatest production at harvest, which agrees with previous research by McCloud (1953). Both of the June samples had the least amount of weed pressure compared to the rest of the season. The lack of weed pressure was due to the transition between cool season chickweed and summer pigweeds (*spiny amaranth*) and not because of conventional control of herbicides. Interestingly, prairie grass was still present as the voluntary grass species switched from ryegrass to crabgrass. This implies that prairie grass may play a role in the grass forage production between the ryegrass and crabgrass seasonal production, as suggested by other forage agronomists (Jung et al., 1994; LaCasha et al., 1999).

PG forage production was significantly less at the June 15 harvest. However, 15 days earlier at the June 1 sample, there was no significant difference between forage production of PG and NPG. In the June 1 sample, the grasses compensated for lost alfalfa production in the PG. However, by June 15, the grasses were unable to compensate for lost alfalfa production. The failure of grass production in the PG could have been caused by two factors. One, it was the end of the cool season grasses and just the beginning of the warm season grass growth. Although prairie grass was still present, its production was declining as air temperatures increased and crabgrass was at its beginning stages of production.

Kalton (1952) had reported that bromegrass production was greatest in the first harvest and declined thereafter. The second factor that could have caused suppressed grass

production was that alfalfa may have been more successful in dealing with moisture stress. From June 1 through June 15, there was only 1.0cm of rainfall. Since alfalfa production in NPG was significantly greater on June 1, it could have led to its continued superior performance through June 15. Alfalfa has been proven to handle drought stress better than grasses, and this may have given it the necessary advantage. The deeper tap root of alfalfa can penetrate deeper, competing effectively for water (Chamblee, 1958). Similar results were observed in the coastal plain of eastern Texas where alfalfa has shown drought tolerance in animal production systems (Haby et al., 1999).

At the July harvest, the weed botanical composition for both PG and NPG was at its greatest, indicating that this time of year is when alfalfa production could be most challenging. Previous studies have found that erect growing spiny pigweed suppressed alfalfa production (Rhodes). Crabgrass production was also the greatest in July for PG and NPG. Thus, alfalfa production was competing not only with weed pressure, but also with this warm season grass. Previous research in Arizona also found alfalfa production to be least in July (Cassida et al., 2006).

Elevated air temperature caused early flowering in alfalfa. These results are similar to previous studies looking at premature flowering of alfalfa at high air temperature in a controlled greenhouse (Greenfield and Smith, 1973). At the August harvest, the PG weed production was significantly less than NPG weed production, although prairie grass was not a part of the botanical composition. Crabgrass was present in July and August harvests, but crabgrass is not as valued in a hay system with alfalfa because different growth habits (Morrow, 1991). PG alfalfa production was significantly less, but

crabgrass seemed to fill in open sites, which made the forage production not significantly different between PG treatments. The presence of crabgrass, although not intentionally planted, suppressed both weed and alfalfa production, similar to the cool season grasses of the May harvest.

The dynamic nature of alfalfa mixtures was prevalent in the samples taken January 18 and March 16. At the beginning growth, alfalfa production was significantly less in the PG compared to NPG. This trend mostly continued for the rest of the season, eluding that prairie grass (and voluntary ryegrass) caused an initial suppression of alfalfa production at establishment.

In conclusion, although the biomass for NPG was significantly greater than the biomass for PG, the weed production also tended to be greater for NPG. So prairie grass was more effective in suppressing weed production, but it also suppressed the production of alfalfa.

*Organic alfalfa production.* In the organic alfalfa production, the cumulative production of alfalfa tended to be greater in NPG. Since all voluntary grasses (annual ryegrass and crabgrass) were included in both PG and NPG, it was the interseeded prairie grass had a suppressive effect on alfalfa production, rather adding to the forage production. Research in Ohio reported that annual ryegrass did not have a suppressive effect on the establishment of alfalfa (Sulc and Albrecht, 1996). NPG cumulative forage production also tended to be greater, but this was because NPG alfalfa production tended to be greater. Prairie grass did not affect the production of ryegrass, which supports the notion that prairie grass is not as competitive at this voluntary cool season grass. Interestingly, the prairie grass

treatment did tend to suppress weed production under organic management. Thus, similar to the conventional production, interseeding prairie grass suppressed weed production, along with alfalfa production.

Before the first harvest April, the January and March biomass samples indicated that the chickweed pressure was at its highest during the being of the growth season. By April, common chickweed production was minimal for both PG and NPG. Like the conventional plots, chickweed is a prostrate growing winter annual by some agronomists and is not a critical concern in forage production. In addition, the low lying growth habit of chickweed does not make it as competitive as some of the weed species that grow upright.

Unlike the effect of prairie grass under conventional management, PG under organic management was significantly greater than NPG in all three biomass samples of January, March, and June 1. For these checkpoints, prairie grass was having an additive effect in forage production. However, by the harvest dates of April and June 15, prairie grass was ineffective in supplementing forage production.

At the June 1 sample, there was no significant difference in the alfalfa production between PG and NPG, however alfalfa production was significantly less in PG by June 15. Thus, prairie grass maintained a part of the botanical composition through the end of ryegrass production and the beginning crabgrass growth, but it may have been the cause of the suppressed alfalfa growth. PG treatment had a similar effect under conventional management.

PG weed production tended to be less in July, but the forage production was not significantly different between the two treatments. It is speculated that the presence of prairie

grass during the beginning growth stages of pigweed could have suppressed its establishment at that point in the season. Although not significantly different, conventional NPG weed production was numerically greater than PG weed production.

In conclusion, interseeding prairie grass significantly decreased the cumulative year-end conventional alfalfa production and tended to suppress the organic alfalfa production. The conventional control of cool season grasses allowed for an increased production of alfalfa. Organic NPG alfalfa production was not significantly greater than conventional PG alfalfa production. Thus, voluntary grasses that were present in NPG alfalfa suppressed alfalfa production, and then interseeding a prairie grass further reduced the production for organic production. Thus, if a producer's goal is to produce pure hay, herbicide use will give him a significant advantage. Organic prairie grass production also tended to be greater than conventional prairie grass production from possible traffic damage or the defoliation management. Previous research has reported that defoliation frequency is more important than residual height (Bell, 1989). Voluntary ryegrass and crabgrass were not different among the two conventional and organic treatments, meaning that the interseeding of prairie grass had no effect on the growth of grasses present in the seedbed.

*Field 1 (planted 2009) harvests 2011*

*Organic and Conventional alfalfa.* In the second year of production, organic plots were cut early again to avoid damage by the alfalfa weevil. Thus, on the May harvest organic had been cut twice and this was the first conventional harvest. Cumulatively, there was more organic alfalfa production because of the two defoliations. Thus, it may be more beneficial for producers to cut forage instead of spraying insecticide because organic alfalfa regrowth

was greater than conventional growth after spraying. Prairie grass did not have a suppressive effect on alfalfa production in either organic or conventional. This was different from the first organic harvest and first conventional harvest of 2010, in which interseeded prairie grass had a suppressive effect on alfalfa production. Prairie grass production was greater in May 2011 than the cumulative prairie grass production of 2010, so prairie grass was not failing to grow. Prairie grass may have not suppressed alfalfa production because alfalfa was well established with a deep root system unlike the short-lived perennials. Prairie grass production tended to be greater in organic PG, which follows the trend of 2010 prairie grass production. Jung et al. (1994) also reported that prairie grass was a biennial, completing their growing season in two years. Interestingly, organic PG had tended to have the greatest forage production compared to any other treatment. This was a similar trend in early 2010, and this was due mostly to the fact that prairie grass was in its peak growing season and that organic alfalfa mixtures maintained a greater production of prairie grass. It could be possible that prairie grass would have a suppressive effect on alfalfa production later in the season, as indicated in 2010.

Field 2, planted fall 2010, was much different in its botanical composition and insect pressure. Field 2 did not reach 3 weevil per stem threshold, and thus the first harvest was not until alfalfa was at 1/10<sup>th</sup> bloom. In terms of forage production, there was no significant difference between organic and conventional management, which was the same trend found in the first organic and conventional harvest of 2010 and 2011 in field 1. Conventional plots, on this site were sprayed with Eptam® herbicide to control broadleaf weeds and enabled the greater production of alfalfa during early establishment. Unlike previous research, herbicide

in these plots no suppressive effect on the production of alfalfa in the first harvest (Beardmore and Linscott, 1988). Interestingly, although conventional production was more, the plant counts were less which means that leaf and stem development of organic production must have been compensating in production.

In terms of the varieties, there was no significant difference in the plant counts of Arriba alfalfa and Haygrazer alfalfa during the first or second year of Field 1 and the first harvest of Field 2. However Arriba alfalfa produced significantly more alfalfa in the Field January 2010 sample, but by June 1, haygrazer alfalfa production was significantly more. The difference in production, but not in plant numbers, is because Arriba alfalfa seemed to be damaged by leaf shatter during moisture stress more than Haygrazer. At the onset of drought weather, visual differences were also apparent between the two varieties. This difference may play more of a role in the persistence of alfalfa, as Arriba alfalfa plant counts might decrease at a faster rate than Haygrazer in the future.

## CONCLUSION

In conclusion, interseeding prairie grass seems to have a suppressive effect on alfalfa production, while also suppressing weed production. And prairie grass should not be interseeded with hopes to boost forage production. In 2011 of field 2, it showed that prairie grass persisted into the second year. In Field 2 (planted fall 2010) Prairie grass numerically reduced alfalfa production and prairie grass did not boost overall production. In terms of growing a pure stand of alfalfa, conventional management will give higher production. However, if voluntary forages are not excluded from the system, there was no difference between managements. Forage production greatly depends on the varieties of voluntary

grasses that are in the seedbed and results will vary across sites. Alfalfa is a perennial crop and its longevity and persistence will change the botanical compositions of the sward from one year to the next. For this reason, it would be beneficial to monitor the production of alfalfa for additional years to evaluate its role in organic and conventional systems.

## REFERENCES

- Ball, D.M., Hoveland, C.S., Lacefield, G.D. 2007. Southern Forages. 4th Edition ed. International Plant Nutrition Institute, Norcross, GA.
- Beardmore, R.A., and D.L. Linscott. 1988. Postemergence Herbicide Suppression of Wheat, *Triticum aestivum*, Growing with Alfalfa, *Medicago sativa*. *Weed Science* 36:636-641.
- Bell, C.C., Ritchie, I.M. 1989. The effect of frequency and height of defoliation on the production and persistence of 'Grassland Matua' prairie grass. *Grass Forage Science* 44:245-248.
- Cassida, K.A., C.B. Stewart, V.A. Haby, and S.A. Gunter. 2006. Alfalfa as an alternative to bermudagrass for pastured stocker cattle systems in the southern USA. *Agron. J.* 98:705-713.
- Chamblee, D.S. 1958. The relative removal of soil moisture by alfalfa and orchardgrass. *Agron. J.* 50:587-589.
- Greenfield, P.L., and D. Smith. 1973. Influence of temperature change at bud on composition of alfalfa at first flower. *Agron. J.* 65:871-874.

- Haby, V.A., J.V. Davis, and A.T. Leonard. 1999. Response of overseeded alfalfa and bermudagrass to alfalfa row spacing and nitrogen rate. *Agron. J.* 91:902-910.
- Jung, G.A., J.A. Shaffer, and J.R. Everhart. 1994. Fall management effects on 'grasslands matua' prairie grass production and sward characteristics. *Agron. J.* 86:1032-1039.
- Kalton, R.R., Wilsie, C.P. 1952. Effect of brome-grass variety on yield and composition of a brome-alfalfa mixture. *Agron J.* 45:308-311.
- LaCasha, P.A., H.A. Brady, V.G. Allen, C.R. Richardson, and K.R. Pond. 1999. Voluntary intake, digestibility, and subsequent selection of matua brome-grass, coastal bermudagrass, and alfalfa hays by yearling horses. *J. Anim Sci.* 77:2766-2773.
- (ed.) 1989. Eleventh North American Prairie Conference.
- McCloud, D.E., and G.O. Mott. 1953. Influence of association upon the forage yield of legume-grass mixtures. *Agron. J.* 45:61-65.
- (ed.) 1991. Amer. Forage and Grassl. Coun., Columbia, MO. April 4-9.
- Prather, T.S.L., W.T.; Vargas, R.; Orloff, S.; Canevari, W.M.; Mueller S. 2000. Interplanting grasses into alfalfa controls weeds in older stands. University of California, California Agriculture 54:37-41.
- Rhodes, N.G., Breeden, G. K., Bates, G., McElroy. Hay Crop and Pasture Weed Management. University of Tennessee Extension:1-23.
- Sulc, R.M., and K.A. Albrecht. 1996. Alfalfa establishment with diverse annual ryegrass cultivars. *Agron. J.* 88:442-447.
- Wilsie, C.P. 1949. Evaluation of grass-legume associations with emphasis on the yields of brome-grass varieties. *Agronomy Journal* 41:412-420.

**Table 1.** Field 1 (planted 2009) Harvests 2010—The effect of **management** (organic vs. conventional) and **treatment** (PG: interseeded prairie grass vs. NPG: no interseeded prairie grass) on alfalfa, prairie grass, ryegrass, crabgrass weed production in four harvests of the establishment year. Values reported are LS means. Values with different letters are significantly different (P<0.10).

Production (kg/ha)	Management	Treatment	Apr/May <sup>1</sup>	June <sup>2</sup>	July <sup>3</sup>	Aug <sup>4</sup>	Cumulative	SE
Alfalfa	Organic	PG	571 <sup>a</sup>	1486 <sup>a</sup>	852 <sup>a</sup>	329 <sup>a</sup>	3238 <sup>a</sup>	344
		NPG	575 <sup>a</sup>	2107 <sup>b</sup>	702 <sup>ab</sup>	674 <sup>b</sup>	4260 <sup>b</sup>	488
	Conventional	PG	1237 <sup>b</sup>	1496 <sup>a</sup>	741 <sup>ab</sup>	418 <sup>a</sup>	3893 <sup>b</sup>	344
		NPG	1429 <sup>b</sup>	2336 <sup>b</sup>	456 <sup>b</sup>	803 <sup>b</sup>	5024 <sup>c</sup>	488
Prairie grass	Organic	PG	114 <sup>a</sup>	337 <sup>a</sup>	0	0	451 <sup>a</sup>	68
		NPG	0 <sup>b</sup>	0	0	0	0	0
	Conventional	PG	123 <sup>a</sup>	126 <sup>b</sup>	0	0	249 <sup>a</sup>	68
		NPG	0 <sup>b</sup>	0	0	0	0	0
Ryegrass	Organic	PG	245 <sup>a</sup>	0	0	0	245 <sup>a</sup>	64
		NPG	309 <sup>a</sup>	0	0	0	309 <sup>a</sup>	92
	Conventional	PG	236 <sup>a</sup>	0	0	0	236 <sup>a</sup>	64
		NPG	0 <sup>b</sup>	0	0	0	0	0
Crabgrass	Organic	PG	0	136 <sup>a</sup>	626 <sup>a</sup>	468 <sup>a</sup>	1230 <sup>a</sup>	272
		NPG	0	209 <sup>a</sup>	850 <sup>a</sup>	586 <sup>a</sup>	1645 <sup>a</sup>	384
	Conventional	PG	0	144 <sup>a</sup>	748 <sup>a</sup>	301 <sup>a</sup>	1193 <sup>a</sup>	272
		NPG	0	63 <sup>a</sup>	1072 <sup>b</sup>	11 <sup>b</sup>	1146 <sup>a</sup>	384
Weeds	Organic	PG	10 <sup>a</sup>	50 <sup>a</sup>	340 <sup>a</sup>	222 <sup>a</sup>	622 <sup>a</sup>	204
		NPG	51 <sup>b</sup>	30 <sup>a</sup>	716 <sup>b</sup>	402 <sup>b</sup>	1199 <sup>b</sup>	256
	Conventional	PG	58 <sup>b</sup>	20 <sup>a</sup>	384 <sup>a</sup>	223 <sup>ab</sup>	685 <sup>a</sup>	204
		NPG	88 <sup>c</sup>	45 <sup>a</sup>	632 <sup>a</sup>	394 <sup>b</sup>	1159 <sup>b</sup>	256

<sup>1</sup>April 8, 2010 organic harvest only for alfalfa weevil control; conventional plots treated with Lorsban® application, grass types were prairie grass and ryegrass; weed type primarily chickweed.

May 5, 2010 conventional only harvest; grass types were prairie grass and ryegrass; weed type primarily chickweed.

<sup>2</sup>June 15, 2010 conventional and organic harvest; grass types were prairie grass and crabgrass; weed type primarily pigweed.

<sup>3</sup>July 23, 2010 conventional and organic harvest; grass type was crabgrass; weed type primarily pigweed.

<sup>4</sup>August 19, 2010 conventional and organic harvest; grass type was crabgrass; weed type primarily pigweed.

**Table 2.** Field 1 (planted 2009) Harvests 2011—The effect of management (organic vs. conventional) on the alfalfa, forage, biomass, and weed production at two harvests for organic management and one harvest for conventional in the second season. Organic alfalfa was harvested in March for weevil control. Forage production included alfalfa, prairie grass, and ryegrass production. Biomass included alfalfa, prairie grass, ryegrass, and weed production. Values reported are LS means and SEM.

Production (kg/ha)	Treatment	Harvest 2011		Cumulative spring 2011
		Mar <sup>1</sup>	May <sup>2</sup>	(kg/ha)
Alfalfa	Organic	569	1964	2533 ± 190
	Conventional	842	2033	2033 ± 155
	SEM	62	155	--
	<i>P</i> -value	0.003	0.679	0.023
Forage	Organic	590	2525	3115 ± 238
	Conventional	876	2487	2487 ± 131
	SEM	69	131	--
	<i>P</i> -value	0.005	0.843	0.018
Biomass	Organic	711	2720	3431 ± 238
	Conventional	1057	2598	2598 ± 116
	SEM	76	116	--
	<i>P</i> -value	0.002	0.484	0.002
Weed	Organic	121	193	314 ± 54
	Conventional	181	112	112 ± 56
	SEM	27	56	--
	<i>P</i> -value	0.067	0.342	0.028

<sup>1</sup> March 25, 2011 organic harvest only, conventional treated with Lorsban®;  
grass types were ryegrass and prairie grass; weed type was principally chickweed

<sup>2</sup> May 10, 2011 organic and conventional harvest;  
grass types were ryegrass and prairie grass; weed type was principally chickweed

**Table 3.** Field 1 (planted 2009) Harvests 2011—The effect of **conventional** alfalfa interseeded prairie grass (PG) or not interseeded with prairie grass (NPG) on alfalfa, forage, biomass, and weed production of March sample and May harvest of the second season. Forage production included alfalfa, prairie grass, and ryegrass production. Biomass included alfalfa, prairie grass, ryegrass, and weed production. Values reported are LS means and SEM.

Conventional Production (kg/ha)	Treatment <sup>1</sup>	2011		Cumulative spring 2011
		Mar <sup>2</sup>	May <sup>3</sup>	(kg/ha)
Alfalfa	PG	832 ± 80	2044 ± 227	2044 ± 227
	NPG	851 ± 97	1912 ± 272	1912 ± 272
	<i>P</i> -value	0.854	0.614	0.614
Forage	PG	910 ± 86	2797 ± 243	2797 ± 243
	NPG	870 ± 104	2332 ± 293	2332 ± 293
	<i>P</i> -value	0.711	0.127	0.127
Biomass	PG	1086 ± 90	2902 ± 216	2902 ± 216
	NPG	1033 ± 105	2450 ± 263	2450 ± 263
	<i>P</i> -value	0.650	0.121	0.121
Weed	PG	179 ± 39	105 ± 47	105 ± 47
	NPG	163 ± 45	118 ± 53	118 ± 53
	<i>P</i> -value	0.716	0.758	0.758

<sup>1</sup>Conventional alfalfa interseeded with prairie grass (PG) and conventional alfalfa not interseeded with prairie grass (NPG)

<sup>2</sup>March 25, 2011 conventional sample and treated with Lorsban® application; grass types were ryegrass and prairie grass; weed type was principally chickweed

<sup>3</sup>May 10, 2011 conventional harvest; grass types were ryegrass and prairie grass; weed type was principally chickweed

**Table 4.** Field 1 (planted 2009) Harvests 2011—The effect of **organic** alfalfa interseeded prairie grass (PG) or not interseeded with prairie grass (NPG) on alfalfa, forage, biomass, and weed production at two harvests of the second season. Organic alfalfa was harvested in March for weevil control. Forage production included alfalfa, prairie grass, and ryegrass production. Biomass included alfalfa, prairie grass, ryegrass, and weed production. Values reported are LS means and SEM.

Organic Production (kg/ha)	Treatment <sup>1</sup>	Harvest 2011		Cumulative 2011
		Mar <sup>2</sup>	May <sup>3</sup>	(kg/ha)
Alfalfa	PG	548 ± 79	2053 ± 234	2601 ± 234
	NPG	634 ± 97	2078 ± 272	2712 ± 278
	<i>P</i> -value	0.495	0.774	0.762
Forage	PG	583 ± 85	3049 ± 239	3632 ± 245
	NPG	653 ± 104	2474 ± 281	3127 ± 246
	<i>P</i> -value	0.845	0.015	0.101
Biomass	PG	746 ± 90	3152 ± 223	3898 ± 235
	NPG	736 ± 105	2668 ± 263	3404 ± 281
	<i>P</i> -value	0.739	0.0213	0.094
Weed	PG	164 ± 39	108 ± 48	272 ± 58
	NPG	83 ± 45	194 ± 53	277 ± 74
	<i>P</i> -value	0.121	0.170	0.933

**Table 5.** Field 1 (planted 2009) Non-destructive Interharvest Samples 2010 and Harvests 2010, Field 2 (planted 2010) Harvest 2011—The effects of alfalfa variety, Arriba (AR) vs. Haygrazer (HG), on alfalfa production. Field 1 production was measured from three samples in 2010 and cumulative harvests of 2010 of the establishment year. In addition, production was measured from cumulative harvests of 2011. Field 2 production was measured from first harvest in 2011 of the establishment year. Values reported are LS means and SEM.

