COVER CROP, SEED PRIMING AND PLANTING DATE EFFECTS ON DIRECT SEEDED PEPPER EMERGENCE IN OKLAHOMA

By

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Abstract: The purpose of this research is to identify and implement more efficient ways to produce bell (*Capsicum annuum*) and spice peppers by eliminating transplant costs via direct seeding planting methods with the addition of various planting dates, seed priming, and cover crops. Seed priming trials were first performed in the greenhouse to determine the most suitable priming agent for bell and spice peppers. California Wonder bell pepper seeds and Okala spice pepper seeds were soaked for 36 hours in a 10 mM concentration of three treatments: Potassium chloride(KCL), calcium chloride ($CaCl_2$), and deionized water. Control seeds were rinsed in a 1% bleach solution prior to planting. All seeds were weighed before soaking and dried to their original weight before planting. Based on the results, KCL and $CaCl_2$ were chosen for spice and bell peppers, respectively. The priming agents along with two planting dates based on soil temperatures were used for field trials. Plots were also planted within four different cover crop treatment areas that have been in rotation for two years. Treatment 1 area consists of sorghum Sudan (*Sorghum biocolor L.*) and cowpea (*Vigna unguiculata*) for warm season crops and cereal rye (*Secale cereale*) and crimson clover (*Trifolium incarnatum*) for cold season crops. Treatment 2 area consists of cowpea for warm season crops and winter wheat (*Triticum aestivum* L.) and crimson clover for cold season crops. Treatment 3 area consists of pearl millet (*Pennisetum glaucum*) and cowpea for warm season crops and cereal rye, Austrian winter pea (*Pisum sativum subs arvense*) and tillage radish (*Raphanus sativus var. longipinnatus*) for cool season crops and treatment 4 is fallow year round. Seeds were sown in strip tilled plots using a research planter. Each plot is 12 feet in length with 50 seeds per plot, planted at 0.5" depth. Data was collected every four days on emergence rate for two weeks. Results showed significance for primed seeds versus control seeds but varied between cover crops. Results indicate that cover crop selection, planting date, and priming agents may have a positive effect on the emergence of direct seeded pepper.

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CHAPTER I

INTRODUCTION

In 2017, 43,300 acres of bell peppers (*Capsicum annuum*) and 18,900 acres of spice peppers were harvested in the United States (USDA-NASS, 2017). In Oklahoma, annual pepper production accounts for approximately 500 to 600 acres, with an overall value of approximately 2 million U.S. dollars (Brandenberger, L., personal communication, 2018). Sweet pepper grown in Oklahoma is primarily for fresh market and spice pepper are grown for capsaicin for medical, salsa flavoring, and other uses. There has been considerable research completed on more efficient bell and spice pepper production, with some taking place in Oklahoma. Pepper producers in Oklahoma face multiple challenges, including high cost and time input associated with greenhouse production of transplants. The purpose of this research was to identify and implement more efficient ways to establish bell and spice peppers by eliminating transplant costs via direct seeding planting methods utilizing different planting dates, seed priming, and cover crop treatments.

LITERATURE REVIEW

SEED PRIMING

It is difficult to obtain uniform germination and sufficient yield via direct seeding, therefore, a majority of bell and spice peppers are germinated and grown in the greenhouse and later transplanted into the field. Seed priming has been proven to improve seed germination of bell peppers and spice peppers (Kaewduangta et al., 2016 and Aloui et al., 2014). Priming involves exposing seeds to an external water potential low enough to restrict germination and yet permit pre-germination, physiological and biochemical activities (Aloui et al., 2014). Seed priming has been used to promote rapid germination and emergence along with more uniform growth. This technique has been used with other vegetable seeds to increase the germination rate, total germination and seedling uniformity, primarily under less than favorable environmental conditions (Korkmaz, 2005). Aloui et al. (2014) determined a difference between primed and control seeds, with highest germination being 95%. Hydro- and osmopriming has also shown to improve seed germination of bell peppers (Kaewduangta et al. 2016). While there are multiple research studies that have been done in seed priming, many options require materials and processes that are not feasible for the average producer. The biggest issues arise with cost, accessibility to priming agents, and environmental control factors during the priming process. For example, Da Silva et al. (2015) found that drum priming bell pepper seeds to be a viable option for commercial growers. Drum priming was described as hydrating seeds to a predetermined water content over a 24-hour period in a horizontal rotating drum into which water vapor is released (Rowse, H.R. 1995). Drum priming is an efficient option, but for most producers access to a drum priming system is nonexistent. Another study found that priming seeds with nanochitin and chitosan greatly improved seed germination in a cold environment (10^{o}C) (Samarah et al., 2016) Chitosan is a long chain polysaccharide polymer that is derived from chitin and nanochitin is derived from nanoparticles of the larger chitosan particles (Samarah et al., 2016). This study showed great improvements in seed germination, but the preparation of the priming agent involved multiple steps carried out in a laboratory which is not feasible for most producers.

PLANTING DATE

The present study explored how varied planting dates affect seedling disease pressure within a direct seeded pepper production system. Transplanting may provide some protection as plants are more mature when planted in the field and less susceptible to seedling diseases. For example, once pepper seedlings reach the 2-3 leaf stage, they are generally no longer susceptible to infection of damping-off (*Pythium* spp.) (Koike et al., 2012). On the other hand, some have speculated that bacterial spot (*Xanthomonas campestri* pv. vesicatoria) infection may originate in the greenhouse and may later be transmitted to the field (Brandenberger L., personal communication, 2018). The prominent seedling diseases for bell and spice peppers in Oklahoma are *Phytophthora* and *Xanthomonas*. The optimum temperature for bacterial spot (*Xanthomonas campestri* pv. vesicatoria) infection is 24^{o}C to 30^{o}C and disease develops best at temperatures that fluctuate between 20^{o}C and 35^{o}C (Gugino, 2015). Conversely, bacterial spot progression is thwarted with night temperatures around 16^{o}C (Gugino, 2015). *Phytophthora* infects pepper plants most aggressively between 24^{o}C and 33^{o}C (Koike et al., 2012). Adjusting planting dates to avoid the optimum conditions for disease development may prove beneficial for improved germination and plant survival, but increases the time for pepper plants to establish, flower, and fruit. This results in planting date becoming a major factor when direct seeding. Bell and spice peppers optimum soil temperatures for germination are within 18°C to 35°C (Maynard and Hockmuth, 1997). In Oklahoma, these temperatures would allow us to plant as early as mid-April up to late June. Hesler et al. (2005) found that planting winter wheat after the 20th of September may significantly reduce the risk of various pests and their consequential disease incidence in South Dakota and the Northern Great Plains. Pivonia et al. (2002) found that occurrence of melon collapse caused by *Monosporascus cannonballus* increased as soil temperature increased and decreased as soil temperature decreased. Jones et al. (2010) also found that using a later planting date in south-central USA reduced the population of tobacco thrips (*Thrips tabaci*) in cowpea seedlings. Research indicates that moving planting dates can be beneficial to producers, but issues may arise when using later planting dates due to changing time frames and their effect on the market. Direct seeding needs to be profitable enough to reduce the need to be competitive at market or provide producers the ability to begin their season earlier in the year.

