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Three Cover Crop Establishment Studies to Assess Optimal Cover Crop Species, Planting Date, and Seeding Method

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ABSTRACT

Cover crops have a variety of benefits, but have not been widely adopted on farms in Turkey. They can reduce erosion and be advantageous in vineyards where the ground between alleyways is bare. Research conducted between 2015-2016 sought to evaluate cover crop establishment in vineyards when planted in the fall (Experiment I), when planted in the spring (Experiment II), and when broadcast and incorporated (Experiment III). Cover crops planted were field peas, oats, barley, perennial ryegrass, white clover, sainfoin, brome, and mixes of pea/oat, pea/barley, ryegrass/clover and sainfoin/brome. Establishment was evaluated on biomass (dry matter) and percent canopy ground cover measured using digital media analysis. Impact of cover crops on soil moisture was measured through gravimetric methods. Field peas alone and mixed with grasses consistently had the highest percent ground cover and biomass regardless of planting date or method. The brome/sainfoin mix had the highest percent canopy cover when planted in the fall, but when planted in the spring, the sainfoin cover crop planted alone had the highest percent canopy cover and biomass. There was little effect of cover crops on soil moisture.

1. Introduction

Agriculture is thriving in Turkey, particularly in grape production. Turkey is the world's leading raisin exporter and second largest producer after the United States [1]. Turkey ranks sixth in the world for grape exports and is the world's largest dried grape producer [2, 3]. To maintain or exceed this level of high productivity, soil management must be considered. Grape production leaves soils particularly susceptible to water and wind erosion because the alleyway between vines is typically left bare. This can leave the ground susceptible to erosion. For example, Karaş and Oğuz [3] found that in the Sarısu Basin, 44.6% is in agricultural production, but agriculture is responsible for 88.4% of total soil losses, amounting to 3.72 ton ha^{-1} soil loss each year. On agricultural land, this loss turns topsoil from a valuable farm resource into a pollutant that contaminates waterways. Cover crops, typically non-cash crops used for building soil quality, are a best management practice that can improve soil health and reduce agricultural runoff. Cover crops can reduce erosion by providing physical cover and increase infiltration by building aggregate stability [4, 5]. Cover crops with high residue can increase soil organic matter [6]. Soil fertility can be increased when cover crops act as a host of mycorrhizal fungi [7]. Cover crops with fast growing canopies can suppress weeds by competing for sunlight and nutrients or through allelopathy with certain cover crops like sunn hemp (Crotalaria juncea L.), wild oat (Avena fatua L.), and cereal rye (Secale cereal L.) [8-10]. Some cover crops can also reduce pest pressure [11]. These improvements to the soil from cover crops can also contribute to a higher yielding, better quality cash crop while at the same time protecting environmental quality [12]. However, the type of benefit derived from the cover crop depends on the specific cover crop species and management [6]. Cover crops can present some management challenges, and in some applications have potential to adversely affect production. Cover crops have the potential to compete with the cash crop for water and thus reduce available moisture through plant uptake [13]. However, depending on the climate and soil type, some amount of water-stress can result in a higher quality fruit in grape production [14]. Some cover crops have allelopathic properties that can reduce weed populations, but may also decrease cash crop yields [10, 15, 16].

Best management practices, like cover crops, will become increasingly important to curb the damage of more frequent and more extreme weather events. The International Panel on Climate Change (IPCC) climate change models predict that Turkey will experience drier summers, elevated flood risk particularly in the winter, and an increase in heavy precipitation events in all seasons of the year [17]. Drier summers will lead to more drought during peak production seasons and an increase in heavy precipitation will result in a higher likelihood of erosion. These conditions threaten

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agricultural production and water quality. Currently, there is minimal documented use of cover crops in agricultural fields in Turkey.

The objective of this study was to evaluate the effect of cover crop species, planting method, and planting date on cover crop establishment and soil moisture in the vineyards of the Trakya region in Turkey. Three experiments were conducted to measure establishment of: 1) fall planted cover crops, 2) spring planted cover crops, and 3) cover crops seeded through incorporation vs. broadcast methods.