Production (kg/ha)	Variety <sup>1</sup>	Samples 2010			2010 Cumulative	2011 Cumulative	
		Jan <sup>2</sup>	March <sup>3</sup>	June <sup>4</sup>	Field 1 <sup>5</sup>	Field 1 <sup>6</sup>	Field 2 <sup>7</sup>
Alfalfa	AR	545	688	588	909	1143	2561
	HG	340	731	750	1080	1561	2423
	SEM	30	41	49	54	91	136
	P-value	0.003	0.478	0.056	0.067	0.018	0.503

<sup>1</sup>Alfalfa varieties were Arriba alfalfa (AR) and Haygrazer alfalfa (HG)

<sup>2</sup>January 18, 2010—sample

<sup>3</sup>March 16, 2010—sample

<sup>4</sup>June 1, 2010—sample

<sup>5</sup>Cumulative production of all harvests of field 1, 2010.

<sup>6</sup>Cumulative production of all harvests of field 1, 2011.

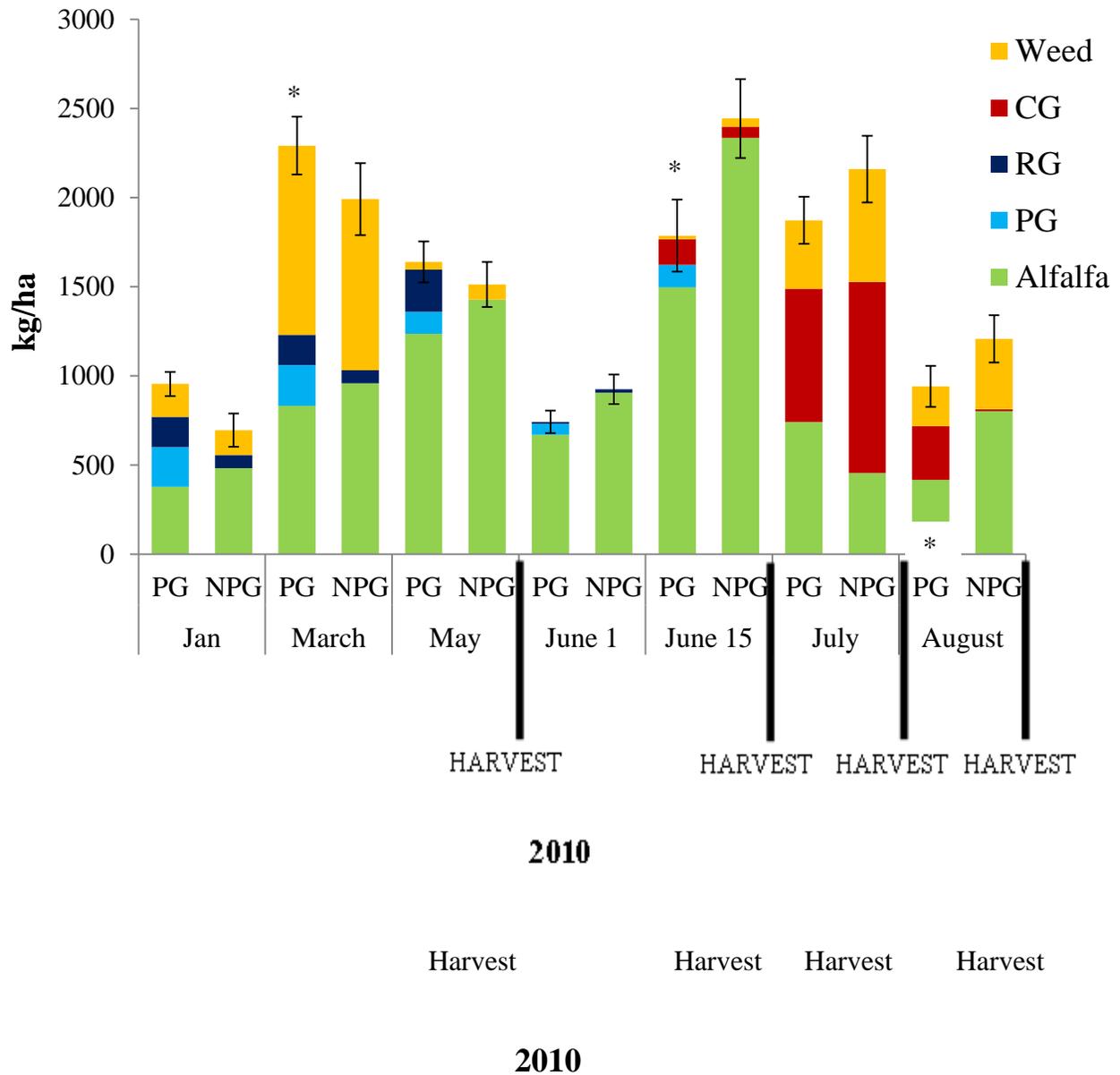
<sup>7</sup>Cumulative production of all harvests of field 2, 2011.

**Table 6.** Field 1 (planted 2009) and Field 2 (planted 2011)—The effects of management (organic vs. conventional) on plant count. Organic (O) and conventional (C) counts were taken three times in Field 1 (Oct 22, 2010; June 15, 2010; March 25, 2011) and twice in Field 2 (December 15, 2010; May 10, 2011). Values reported are LS means and SEM.

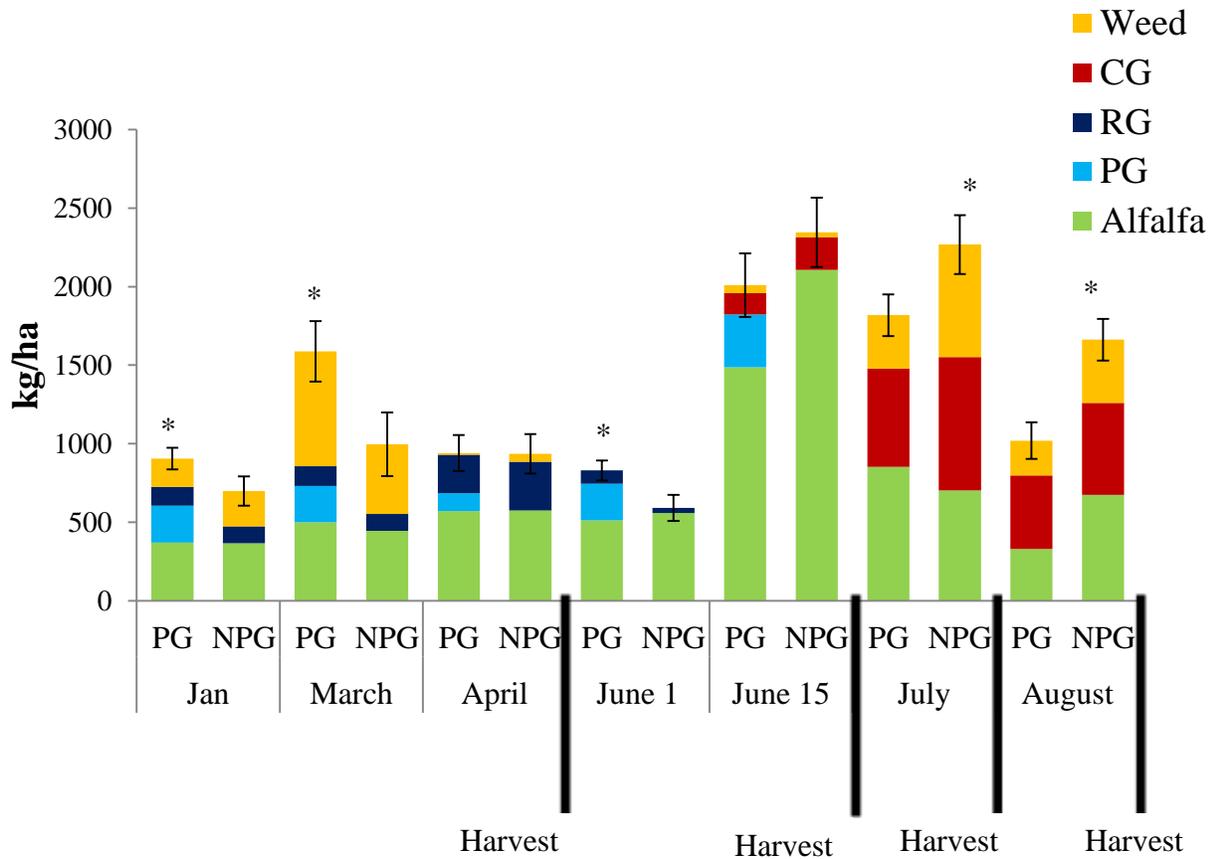
Treatment	Field 1			Field 2	
	Plant Counts 2010		Plant Counts 2011	Plant Counts 2011	
	Oct	June	March	Dec	May
<b>O</b>	54	52	49	64	57
<b>C</b>	56	51	54	58	62
<b>SEM</b>	5	6	5	2	2
<b>P-value</b>	0.839	0.882	0.497	0.047	0.041

**Table 7.** Field 1 (planted 2009) and Field 2 (planted 2011)—The effects of alfalfa variety on plant count. Arriba alfalfa (AR) and Haygrazer alfalfa (HG) counts were taken three times in Field 1 (Oct 22, 2010; June 15, 2010; March 25, 2011) and twice in Field 2 (December 15, 2010; May 10, 2011). Values reported are LS means and SEM.

Treatment	Field 1			Field 2	
	Plant Counts 2010		Plant Counts 2011	Plant Counts 2011	
	Oct	June	March	Dec	May
<b>AR</b>	53	50	50	61	59
<b>HG</b>	56	52	52	62	61
<b>SEM</b>	5	6	5	2	2
<b>P-value</b>	0.640	0.821	0.788	0.807	0.903



**Figure 1.** Field 1 (Planted 2009) Harvests 2010—The effect **conventional** alfalfa with interseeded prairie grass (PG) vs. not interseeded with prairie grass (NPG) on the biomass of three non-destructive interharvest samples (January 18, March 16, June 1) and four harvests (May 5, June 15, July 23, Aug 19) of the establishment year. Biomass included alfalfa, prairie grass (PG), ryegrass (RG), crabgrass (CG), and weed production. Bars represent LS means ± SEM. Asterisk (\*) represents significant difference in PG treatment at the given sample/harvest (P<0.10).

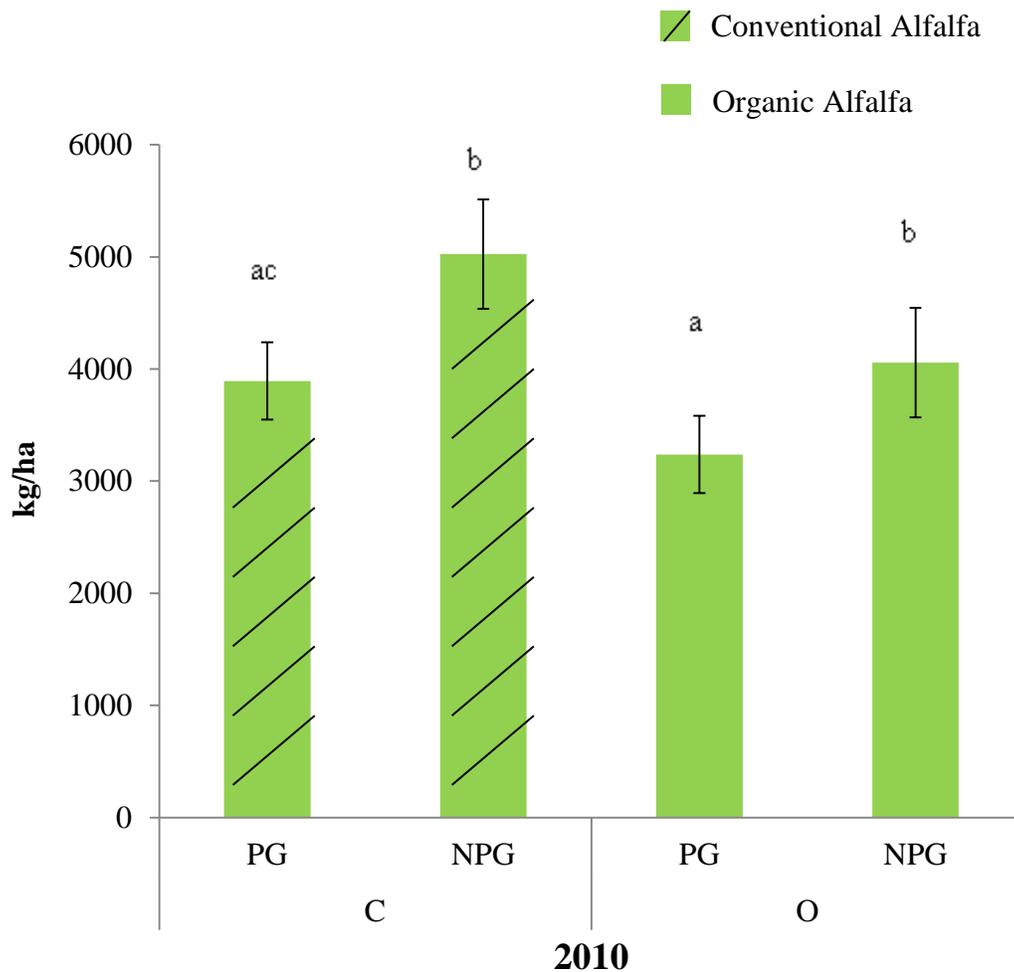


2010

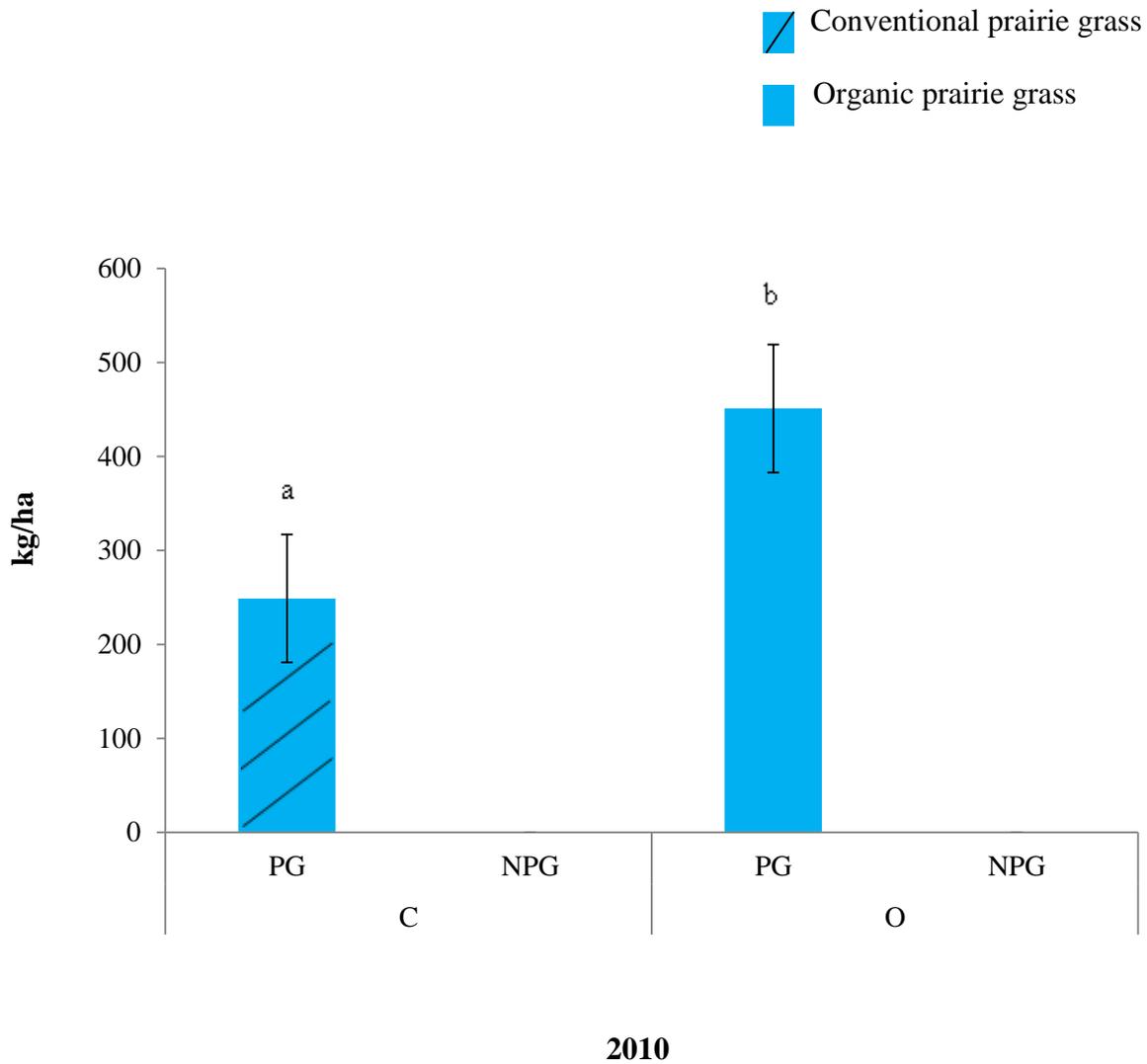
**Figure 2.** Field 1 (Planted 2009) Harvests 2010 –The effect of **organic** alfalfa interseeded prairie grass (PG) vs. not interseeded with prairie grass (NPG) on the biomass of three non-destructive interharvest samples (January 18, March 16, June 1) and four harvests (April 8, June 15, July 23, Aug 19) of the establishment year. Biomass included alfalfa, prairie grass (PG), ryegrass (RG), crabgrass (CG), and weed production. Bars represent LS means  $\pm$  SEM. Asterisk (\*) represents significant difference in PG treatment at the given sample/harvest ( $P < 0.10$ ).

**Table 16.** Field 1 (Planted 2009) Cumulative Production 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on cumulative alfalfa, prairie grass (PG), ryegrass (RG), crabgrass (CG), and weed production of the establishment year. Values reported are LS means and SEM.

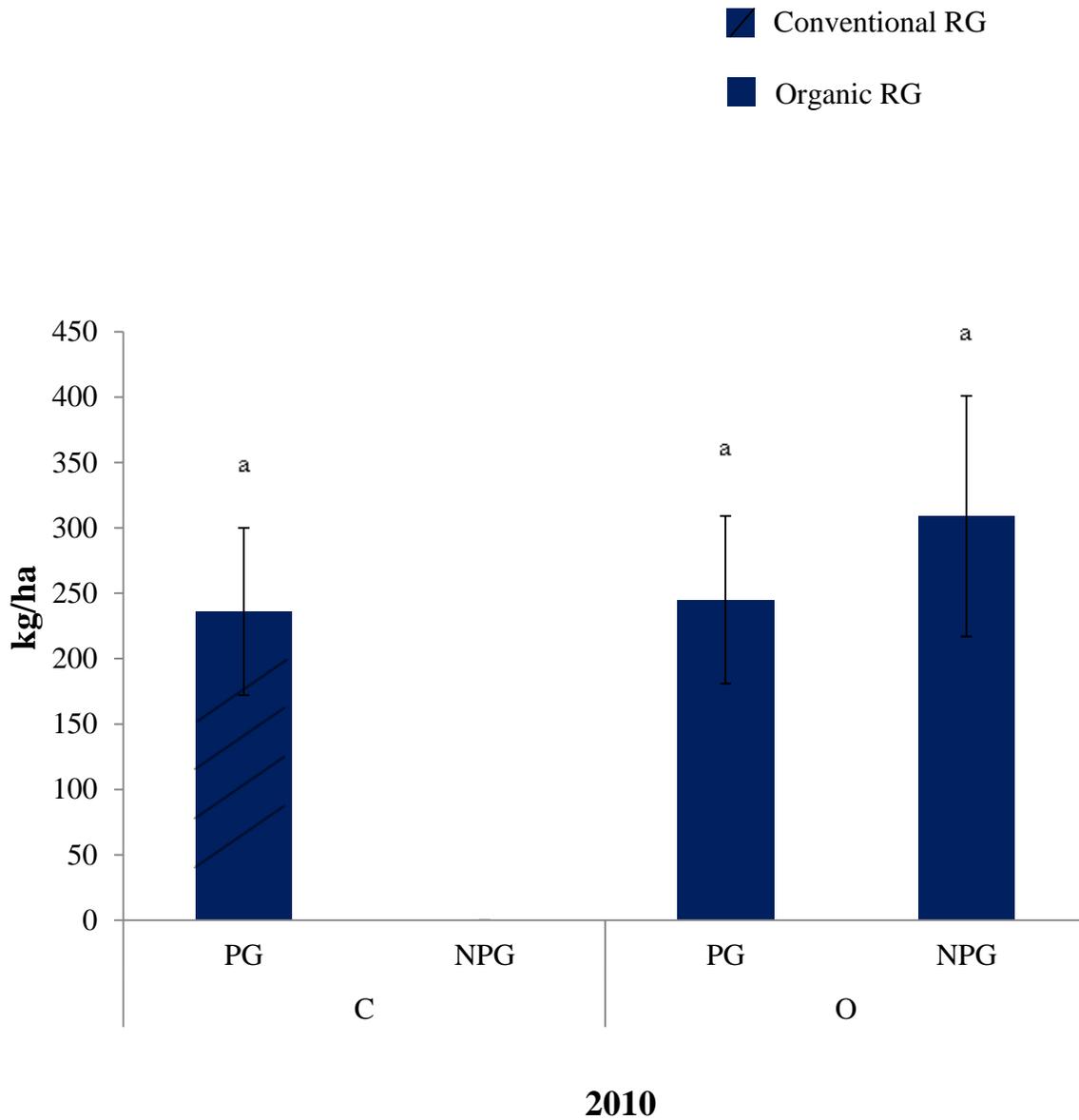
		<b>Cumulative Production (kg/ha)</b>				
		<b>Alfalfa</b>	<b>PG</b>	<b>RG</b>	<b>CG</b>	<b>Weed</b>
<b>C</b>	<b>PG</b>	3893 ± 344	249 ± 68	236 ± 64	1193 ± 272	670 ± 204
	<b>NPG</b>	5024 ± 488	0	0	1146 ± 384	1155 ± 256
	<b>P-value</b>	0.029	<0.001	<0.001	0.895	0.100
<b>O</b>	<b>PG</b>	3238 ± 344	451 ± 68	245 ± 64	1230 ± 272	622 ± 204
	<b>NPG</b>	4058 ± 488	0	309 ± 92	1645 ± 384	1199 ± 256
	<b>P-value</b>	0.089	<0.001	0.418	0.224	0.085