COVER CROPS

A cover crop is a crop that is used primarily to reduce soil erosion, increase soil organic matter, and enhance water availability. They can also improve crop production by smothering weeds, assist in control of pests and diseases, fix nitrogen, mine nutrients from the subsoil, and increase biodiversity (Clark, 2015). The present research will examine the benefits of using cover crops to improve soil health by increasing organic matter content. Soil organic matter (SOM) plays an important role for soil quality and productivity maintenance. SOM acts as an energy source, promotes biological diversity, and enhances terrestrial ecosystem composition (Martins et al., 2015). Soil organic matter content has been found to have an effect on nutritional value of crops (Woods and Baudron, 2018). Woods and Baudron (2018) found that wheat yield and protein content were related to soil organic matter, nitrogen, and zinc related to organic matter carbon. This same study discovered that a 1% increase in organic matter carbon increased the available zinc and protein equivalents for human consumption by an additional 0.2 and 0.1 person per hectare, respectively (Woods and Baudron, 2018). It is well known that improved soil organic matter content is beneficial to crop productivity but it can require considerable time to see major increases. Due to this project being under year-round cover crop rotation and reduced tillage in areas used for crop production, we hypothesize that there will be a more rapid increase in SOM than is generally observed. While cover crops can improve soil quality, the type of cover crop chosen will determine its ability to improve crop yield (Alvarez et al., 2017). Cover crops have been researched for their ability to improve cash crop performance and have been proven beneficial among multiple crops such as winter wheat, grain sorghum and olives to name a few (Blanco et al., 2012, Correia et al., 2015). Radicetti et al. (2013) found that hairy vetch (*Vicia villosa*) cover crops improved bell pepper yields in a Mediterranean environment. Treatments used in those studies included four winter cover crop treatments (hairy vetch, oat (*Avena sativa*), canola (*Brassica napus*), and fallow) and three cover crop residue management treatments (no-till, green manure incorporated at 10cm soil depth, and green manure incorporated at 30cm soil depth) (Radicetti et al., 2013). Lee et al. (2014) also found similar results with hairy vetch cover crop rotation in spice pepper in North Korea. Campiglia et al. (2014) found improved marketable fruits quality in bell peppers with a legume cover crop rotation compared to an oat cover crop. In Oklahoma, it is generally believed that for cover crops to be beneficial, cash crops must have irrigation or there is too much competition for resources (Haggard, B. personal communication. 2018). In this study, peppers will be irrigated via drip irrigation system therefore there is no expectation of negative effects from water competition.

HYPOTHESIS AND OBJECTIVES

There has been little, or no, research conducted for direct seeding of peppers in Oklahoma. There is evidence that seed priming, planting dates and cover crops can have positive effects on various crops, including peppers, but few studies have been completed in the state. Providing Oklahoma producers with a realistic protocol for direct seeding peppers that is practical was the primary focus of the study. We hypothesized that improving germination and emergence of direct seeded pepper through the addition of seed priming, cover crops, and adjusted planting dates would increase the efficiency and profitability of commercial pepper crops grown in Oklahoma.

The first objective was to determine if seed priming could reduce time to emergence under a greenhouse conditions, then use the most effective priming agents in field trials to validate their abilities in a field environment. The objective of this part of the research was to determine a simple protocol for priming bell and spice pepper seeds with cost effective agents and methods.

The second objective was to determine an effective planting date for direct seeded peppers in Oklahoma. As the literature has shown, certain planting dates may have positive effects on avoiding seedling disease and may also allow farmers to plant earlier to avoid lost market time throughout the growing season. The research plans were to determine a planting date that provides pepper with optimum growing conditions, better protection from potential seedling diseases. Furthermore, results from the research will help retain profits for producers by either extending the harvest or keeping the production and harvest in unison with crops grown using transplants.

The third objective was to determine the effects of cover crops on pepper yield in Oklahoma. Four treatment areas in the field have been in rotation for two years using different cover crop treatments. Plant emergence will be determined through plant counts during the growing season and overall crop yield through the measurement of fresh and dry weights of the crops at the end of the growing season.

CHAPTER II

SEED PRIMING AGENT SELECTION IN GREENHOUSE TRIALS

INTRODUCTION

The purpose of the preliminary greenhouse study was to select the most effective seed priming agents for use in field trials. Seed priming involves exposing seeds to an external water potential low enough to restrict germination and yet permit pre-germination physiological and biochemical activities (Aloui et al., 2014). Seed priming is used to promote rapid and increased uniform growth. The technique has been used in several vegetable species to increase the germination rate, total germination and seedling uniformity, primarily under less than favorable environmental conditions (Korkmaz, 2005). While the focus is on direct field seeding, determining the most effective priming agents in a controlled environment will reduce variation from exterior factors.

MATERIALS AND METHODS

Four seed priming treatments were used for the greenhouse trials: calcium chloride (TRT 1), potassium chloride (TRT 2), deionized water (TRT 3), and the control (TRT 4) which had a 1% bleach-water rinse before planting. Seeds in treatments 1-3 were soaked in 10mM solution of their respective material for 36 hours. Seeds weights were determined prior to being placed in the solution and then dried back down to their pre-soak weight prior to planting. Drying took place in a laboratory at room temperature with the use of a small fan and seeds placed on screens so air could circulate underneath. Seeds with TRT 4 were weighed and dried similarly but drying took considerably less time with the bleach-water rinse.