2. Materials and Methods

2.1. Site Description

According to the Köppen climate classification system, the Trakya region has a dry-summer subtropical or Mediterranean climate [18]. It receives 400-600 mm of precipitation, is semi-humid, and has a drought coefficient of 0.75-0.50 [19]. The soils in this region are predominantly a Rendzic Leptisols [20]. This land is classified as moderately eroded, a degree of erosion that affects about 20% of Turkey [21]. According to the Soil Management Map of Turkey, the area in and around the Trakya region is comprised of soils that range from 2-20% slope and are slightly to moderately eroded [22]. Wheat is the predominant crop grown in the Trakya region [23]. However, this area also supplies 75% of Turkey's sunflower for oil production and the Marmara region, of which Trakya is a part, is also one of the five major wine growing regions in Turkey [24, 25].

This study occurred on four vineyards located within the Trakya region of Turkey, Şuleymanpaşa (ŞP), Gündoğdu Mahallesi (GM), Çeşmeli (ÇM), and Barbaros (BB). Cover crops were planted at one vineyard research facility, and three commercially operated vineyards. ŞP is the research facility and applies herbicide as needed, insecticides in the spring, and fungicides throughout the year. Cultivation is done in the spring for weed suppression and fertility is applied as chicken manure and pellet manure in the fall and as 10-20-20 commercial fertilizer in the winter. GM typically applies herbicide and cultivates in the spring for weed suppression. Fertilizer as 20-20-20 is applied in the winter and fungicides are applied throughout the year. ÇM is a no-till operation that does not apply any herbicides. Grape compost is applied to add fertility and copper sulfate is applied in the summer to control fungus. BB applies herbicide as needed, insecticides in the spring, and fungicides throughout the year.

2.2. Plot Management

Seeding recommendations were based on the Turkish Journal of Field Crops by Mustafa TAN and increased by 50% in an effort to adjust for broadcasted by hand, non-incorporated planting methods (Table 1). With the exception of GM, which was tilled with a roto-tiller, all plots were disked prior to planting. Experimental design was random block, split-plot and treatment plot sizes were based on width of alleyway and distance between fence posts at each site (6.0 x 2.7 m^2 at GM and ÇM, 5.8 x 2.2 m^2 at ŞP, and 3.0 x 3.0 m^2 at BB). Treatments can be grouped as large seeded annuals (peas, oats, barley, pea/oat mix, pea/barley mix), small seeded perennials (ryegrass, clover, ryegrass/clover mix), and large seeded perennials (sainfoin, brome, sainfoin/brome mix).

Table 1. Treatments and seeding rates in Gündoğdu Mahallesi (GM), Çeşmeli (ÇM), Şuleymanpaşa (ŞP), and Barbaros (BB).

Treatment	Recommended seeding rate (kg ha^{-1})	Actual seeding rate (kg ha^{-1})	Experiment: Location
White clover	4	6	Fall: GM, ÇM, ŞP Methods: ÇM Spring:BB
Perennial ryegrass	20	30	Fall: GM, ÇM, ŞP Methods: ÇM Spring:BB
Clover/ryegrass mix	2 & 10	3 & 15	Fall: GM, ÇM, ŞP Methods: ÇM Spring:BB
Field pea	120	180	Fall: GM, ÇM, ŞP Methods: ÇM Spring:BB
Oat	120	180	Fall: GM, ÇM, ŞP Methods: ÇM
Oat/pea mix	60 & 60	90 & 90	Fall: GM, ÇM, ŞP Methods: ÇM
Barley	120	180	Spring: BB
Barley/pea mix	60 & 60	90 & 90	Spring: BB
Sainfoin	120	180	Fall: GM, ÇM, ŞP Methods: ÇM
Brome	n/a	200	Fall: GM, ÇM, ŞP Methods: ÇM
Sainfoin/brome mix	n/a	75 & 100	Fall: GM, ÇM, ŞP Methods: ÇM

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2.3. Cover Crop Species, Locations, and Evaluations