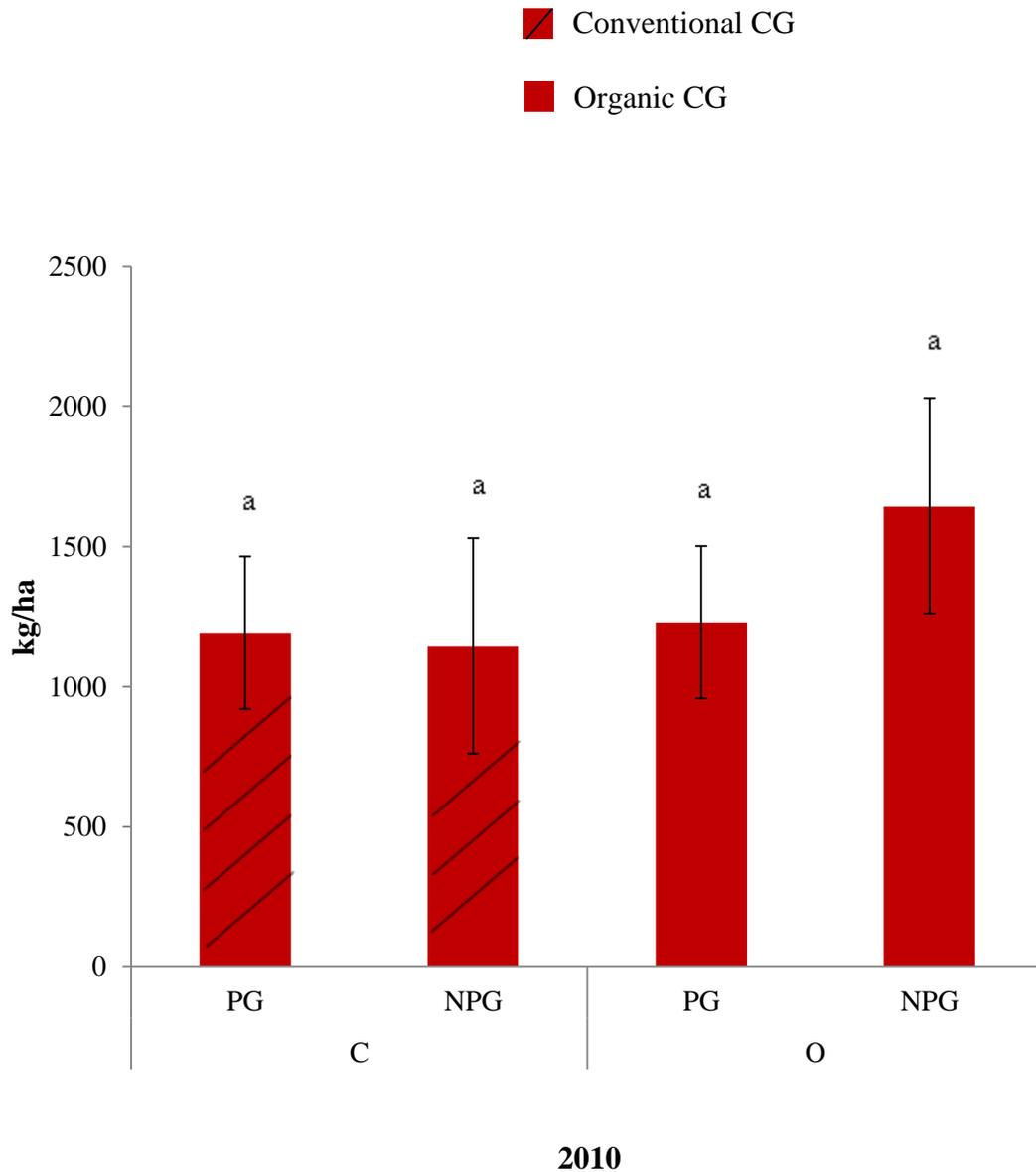
**Figure 3.** Field 1 (Planted 2009) Harvests 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. not interseeded with prairie grass (NPG) on **conventional** cumulative alfalfa production and **organic** cumulative alfalfa production of the establishment year. Bars represent least squared means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).



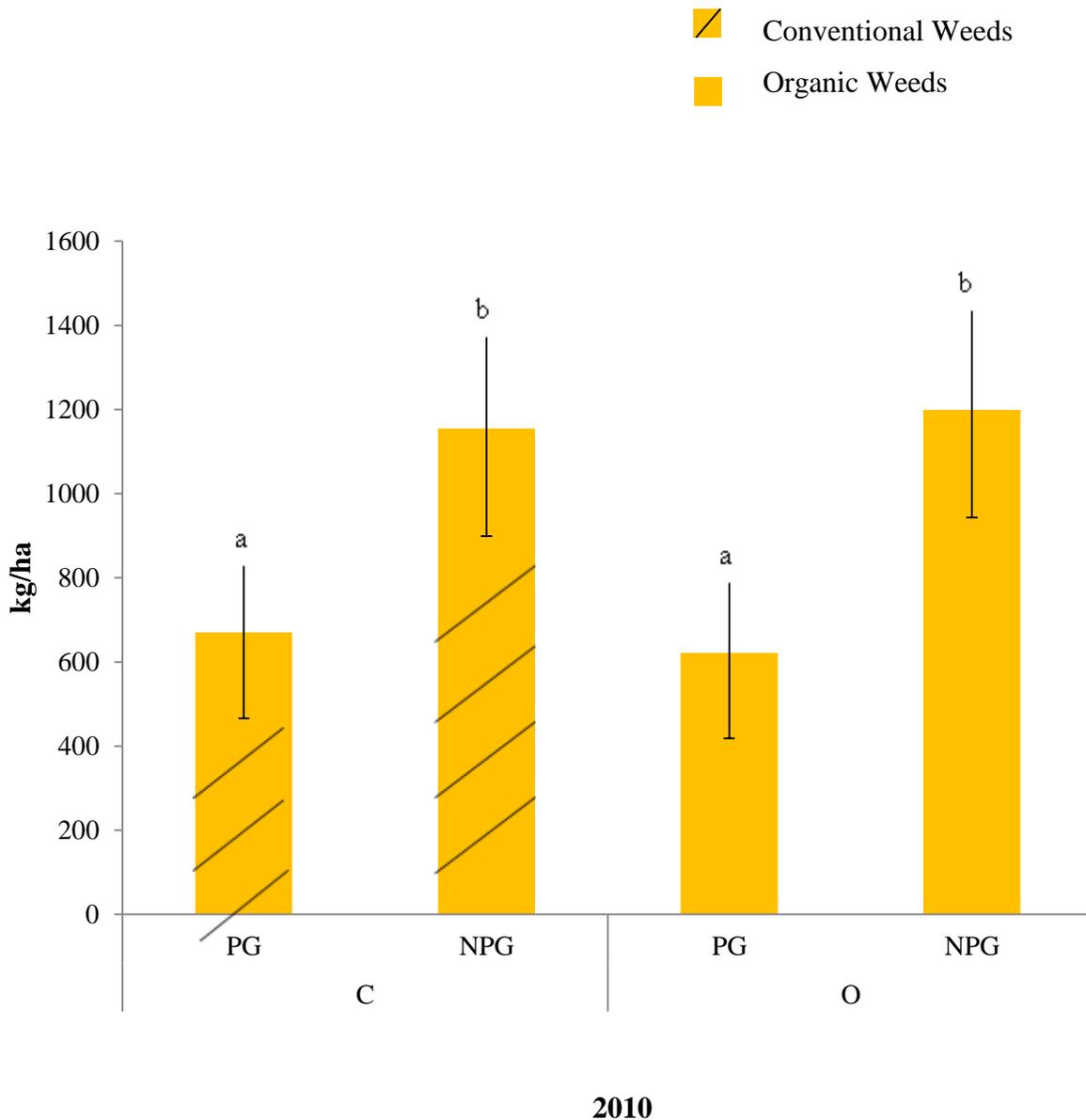
**Figure 4.** Field 1 (Planted 2009) Harvests 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. not interseeded with prairie grass (NPG) on **conventional** cumulative prairie grass production and **organic** cumulative prairie grass production in the establishment year. Bars represent least squared means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.05$ ).



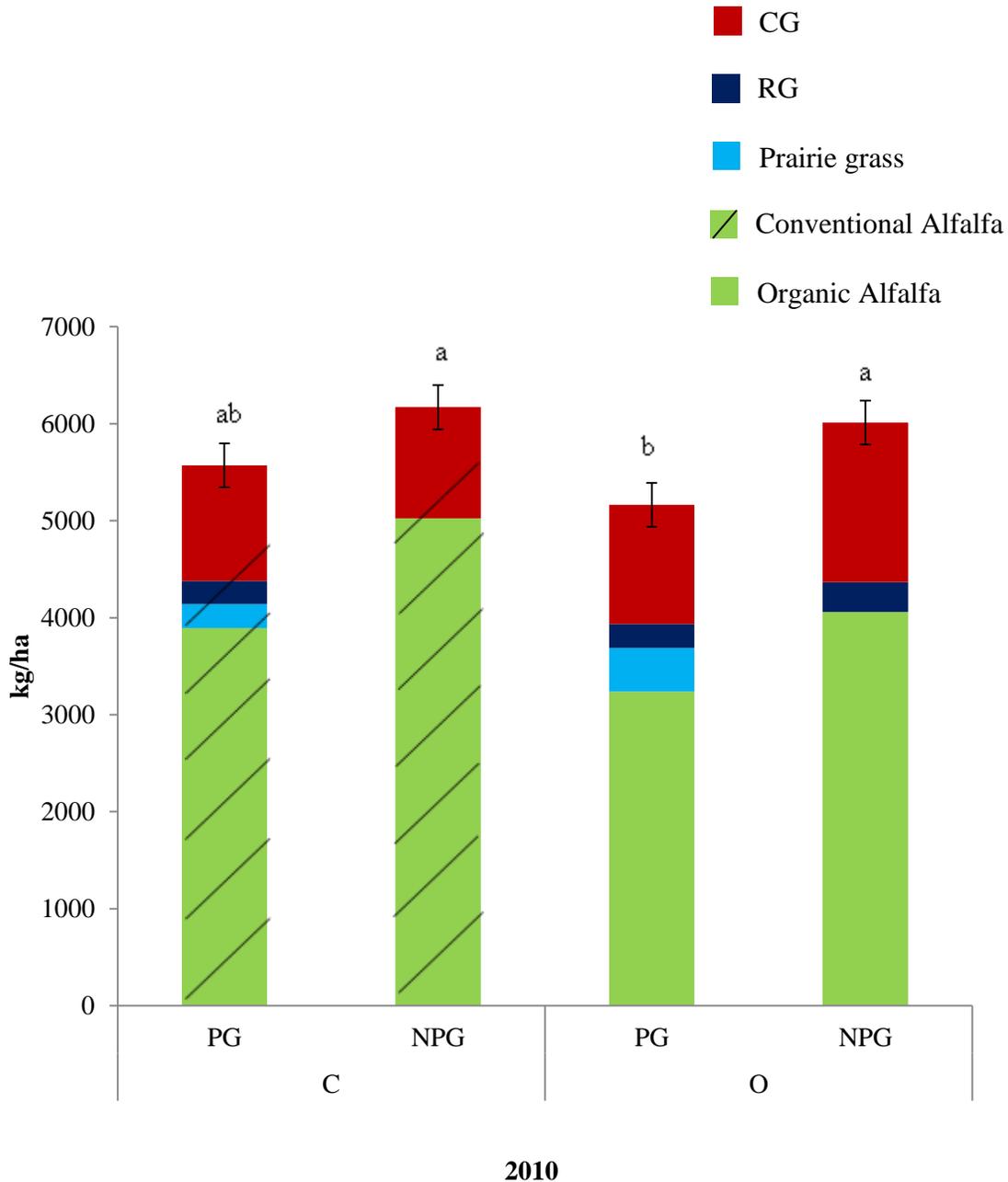
**Figure 5.**Field 1 (Planted 2009) Harvests 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on **conventional** cumulative ryegrass production (RG) and **organic** cumulative ryegrass production (RG) in the establishment year. Bars represent least squared means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).



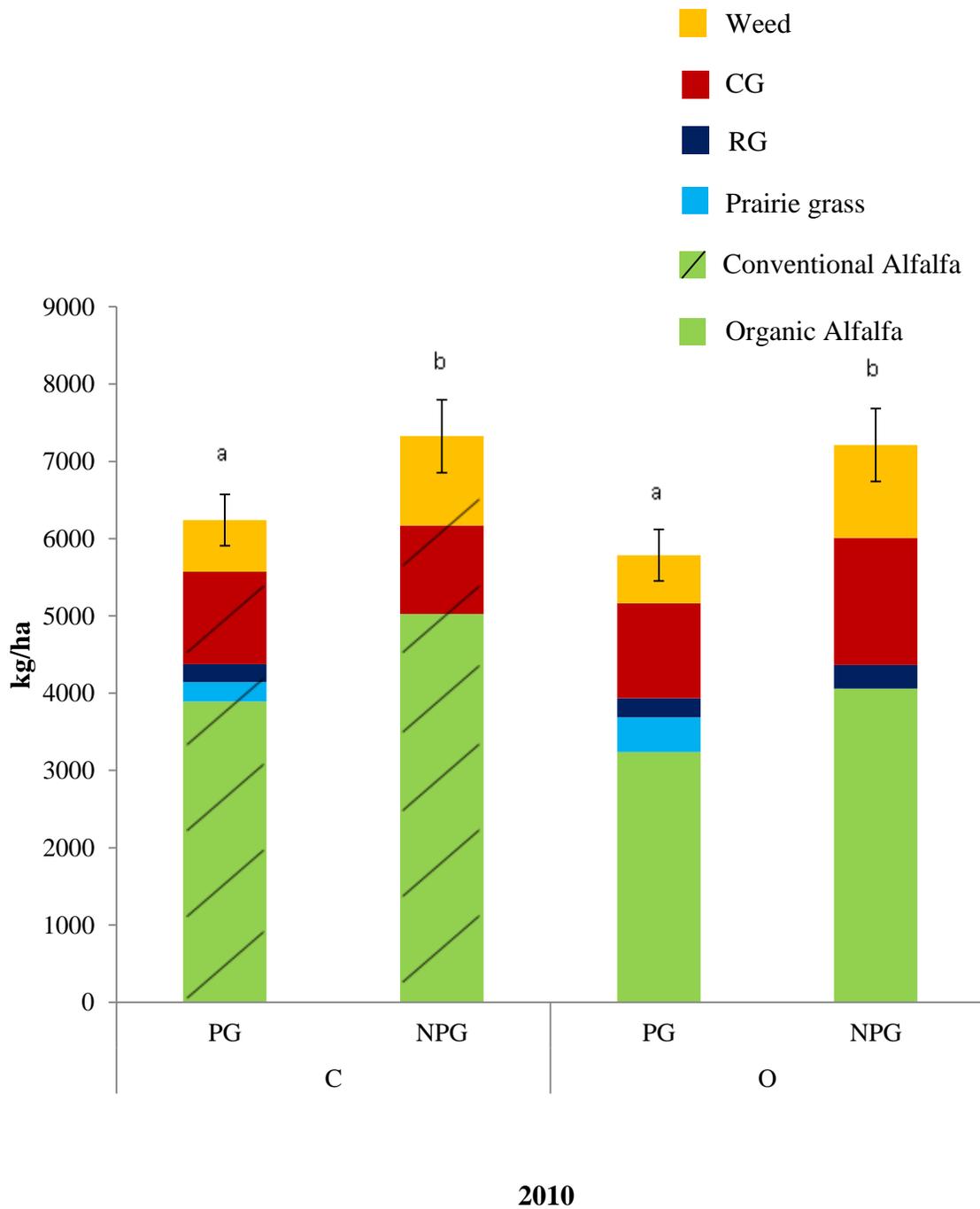
**Figure 6.**Field 1 (Planted 2009) Harvests 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on **conventional** cumulative crabgrass production (CG) and **organic** cumulative crabgrass (CG) production in the establishment year. Bars represent least squared means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).



**Figure 7.** Field 1 (Planted 2009) Harvests 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on **conventional** cumulative weed production and **organic** cumulative weed production in the establishment year. Weed production included henbit, common chickweed, and pigweed. Bars represent least squared means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).



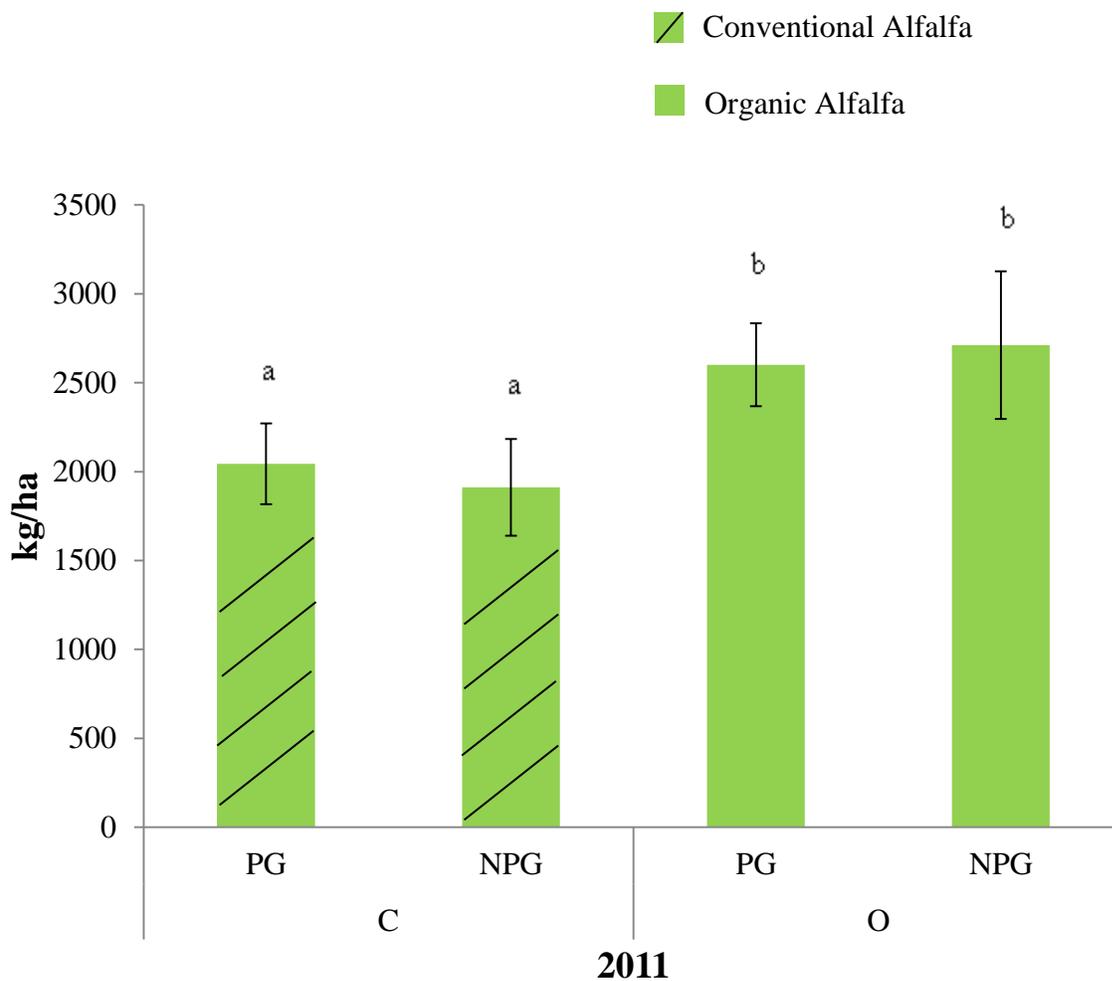
**Figure 8.** Field 1 (Planted 2009) Harvests 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on **conventional** cumulative forage production and **organic** cumulative forage production in the establishment year. Forage production included alfalfa, prairie grass, ryegrass, and crabgrass production. Bars represent least squared means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).



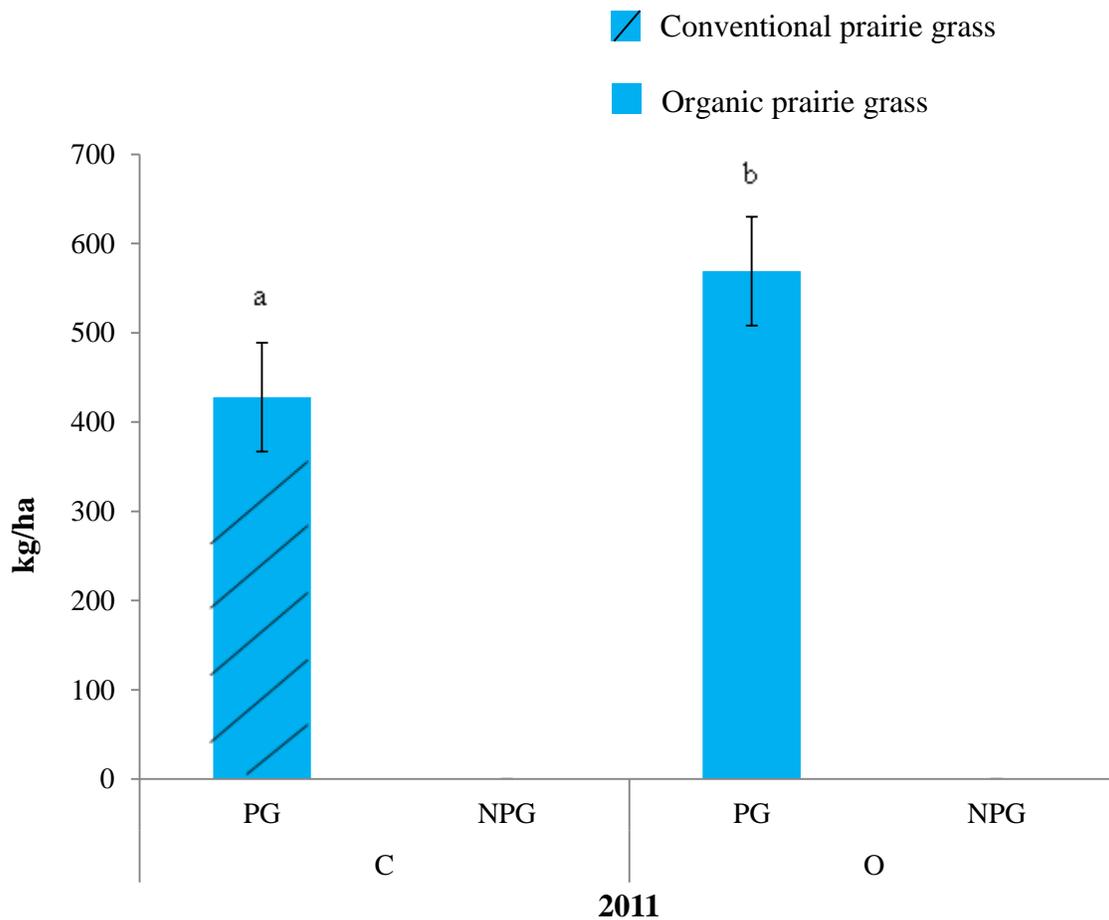
**Figure 9.** Field 1 (Planted 2009) Harvests 2010—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on **conventional** cumulative biomass and **organic** cumulative biomass in the establishment year. Biomass included alfalfa, prairie grass, ryegrass (RG), crabgrass (CG), and weed production. Bars represent least squared means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).