Seeds were planted in "150" Speedling trays at 0.50" planting depth, kept consistent with the use of a dibble board to provide uniform depth depressions for individual seeds. The "150" Speedling trays were comprised of Styrofoam with 1" x 1" cells. Treatments were replicated three times, and there were 24 seeds per treatment per replication. Sun Gro Horticulture soilless media was used as the planting media. Cells were filled with media, wetted, pressed with dibble board and seeds were planted, then seed depressions were covered with more media and wetted once more. Trays were then placed in the greenhouse directly after seeding. Year one planting date was March14, 2018 and year two was March 20, 2019. The seeded trays were checked for emergence and watered each day following seeding. New seedling emergence data collection began after the first seedling emerged and continued daily for two weeks. Data were recorded for the number of new plants emerged each day. Soil and greenhouse temperatures were recorded from the day of planting. Greenhouse temperatures in 2018 had a low, average, and high of 22.7ºC, 25.5ºC, and 30.7ºC, respectively. Soil temperatures varied slightly more with a low of 17.7ºC, an average of 22.7ºC, and a high of 30.4ºC. Greenhouse temperatures in 2019 had a low of 21.5ºC, average of 23.7ºC, and a high of 32.4ºC. Soil temperatures also varied with a low, average, and high of 18.4ºC, 24.2ºC, and 34.9ºC, respectively. Irrigation was provided through hand watering with tap water at the same time as data collection each day.

STATISTICAL METHODS

Greenhouse trials were in a randomized block design and results were analyzed using SAS v9.4 (SAS Institute Inc., Cary, NC). Data was subjected to an analysis of variance. Significant effects were further analyzed using the Probit procedure to determine differences in treatment means. Significance levels were set at 0.05.

RESULTS AND DISCUSSION

Data were analyzed separately based on pepper type. Bell peppers were significantly affected by seed priming treatment in 2019 but not in 2018 (Figures 1 and 2). Seeds germinated well in 2018, reaching 94% germination by 8 days after planting (Table 1). The lack of effect in 2018 may be attributed to the small cold snap that took place that year. Exterior temperatures dropped to minus 4-7^{o}C and may have stalled germination. This cold period resulted in 6 days of below freezing temperatures during the 2018 growing season while 2019 only had 2 days at below freezing temperatures. 2018 displayed no significance or trends among treatments, but TRT 2 was selected for field studies based on visual observations of its performance in the greenhouse trials (Tables 1 and 2). The seedlings displayed increased growth and vigor compared to other treatments once they were emerged. Data had significantly higher emergence rates for TRT 2 in 2019; therefore, the author conclude that with improved environmental controls in the greenhouse the results may have been similar in 2018. Based on the data and analysis, seed TRT 2 was used for bell pepper field trials.

Spice pepper seed germination was affected by seed priming treatments each year, but results varied between years. The highest germination rates were for TRT 3 in 2018 and TRT 2 in 2019 (Tables 3 and 4). Although TRT 1 did not result in the highest emergence for either year it was the most consistent, having the second highest emergence each year of the study (Figures 3 and 4). Based upon the greenhouse study results, TRT 1 was selected for use in the field trials.

Figure 1. Greenhouse Seed Priming Agent Trials: Bell Pepper 2018

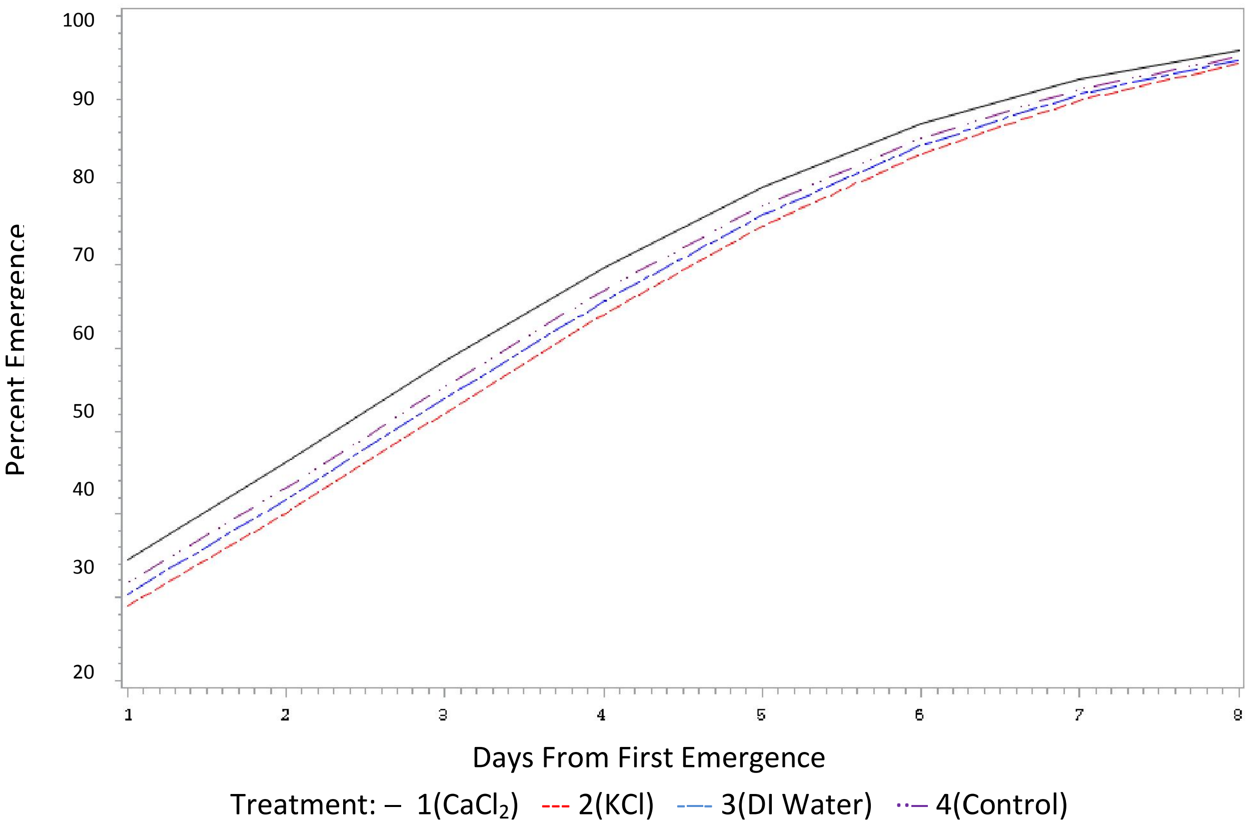


Table 1. Effect of seed priming treatment on emergence rate of bell pepper at 4, 6, and 8 d after first emergence under greenhouse conditions in 2018

Treatments	**Days after first emergence**		
	4 d	**6 d**	**8 d**
	---------------------------% emergence-------------------------------		
1 ($CaCl_2$)	70 A[z]	87 A	96 A
2 (KCl)	64 A	83 A	94 A
3 (DI Water)	66 A	84 A	95 A
4 (Control)	67 A	85 A	95 A

[z] Means having the same letter assigned to them are not significantly different using Fisher's least significant different test ($P < 0.05$).