Experiment I sought to evaluate the establishment of cover crops planted in the fall. In mid-October of 2015, at GM, ÇM, and ŞP, fall planted cover crop treatments of field peas (Pisum sativum), oats (Avena sativa), perennial ryegrass (Lolium perenne), white clover (Trifolium repens), were planted alone and as mixes of pea/oat, ryegrass/clover, in a random block design with three replicates, including a control (no cover crops planted) in a randomized complete block design. Percent canopy cover was assessed at GM and ÇM roughly 5, 14, 21, and 27 weeks after planting, biomass samples were collected 21 and 27 weeks after planting, and soil samples were collected 5, 21, and 27 weeks after planting (Table 2).

At ŞP, very few seeds germinated after the first planting. It is possible that cover crop growth was inhibited due to legacy effects of an aggressive late-season herbicide management program. In an attempt to continue observations with limited space, replicates two and three were disked, replanted, and lightly incorporated with rakes on November 20th, 2015. It was observed that the initial planting had delayed germination and replicates two and three had typical germination. However, these plantings are excluded from statistical analysis because there were not enough replicates. On that same date in November, three replicates of sainfoin (Onobrychis), brome (Bromus), and a sainfoin/brome mix were planted in a randomized complete block design and lightly incorporated. Percent canopy cover was assessed at ŞP on January 12th, March 5th, and April 28th, 2016. Biomass and soil samples were also collected on March 5th, and April 28th. Experiment II sought to evaluate the establishment of cover crops planted in the spring. Spring planted cover crop treatments were seeded in late March 2016 at BB with the same treatments as the initial fall planted cover crops, except barley (Hordeum vulgare) was planted instead of oats. Due to observed low germination rates in the fall planting, seeding rates for clover, ryegrass, and brome were doubled and the sainfoin rate was reduced by 25%. The actual seeding rate is listed in Table 1. Percent canopy cover was assessed, and biomass and soil samples were collected 8 weeks after planting (Table 2).

Experiment III sought to examine the effects of broadcast versus light incorporation seeding methods on cover crop establishment success. In addition to the fall seeding study, a separate study was initiated at ÇM. The experimental design was a randomized complete block, split-plot design. The main plots were used for cover crop species comparison and subplots were used for evaluation of seeding method. Cover crops were broadcast by hand and incorporated with a rake to simulate light harrowing. Cover crops treatments of oats, peas, oat/pea, ryegrass, clover, ryegrass/clover, sainfoin, brome, and sainfoin brome were planted mid-November 2015. Percent canopy cover was assessed 9 and 16 weeks after planting. Biomass and soil samples at a depth of 0-5 cm were collected 24 weeks after planting (Table 2). Samples for soil moisture were not collected.

2.4. Evaluation Methods

In all experiments, percent canopy cover over the ground and biomass production were measured to assess establishment success. Soil samples were collected to measure soil moisture. Percent canopy ground cover was performed using methodology outlined by Rasmussen and Nørremark using imagin-crops.dk analysis [26]. Percent canopy cover includes cover from cover crops and weeds. Both weeds and cover crops can provide physical cover for the soil thus potentially reducing erosion so percent cover from the weeds in the control were used in percent canopy cover analysis. Biomass was cut at a height of five cm within a 51-centimeter square quadrat, weed and cover crop biomass was separated, weighed wet, dried at 80°C for 24-48 hours, and weighed dry [27]. Results are reported on a dry matter (DM) basis. Soil moisture was determined by aggregating three soil samples per plot, at 0-5 cm and 5-10 cm or until rocks prevented probe insertion (common at ÇM). Rocks greater than 2mm were removed via a sieve, the aggregate soil sample was weighed wet, then weighed after drying at 105°C for 48 hours.

Table 2. Planting and field data collection dates for all experiments.