**Table 17.**Field 1 (Planted 2009) Harvests 2011—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on cumulative alfalfa, prairie grass (PG), ryegrass (RG), crabgrass (CG), and weed production in the spring of the second season. Values reported are LS means and SEM.

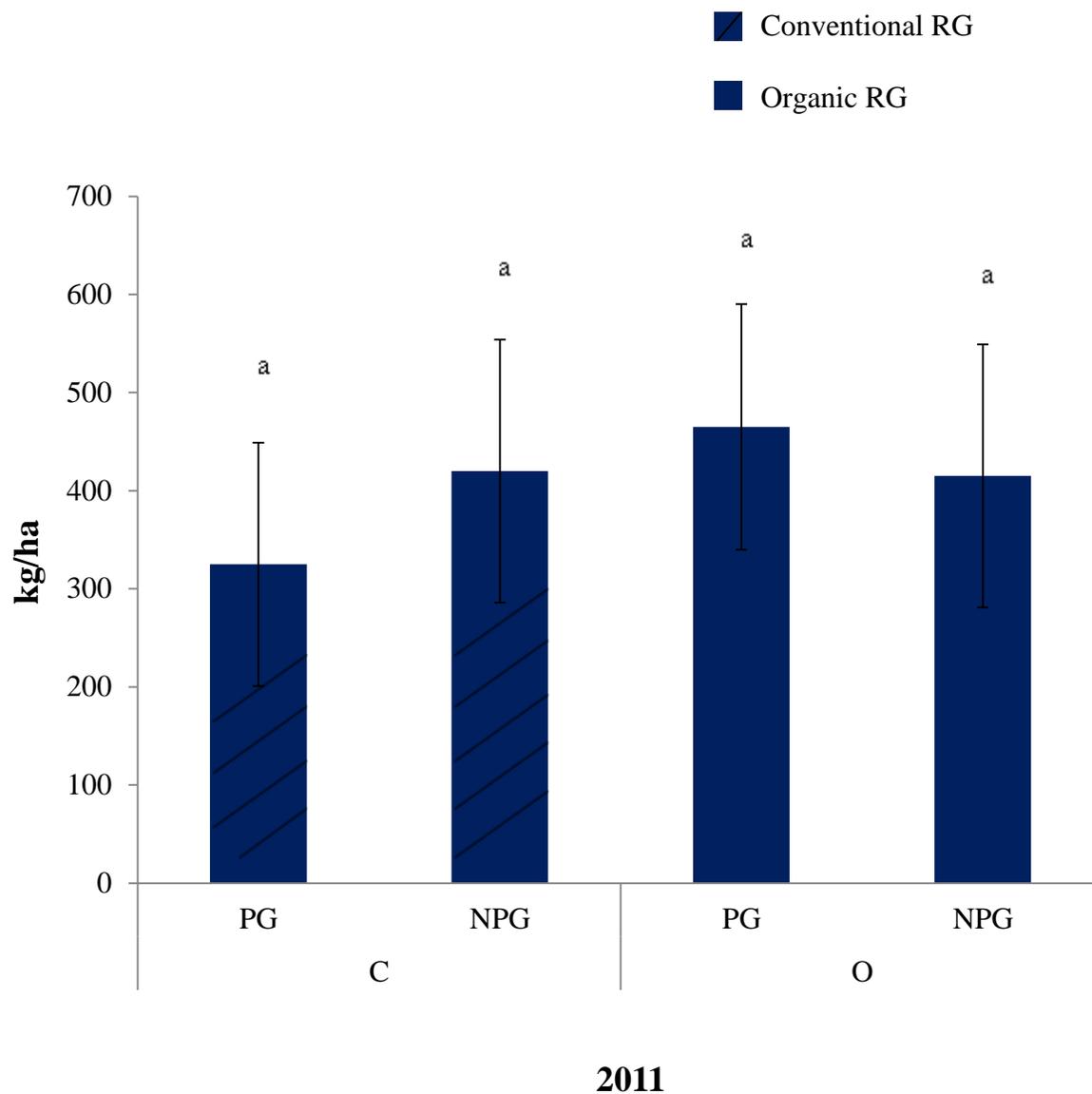
		<b>Field 1: Cumulative Production 2011 (kg/ha)</b>				
		<b>Alfalfa</b>	<b>PG</b>	<b>RG</b>	<b>CG</b>	<b>Weed</b>
<b>C</b>	<b>PG</b>	2044 ± 227	428 ± 61	325 ± 124	0.0	105 ± 47
	<b>NPG</b>	1912 ± 272	0	420 ± 134	0.0	118 ± 53
	<b>P-value</b>	0.614		0.579	0.0	0.758
<b>O</b>	<b>PG</b>	2601 ± 234	569 ± 61	465 ± 125	0.0	272 ± 58
	<b>NPG</b>	2712 ± 278	0	415 ± 134	0.0	277 ± 74
	<b>P-value</b>	0.762		0.872	0.0	0.933



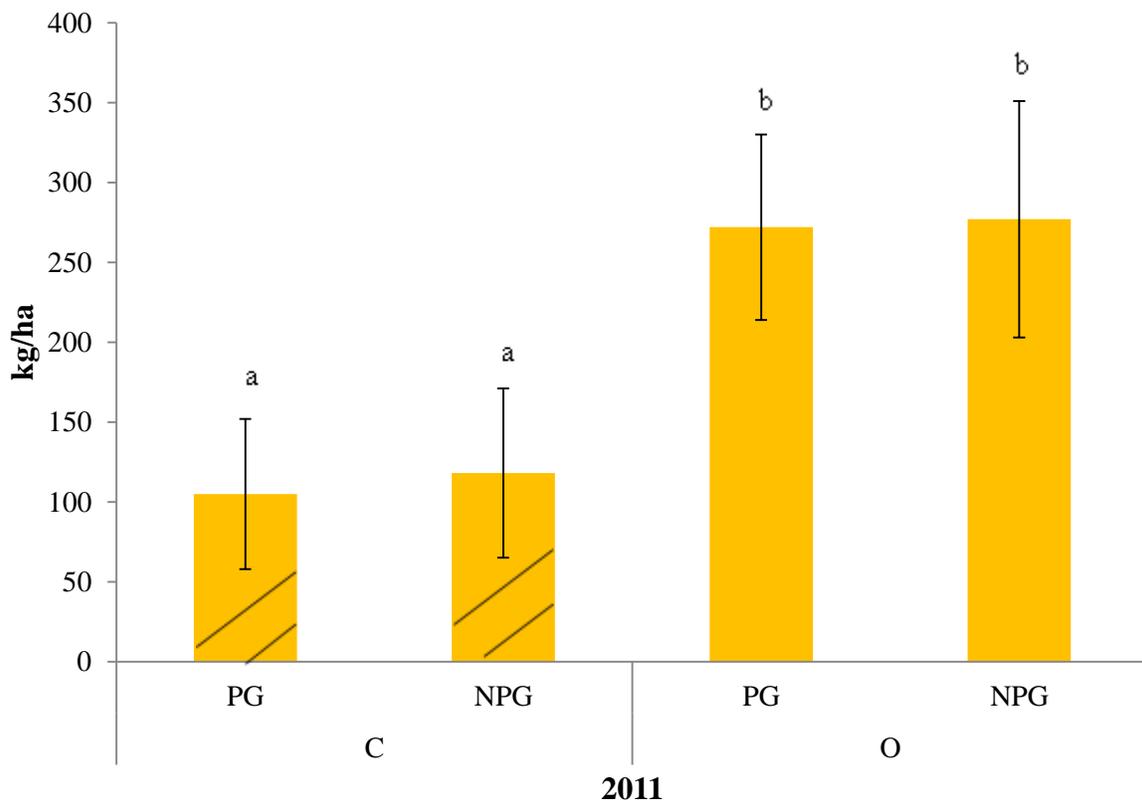
**Figure 10.**Field 1 (Planted 2009) Harvest 2011—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on **conventional** cumulative alfalfa production and **organic** cumulative alfalfa production of the second season. Bars represent least squared means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).



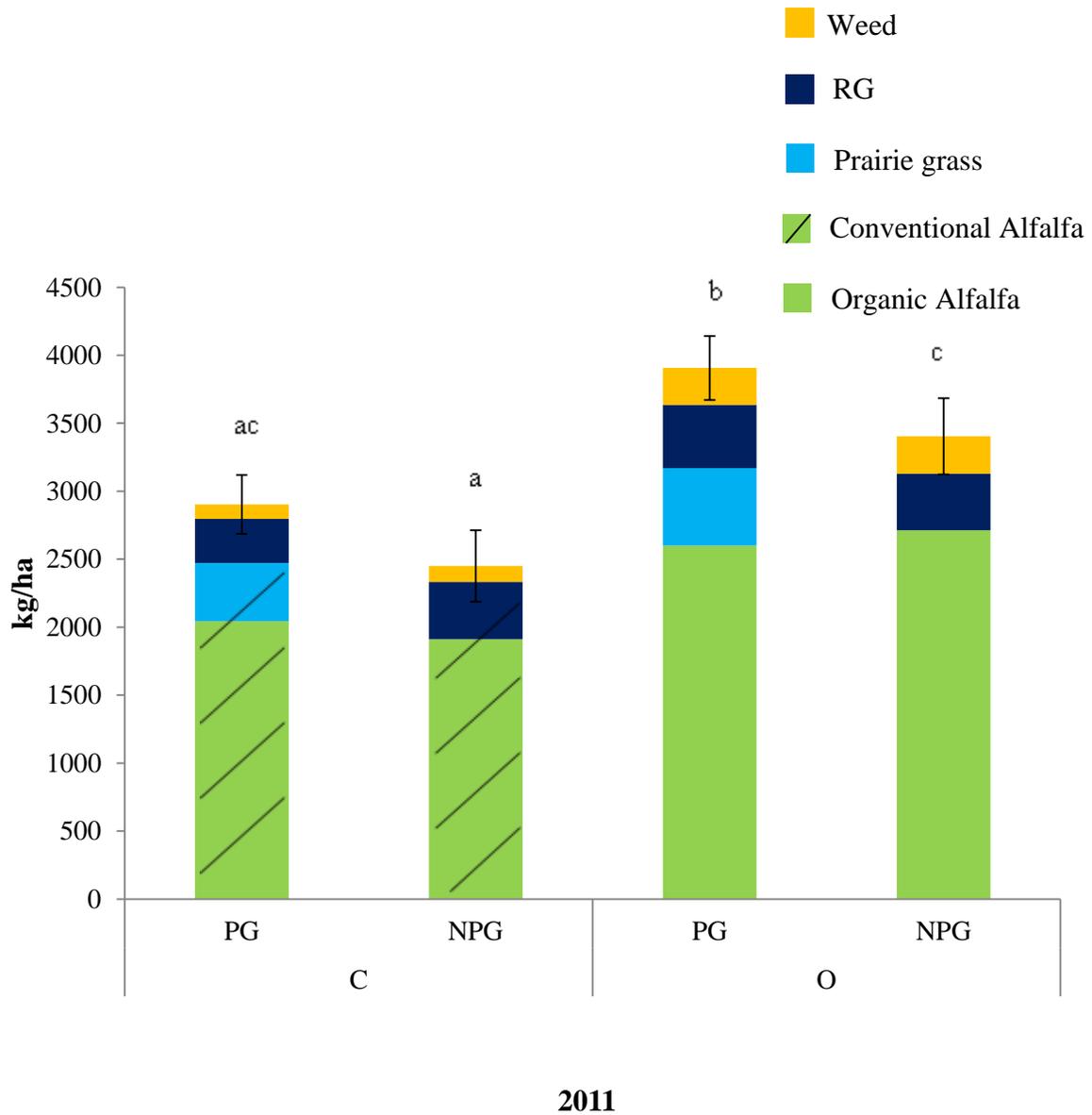
**Figure 11.** Field 1 (Planted 2009) Harvests 2011—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on **conventional** cumulative prairie grass production and **organic** cumulative prairie grass production of the second season. Bars represent least squared means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).



**Figure 12.**Field 1 (Planted 2009)Harvests 2011—Theeffect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on **conventional** cumulative ryegrass production (RG) and **organic** cumulative ryegrass production of the second season. Bars represent least squared means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).



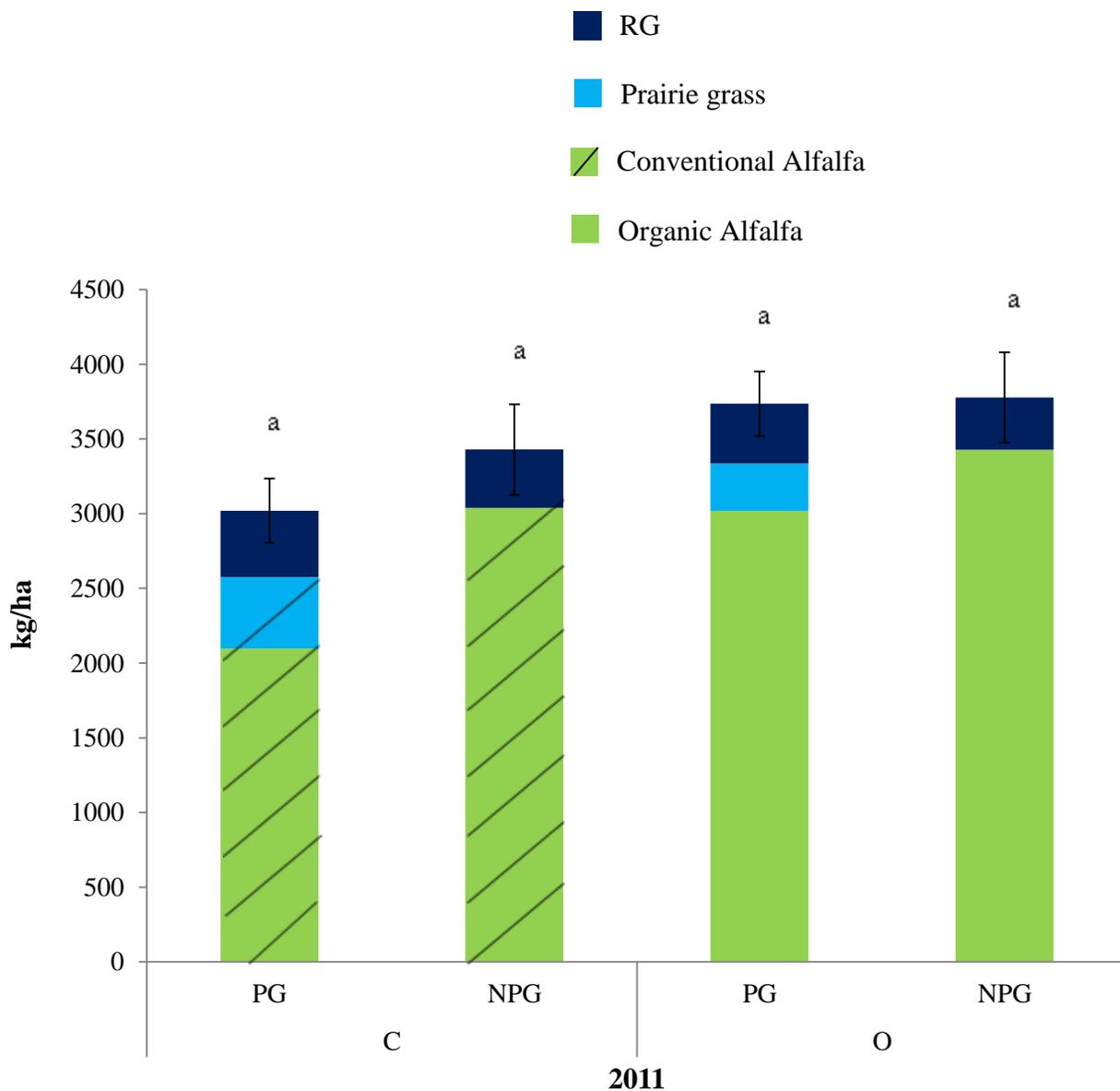
**Figure 13.**Field 1 (Planted 2009) Harvests 2011—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on **conventional** cumulative weed production and **organic** cumulative weed production of the second season. Bars represent least squared means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).



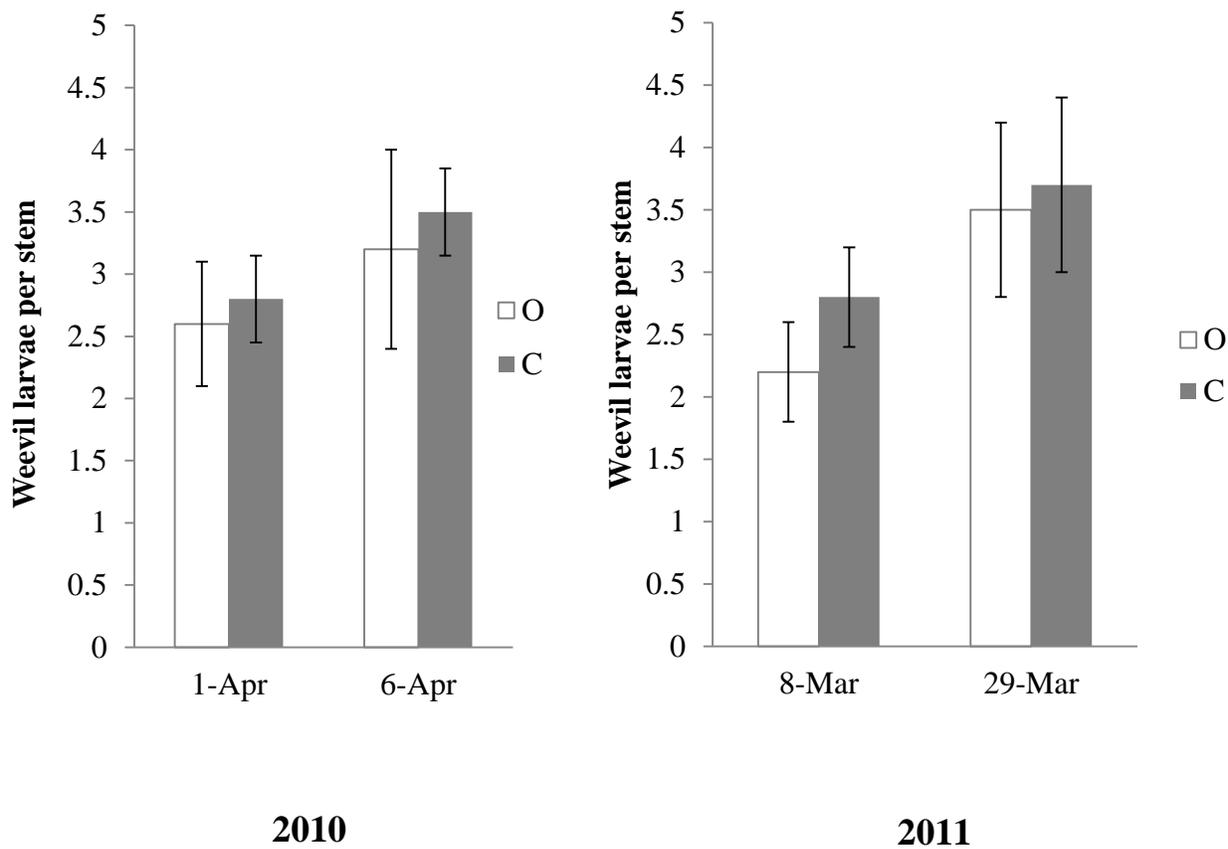
**Figure 15.**Field 1 (Planted 2009) Harvests 2011—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on **conventional** cumulative biomass and **organic** cumulative biomass of the second season. Biomass included alfalfa, prairie grass, ryegrass (RG), and weed production. Bars represent least squared means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).

**Table 18.** Field 2 (Planted 2010) Harvest2011—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on cumulative alfalfa, prairie grass (PG), ryegrass (RG), and crabgrass (CG) production in the first harvest of the establishment year. There was no weed production in the first harvest. Values reported are LS means and SEM.