Figure 2. Greenhouse Seed Priming Agent Trials: Bell Pepper 2019

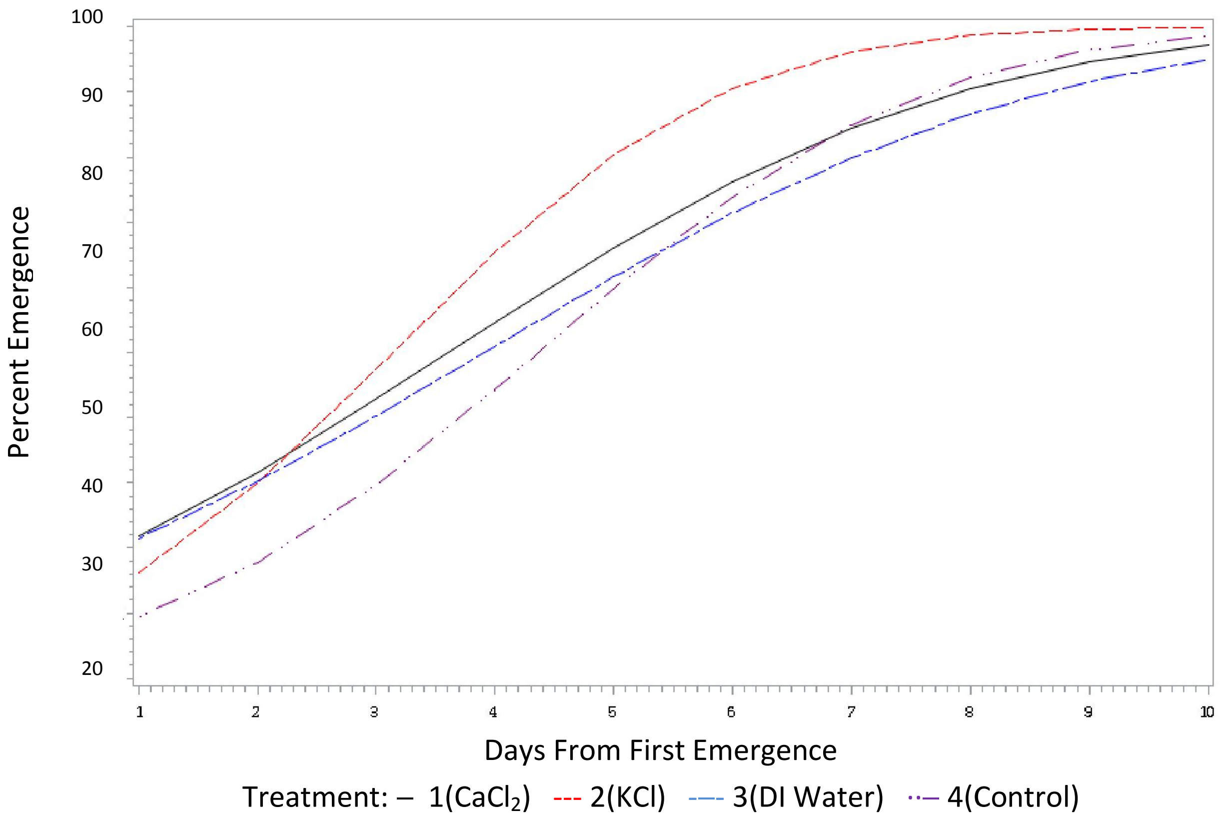


Table 2. Effect of seed priming treatment on emergence rate of bell pepper at 4, 6, and 8 d after first emergence under greenhouse conditions in 2019

Treatments	**Days after first emergence**		
	4 d	**6 d**	**8 d**
	------------------------------% emergence-----------------------------		
1 ($CaCl_2$)	55 B[z]	76 B	90 B
2 (KCl)	65 A	91 A	99 A
3 (DI Water)	51 B	71 B	87 C
4 (Control)	44 C	74 B	92 B

[z] Means having the same letter assigned to them are not significantly different using Fisher's least significant different test ($P < 0.05$).

Figure 3. Greenhouse Seed Priming Agent Trials: Spice Pepper 2018

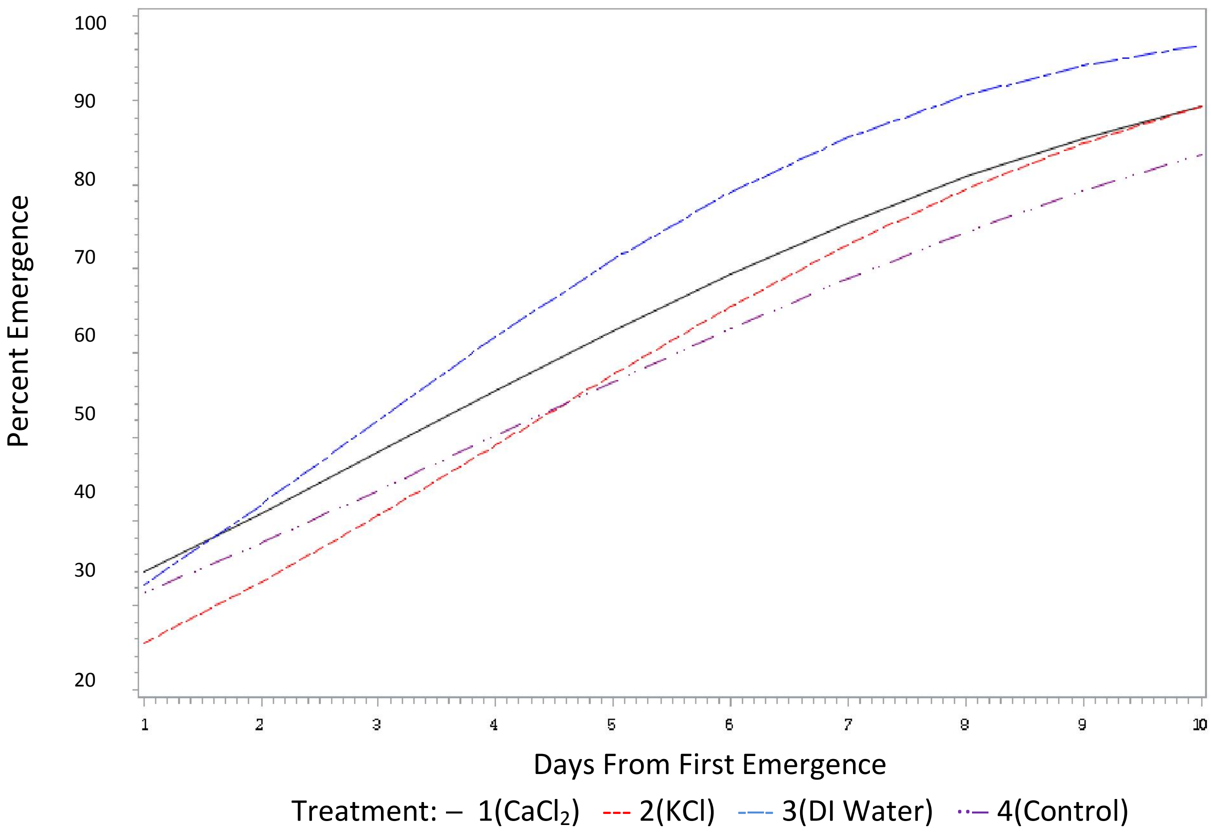


Table 3. Effect of seed priming treatment on emergence rate of spice pepper at 4, 6, and 8 d after first emergence under greenhouse conditions in 2018