Location: Study	Planting date	Percent canopy cover assessment date	Biomass sample date	Soil sample date
GM: Fall planting	15-Oct-15	18-Nov-15 15-Jan-16 6-Mar-16 15-Apr-16	6-Mar-16 15-Apr-16	18-Nov-15 6-Mar-16 15-Apr-16
ÇM: Fall planting	9-Oct-15	17-Nov-15 12-Jan-16 6-Mar-16 16-Apr-16	6-Mar-16 16-Apr-16	17-Nov-15 6-Mar-16 16-Apr-16
ŞM: Fall planting	8-Oct-15 20-Nov-15	n/a 12-Jan-16 5-Mar-16 28-Apr-16	n/a 5-Mar-16 28-Apr-16	n/a 5-Mar-16 28-Apr-16
ÇM: Seeding methods	11-Nov-15	12-Jan-16 6-Mar-16	29-Apr-16	29-Apr-16
BB: Spring planting	22-Mar-16	14-May-16	14-May-16	14-May-16

2.5. Data Analysis

All statistical analyses was performed with JMP® version 14 software using Fit Model with Standard Least Squares [28]. Pairwise comparisons were performed using Tukey's Honest Significant Difference (HSD) test. All values are expressed as average values. The significance between treatments was tested by location for each experiment using the Tukey's HSD test at $p<0.05$. The following data was excluded from analysis in Experiment I: all metrics across all sampling dates for clover and clover/rye plots in GM and ÇM due to low or irregular germination, all data from April sampling in ÇM due to extreme biomass loss, and the first planting of cover crop treatments in ŞP due to widespread stunted growth from a legacy herbicide effect. Furthermore, in Experiment I, the ryegrass treatment was only tall enough (>0.5cm) to harvest at GM in April. However, the ryegrass did germinate and therefore was included in percent canopy cover statistical analysis.

3. Results

3.1. Experiment I: Fall Establishment

There were location by treatment interactions for cover crop biomass in March ($p = 0.0034$). Due to these location by treatment interactions, data was not pooled for biomass. Although there were no location by treatment interactions for weed biomass, data were not pooled because weed biomass was collected as a component of the same biomass sample that was used to measure cover crop biomass. There were no location by treatment interactions at any of the four sampling dates for percent canopy cover, weed biomass, or soil moisture at depth of 0-5 or 5-10 cm. Therefore, data was pooled across locations for these variables.

3.1.1. Location Effect

Cover crop biomass, weed biomass, percent canopy cover were higher at GM than at ÇM. Average cover crop biomass across treatments was more than double at GM (1,388 kg ha^{-1}) than at ÇM (667 kg ha^{-1}) in March ($p = 0.0069$). Although not statistically significant ($p = 0.0745$), average weed biomass across treatments in March was over 100 times higher at GM (272 kg ha^{-1}) than at ÇM (2.53 kg ha^{-1}). Percent canopy cover was over twice as high in November 29 ($p = 0.0004$) and January ($p < 0.0001$), and 25% higher in March ($p = 0.0406$) at GM (39.4%, 72.0%, 81.9%, respectively) than at ÇM (13.8%, 26.3%, 62.2%, respectively).

ÇM had higher soil moisture than GM. Soil moisture was significantly higher in the top 5 cm in March ($p < 0.0001$) and April ($p = 0.0027$) at ÇM (25.6% and 14.3%, respectively) than GM (20.0% and 12.3%, respectively). Soil moisture was significantly higher at a depth of 5-10 cm in November ($p = 0.0006$) and March ($p < 0.0001$) at ÇM (16.1% and 23.3%, respectively) than GM (13.7% and 18.3%, respectively). Soil moisture was significantly higher at a depth of 5-10 cm in April ($p = 0.0314$) at GM (15.8%) than ÇM (13.6%).