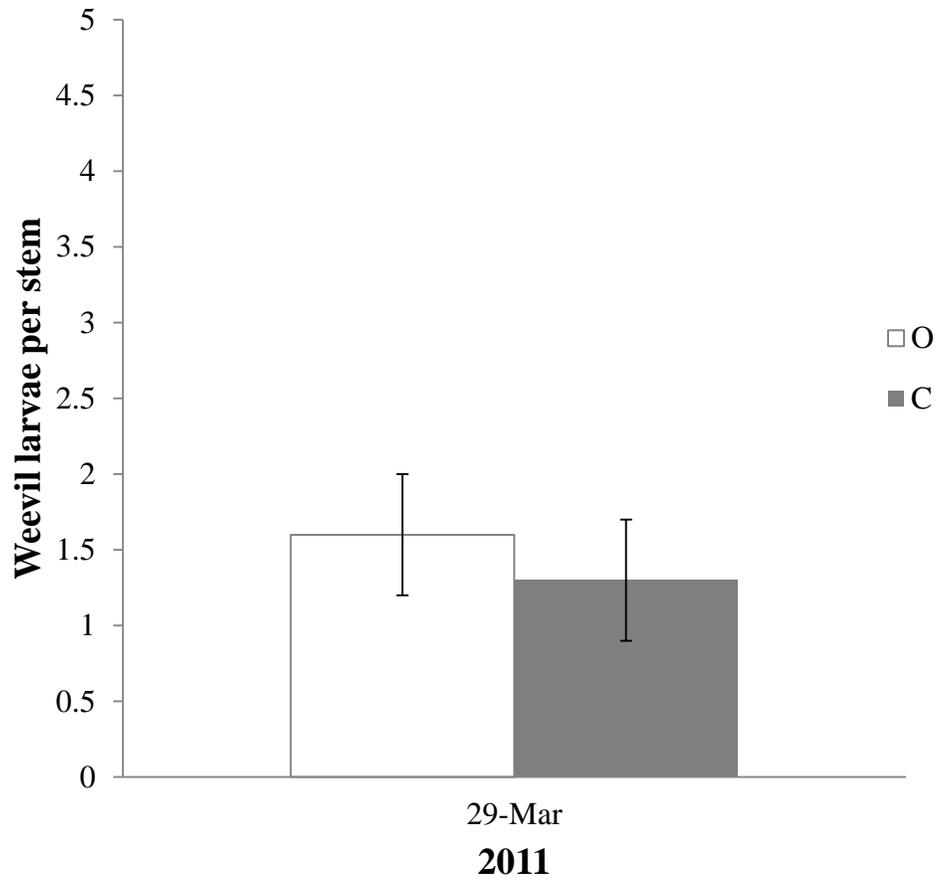
		<b>Alfalfa</b>	<b>PG</b>	<b>RG</b>
<b>C</b>	<b>PG</b>	2099 ± 215	477 ± 89	444 ± 131
	<b>NPG</b>	3038 ± 280	0	391 ± 152
	<b>P-value</b>	0.006	<0.001	0.706
<b>O</b>	<b>PG</b>	2345 ± 215	316 ± 89	401 ± 132
	<b>NPG</b>	2635 ± 303	0	349 ± 152
	<b>P-value</b>	0.282	<0.001	0.788



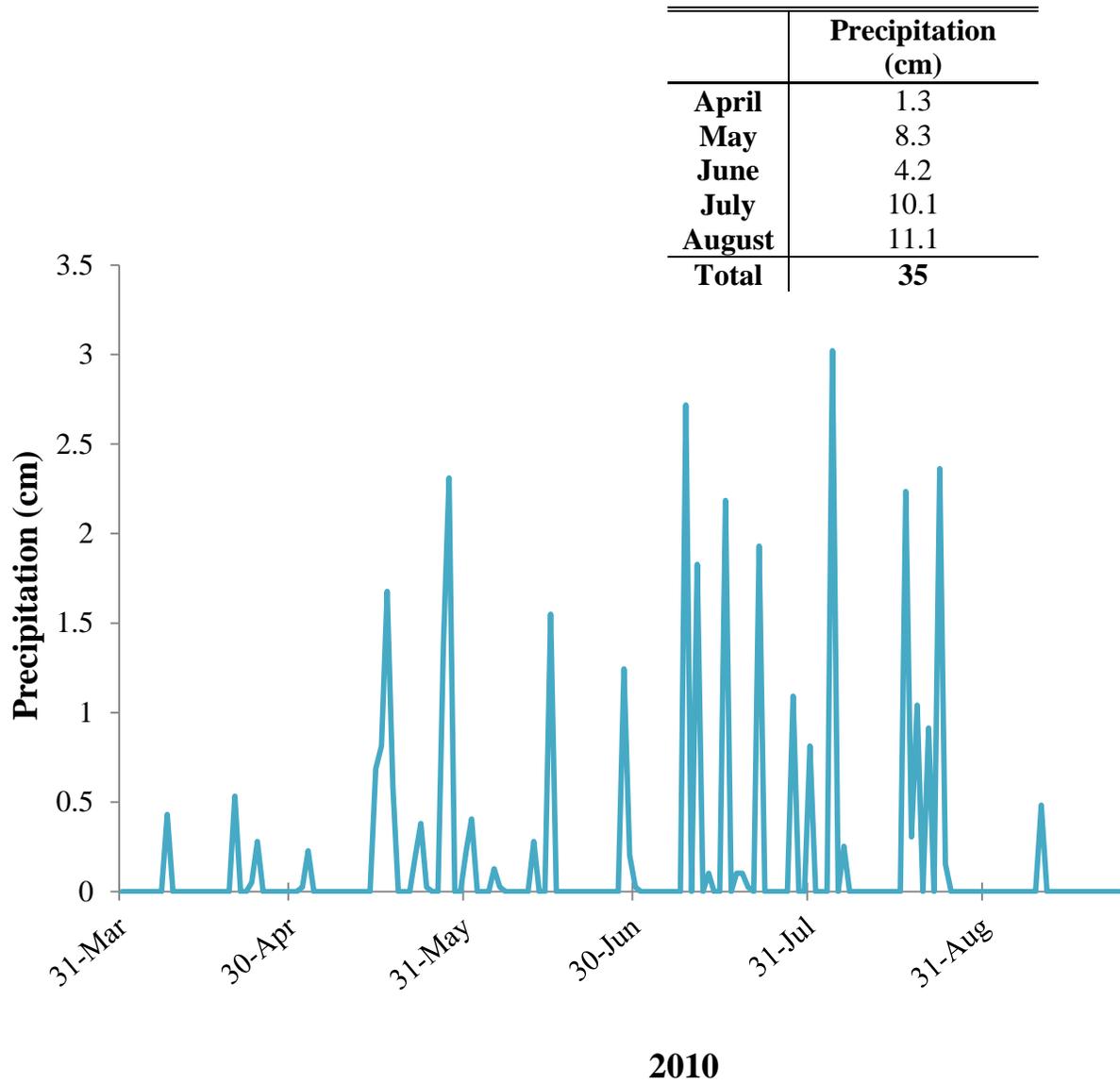
**Figure 18.**Field 2 (Planted 2010) Harvest 2011—The effect of alfalfa interseeded with prairie grass (PG) vs. alfalfa not interseeded with prairie grass (NPG) on **conventional** cumulative forage production and **organic** cumulative forage production in the first harvest of the establishment year. Forage production included alfalfa, prairie grass, and ryegrass production. Bars represent least squared means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).



**Figure 19.** Field 1 (planted fall 2009) April 2010 and March 2011—The effects of management (organic vs. conventional) on the counts of alfalfa weevil larvae per stem of alfalfa. At economic threshold of three weevil larvae per stem, alfalfa should be treated by defoliation (organic) or chemical use (conventional).

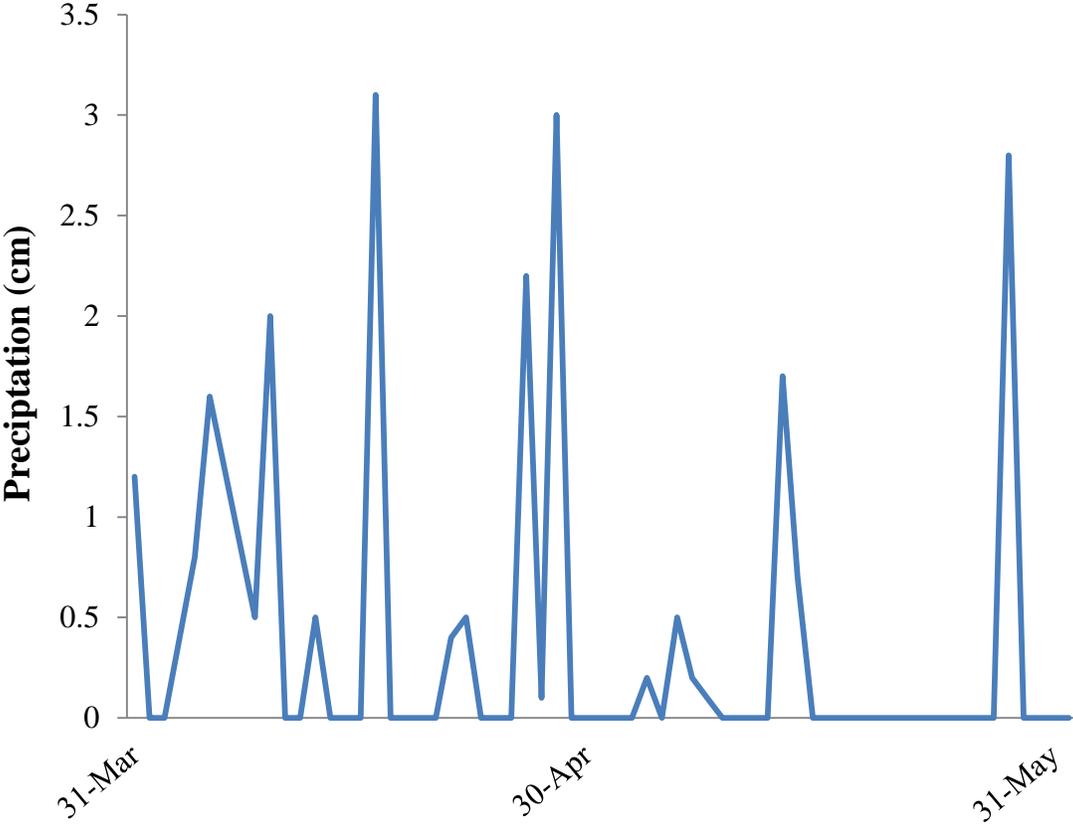


**Figure 20.** Field 2 (planted fall 2010) spring 2011—counts of alfalfa weevil larvae per stem of alfalfa under conventional vs. organic management on March 29, 2011.



**Figure 21.** Precipitation of growing season 2010.

	Precipitation (cm)
<b>April</b>	16
<b>May</b>	6.2
<b>Total</b>	22.2



**2011**

**Figure 22.**Precipitation of 2011 spring season.

**CHAPTER III:**  
**The establishment of organic and conventional alfalfa-grass mixtures  
in grazing systems**

## ABSTRACT

North Carolina livestock producers are interested in high quality pastures for milk and grass-fed beef production. Organic producers are particularly interested in forage production without chemical control of weeds and pests. The objective of this study was to measure the production of grazing alfalfa under organic and conventional management. Conventional alfalfa was treated with Eptam® at planting. Biomass samples were taken randomly across field at every grazing and at interharvest samples.

Conventional and organic alfalfa was grazed four times. In field 1 organic reached weevil threshold before conventional alfalfa. In the first grazing season (2010), cumulative conventional alfalfa production was not different ( $p=0.421$ ) from organic alfalfa production. Conventional alfalfa was significantly greater February and organic alfalfa production was significantly greater in August. Interestingly, cumulative organic forage production (alfalfa, prairie grass, ryegrass, and crabgrass) tended to be greater ( $P=0.096$ ) than conventional forage production. Management did not make a difference ( $P=0.376$ ) in cumulative weed production, mainly due to pigweed production in the summer months.

Field 1, in the beginning of the second season (2011), both organic and conventional plots were grazed in February to reduce alfalfa weevil egg population in the alfalfa stem. Organic plots reached weevil threshold first and were grazed March 18, 2011. In the cumulative spring production, conventional alfalfa production tended to be greater ( $P=0.089$ ) than organic alfalfa production. However, management did not make a difference ( $P=0.238$ ) on forage production. Organic alfalfa weed production tended to be less ( $P=0.081$ ) than conventional alfalfa weed production.

Field 2, in the first season (2011), did not reach alfalfa weevil threshold and had much different results than field 1. On the first grazing, organic alfalfa produced significantly more ( $P < 0.05$ ) alfalfa than conventional management ( $1429 \pm 52$  vs.  $1104 \pm 52$  kg/ha). Organic management also produced more ( $P < 0.05$ ) forage compared to conventional production ( $1540 \pm 58$  vs.  $1104 \pm 58$ ). Management did not have an effect on weed production ( $P = 0.112$ ). Interseeding prairie grass did not change the alfalfa, forage, or weed production of organic plots. Conventional plant counts tended to be higher at the first grazing.

In a grazing system, organic management was more successful than conventional management. Although it depends on the seed bank, voluntary grasses that are allowed to grow in the organic system significantly boost forage production. As nutrients are being recycled directly back into the environment, the regrowth of forage behaves much differently than a hay system.

## **Introduction**

North Carolina livestock producers are interested in nutritive forages for their pasture-based production systems. Grazing alfalfa can be more profitable than hay production because of less machine maintenance, the ability to graze weed species at a vegetative stage, and less production loss from leaf shatter (Briske and Stuth, 1982). Organic producers are specifically interested in grazing forages, such as alfalfa, that are high in protein because of the expense of organic grain (1992). Grazing can also be an effective management of pests in organic systems where chemical control is not an option (Long, 2009). Under grazing conditions, most of plant nutrients are efficiently returned to the system

through manure and urine (Ball, 2007). Grazing tolerant varieties of alfalfa are also characterized by leaves near the soil surface, and higher root carbohydrate levels (Ball, 2007). Alfalfa generally does not persist well under continuous grazing, although grazing cultivars persist better than hay-type varieties (Smith et al., 1989). Alfalfa must be intensively grazed, as longer rotations slow alfalfa regrowth and increase weed pressure (Lacefield, 1996). Recommended rotational grazing includes grazing a paddock for one week and resting that pasture for about four weeks. Plants should not be grazed for more than 10-12 days at the risk of damaging the new shoots developing at crown bud. On productive stands, alfalfa can support a stocking rate of 3-5 cows acre<sup>-1</sup>. Alfalfa should be grazed short enough that regrowth occurs from the crown. It is important to give the plants enough time to build reserves in roots before the winter freezedown. Thus, the last grazing should occur in mid-September for overwintering. Grazing alfalfa in the late fall should be done carefully, while leaving 8 inches of growth (Ball, 2007).

Short-duration intensive grazing encourages more uniform utilization of the pastures (Briske and Stuth, 1982). A pasture that is established with an equal botanical composition of legumes and grasses can change depending on the grazing management. A brome-alfalfa-creeping red fescue pasture that is rotationally grazed can increase its alfalfa composition from 23 to 47% in four years (Walton et al., 1981). Compared to ryegrass, Matua does not persist well under frequent grazing. During periods of growth, the recommended rest period for Matua was 30-40 days (Sellars, 1988). Alfalfa was more persistent at watering sites than cool season grasses (Campbell, 1961).

## Materials and Methods

This study started in October 2009 at Cherry Research Farm at the Center for Environmental Farming Systems in Goldsboro, NC (35° 22' 55" N, 77° 58' 41" W) on sandy loam soils (Kenansville loamy sand and Lakeland sand). Plots had history of annual ryegrass (*Lolium multiflorum*) and sorghum (*sorghum bicolor*), with historical pigweed (*Amaranthus spinosus*) weed pressure. Soil samples were taken in August 2009 and again in August 2010. In August 2009, calcitic lime (CaCO<sub>3</sub>) was applied at 1.5 t ha<sup>-1</sup>. Plots were disked twice in August to disrupt cool season grass establishment, and then disked a third time after a second lime application (1.3 t ha<sup>-1</sup>) on September 3, 2009. Boron was applied at 34.8 kg ha<sup>-1</sup> and potash (K<sub>2</sub>SO<sub>4</sub>) was applied at 247 kg ha<sup>-1</sup> according to soil test recommendations. In October 2010, lime (3.4 t ha<sup>-1</sup>), potash (112 kg ha<sup>-1</sup>), and boron (2.2 kg ha<sup>-1</sup>) were applied according to soil test recommendations.

### *Field 1: Planting 2009*

Two varieties of alfalfa were planted in 0.8 ha plots under organic or conventional management in a split-block design (management x variety). Before planting alfalfa, Eptam® (EPTC, s-ethyl dipropylthiocarbamate) was incorporated into conventional plots at 4.1 liters/ha. Biomass and botanical composition samples were taken in December 2009. Matua prairie grass (*Bromus willdenowii*) was drilled into organic and conventional plots in February at a rate of 16.8 kg ha<sup>-1</sup>. Alfalfa weevil (*Hyperapostica* Gyllenhal) scouting started in February and continued through April. For organic management, alfalfa was grazed at an economic threshold of 3 weevil larvae per stem. Otherwise, plots were grazed when maturity reached 1/10<sup>th</sup> bloom. Alfalfa was grazed to a stubble height of 4-6 inches. Plots were

intensively grazed with a stocking rate of 200 cows ha<sup>-1</sup>. Cows were Jersey-Holstein crosses and separated into organic or conventional groups. Plots were sampled for biomass and botanical composition before each grazing using a 0.25m<sup>2</sup> frame. Organic plots were grazed in early April, early June, late July, and mid August of 2010. Conventional plots were grazed in late April, early June, late July, and mid August of 2010. Conventional plots were wicked with glyphosate (Roundup Powermax®) for pigweed control on August 23, 2010. In late August 2010, Matua prairie grass was drilled into organic and conventional grazing plots at 22.5 kg ha<sup>-1</sup>. Organic and conventional plots were managed for weevil control in spring 2011. Organic plots were grazed February, mid March, and early May of 2011. Conventional plots were grazed February, early April, and early May of 2011.

#### *Field 2: Planting 2010*

Two varieties of alfalfa were planted in 0.5 ha plots under organic or conventional management in a split-block design. Before planting alfalfa, Eptam® (EPTC, s-ethyl dipropylthiocarbamat,) was incorporated into conventional plots at 4.1 liters/ha. Matua prairie grass (*Bromus willdenowii*) was drilled into organic at a rate of 22.5 kg ha<sup>-1</sup>. Alfalfa weevil (*Hyperapostica* Gyllenhal) scouting started in February 2011 and continued through April. Plots were grazed when maturity reached 1/10<sup>th</sup> bloom. Alfalfa was grazed to a stubble height of 4-6 inches. Plots were intensively grazed with a stocking rate of 200 cows ha<sup>-1</sup>. Cows were Jersey-Holstein crosses and separated into organic or conventional groups. Plots were sampled for biomass and botanical composition before each grazing using a 0.25m<sup>2</sup> frame. Organic and conventional plots were grazed in early May 2011.

*Statistical Analysis.* Data were analyzed using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Fixed effects of individual grazing included only management (organic vs. conventional). Random effects included rep effect. Cumulative production was analyzed using repeated measures. Degrees of freedom, least squared means and standard errors were calculated applying the correction method of Kenward and Rogers (SAS Institute, 2006).

## **Results**

### ***Field 1: Grazing 2010***

#### *Management*

*Grazing 1.* Management effects on grazing plots are shown in Table 1. Organic plots were first grazed April 7, 2010 and conventional plots were grazed April 28, 2010 (21 days later) because of different managements for alfalfa weevil in conventional and organic treatments. Conventional plots did not reach economic threshold in 2010. Conventional alfalfa production was tended to be greater ( $P=0.083$ ) than organic ( $1165 \pm 48$  vs.  $879 \pm 101$  kg/ha, respectively). However, conventional forage production did not differ ( $P=0.158$ ) from organic ( $1196 \pm 59$  vs.  $1464 \pm 125$  kg/ha, respectively). Conventional biomass did not differ from organic biomass ( $1217 \pm 58$  vs.  $1518 \pm 122$  kg/ha, respectively). Organic weed production was significantly greater ( $P<0.05$ ) than conventional ( $64 \pm 10$  vs.  $20 \pm 5$  kg/ha, respectively).

*Grazing 2.* Organic and conventional plots were grazed for the second time June 5, 2010. Management did not affect alfalfa production ( $P=0.933$ ). Organic forage production tended to be greater ( $P=0.098$ ) than conventional ( $3370 \pm 221$  vs.  $2695 \pm 180$  kg/ha, respectively). In addition, organic biomass tended to be greater ( $P=0.083$ ) than conventional

(3437± 210 vs. 2742± 171 kg/ha, respectively). Management did not affect weed production (P=0.636).

*Grazing 3.* Organic and conventional plots were grazed for the third time July 20, 2010. Management did not affect alfalfa production (P=0.639), forage production (P=0.744), biomass (P=0.329), or weed production (P=0.459). Organic and conventional plots were grazed for the fourth time August 19, 2010. Management did not affect alfalfa production (P=0.147), forage production (P=0.147), biomass (P=0.216), or weed production (P=0.751).

*Cumulative Production Grazing 2010.* In terms of cumulative production over 2010, organic alfalfa production did not differ from conventional alfalfa production (6116± 472 vs. 5572± 352 kg/ha, respectively). However, organic forage production tended to be greater than conventional forage production (7256± 504 vs. 5740± 376 kg/ha, respectively). Organic biomass production tended to be greater (P=0.061) than conventional biomass production (8028± 476 vs. 6288± 352 kg/ha, respectively). Management did not affect weed production (P=0.376).

### ***Field 1(Planted 2009): Grazing 2011***

#### ***Management***

*Grazing 1.* Management effects on grazing are shown in Table 2. Organic and conventional plots were grazed February 6, 2011. Management did not affect alfalfa production (P=0.924), forage production (P=0.722), biomass (P=0.841), or weed production (P=0.737).

*Grazing 2.* Organic plots were grazed for a second time 17 days earlier (March 18, 2010) than conventional plots (April 4, 2010) because of weevil pressure. Management did

not affect alfalfa production ( $P=0.444$ ), forage production ( $P=0.198$ ), or biomass ( $P=0.449$ ). However, conventional weed production was significantly greater ( $P<0.05$ ) than organic ( $440 \pm 40$  vs.  $216 \pm 48$  kg/ha, respectively).

*Grazing 3.* Organic plots (April 29, 2010) and conventional plots (May 7, 2010) were grazed about a week apart for a third time. Conventional alfalfa production was significantly greater ( $P<0.10$ ) organic ( $3204 \pm 126$  vs.  $2712 \pm 153$  kg/ha, respectively). However, management did not affect forage production ( $P=0.213$ ), biomass ( $P=0.269$ ), or weed production ( $P=0.474$ ).

*Cumulative Production Grazing 2011.* In terms of cumulative production, conventional alfalfa production tended to be greater ( $P<0.10$ ) than organic alfalfa production ( $3204 \pm 126$  vs.  $2712 \pm 153$  kg/ha, respectively). However, management did not affect forage production ( $P=0.238$ ) or biomass ( $P=0.779$ ). Cumulative conventional weed production tended to be greater ( $P<0.10$ ) than organic weed production ( $600 \pm 66$  vs.  $324 \pm 81$ , respectively).