Treatments	Days after first emergence		
	4 d	6 d	8 d
	--------------------------% emergence---------------------------		
1 ($CaCl_2$)	55 B[z]	69 B	81 B
2 (KCl)	49 C	65 CB	79 CB
3 (DI Water)	62 A	79 A	91 A
4 (Control)	50 CB	62 C	74 C

[z]Means having the same letter assigned to them are not significantly different using Fisher's least significant different test ($P < 0.05$).

Figure 4. 2019 Greenhouse Seed Priming Agent Trials: Spice Pepper

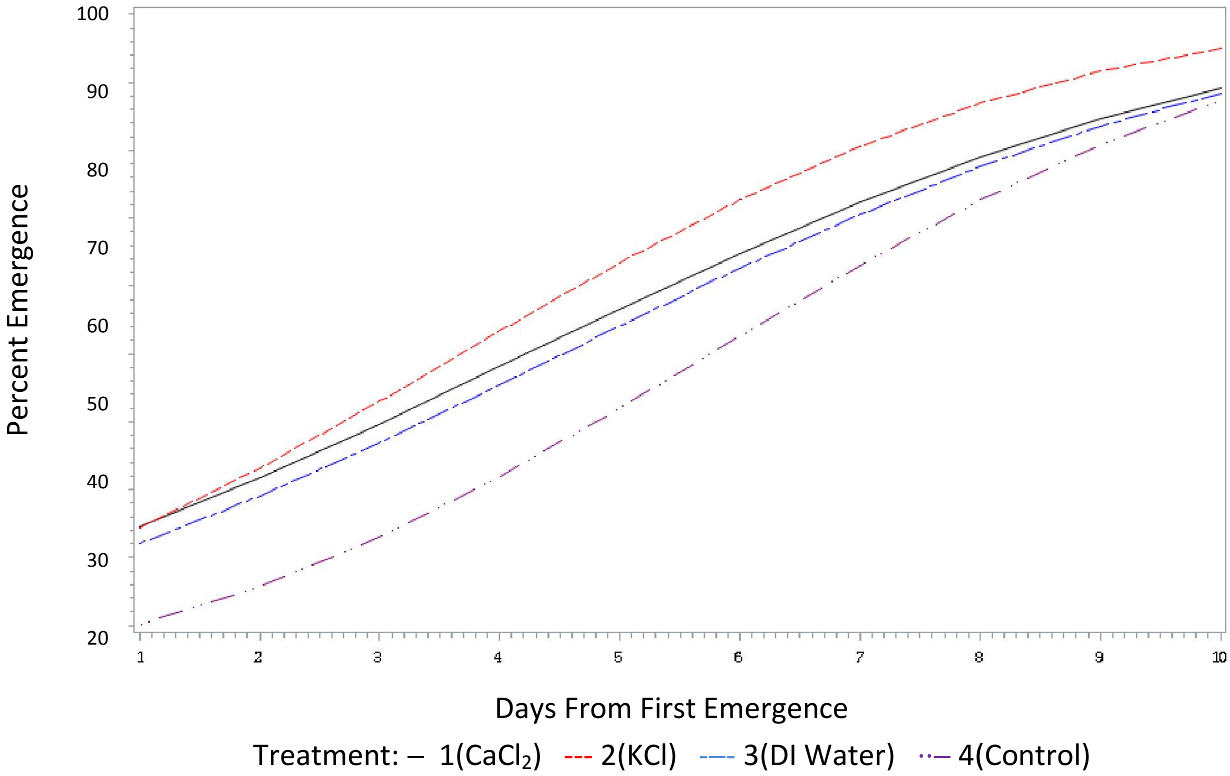


Table 4. Effect of seed priming treatment on emergence rate of spice pepper at 4, 6, and 8 d after first emergence under greenhouse conditions in 2019

Treatments	**Days to first emergence**					
	4 d		**6 d**		**8 d**	
	---------------------% emergence----------------------					
1 ($CaCl_2$)	48	BA[z]	65	B	79	B
2 (KCl)	53	A	73	A	87	A
3 (DI Water)	45	B	63	B	77	CB
4 (Control)	32	C	53	C	73	C

[z] Means having the same letter assigned to them are not significantly different using Fisher's least significant different test ($P < 0.05$).

CHAPTER III

FIELD TRIALS FOR TESTING PLANTING DATES AND PRIMING AGENTS WITHIN COVER CROP AREAS

METHODS AND MATERIALS

Field trials took place at Cimarron Valley Research Station in Perkins, Oklahoma during the 2018 growing season and repeated during the 2019 growing season. The study examined the effects of planting date, cover crop rotations, and seed priming on emergence and production of two types of peppers (bell and spice). The soil in the field where the experiments were conducted consisted of two types, Teller loam in the northern quarter and Teller loam with a Konawa fine sandy loam in the southern three quarters of the test site (Natural Resource Conservation Service). The study was organized as a randomized complete block design (RCB) with four replications as a 2 x 2 x 4 factorial, it was not possible for authors to properly replicate cover crops, instead, planting date and seed treatments were pseudo-replicated within each cover crop area. Factors consisted of two planting dates, two seed priming treatments, and four cover crop treatments. Field rows ran north to south in each section and contained sixteen plots per row, including four replications of each seed and planting-timing treatment, plots were 12 feet in length. The planting dates were chosen based on soil temperatures that were optimum for pepper production. The first planting date was at the lowest end of the optimum range, 15^{o}C, and the second planting date was at soil temperatures of approximately 24^{o}C, which falls in the middle of the optimum range. Based on results from the greenhouse, KCl was used as the priming agent for bell peppers, and $CaCl_2$ was used as the priming agent for spice peppers. Each priming agent was compared to the non-primed control treatment. Cover crop treatments are part of the overall field system that had been in place for 2 years prior to the pepper study and will continue for the next three years. Pepper plot areas were strip tilled in each of the four cover crop treatment areas using a tractor drawn rototiller following rotary mowing of the strips to allow the cover crop rotation to continue in the unused areas of the field. Pepper was seeded utilizing a Hege cone plot planter at a depth of 0.25-0.5 inch, seeds were seeded at a rate of 50 seeds per plot approximately 13 seeds/row meter. Cover crop treatment 1 included sorghum x sudan (*Sorghum biocolor* L.) plus cowpea (*Vigna unguiculat*a) for the warm season and cereal rye (*Secale cereale*) and crimson clover (*Trifolium incarnatum*) for a cold season cover crop. Treatment 2 included cowpea for warm season and winter wheat (*Triticum aestivum* L.) with crimson clover for a cool season cover crop. Treatment 3 included pearl millet (*Pennisetum glaucum*) and cowpea for warm season and cereal rye, Austrian winter pea (*Pisum sativum subs. arvense*) and tillage radish (*Raphanus sativus var. longipinnatus*) for a cool season cover crops. Treatment area 4 was fallowed both in summer and winter with some summer tillage and mowing to control weedy species.