3.1.1. Effect of Cover Crop Species

The ryegrass established poorly and was only tall enough (> 0.5 cm) to harvest for biomass in April at GM. There were no treatment differences in cover crop biomass among the oat (1,595 kg ha^{-1}), oat/pea mix (1,530 kg ha^{-1}), and pea (1,040 kg ha^{-1}) treatments at GM in March. There was significantly less cover crop biomass in the rye treatment (396 kg ha^{-1}) than the pea/oat mix (3,525 kg ha^{-1}), oat (2,949 kg ha^{-1}), and pea (2,605 kg ha^{-1}) treatments ($p=0.0080$; HSD: 2,049) in April. There were no significant differences in weed biomass at GM in March among the control (832 kg ha^{-1}), pea (244 kg ha^{-1}), oat/pea, oat (12.9 kg ha^{-1}), and ryegrass treatments (0.0 kg ha^{-1}) ($p = 0.1055$), but in April the weed biomass in the oat, peas, and oat/pea treatments was 0.0 kg ha^{-1}, and was significantly less than the control (1,179 kg ha^{-1}) ($p = 0.0099$; HSD: 826). Weed biomass in the ryegrass treatment (421 kg ha^{-1}) at GM in April was not significantly different from the other cover crop treatments or the control. At ÇM in March, the oat treatment (80.5 kg ha^{-1}) had significantly lower cover crop biomass than either the pea (1,153.5 kg ha^{-1}) or oat/pea (767 kg ha^{-1}) treatments ($p = 0.0031$; HSD: 471). There were no significant differences in weed biomass at ÇM in March among the control (0.0 kg ha^{-1}), oat/pea (8.55 kg ha^{-1}), oat (1.05 oat kg ha^{-1}), pea (0.53 kg ha^{-1}), and ryegrass treatments (0.0 kg ha^{-1}) ($p=0.3372$). There was better establishment of the annual cover crops at GM than ÇM. In 41 days of growth at GM, there was an 84% increase in the oat biomass, 130% increase in the oat/pea biomass, and a 150% increase in the pea biomass.

At ŞP in April, the sainfoin treatment (498 kg ha^{-1}) had significantly less cover crop biomass than the sainfoin/brome (864 kg ha^{-1}) or brome (715 kg ha^{-1}) treatments ($p = 0.0170$; HSD: 254). Despite the difference in cover crop biomass, there was no difference in weed biomass among the control (28.1 kg ha^{-1}), sainfoin/brome (100 kg ha^{-1}), brome (77.5 kg ha^{-1}), and sainfoin (26.3 kg ha^{-1}) treatments ($p = 0.4726$).

Across locations, there were significant differences among treatments in percent canopy cover in November ($p = 0.0029$) and January ($p = 0.0156$). In November, the top three treatments with the highest percent canopy cover were oats (42.5%), oat/pea (34.0%), and pea (28.4%). All other treatments had a canopy cover of 15% or less. In January, the ryegrass treatment (31.1%) had significantly lower percent canopy cover than the pea (66.3%), oat/pea (65.5%), oat (46.2%) treatments, and control (36.4%).

At GM, there were significant differences in percent canopy cover shortly after planting ($p = 0.0259$) and at the end of the trial in April ($p = 0.0172$), but not in January or March (Table 3). In November, the oat treatment (64.6%) was not significantly different from the pea (36.4%) or oat/pea (52.5%) treatments, but was significantly different from the ryegrass (21.8%) treatment and control (21.9%). In April, the pea (90.6%) and oat/pea (76.5%) treatments were not significantly different from the oat (73.3%) or ryegrass (55.4%) treatments, but were significantly different from the control (22.5%). At ÇM, percent canopy cover among treatments was significantly different at each sampling date. The average percent cover across sampling dates at ÇM were highest in the pea (54.5%) and oat/pea (52.3%) treatments. All other treatments had 33.7% canopy cover or less. Overall, percent canopy cover increased throughout the season until March at both locations (Table 3). In April, percent canopy cover of all treatments and the control decreased at GM. This decrease may be due to drier conditions that were less conducive to sustaining the cover crop.

Table 3. Experiment I: Percent canopy cover (%) by sampling date and treatment in GM and ÇM.