## ***Field 2: Grazing 2011***

### ***Management***

Field 2 (May 7, 2011) is summarized in Table 3. Organic alfalfa production was significantly greater ( $P<0.01$ ) than conventional alfalfa production ( $1429 \pm 52$  vs.  $1104 \pm 52$  kg/ha, respectively). Organic forage production was also significantly greater ( $P<0.01$ ) than conventional forage production ( $1540 \pm 58$  vs.  $1104 \pm 52$  kg/ha, respectively). Organic biomass was significantly greater ( $P<0.01$ ) than conventional biomass ( $1589 \pm 61$  vs.  $1195 \pm 61$ ). Management did not affect weed production ( $P=0.112$ ).

### *Prairie Grass Treatment*

The effect of interseeding prairie grass in organic alfalfa is summarized in Table 4. PG treatment did not significantly affect the alfalfa production ( $P=0.453$ ), forage production ( $P=0.488$ ), biomass ( $P=0.453$ ) or weed production ( $P=0.701$ ).

### ***Other Results***

*Field 1 (planted 2009) grazing 2010.* Plots were grazed at 1/10<sup>th</sup> bloom because previous research has found that alfalfa has the highest crude protein at this stage and least amount of neutral detergent fiber (Sheaffer, 2009). The biomass samples taken indicated that voluntary ryegrass did not suppress alfalfa production in December 2009 or February 2010. Although weed pressure was higher in organic plots, the forage production was greater when voluntary grasses were not controlled. Thus, the control of grasses and broadleaf weeds did not increase the production of alfalfa. For grazing producers of North Carolina annual ryegrass could be a possible option for boosting production. None of the dairy cattle used in this study suffered from bloat, but the interseeded prairie grass could have been beneficial in bloat prevention, along with feeding before grazing (Lacefield, 1996). Conventional alfalfa production in February was significantly greater, so if producers are looking for a greater production of alfalfa, then conventional management would be recommended. In terms of forage production, voluntary annual ryegrass production compensated for lost production of alfalfa. Annual ryegrass has been found to be compatible with alfalfa by other agronomists (Sulc and Albrecht, 1996). In fact, short-lived annuals are commonly used for the establishment of perennial legumes (Tesar, 1976). For producers that are grazing alfalfa,

mixtures are often preferred to reduce the chance of bloat, while not decreasing over forage production.

Herbicide control and grazing time were the two main management differences between the organic and conventional grazing plots. Herbicide application at planting prevented the establishment of broad leaf weeds at planting in 2009. Organic plots were grazed 21 days earlier due to weevil pressure. Action was taken when the economic threshold of three weevils per stem was reached (Long, 2009). The less alfalfa production in the first grazing was expected from the earlier grazing date. Conventional plots were grazed at 1/10<sup>th</sup> bloom because weevil pressure did not increase to threshold level. Weevil pressure was thought to be less because of the lack of henbit (weed) pressure that was treated with Eptam application. January and February biomass samples indicated high henbit pressure in organic plots. Previous research has suggested that some weeds, such as henbit can serve as an ovipositioning site for the alfalfa weevil (Norris, 2000). Although weevil larvae do not feed henbit, they use the stem as an ovipositioning site. Interestingly, the voluntary ryegrass production of the organic plots made the forage production of alfalfa not significantly different, although it was harvested 21 days earlier. The higher weed pressure of organic was expected because conventional plots were controlled with herbicide. Overall production was greatest in June, at the second grazing. This is similar to the production of alfalfa in a hay system because research reports that the second cutting is the greatest production (McCloud, 1953). Although there was no significant difference in alfalfa production, organic forage production was significantly greater than conventional because ryegrass added a significant amount of forage to the sward. Organic plant counts were lower at this point, which shows

that grasses did compete against alfalfa for plant establishment. Organic alfalfa production had longer re-growth period than conventional, which allowed alfalfa production to be similar with conventional at the second grazing. From May 1 –May 15 2010 this site only accumulated 0.2 cm of rain, so alfalfa went into dormancy during the time of moisture stress. Other alfalfa research has also reported summer dormancy during months of less precipitation (Cassida et al., 2006).

Increased production of pigweed was not significantly different under organic or conventional management for July, which means that the open sites that were created for the interseeding of a grass did not affect the production of summer weeds. From this, it can be concluded that pigweed is more competitive than alfalfa and that its production will not change depending on the alfalfa production of the previous grazing. Previous studies have also reported that alfalfa percent composition decreases when conditions are dry, compared to humid conditions (Lorenz et al., 1961). As a forage, pigweed is not as palatable to the cow once it forms a seed head, however cows have been found to graze it in the vegetative stage. There are many weed species that are palatable to cows if grazed before the seedhead development (Lawrence, 1989). Unlike alfalfa production in a hay system, these weeds can be consumed at a palatable stage in a grazing system and offer some nutritional value. In the course of the establishment year, alfalfa production, along with grass production was very dynamic, shifting at each harvest. Other research has reported the fluctuation of alfalfa production throughout the season, with the greatest weed pressure during July and August (Kalton, 1952).

In terms of cumulative production, management did not change the production of alfalfa or weed production, with pigweed being the greatest contribution to cumulative weed production. In fact, the voluntary ryegrass under organic alfalfa production provided a significantly greater forage production without suppressing the cumulative production of alfalfa. Organic alfalfa competed well with voluntary ryegrass, and previous research has explained that alfalfa roots penetrate deeper than grass roots, and can compete effectively for water (Chamblee, 1958) and nutrients (Havlin, 2005). Thus, successful forage production in an organic system depends on the voluntary grasses that are in the seedbed, and voluntary annual ryegrass can boost cumulative production over four grazings in the establishment year.

*Field 1 (planted 2009) grazing 2011.* In the second grazing season, the plots were grazed February 27 in order to clear dead plant material from the field and reduce overwintering populations of alfalfa weevil (2008). Unlike 2010, organic alfalfa was interseeded with prairie grass in the fall as an organic management choice to suppress weed production. Conventional plots tended to have greater weed production at May 2011, so the use of herbicide at establishment did not have a lasting affect into the second year of grazing. Prairie grass was allowed to grow in open sites of organic alfalfa production. These results are supported by previous research where grasses invaded open sites to keep forage production high and reduce weed production (Smith, 1981; Triplett et al., 1977). Interseeding prairie grass did not boost forage production, compared to conventional forage production. These results were similar to a five year study conducted that reported the inclusion of brome grass with alfalfa did not increase yields (Wilsie, 1949). However, McCould ( 1953)

reported in Indiana that that alfalfa mixtures with bromegrass had higher yields compared to alfalfa alone. Interestingly, the initial use of herbicide at conventional establishment did prevent voluntary ryegrass production in the second season. Organic plots were grazed early to avoid production loss from the alfalfa weevil. Organic alfalfa was grazed for the first time in March, instead of April (as in 2010) because the weevil pressure appeared sooner than the establishment year. Conventional plots experienced higher weevil pressure than the establishment year, which could be attributed to the higher production of weeds. When weevils reached threshold, conventional grazing plots could have been sprayed with insecticide, but the holding time for grazing was 14 days, which would have allowed alfalfa to become overly mature. Grazing to manage weevil population is also a conventional practice (ISU, 1992).

In terms of cumulative alfalfa production, conventional management production was higher in spring 2011, but organic prairie grass and voluntary annual ryegrass production compensated for lost alfalfa production. Organic alfalfa also had lower plant counts, indicating that ryegrass and prairie grass had a competitive role in the persistence of alfalfa in the second year. Both organic and conventional plant counts were lower in second season, and these results are supported by previous research that reported a linear stand decline with time (Cassida et al., 2006). Since the economic guideline is to have 20-40 plants/m<sup>2</sup> (Triplett et al., 1977), both organic and conventional alfalfa stands were viable in the second season. It is recommended that if counts are 30-40 plants/m<sup>2</sup> (Orloff, 2010), then action should be taken to prevent invading weeds. Thus, interseeding prairie grass was an appropriate decision for organic alfalfa production. This trend was also present in the early grazing of 2010, where

ryegrass compensated for lost alfalfa production. Sampling through the entire season of 2011 would be necessary to determine if management significantly affected the production of alfalfa. Thus, the spring 2011 alfalfa production followed a similar trend as the early 2010 alfalfa production. No rainfall May 16-May 28 caused both organic and conventional alfalfa to enter dormancy. After the last grazing of the season, conventional plots were wicked with glyphosate (Roundup Powermax®). This effect would be more interesting in the second season, to see if it reduced the pigweed production in the second year.

The identification of *Bathyplectes anurus* was a beneficial insect that acts as a parasite to the alfalfa weevil. These were unintentionally introduced to this area and exemplify integrated pest management. If conventional plots had been treated with insecticide, this natural predator may have been eliminated in the process.

*Field 2 (planted 2010) grazing 2011.* Unlike the establishment of field 1, the first grazing of field 2 had greater organic alfalfa production. Reasons for this difference are that Eptam application seemed to have a suppressive effect on the establishment of alfalfa. This effect has been found in other alfalfa establishment studies (Beardmore and Linscott, 1988), although not with this particular herbicide. In the establishment year of field 1, the voluntary ryegrass pressure was high enough in organic plots to suppress alfalfa production beyond any suppressive effect of conventional herbicide use. Because field 2 had less voluntary grass pressure, herbicide suppression was detected.

Unlike field 1, half of organic plots were interseeded to prairie grass at establishment in fall 2010. Prairie grass in these plots did not suppress alfalfa production, but also did not boost overall production in the first grazing. These results were much different than the

suppressive effects of ryegrass to alfalfa production in field 1. These results are similar to the affects of prairie grass interseeded to field 1 in fall 2010, where voluntary ryegrass did not suppress alfalfa production. Chickweed production was not suppressed, which was different than the interseeding of prairie grass into field 1. Reason for differences is that chickweed pressure in field 2 was low for organic and conventional treatments (3%-7%).

In conclusion, voluntary annual ryegrass played an important role in forage production of organic alfalfa in the establishment year. Voluntary ryegrass did not suppress cumulative organic alfalfa production, but allowed forage production to surpass conventional forage production, which controlled for grasses. Grasses suppressed alfalfa production in the start of the second year, and thus could eventually affect the persistence of alfalfa. Summer weed production was the most competitive weed in both organic and conventional alfalfa production, and its conventional control could determine the persistence of alfalfa production. The production of alfalfa was highest in the second grazing, which was early June, so alfalfa could be an important contribution to the grazing system before the summer forages.

## **Discussion**

*Field 1 (planted 2009) grazing 2010.* Plots were grazed at 1/10<sup>th</sup> bloom because previous research has found that alfalfa has the highest crude protein at this stage and least amount of neutral detergent fiber (Sheaffer, 2009). The biomass samples taken indicated that voluntary ryegrass did not suppress alfalfa production in December 2009 or February 2010. Although weed pressure was higher in organic plots, the forage production was greater when voluntary grasses were not controlled. Thus, the control of grasses and broadleaf weeds did not increase

the production of alfalfa. For grazing producers of North Carolina annual ryegrass could be a possible option for boosting production. None of the dairy cattle used in this study suffered from bloat, but the interseeded prairie grass could have been beneficial in bloat prevention, along with feeding before grazing (Lacefield, 1996). Conventional alfalfa production in February was significantly greater, so if producers are looking for a greater production of alfalfa, then conventional management would be recommended. In terms of forage production, voluntary annual ryegrass production compensated for lost production of alfalfa. Annual ryegrass has been found to be compatible with alfalfa by other agronomists (Sulc and Albrecht, 1996). In fact, short-lived annuals are commonly used for the establishment of perennial legumes (Tesar, 1976). For producers that are grazing alfalfa, mixtures are often preferred to reduce the chance of bloat, while not decreasing over forage production.

Herbicide control and grazing time were the two main management differences between the organic and conventional grazing plots. Herbicide application at planting prevented the establishment of broad leaf weeds at planting in 2009. Organic plots were grazed 21 days earlier due to weevil pressure. Action was taken when the economic threshold of three weevils per stem was reached (Long, 2009). The less alfalfa production in the first grazing was expected from the earlier grazing date. Conventional plots were grazed at 1/10<sup>th</sup> bloom because weevil pressure did not increase to threshold level. Weevil pressure was thought to be less because of the lack of henbit (weed) pressure that was treated with Eptam application. January and February biomass samples indicated high henbit pressure in organic plots. Previous research has suggested that some weeds, such as henbit can serve as an ovipositioning site for the alfalfa weevil (Norris, 2000). Although weevil larvae do not feed

henbit, they use the stem as an ovipositioning site. Interestingly, the voluntary ryegrass production of the organic plots made the forage production of alfalfa not significantly different, although it was harvested 21 days earlier. The higher weed pressure of organic was expected because conventional plots were controlled with herbicide. Overall production was greatest in June, at the second grazing. This is similar to the production of alfalfa in a hay system because research reports that the second cutting is the greatest production (McCloud, 1953). Although there was no significant difference in alfalfa production, organic forage production was significantly greater than conventional because ryegrass added a significant amount of forage to the sward. Organic plant counts were lower at this point, which shows that grasses did compete against alfalfa for plant establishment. Organic alfalfa production had longer re-growth period than conventional, which allowed alfalfa production to be similar with conventional at the second grazing. From May 1 –May 15 2010 this site only accumulated 0.2 cm of rain, so alfalfa went into dormancy during the time of moisture stress. Other alfalfa research has also reported summer dormancy during months of less precipitation (Cassida et al., 2006).

Increased production of pigweed was not significantly different under organic or conventional management for July, which means that the open sites that were created for the interseeding of a grass did not affect the production of summer weeds. From this, it can be concluded that pigweed is more competitive than alfalfa and that its production will not change depending on the alfalfa production of the previous grazing. Previous studies have also reported that alfalfa percent composition decreases when conditions are dry, compared to humid conditions (Lorenz et al., 1961). As a forage, pigweed is not as palatable to the cow

once it forms a seed head, however cows have been found to graze it in the vegetative stage. There are many weed species that are palatable to cows if grazed before the seedhead development (Lawrence, 1989). Unlike alfalfa production in a hay system, these weeds can be consumed at a palatable stage in a grazing system and offer some nutritional value. In the course of the establishment year, alfalfa production, along with grass production was very dynamic, shifting at each harvest. Other research has reported the fluctuation of alfalfa production throughout the season, with the greatest weed pressure during July and August (Kalton, 1952).

In terms of cumulative production, management did not change the production of alfalfa or weed production, with pigweed being the greatest contribution to cumulative weed production. In fact, the voluntary ryegrass under organic alfalfa production provided a significantly greater forage production without suppressing the cumulative production of alfalfa. Organic alfalfa competed well with voluntary ryegrass, and previous research has explained that alfalfa roots penetrate deeper than grass roots, and can compete effectively for water (Chamblee, 1958) and nutrients (Havlin, 2005). Thus, successful forage production in an organic system depends on the voluntary grasses that are in the seedbed, and voluntary annual ryegrass can boost cumulative production over four grazings in the establishment year.

*Field 1 (planted 2009) grazing 2011.* In the second grazing season, the plots were grazed February 27 in order to clear dead plant material from the field and reduce overwintering populations of alfalfa weevil (2008). Unlike 2010, organic alfalfa was interseeded with prairie grass in the fall as an organic management choice to suppress weed production.

Conventional plots tended to have greater weed production at May 2011, so the use of herbicide at establishment did not have a lasting affect into the second year of grazing. Prairie grass was allowed to grow in open sites of organic alfalfa production. These results are supported by previous research where grasses invaded open sites to keep forage production high and reduce weed production (Smith, 1981; Triplett et al., 1977). Interseeding prairie grass did not boost forage production, compared to conventional forage production. These results were similar to a five year study conducted that reported the inclusion of brome grass with alfalfa did not increase yields (Wilsie, 1949). However, McCould ( 1953) reported in Indiana that that alfalfa mixtures with brome grass had higher yields compared to alfalfa alone. Interestingly, the initial use of herbicide at conventional establishment did prevent voluntary ryegrass production in the second season. Organic plots were grazed early to avoid production loss from the alfalfa weevil. Organic alfalfa was grazed for the first time in March, instead of April (as in 2010) because the weevil pressure appeared sooner than the establishment year. Conventional plots experienced higher weevil pressure than the establishment year, which could be attributed to the higher production of weeds. When weevils reached threshold, conventional grazing plots could have been sprayed with insecticide, but the holding time for grazing was 14 days, which would have allowed alfalfa to become overly mature. Grazing to manage weevil population is also a conventional practice (author? 1992).

In terms of cumulative alfalfa production, conventional management production was higher in spring 2011, but organic prairie grass and voluntary annual ryegrass production compensated for lost alfalfa production. Organic alfalfa also had lower plant counts,

indicating that ryegrass and prairie grass had a competitive role in the persistence of alfalfa in the second year. Both organic and conventional plant counts were lower in second season, and these results are supported by previous research that reported a linear stand decline with time (Cassida et al., 2006). Since the economic guideline is to have 20-40 plants/m<sup>2</sup> (Triplett et al., 1977), both organic and conventional alfalfa stands were viable in the second season. It is recommended that if counts are 30-40 plants/m<sup>2</sup> (Orloff, 2010), then action should be taken to prevent invading weeds. Thus, interseeding prairie grass was an appropriate decision for organic alfalfa production. This trend was also present in the early grazing of 2010, where ryegrass compensated for lost alfalfa production. Sampling through the entire season of 2011 would be necessary to determine if management significantly affected the production of alfalfa. Thus, the spring 2011 alfalfa production followed a similar trend as the early 2010 alfalfa production. No rainfall May 16-May 28 caused both organic and conventional alfalfa to enter dormancy. After the last grazing of the season, conventional plots were wicked with glyphosate (Roundup Powermax®). This effect would be more interesting in the second season, to see if it reduced the pigweed production in the second year.

The identification of *Bathyplectes anurus* was a beneficial insect that acts as a parasite to the alfalfa weevil. These were unintentionally introduced to this area and exemplify integrated pest management. If conventional plots had been treated with insecticide, this natural predator may have been eliminated in the process.

*Field 2 (planted 2010) grazing 2011.* Unlike the establishment of field 1, the first grazing of field 2 had greater organic alfalfa production. Reasons for this difference are that Eptam application seemed had a suppressive affect on the establishment of alfalfa. This

effect has been found in other alfalfa establishment studies (Beardmore and Linscott, 1988), although not with this particular herbicide. In the establishment year of field 1, the voluntary ryegrass pressure was high enough in organic plots to suppress alfalfa production beyond any suppressive effect of conventional herbicide use. Because field 2 had less voluntary grass pressure, herbicide suppression was detected.

Unlike field 1, half of organic plots were interseeded to prairie grass at establishment in fall 2010. Prairie grass in these plots did not suppress alfalfa production, but also did not boost overall production in the first grazing. These results were much different than the suppressive effects of ryegrass to alfalfa production in field 1. These results are similar to the affects of prairie grass interseeded to field 1 in fall 2010, where voluntary ryegrass did not suppress alfalfa production. Chickweed production was not suppressed, which was different than the interseeding of prairie grass into field 1. Reason for differences is that chickweed pressure in field 2 was low for organic and conventional treatments (3%-7%).

## CONCLUSION

In conclusion, voluntary annual ryegrass played an important role in forage production of organic alfalfa in the establishment year. Voluntary ryegrass did not suppress cumulative organic alfalfa production, but allowed forage production to surpass conventional forage production, which controlled for grasses. Grasses suppressed alfalfa production in the start of the second year, and thus could eventually affect the persistence of alfalfa. Summer weed production was the most competitive weed in both organic and conventional alfalfa production, and its conventional control could determine the persistence of alfalfa production. The production of alfalfa was highest in the second grazing, which was early

June, so alfalfa could be an important contribution to the grazing system before the summer forages.

## REFERENCES

- Ball, D.M., Hoveland, C.S., Lacefield, G.D. 2007. Southern Forages. 4th Edition ed.  
International Plant Nutrition Institute, Norcross, GA.
- (ed.) 1996. 26th Natl. Alfalfa Symp., East Lansing, MI. 4-5 Mar. 1996. Certified Alfalfa  
Seed Council, Davis, CA.
- (ed.) 2009. 2009 western alfalfa and forage conference, Reno, NV. UC Cooperative  
Extension.
- Beardmore, R.A., and D.L. Linscott. 1988. Postemergence Herbicide Suppression of Wheat,  
*Triticum aestivum*, Growing with Alfalfa, *Medicago sativa*. *Weed Science* 36:636-  
641.
- Briske, D.D., and J.W. Stuth. 1982. Tiller defoliation in a moderate and heavy grazing  
regime. *Journal of Range Management* 35:511-514.
- Cassida, K.A., C.B. Stewart, V.A. Haby, and S.A. Gunter. 2006. Alfalfa as an alternative to  
bermudagrass for pastured stocker cattle systems in the southern USA. *Agron. J.*  
98:705-713.
- Chamblee, D.S. 1958. The relative removal of soil moisture by alfalfa and orchardgrass.  
*Agron. J.* 50:587-589.
- Havlin, J.L., Beaton, J.D., Tisdale, S.L., Nelson, W.L. 2005. Soil fertility and fertilizers  
Pearson Education, Upper Saddle River, NJ.
- ISU, 1992. Biological Control of the Alfalfa Weevil. Iowa State University Extension

- Kalton, R.R., Wilsie, C.P. 1952. Effect of bromegrass variety on yield and composition of a brome-alfalfa mixture. *Agron J.* 45:308-311.
- (ed.) 1996. 26th Natl. Alfalfa Symp., East Lansing, MI. 4-5 Mar. 1996. Certified Alfalfa Seed Council, Davis, CA.
- (ed.) 1989. Eleventh North American Prairie Conference.
- (ed.) 2009. 2009 western alfalfa and forage conference, Reno, NV. UC Cooperative Extension.
- Lorenz, R.J., C.W. Carlson, G.A. Rogler, and H. Holmen. 1961. Bromegrass and bromegrass-alfalfa yields as influenced by moisture level, fertilizer rates, and harvest frequency. *Agron. J.* 53:49-52.
- McCloud, D.E., and G.O. Mott. 1953. Influence of association upon the forage yield of legume-grass mixtures. *Agron. J.* 45:61-65.
- Norris, R.F.K.M. 2000. Interactions between weeds, arthropod pests, and their natural enemies in managed ecosystems. *Weed Science* 48:94-158.
- (ed.) 2010. 2010 Alfalfa & forage symposium and corn/cereal soilage mini-symposium, Visalia, CA. UC Cooperative Extension.
- Sellars, M.D. 1988. Manawatu dairy farmers experiences with matua prairie grass. *Proc. N.Z. Grassl. Assoc.* 49:185-186.
- Sheaffer, C., Moncada, K. 2009. Introduction to agronomy food, crop, and environment Delmar Cengage Learning, Clifton Park, NY.
- Smith, S.R., J.H. Bouton, and C.S. Hoveland. 1989. Alfalfa persistence and regrowth potential under continuous grazing. *Agronomy Journal* 81:960-965.