Plant counts and soil temperature readings were collected every three days following the date of first emergence. Plant fresh-weights and dry-weights were collected following termination of field studies at the end of the growing season for both years.

MANAGMENT PRACTICES

Supplemental irrigation was provided via a drip irrigation system. Fertility needs followed protocols laid out by Brandenberger et al. (2014) and delivered through the drip irrigation system through the use of a fertilizer injector made from a swimming pool chlorinator. Pesticide applications were utilized as needed according to protocols laid out by recommendations from the Extension Agent's Handbook of Insect, Plant Disease, and Weed Control (E-832 Cooperative Extension Service, 2017). Weeds were managed via hand hoeing, postemergence herbicides, and mechanical cultivation as necessary.

STATISTICAL METHODS

Statistical analysis was performed using SAS v9.4 (SAS Institute Inc., Cary, NC). All data were subjected to an analysis of variance. Plant count and yield significant effects were further analyzed using the GLIMMIX procedure, and soil organic matter data were also analyzed using GLIMMIX to determine differences in treatment means. All statistical tests were conducted at the 0.05 significance level.

RESULTS

Bell pepper emergence exhibited significant differences between controls and seed treatments, but this response varied between cover crop treatments (Figure 5). The cover crop treatments were pseudo replicated because there was not adequate field space. Readers should be aware of this limitation and understand that results are based upon the potential of the cover crops rather than complete data sets. The data exhibited the highest difference between control and treated seeds in cover crop areas 1 and 2, but recorded no difference within treatments 3 and 4 (Figure 5 and Table 5). The data indicates that seed priming improved establishment for direct seeding. Producers would likely observe higher emergence rates through the use of strip tilling and cover crops and the use of a seed priming agent. The type of cover crop used may also affect seed priming efficacy. Results indicate that using KCl as a seed priming agent may improve emergence of direct seeded bell pepper depending on specific cover crops that will be used (Table 5).

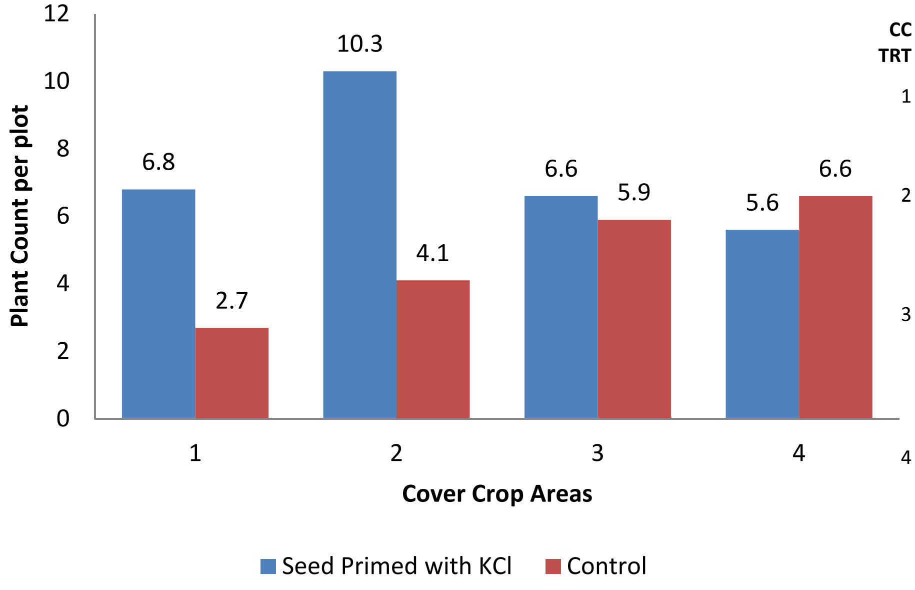
Spice pepper emergence also exhibited significant differences between controls and seed treatments, and this response again varied with cover crop treatments (Figure 6). In cover crop area 1, seed priming improved emergence, while in cover crop 2, seed priming reduced emergence, and seed priming again had no effect in cover crops 3 or 4. The inconsistency in response to seed priming suggest this method, or the specific priming agents, may not be a beneficial option for producers to implement when direct seeding spice pepper.

Planting date based on soil temperature had various effects on pepper emergence each year. While the planting date data did not vary statistically, there were noticeable trends in the raw data. The soil temperatures for the planting dates were different in 2018 and 2019, which provided authors with a wider view of production based on the soil temperature (Table 7). Bell peppers (TRT 1) had the largest number of emerged plants from the 4/11/18 planting date with a soil temperature of 20ºC (Table 7). While the plant count was considerably higher, it also took 18 days for emergence to begin versus the 7 days to emergence at the later planting date with a soil temperature of 29ºC. Spice peppers (TRT 3) saw the largest number of emerged plants from the 5/15/19 planting date with a soil temperature of 17ºC. The plant count was considerably higher and took less time to emerge (9 days) than the later planting date. Soil organic matter had several differences among cover crop treatments. For years 2016-2018, there were multiple differences between each cover crop treatment area (Figure 7 and Table 7).

There were no significant differences among cover cropping treatments in 2019, largely due to high variability between samples (Figure 7). However, cover crop treatment 2 saw a major jump in soil organic matter percent in 2019, which may contribute to the improved emergence of peppers in the treatment 2 area as well.