	Nov		Jan		Mar		Apr	
	GM	ÇM	GM	ÇM	GM	ÇM	GM	ÇM
Control	21.9^{b}	7.0^{b}	65.1	7.68^{b}	68.4	48.6^{bc}	22.5^{b}	n/a
Oats	64.5^{a}	20.5^{a}	78.6	13.8^{b}	81.4	50.8^{bc}	73.3^{ab}	n/a
Peas	36.4^{ab}	20.5^{a}	85.2	47.3^{a}	89.5	90.2^{a}	90.6^{a}	n/a
Oat/pea	52.5^{ab}	15.4^{ab}	80.2	50.9^{a}	85.1	83.5^{ab}	76.5^{a}	n/a
Ryegrass	21.8^{b}	5.95^{b}	50.8	11.5^{b}	85.3	37.6^{c}	55.4^{ab}	n/a
Mean	39.4	13.9	72.0	26.2	81.9	62.2	63.7	n/a
p-value	0.0259	0.0046	0.3775	0.0017	0.8467	0.0038	0.0172	n/a
HSD	41.4	11.5	ns	29.4	ns	36.6	53.1	n/a

Within a location or sampling date, treatments that share a letter were not significantly different from one another.
n/a indicates that this measurement is not applicable.
ns is abbreviation for not significant.

At ŞP, there were no statistical differences in percent canopy cover in January among the control (0.0%), sainfoin/brome (3.71%), sainfoin (3.54%), or brome (2.15) treatments. Nor were there statistical differences in percent canopy cover in March among the control (0.0%), sainfoin/brome (17.5%), sainfoin (10.8%), or brome (13.6%) treatments. However, by April, the control (10.7%) had significantly lower percent canopy cover than the sainfoin/brome (90.0%), and sainfoin (70.2%) treatments (p=0.0113; HSD: 54.1). Percent canopy cover in the brome treatment (53.3%) at ŞP in April was not significantly different from the other cover crop treatments or the control. The trend among all three sampling dates was that the lowest percent canopy cover was in the control and the highest percent canopy cover was in the sainfoin/brome treatment.

3.2. Experiment II: Spring Establishment

3.2.1. Effect of Cover Species

In January at BB, 53 days after planting, the mean percent canopy cover of all treatments was 41.0%. The sainfoin, barley/pea, and brome treatments had the highest percent canopy cover (Table 4). Despite its relatively low population counts, the barley/oat treatment had high percent canopy cover. Clover and pea treatments had low percent canopy cover. Pea, barley/pea, and sainfoin treatments had the most cover crop biomass whereas ryegrass, clover, and ryegrass/clover had the least. There was no difference in weed biomass among treatments. This indicates that cover crop treatments had no effect on weed suppression (Table 4).

Overall, moisture was higher at 5-10 cm depths than the top five cm. Moisture in the top 0-5 cm was significantly different among the treatments (p=0.0122; HSD: 4.17). Barley (9.4%), sainfoin (9.0%), and brome (8.2%) treatments had significantly lower moisture than the clover (13.7%) treatment, which had the highest moisture. There were no statistical differences in moisture in the top 0-5 cm among the control (10.6%), pea (10.0%), barley/pea (9.9%), ryegrass (10.2%), ryegrass/clover (11.3%), sainfoin/brome (11.6%) and other treatments. Moisture in at 5-10 cm was significantly different among the treatments (p=0.0001; HSD: 3.20). Barley (15.6%), barley/pea (14.7%), sainfoin (14.6%), and brome/sainfoin (15.3%) treatments had significantly lower moisture than the control (19.6%), which had the highest moisture. There were no statistical differences in moisture at depths of 5-10 cm among the pea (17.8%), ryegrass (16.9%), ryegrass/clover (17.2%), brome (16.7%), and other treatments.

3.3. Experiment III: Seeding Methods

3.3.1. Main Effect

There was no statistical difference between non-incorporated and incorporated seeding methods nor were there treatment by method interactions for any of the metrics analyzed (percent canopy cover or moisture at depths of 0-5 cm). Therefore, data was pooled for non-incorporated and incorporated seeding methods. However, there were differences among treatments when planting method was not a factor.

3.3.2. Effect of Cover Crop Species

In January, 62 days after planting, mean percent canopy cover was relatively low (8.0%). There were no statistically significant differences among treatments. By March, the mean of all treatments increased to 36.7% and there was statistical difference among treatments (p<0.0001). The pea and oat/pea treatments had the highest percent canopy cover (71.5% and 66.5%, respectively) (Table 5).