- Smith, D. 1981. Seeding establishment of legumes and grasses Kendall/Hunt, Dubuque, IA.
- Sulc, R.M., and K.A. Albrecht. 1996. Alfalfa establishment with diverse annual ryegrass cultivars. *Agron. J.* 88:442-447.
- Tesar, M.B. 1976. Sod seeding birdsfoot trefoil and alfalfa. *Mich. Coop. Ext. Serv.:*E-956.
- Triplett, G.B., R.W.V. Keuren, and J.D. Walker. 1977. Influence of 2,4-D, pronamide, and simazine on dry matter production and botanical composition of an alfalfa-grass sward. *Crop Sci.* 17:61-65.
- UC, 2008. Integrated Pest Management. Statewide IPM Program, University of California Extension Office.
- Walton, P.D., R. Martinez, and A.W. Bailey. 1981. A comparison of continuous and rotational grazing. *Journal of Range Management* 34:19-21.
- Wilsie, C.P. 1949. Evaluation of grass-legume associations with emphasis on the yields of brome grass varieties. *Agronomy Journal* 41:412-420.

**Table 1.** Field 1 (planted 2009) Grazing 2010—The effect of management (organic vs. conventional) on the alfalfa, forage, biomass, and weed production at four grazing events. Forage production included alfalfa, ryegrass, and crabgrass production. Biomass included alfalfa, ryegrass, crabgrass, and weed production. Values reported are LS means and SEM.

Production (kg/ha)	Treatment	Grazing 2010				Cumulative 2010
		April <sup>1</sup>	June <sup>2</sup>	July <sup>3</sup>	Aug <sup>4</sup>	
Alfalfa	Organic	879 ± 101	2636 ± 240	1216 ± 138	954 ± 111	6116 ± 472
	Conventional	1165 ± 48	2607 ± 196	1123 ± 113	676 ± 91	5572 ± 352
	<i>P</i> -value	0.083	0.933	0.639	0.100	0.421
Forage	Organic	1454 ± 125	3370 ± 221	1237 ± 137	954 ± 111	7256 ± 504
	Conventional	1196 ± 59	2695 ± 180	1173 ± 112	676 ± 91	5740 ± 376
	<i>P</i> -value	0.158	0.098	0.744	0.100	0.096
Biomass	Organic	1518 ± 122	3437 ± 210	1612 ± 120	1134 ± 118	8028 ± 476
	Conventional	1217 ± 58	2742 ± 171	1432 ± 98	899 ± 167	6288 ± 352
	<i>P</i> -value	0.112	0.083	0.329	0.219	0.061
Weed	Organic	64 ± 10	67 ± 29	375 ± 107	180 ± 96	772 ± 172
	Conventional	20 ± 5	47 ± 24	259 ± 87	223 ± 79	548 ± 128
	<i>P</i> -value	0.031	0.636	0.459	0.751	0.376

<sup>1</sup>April 7-9 Organic only grazed for weevil control; grass type was ryegrass; weed type was primarily common chickweed

April 28-30 Conventional only grazed; grass type was ryegrass; weed type was primarily common chickweed

<sup>2</sup>June 5-8 Organic and conventional grazed; grass type was ryegrass; weed type was primarily pigweed

<sup>3</sup>July 20-22 Organic and conventional grazed; grass type was crabgrass; weed type was primarily pigweed

<sup>4</sup>August 19-21 Organic and conventional grazed; no grass production; weed type was primarily pigweed

**Table 2.** Field 1 (planted 2009) Non-destructive Interharvest Samples —Theeffect of management (organic vs. conventional) on the alfalfa, forage, biomass, and weed production at two samples prior to grazing. Forage production included alfalfa, ryegrass, and crabgrass production. Biomass included alfalfa, ryegrass, crabgrass, and weed production. Values reported are LS means and SEM.

Production (kg/ha)	Treatment	Grazing	
		Dec <sup>1</sup> -09	Feb <sup>2</sup> -10
Alfalfa	Organic	221 ± 23	144 ± 12
	Conventional	219 ± 21	236 ± 15
	<i>P</i> -value	0.964	0.017
Forage	Organic	345 ± 28	203 ± 16
	Conventional	219 ± 30	243 ± 15
	<i>P</i> -value	0.12	0.187
Biomass	Organic	471 ± 30	277 ± 18
	Conventional	221 ± 33	251 ± 15
	<i>P</i> -value	0.033	0.355
Weed	Organic	126 ± 9	73 ± 2
	Conventional	0	8 ± 5
	<i>P</i> -value	0.011	0.002

<sup>1</sup>December 17, 2009 Organic and conventional sample; grass type was ryegrass;weed type was primarily henbit

<sup>2</sup>February 27, 2010 Organic and conventional sample; grass type was ryegrass;weed type was primarily henbit

**Table 3.** Field 1 (planted 2009) Grazing 2011—The effect of management (organic vs. conventional) on the alfalfa, forage, biomass, and weed production at three grazing events. Forage production included alfalfa, ryegrass, and prairie grass production. Biomass included alfalfa, ryegrass, prairie grass, and weed production. Values reported are LS means and SEM.

Production (kg/ha)	Treatment	Grazing 2011			Cumulative 2010
		Feb <sup>1</sup>	Mar/Apr <sup>2</sup>	Apr/May <sup>3</sup>	
Alfalfa	Organic	743 ± 51	837 ± 58	1131 ± 84	2712 ± 153
	Conventional	736 ± 41	903 ± 47	1564 ± 68	3204 ± 126
	<i>P</i> -value	0.924	0.444	0.028	0.089
Forage	Organic	761 ± 50	1031 ± 60	1761 ± 96	3552 ± 183
	Conventional	736 ± 41	903 ± 49	1565 ± 79	3204 ± 150
	<i>P</i> -value	0.722	0.198	0.213	0.238
Biomass	Organic	828 ± 57	1247 ± 86	1803 ± 88	3879 ± 189
	Conventional	811 ± 47	1343 ± 70	1649 ± 72	3804 ± 153
	<i>P</i> -value	0.841	0.449	0.269	0.779
Weed	Organic	66 ± 19	216 ± 48	43 ± 39	324 ± 81
	Conventional	75 ± 16	440 ± 40	84 ± 32	600 ± 66
	<i>P</i> -value	0.737	0.038	0.474	0.081

<sup>1</sup> February 6-8, 2011 Organic and conventional grazed as preventative weevil control; grass types were ryegrass and prairie grass; weed type was primarily henbit

<sup>2</sup> March 18-21, 2011 Organic only grazed; grass types were ryegrass and prairie grass; weed type was primarily chickweed  
April 4-7, 2011 Conventional only grazed; grass types were ryegrass and prairie grass; weed type was primarily chickweed

<sup>3</sup> April 29-30, 2011 Organic only grazed; grass types were ryegrass and prairie grass; weed type was primarily chickweed  
May 7-9, 2011 Conventional only grazed; grass types were ryegrass and prairie grass; weed type was primarily chickweed

**Table3.** Field 2 (planted 2010) Grazing 2011—The effect of management (organic vs. conventional) on the alfalfa, forage, biomass, and weed production at the first grazing of the establishment year. Forage production included alfalfa, ryegrass, and prairie grass production. Biomass included alfalfa, ryegrass, prairie grass, and weed production. Values reported are LS means and SEM.

<b>Production (kg/ha)</b>	<b>Treatment</b>	<b>Field 2 2011</b>
		<b>May<sup>1</sup></b>
<b>Alfalfa</b>	<b>Organic</b>	1429
	<b>Conventional</b>	1104
	<b>SEM</b>	52
	<b>P-value</b>	0.004
<b>Forage</b>	<b>Organic</b>	1540
	<b>Conventional</b>	1104
	<b>SEM</b>	58
	<b>P-value</b>	0.001
<b>Biomass</b>	<b>Organic</b>	1589
	<b>Conventional</b>	1195
	<b>SEM</b>	61
	<b>P-value</b>	0.004
<b>Weed</b>	<b>Organic</b>	49
	<b>Conventional</b>	90
	<b>SEM</b>	16
	<b>P-value</b>	0.112

<sup>1</sup> May 7-9, 2011 Conventional and organic grazed, neither reached weevil threshold; grass types were ryegrass and prairie grass (organic only); weed type was primarily chickweed

**Table 4.** Field 2 (planted 2010) Grazing 2011—The effect of organic alfalfa interseeded with prairie grass (PG) vs. organic alfalfa not interseeded with prairie grass (NPG) on the alfalfa, forage, biomass, and weed production at the first grazing of the establishment year. Forage production included alfalfa, ryegrass, and prairie grass production. Biomass included alfalfa, ryegrass, prairie grass, and weed production. Values reported are LS means and SEM.

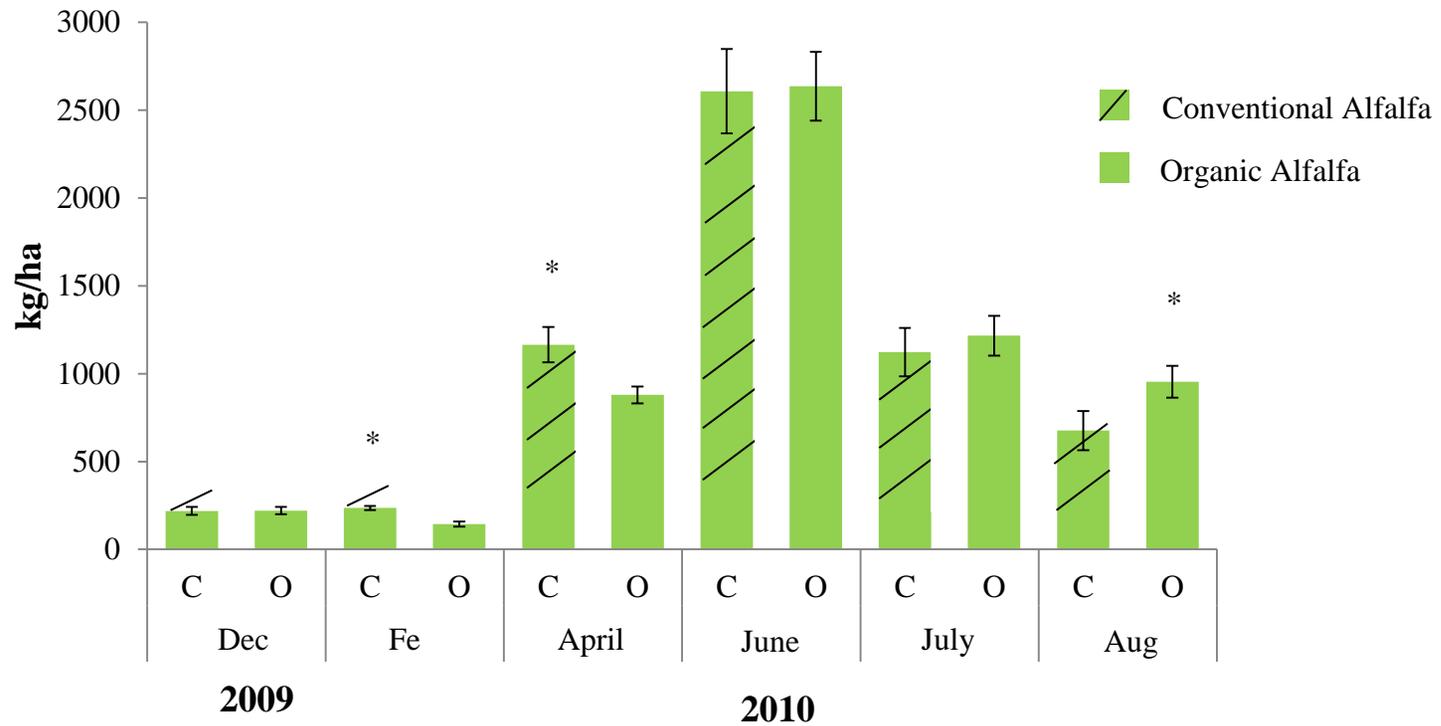
<b>Organic Production (kg/ha)</b>		<b>Field 2 2011</b>	
		<b>Treatment<sup>1</sup></b>	<b>May<sup>2</sup></b>
<b>Alfalfa</b>	<b>PG</b>		1370
	<b>NPG</b>		1465
	<b>SEM</b>		72
	<b>P-value</b>		0.453
<b>Forage</b>	<b>PG</b>		1638
	<b>NPG</b>		1483
	<b>SEM</b>		130
	<b>P-value</b>		0.488
<b>Biomass</b>	<b>PG</b>		1688
	<b>NPG</b>		1527
	<b>SEM</b>		123
	<b>P-value</b>		0.453
<b>Weed</b>	<b>PG</b>		55
	<b>NPG</b>		45
	<b>SEM</b>		20
	<b>P-value</b>		0.701

<sup>1</sup>Organic alfalfa interseeded with prairie grass (PG) and organic alfalfa not interseeded with prairie grass (NPG).

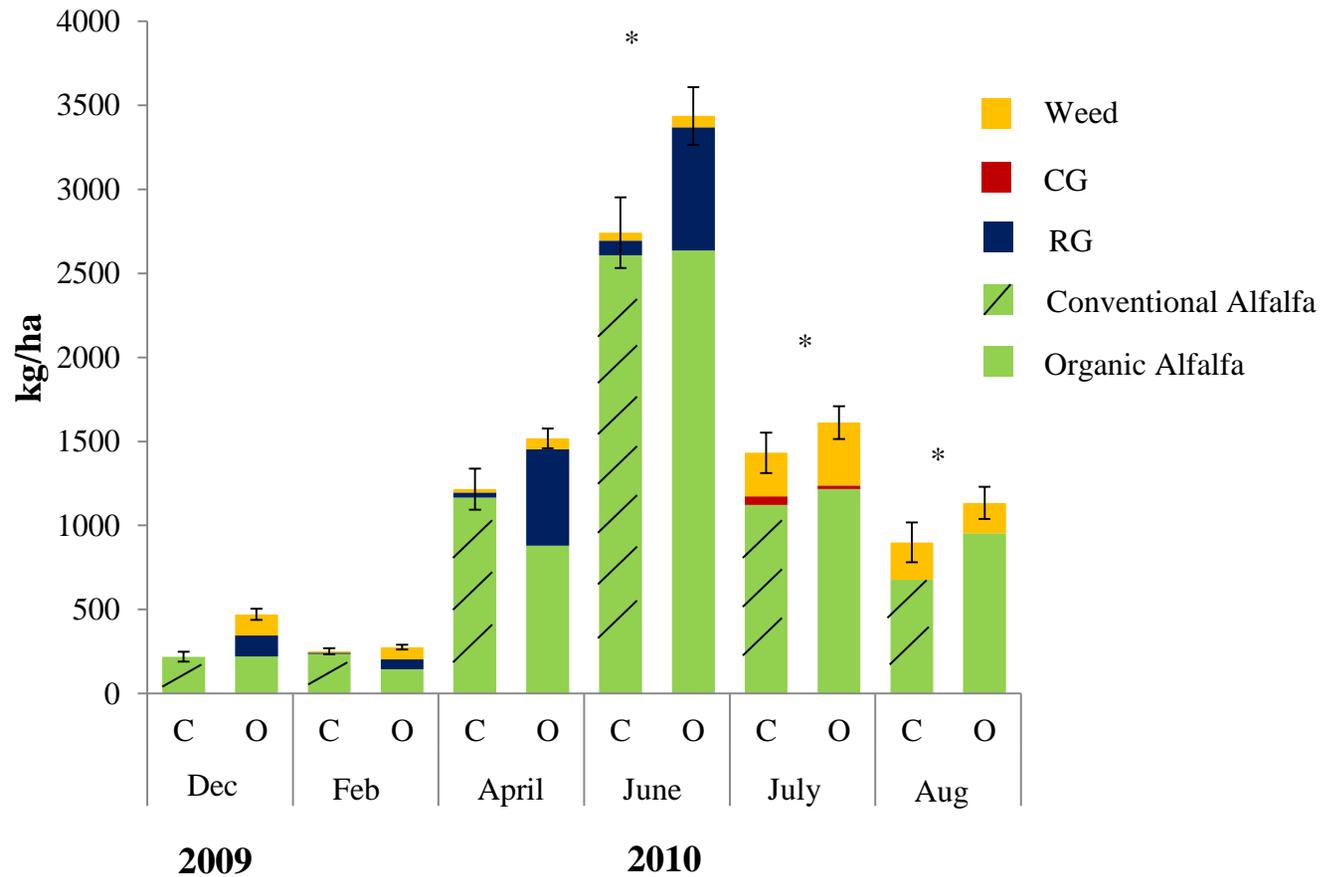
<sup>2</sup>May 7-9, 2011 Organic grazed, did not reach weevil threshold; grass types were ryegrass and prairie grass; weed type was primarily chickweed

**Table 5.** Field 1 (planted 2009) Grazing 2010 and Field 2 (planted 2010) Grazing 2011—The effects of management (organic vs. conventional) on alfalfa plant count. Organic (O) and conventional (C) counts were taken three times in Field 1 (Oct 22, 2010; June 15, 2010; March 25 2011) and twice in Field 2 (December 15, 2010; May 10, 2011).

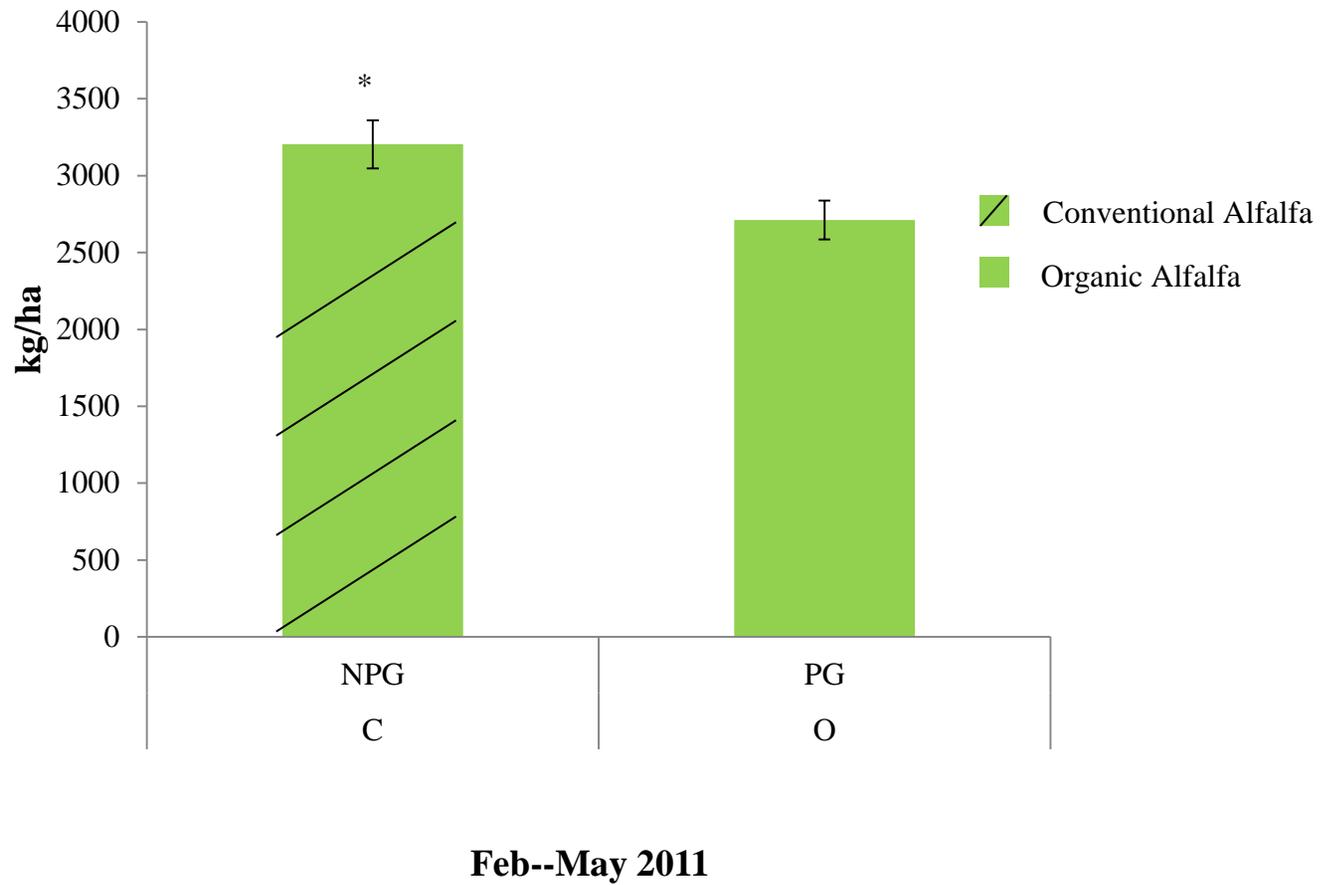
Treatment	Field 1			Field 2	
	Plant Counts 2010		Plant Counts 2011	Plant Counts 2011	
	Oct	June	March	Dec	May
<b>O</b>	46	41	37	64	58
<b>C</b>	45	45	42	60	62
<b>SEM</b>	3	1	3	1.8	1.2
<b>P-value</b>	0.857	0.065	0.068	0.06	0.074



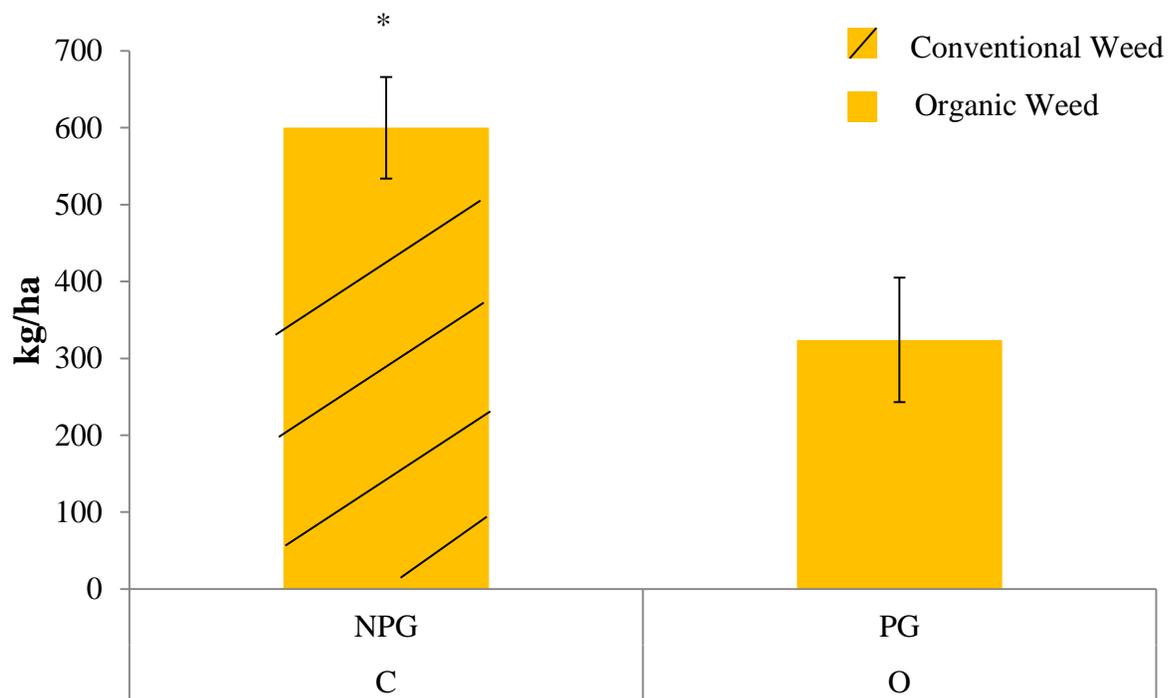
**Figure 1.** Field 1 (Planted 2009) Grazing 2010—The effect of management (organic vs. conventional) on alfalfa production of two samples and four grazing events of the establishment year. Bars represent LS means  $\pm$  SEM. Asterisk (\*) represents significantly difference in management at given sample/harvest ( $P < 0.10$ ).