Plant dry weights showed few differences among treatments but did not follow any obvious trends as seen with the other measured parameters (emergence, SOM, cover crop effect). Plant dry weight was analyzed by cover crop treatment and the results indicate that treatment areas 1, 2, and 4 were not significantly different, but treatment 3 was (Table 9).

Figure 5. 2018 and 2019 Bell Pepper Emergence by Cover Crop Treatment



CC TRT	Warm Season	Cool Season
1	Sorghum sudan, Cowpeas	Cereal rye, Crimson clover
2	Cowpea	Winter wheat, Crimson clover
3	Pearl millet, Cowpea	Cereal rye, Austrian winter pea, tillage radish
4	Fallow	Fallow

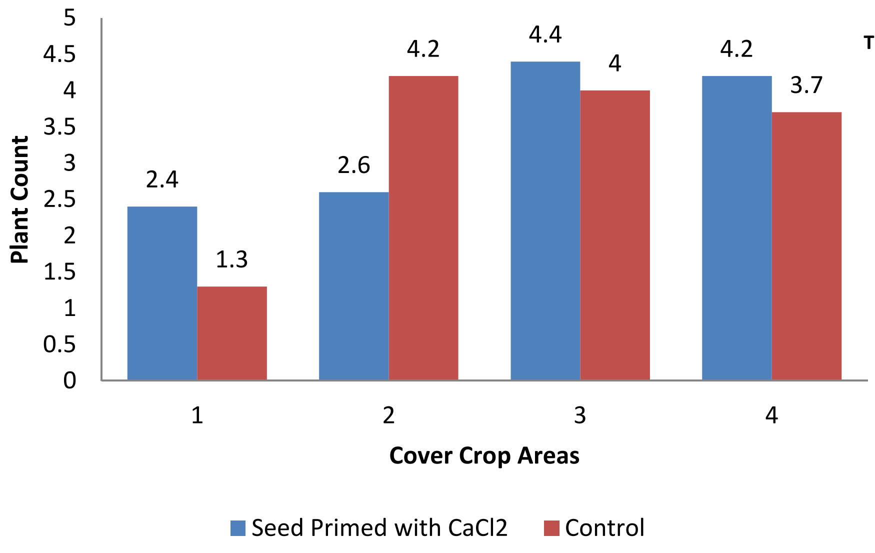
Table 5. 2018-2019 Bell Pepper Field Emergence Results For Seed Treatment Within Each Cover Crop Area

COVER CROP TRT^Y	SEED TRT	PLANT COUNT MEAN	
		Pr > F	Number of plants/plot
1	**1**	**<.0001^z**	6.8
1	**2**		2.7
2	**1**	**<.0001**	**10.3**
2	**2**		4.0
3	1	0.5544	6.6
3	2		5.9
4	1	0.3088	5.6
4	2		6.6

^{Z} Values <0.05 are significantly different

^{Y}**CC Treatment**	1	**2**	**3**	**4**
Warm Season	Sorghum sudan & Cowpeas	Cowpea	Pearl millet & Cowpea	Fallow
Cool Season	Cereal rye & Crimson clover	Winter wheat & Crimson clover	Cereal rye, Austrian winter pea, tillage radish	Fallow

Figure 6. 2018 and 2019 Spice Pepper Emergence by Cover Crop Treatment



CC TRT	**Warm Season**	**Cool Season**
1	Sorghum sudan, Cowpeas	Cereal rye, Crimson clover
2	Cowpea	Winter wheat, Crimson clover
3	Pearl millet, Cowpea	Cereal rye, Austrian winter pea, tillage radish
4	Fallow	Fallow

Table 6. Spice Pepper Field Emergence Results For Seed Treatment Within Each Cover Crop Area 2018-2019

COVER CROP TRT[Y]	SEED TRT	PLANT COUNT MEAN	
		Pr > F	number of plants/plot
1[Y]	**3**		2.4
1	**4**	**0.0074**	1.3
2	**3**		2.6
2	**4**	**0.0021**	**4.2**
3	3		4.4
3	4	0.4616	4.0
4	3		4.2
4	4	0.4622	1.3

[Z] Values <0.05 are significantly different

[Y] **CC Treatment**	**1**	**2**	**3**	**4**
Warm Season	Sorghum sudan & Cowpeas	Cowpea	Pearl millet & Cowpea	Fallow
Cool Season	Cereal rye & Crimson clover	Winter wheat & Crimson clover	Cereal rye, Austrian winter pea, tillage radish	Fallow

Table 7. Raw Data Comparison of Total Plant Count on First Day of Emergence by Trial Year, Seed Treatment, and Planting Date

Trial Year	Seed Treatment	Planting Date	Date of First Emergence	Days to First Emergence	Total Plant Count on First Date of Emergence	Soil Temp(°F)
	Bell					
2018	1[Z] (KCl)	5/15/2018	5/24/2018	9	30	68
2018	1 (KCl)	5/29/2018	6/9/2018	11	6	85
2019	1 (KCl)	4/11/2019	4/29/2019	18	91	63
2019	1 (KCl)	6/11/2019	6/18/2019	7	21	72
2018	2 (Control)	5/15/2018	5/24/2018	9	11	68
2018	2 (Control)	5/29/2018	6/9/2018	11	2	85
2019	2 (Control)	4/11/2019	4/29/2019	18	33	63
2019	2 (Control)	6/11/2019	6/18/2019	7	16	72

	Spice					
2018	3 ($CaCl_2$)	5/15/2018	5/24/2018	9	84	68
2018	3 ($CaCl_2$)	5/29/2018	6/9/2018	11	5	85
2019	3 ($CaCl_2$)	4/11/2019	4/29/2019	18	23	63
2019	3 ($CaCl_2$)	6/11/2019	6/18/2019	7	37	72
2018	4 (Control)	5/15/2018	5/24/2018	9	31	68
2018	4 (Control)	5/29/2018	6/9/2018	11	13	85
2019	4 (Control)	4/11/2019	4/29/2019	18	40	63
2019	4 (Control)	6/11/2019	6/18/2019	7	22	72

Table 8. Soil Organic Matter Comparison for Significance Between Cover Crop Areas and Year