The brome and clover growth was poor. What little clover did germinate, was not tall enough to harvest. Any brome that germinated was indistinguishable from other grasses. In April, biomass samples were collected from the pea, oat, oat/pea, ryegrass, and sainfoin treatments. The pea and oat/pea treatments had significantly more cover crop biomass than the other treatments (Table 5). Although not statistically

Table 4. Experiment II: Percent canopy cover, cover crop biomass, and weed biomass of cover crop treatments and control at Barbaros in May.

	Canopy cover (%)	Cover crop biomass (DM kg ha^{-1})	Weed biomass (DM kg ha^{-1})
Control	11.7^{d}	n/a	37.6
Barley	36.8^{bcd}	169^{cd}	4.43
Peas	47.6^{bc}	353^{a}	30.2
Barley/pea	68.2^{ab}	346^{a}	4.61
Clover	10.9^{d}	63.3^{def}	8.04
Ryegrass	29.5^{cd}	13.2^{f}	7.40
Ryegrass/clover	21.0^{cd}	45.6^{ef}	17.2
Sainfoin	84.0^{a}	289^{ab}	9.10
Brome	53.1^{abc}	148^{cde}	36.9
Sainfoin/brome	47.3^{bc}	216^{bc}	3.94
Mean	41.0	183	16.0
p-value	0.0001	0.0001	0.1096
HSD	33.8	112	ns

Treatments that share a letter were not significantly different from one another.
n/a indicates that this measurement is not applicable.
ns is abbreviation for not significant.

Table 5. Experiment III: Percent canopy cover (%) in January and March, cover crop biomass and weed biomass in April, averaged across methods, by sampling date and treatment at ÇM.

	Canopy cover (%)	Canopy cover (%)	Cover crop biomass (DM kg ha^{-1})	Weed biomass (DM kg ha^{-1})
	Jan	Mar	April	April
Control	1.69	14.5^{de}	n/a	185
Oats	12.2	31.8^{cde}	119^{b}	108
Peas	12.4	71.5^{a}	269^{a}	83.2
Oat/pea	13.9	66.5^{ab}	131^{ab}	146
Ryegrass	6.53	23.1^{cde}	16.0^{b}	116
Clover	10.8	42.3^{bc}	n/a	n/a
Ryegrass/clover	3.92	9.88^{e}	n/a	n/a
Sainfoin	9.18	40.6^{bcd}	98.1^{b}	158
Brome	3.18	23.5^{cde}	n/a	n/a
Sainfoin/brome	6.15	43.6^{bc}	n/a	n/a
Mean	8.00	36.7	135	129
p-value	0.0535	0.0001	0.0011	0.4223
HSD	ns	26.5	164	ns

Within a sampling date, treatments that share a letter were not significantly different from one another.
n/a indicates that this measurement is not applicable.
ns is abbreviation for not significant.

significant, the pea treatment had 100 kg ha^{-1} less weed biomass than the control. All cover crop treatments had less weed biomass than the control, but cover crop treatments did not have a statistical impact on weed suppression. There were no significant differences in soil moisture among the treatments at depths of 0-5 cm in April (data not shown). Soil measurements were not taken at depths below 5 cm.

4. Discussion

In Experiment I, it was not surprising that there were location by treatment interactions and that location impacted cover crop biomass. It is widely documented that cover crops are affected by site conditions including soil properties, climate, and management [6]. However, although biomass did have location by treatment interactions, percent canopy cover did not. This may be due to plant growth structure. There may be enough plant material to create similar percent canopy cover and at the same time not have enough plant density to impact biomass to the same extent.