**Figure 3.** Field 1 (Planted 2009) Grazing 2010—The effect of management (organic vs. conventional) on biomass of two samples and four grazing events of the establishment year. Biomass included alfalfa, ryegrass (RG), crabgrass (CG), and weed production. Bars represent LS means  $\pm$  SEM. Asterisk (\*) represents significant difference in management at the given sample/harvest ( $P < 0.10$ ).

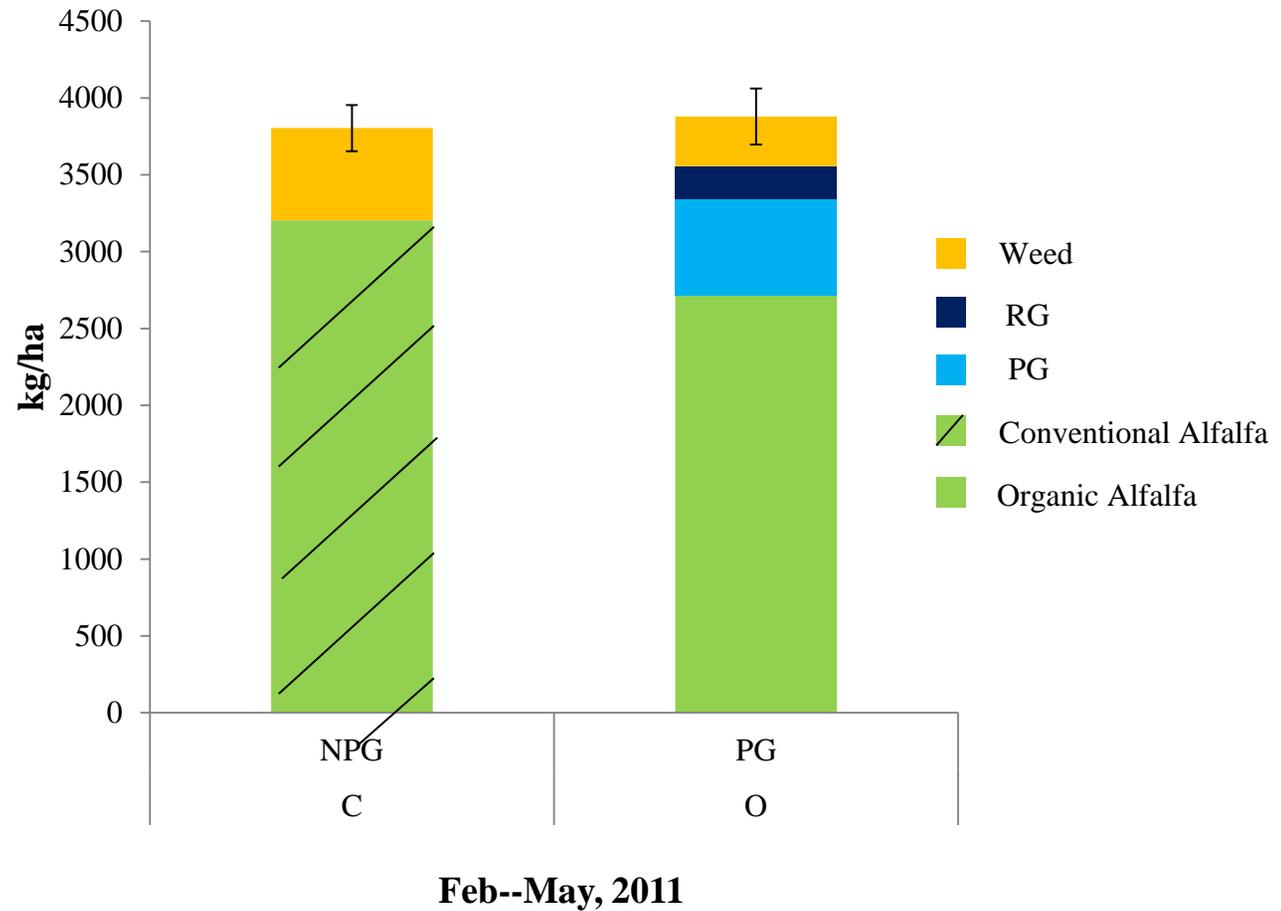


**Figure 4.** Field 1 (Planted 2009) Grazing 2011—The effect of **conventional** alfalfa not interseeded with prairie grass (NPG) vs. **organic** alfalfa interseeded with prairie grass (PG) on the cumulative alfalfa production of three grazing events in the second season (2011). Bars represent LS means  $\pm$  SEM. Asterisk (\*) represents significant difference in production ( $P < 0.10$ ).

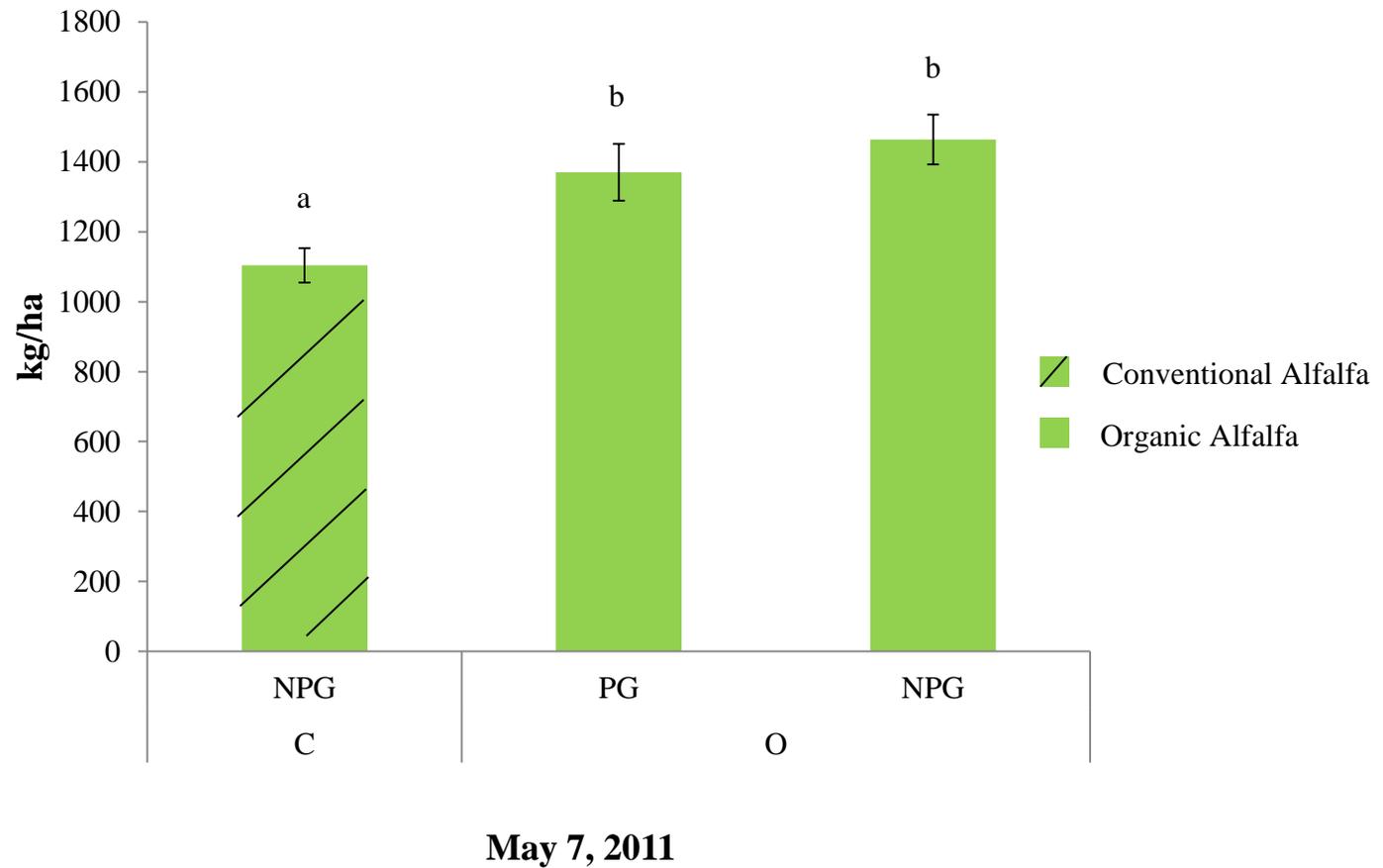


**Feb--May 2011**

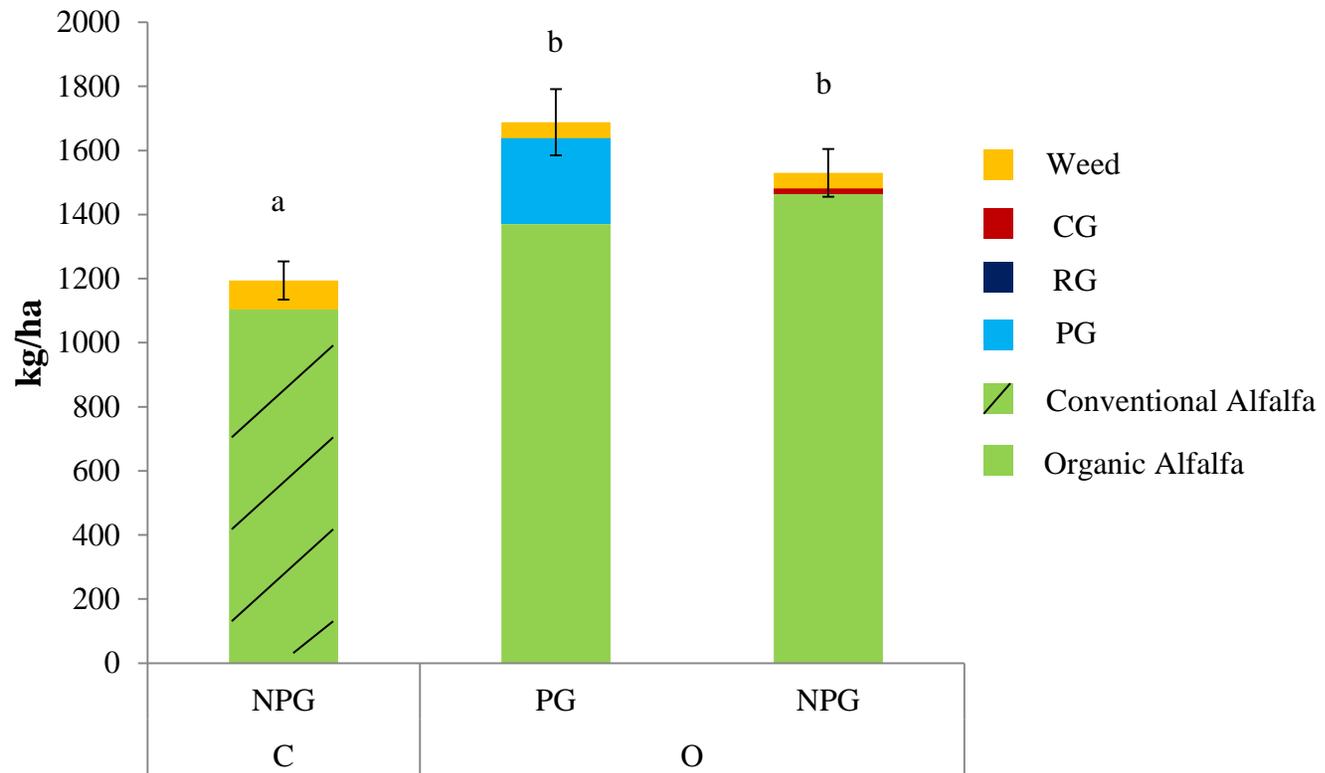
**Figure 5.** Field 1 (Planted 2009) Grazing 2011—The effect of **conventional** alfalfa not interseeded with prairie grass (NPG) vs. **organic** alfalfa interseeded with prairie grass (PG) on the cumulative weed production of three grazing events in the second season (2011). Weed production was primarily common chickweed. Bars represent LS means  $\pm$  SEM. Asterisk (\*) represents significant difference in production ( $P < 0.10$ ).



**Figure 6.** Field 1 (Planted 2009) Grazing 2011—The effect of **conventional** alfalfa not interseeded with prairie grass (NPG) vs. **organic** alfalfa interseeded with prairie grass (PG) on the cumulative biomass of three grazing events in the second season (2011). Biomass included alfalfa, prairie grass (PG), ryegrass (RG), and weed production. Weed production was primarily common chickweed. Bars represent LS means  $\pm$  SEM. Asterisk (\*) represents significant difference in management ( $P < 0.10$ ).

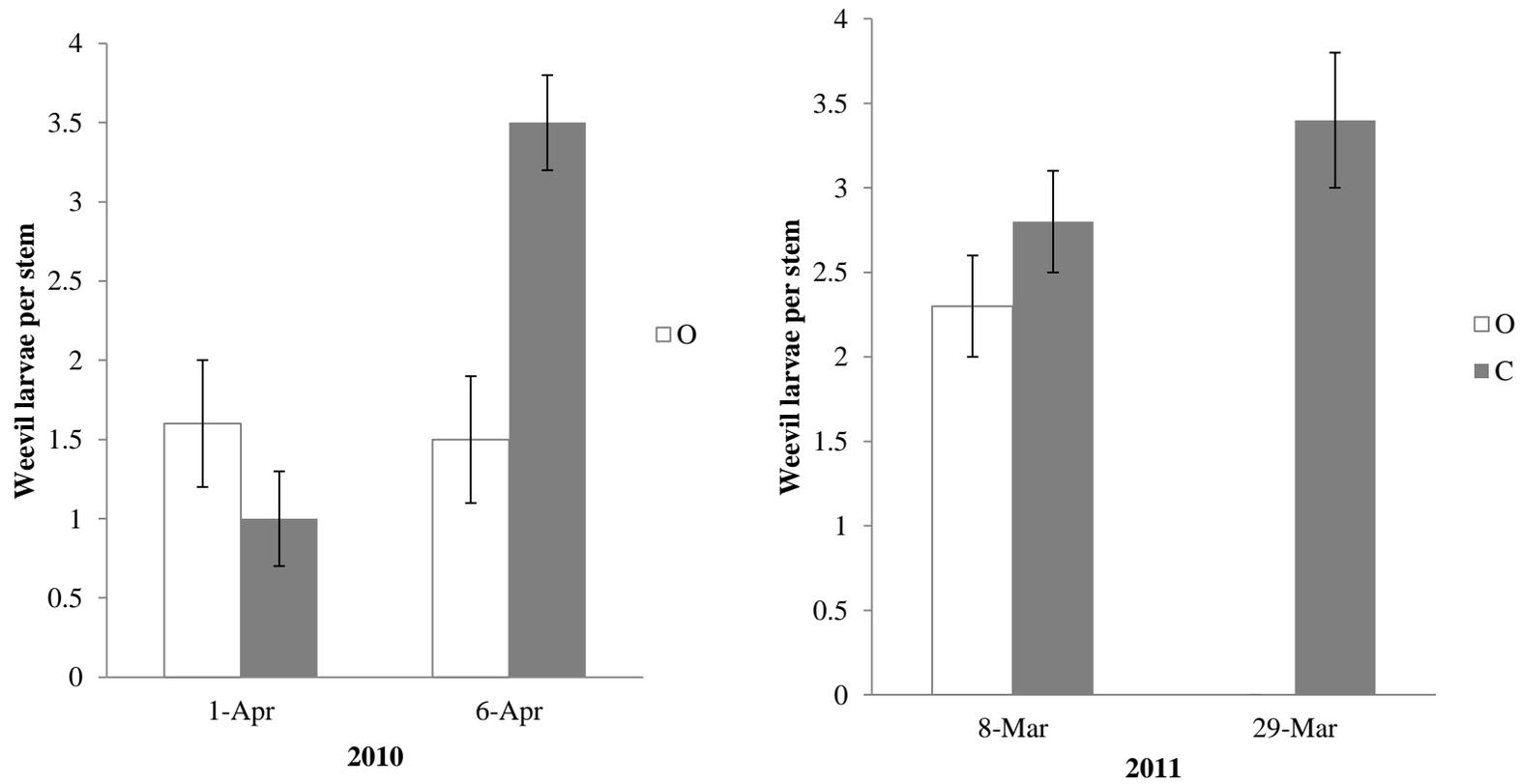


**Figure 7.** Field2 (Planted 2010) Grazing 2011—The effect of **conventional** alfalfa not interseeded with prairie grass (NPG) vs. **organic** alfalfa interseeded with prairie grass (PG) vs. not interseeded with prairie grass (NPG) on cumulative alfalfa production in first grazing of the establishment year on May 7, 2011. Bars represent LS means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).

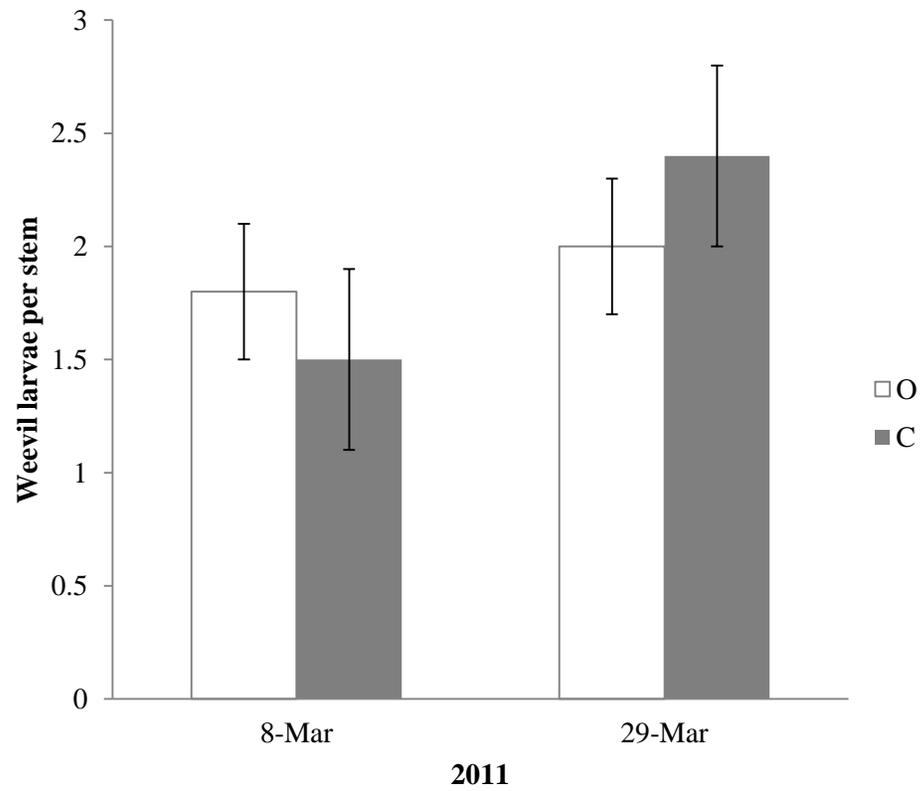


**May 7, 2011**

**Figure 8.** Field2 (Planted 2010) Grazing 2011—The effect of **conventional** alfalfa not interseeded with prairie grass (NPG) vs. **organic** alfalfa interseeded with prairie grass (PG) vs. not interseeded with prairie grass (NPG) on cumulative biomass in first grazing of the establishment year on May 7, 2011. Biomass production included alfalfa, prairie grass (PG), ryegrass (RG), crabgrass (CG), and weed production. Weed production was primarily chickweed. Bars represent LS means  $\pm$  SEM. Within bars, means without a common letter differ ( $P < 0.10$ ).



**Figure 9.** Field 1 (planted fall 2009) Grazing 2010 and 2011—counts of alfalfa weevil larvae on a stem of alfalfa under conventional and organic management.



**Figure 10.** Field 2 (planted fall 2010) counts of alfalfa weevil larvae on a stem of alfalfa under conventional and organic management.