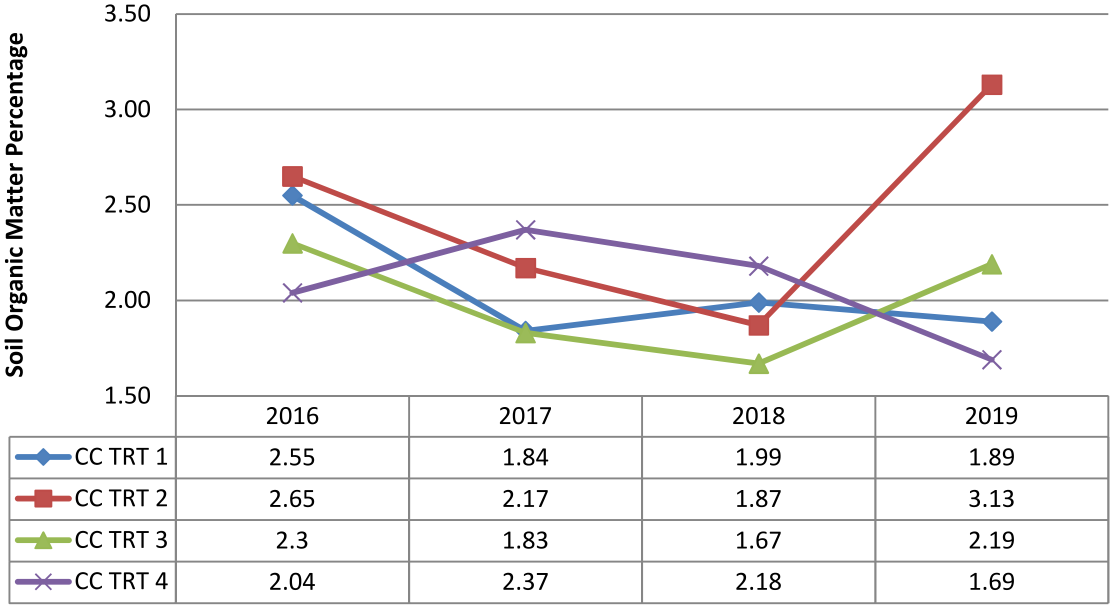
Sampling Year	Cover Crop Treatment	Cover Crop Treatment	Adj P
2016	1^{A}	2	0.8265
2016	1	3	0.1696
2016	**1**	**4**	**0.0019**
2016	**2**	**3**	**0.0335**
2016	**2**	**4**	**0.0003**
2016	3	4	0.1615
2017	**1**	**2**	**0.0133**
2017	1	3	0.9996
2017	**1**	**4**	**0.0002**
2017	**2**	**3**	**0.0106**
2017	2	4	0.1893
2017	**3**	**4**	**0.0001**
2018	1	2	0.5644

2018	**1**	**3**	**0.0129**
2018	1	4	0.2146
2018	2	3	0.1694
2018	**2**	**4**	**0.0174**
2018	**3**	**4**	**0.0002**
2019	1	2	0.3862
2019	1	3	0.9758
2019	1	4	0.9945
2019	2	3	0.6217
2019	2	4	0.2712
2019	3	4	0.9112

[Z] Values <0.05 are significantly different

[A] **CC Treatment**	**1**	**2**	**3**	**4**
Warm Season	Sorghum sudan & Cowpeas	Cowpea	Pearl millet & Cowpea	Fallow
Cool Season	Cereal rye & Crimson clover	Winter wheat & Crimson clover	Cereal rye, Austrian winter pea, tillage radish	Fallow

Figure 7. Average Percent Soil Organic Matter of Cover Crop Areas By Sampling Year



	2016	2017	2018	2019
CC TRT 1	2.55	1.84	1.99	1.89
CC TRT 2	2.65	2.17	1.87	3.13
CC TRT 3	2.3	1.83	1.67	2.19
CC TRT 4	2.04	2.37	2.18	1.69

CC Treatment	**1**	**2**	**3**	**4**
Warm Season	Sorghum sudan & Cowpeas	Cowpea	Pearl millet & Cowpea	Fallow
Cool Season	Cereal rye & Crimson clover	Winter wheat & Crimson clover	Cereal rye, Austrian winter pea, tillage radish	Fallow

Table 9. Total Plant Dry Weight Comparison by Cover Crop Area 2018-2019

Cover Crop Treatment[A]	**Plant Weight (g)**
1	63.5 A[Z]
2	53.1 A
3	29.5 B
4	45.3 BA

[A] **CC Treatment**	**1**	**2**	**3**	**4**
Warm Season	Sorghum sudan & Cowpeas	Cowpea	Pearl millet & Cowpea	Fallow
Cool Season	Cereal rye & Crimson clover	Winter wheat & Crimson clover	Cereal rye, Austrian winter pea, tillage radish	Fallow

CHAPTER IV

CONCLUSIONS

In conclusion, direct seeding has the potential to be beneficial to producers with the right production plan in place. The results indicate that cover crops may increase production, seed priming may increase production depending on the type of pepper being produced, and planting dates can be earlier than traditional methods would suggest.

Based on the results from this research, all treatments performed at a higher rate for both pepper types within cover crop area 2 (Table 5 and 6). Cover crop treatment 2 area consists of cowpea for warm season cover crops and winter wheat mixed with crimson clover for the cool season. Cover Crop treatment 2 also saw a major jump in soil organic matter in 2019 (Figure 7). While high variability in the results for 2019 soil tests resulted in no differences being observed, there is potential to see further increased organic matter as the cover crop trials persist. Furthermore, both pepper types recorded some of the highest dry weight yields within cover crop treatment 2. While TRT 1 and 2 were not significantly different, they did perform better than TRT 3 and 4 which leads the author to conclude that TRT 2 has more potential overall. As previously stated, it was not possible for authors to properly replicate cover crops, instead, planting date and seed treatments were pseudo-replicated within each cover crop area. Readers should keep this in mind while considering the results. Further research is needed to determine the potential effects of different cover crops on direct seeded pepper production. Seed priming agents also proved to be beneficial in the greenhouse and field trials. While no significance was observed in the greenhouse in 2018, results from 2019 were significant between seed priming treatments and the control (Figure 5 and Figure 6). The results varied between types of pepper which indicates that pepper type may play a role in priming agents success. Again, these results varied based on which cover crop treatment area they were in.

Planting date needs to be examined further, but the results from this research are encouraging. The soil temperatures varied at each planting date as did emergence counts. This could be evidence of soil temperature having a greater effect on pepper emergence than originally thought as plant counts varied greatly when soil temperatures varied by a few degrees.

This provides further evidence that not just one aspect of the study can be implemented with the expectation of similar results. Research into nitrogen fixing cover crops could prove beneficial. Exploring other seed priming agents that also require minimal equipment and processes or that are proven performers in cold soil temperatures is encouraged as well. Examination into cold temperature tested priming agents could also lead to using earlier planting dates which could improve production.

The results from this research are promising for the future of direct seeding bell and spice peppers. While significance was displayed in a variety of areas of this project, further research is needed to further refine and uncover other reliable protocols.

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