According to Managing Cover Crops Profitably [6], depending on seeding rate and method, the potential dry matter for clover is 2,250-6,725 kg ha^{-1}, annual ryegrass is 2,250-10,000 kg ha^{-1}, oats is 2,250-11,200 kg ha^{-1}, and field peas is 4,480-5,600. Perhaps due to the relatively low seeding and germination rates, the ryegrass and clover consistently fell below those rates no matter the location, seeding method, or planting date. It was only in Experiment I that the cover crop biomass of the oats and peas were within their respective expected ranges during the final biomass collection in April. In Experiments II and III, the treatments with peas had the highest biomass. Specifically, in the fall planting of Experiment III the addition of oats, or reduction of pea seeding rate, decreased biomass. Stated differently, the addition of peas increased biomass by 12 kg ha^{-1}. Given that the ryegrass and clover did not establish well at any location, with either planting method, or at either planting date, the soil conditions and climatic parameters of the Trakya region may not be suitable for these smaller seeded cover crops.

In Experiment I, the sainfoin and sainfoin/brome mix had significantly higher biomass than the brome treatment. However, in the spring planting of Experiment II, the sainfoin treatment had higher biomass than sainfoin/brome treatment. Although not statistically significant, in the fall plantings of Experiments I and III, the sainfoin and sainfoin/brome treatments had 17% or more canopy cover. The prostrate nature and leafy structure of the sainfoin may have increased its capability to cover more ground. However, in the spring planting, the sainfoin treatment had significantly higher percent canopy cover than the sainfoin/brome treatment. Further study is needed to determine if this difference is due to site conditions or planting date.

Throughout locations, seeding methods, and planting date, the grass/pea treatments were consistently among the highest percent cover. This may be due to the seeding rate and synergistic structure of the plants. The thick oat stands provided enough structural support for the peas to climb up and the broadleaves of the peas filled in the space between the thin oat blades. Overall, plant (weed and cover crop) biomass was higher at GM than at ÇM. GM may have had different soils or climatic conditions more suitable for cover crop growth. Weed biomass was consistently the highest in the control at all sites except at ŞP where weed biomass was not statistically different among the treatments. However, the lowest weed biomass differed among the other treatments in Experiment I, II, and III. In Experiment I, the pea treatment had the highest weed biomass. With regards to weed suppression, oats have been reported to outperform field peas [6]. The pea treatment also had the lowest cover crop biomass which may have led to less weed suppression. It is worthwhile to note that in Experiments II and III, there were statistically significant differences in cover crop biomass among treatments, but there were no statistically significant differences among treatments in weed biomass. Further study is needed in Turkey to determine which cover crops can provide the best weed suppression.

Soil moisture may have been different among ÇM and GM due to moisture uptake by cover crops. There was higher cover crop establishment success at GM than at ÇM leading to less soil moisture at GM. Soil moisture was only statistically different among treatments in Experiment II at depths of 0-5 cm and 5-10 cm. This may be due to water demands of the cover crops. Further study over multiple growing seasons and additional replicates are needed to determine if this effect is consistently observed, and if it is influence by other factors such as soil textures and annual variability in climatic conditions.

5. Conclusion

Regardless of location or planting date, the oat/pea mix outperformed the other treatments in terms of ease of establishment and success rate as indicated by trends of high percent canopy cover, high March cover crop biomass and low weed biomass. Overall, cover crops tended to have higher percent ground cover than the control indicating that planting cover crops can provide more erosion control than leaving the ground bare. Given the soil and weather conditions of the area, seed size may matter. The large seeded annuals, oats and peas, have considerably larger mass with more energy reserves than the other treatments that may be able to better withstand longer periods without rain. Although the large seeded perennials did not have as prolific cover crop biomass, they did show promise as a cover crop. It is possible that the smaller seeded ryegrass and clover may be more sensitive to environmental conditions and may benefit from better seed preparation.

Location and environmental conditions play a role in cover crop establishment and growth. With the exception of the spring planted cover crops at Barbaros, there was no impact of cover crops on soil moisture. These preliminary results indicate that cover crop treatments can be established in the Trakya region with few mechanical or other agricultural inputs. It is important to note that these results only represent one year of data. Further study is needed over multiple growing seasons and different regions to determine best management practices to establish and terminate cover crops, which cover crops are best suited for different cropping systems, impact on soil properties, and effect on the cash crop.

Declaration

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