Comparison of Organic and Conventional Crops at the Neely-Kinyon Long-term Agroecological Research (LTAR) Site, 2017

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Materials and Methods

The Neely-Kinyon LTAR site was established in 1998 to study the long-term effects of organic production in Iowa. Treatments at the LTAR site, replicated four times in a completely randomized design, include the following rotations: conventional Corn-Soybean (C-S), organic Corn-Soybean-Oats/Alfalfa (C-S-O/A), organic Corn-Soybean-Oats/Alfalfa-Alfalfa (C-S-O/A-A) and organic Corn-Soybean-Corn-Oats/Alfalfa (C-SB-C-O/A). Oat/alfalfa plots were field cultivated on March 21, 2017, and 'Deon' oats were underseeded with 'Viking 372HD' alfalfa (Albert Lea Seed, Albert Lea, MN) at a rate of 90 lbs/acre and 15 lb/acre, respectively, on March 22. Plots were cultipacked on the same day as planting. Following harvest of the organic corn plots in 2016, winter rye was no-till drilled at a rate of 75 lb/acre on October 24, 2016.

Conventional corn plots were disked on May 5, 2017, injected with 32% UAN on May 12, at 150 lb/acre, and field cultivated on May 13. Plots were planted and sprayed on May 15 with Dual II Magnum™ at 1 pt/acre and Atrazine 4L™ at 1 qt/acre. Conventional corn plots were rotary hoed on May 26 to deal with crusting problems. Plots were sprayed with Status™ at 7 oz/acre, Succeed™ at 1 pt/acre, and AMS at 8 oz/acre on May 20.

Conventional soybean plots were disked on May 5 and field cultivated on May 13. Plots were planted and received applications of Sonic™ at 4 oz/acre on May 15. Plots were cultivated on May 13 and July 3 to deal with weeds still emerging after herbicides; plots also were rotary hoed on May 26 to deal with crusting problems. On June 20, plots were sprayed with Flexstar™ at 1 pt/acre, AMS at 8 oz/acre, Fusilade™ at 5 oz/acre, and MSO™ at 1.5 qt/acre to control remaining weeds.

Chicken manure (S.W. Iowa Egg Cooperative, Massena, IA) was applied at a rate of 3,105 lb/acre on April 4 to organic C-SB-O/A and C-CB-O/A-A plots; manure was applied to C-SB-C-O/A plots at a rate of 1,290 lb/acre.

The alfalfa and compost that was applied in the organic corn plots were plowed under on April 11, 2017. Plots were disked on May 5 and field cultivated on May 13. Organic corn plots were rotary-hoed on May 25, 31, and June 5; and row-cultivated on June 13, 20, 26, and July 3.

Corn and soybean variety selection and planting methods in 2016 were as follows: Viking VEF6102 (Albert Lea Seed, Albert Lea, MN) corn was planted at a depth of 2.5 in. as untreated seed at a rate of 34,000 seeds/acre in the organic and conventional plots, on May 15, 2017. IA3051RA12 (ISU, Ames, IA) soybeans were planted at a depth of 2 in. in organic and conventional plots at a rate of 170,000 seeds/acre on May 15, 2017.

Rye was disked in organic soybean plots on May 5 and twice on May 13 before soybean planting on May 15. Organic soybean plots were rotary hoed on May 25, 31, and June 5; and row-cultivated on June 13, 20, July 3, and 18. The length of time between planting and the first rotary hoeing (10 days) was damaging to weed management, so considerable time was invested in "walking" each organic soybean plot for large weeds above the canopy from June 26 to July 7. There was a problem of weeds in conventional plots in 2017, even after repeated herbicide applications, but these were not "walked" in keeping with the protocol of herbicide applications only in conventional plots.

Corn and soybean stands were counted on June 2 and 22, and weeds were counted within square foot quadrats at three randomly selected areas within a plot. Corn borer populations and damage were estimated on July 18; SPAD readings were also taken on this date. Soybean pest and beneficial insects were collected on August 4 by sweeping across randomly selected soybean rows 20 times with a 15-inch sweep net. Corn stalk nitrate samples were collected on September 30 from three randomly selected plants in each plot. Soybean cyst nematode sampling occurred in all soybean plots on November 14 by sampling at a 6-inch depth in three randomly selected areas in soybean rows in each plot. All plant and soil fertility analyses were conducted at the Iowa State University Soil and Plant Analysis Laboratory, Ames, IA, and nematode analysis was conducted at the ISU Plant Disease Clinic (Ames, IA). Soil quality was determined by sampling soil at a 6-inch depth in three randomly selected areas in each plot every Fall before any tillage, and analyzed by Dr. Cynthia Cambardella, Soil Scientist, USDA-ARS (Ames, IA). The amount of stained soybeans was determined in the laboratory from a random 200-g sample of harvested soybeans from each plot.

Alfalfa was harvested by mowing, raking and baling, on June 2, July 3, and August 2. Oat grain was harvested on July 21. Corn and soybean plots were harvested on November 3 and October 25, respectively. Grain samples were collected from each corn and soybean plot for grain quality analysis, which was conducted at the ISU Grain Quality Laboratory, Ames, IA.

Results and Discussion

The weather in 2017 was again challenging, with a wet spring and drought conditions in mid-summer. Corn and soybean stands were much lower than previous years, due to cool, wet weather and slow emergence. Similar corn plant populations were observed between organic and conventional systems at the first sampling on June 2, averaging 24,625 plants/acre (Table 1), compared to an average of 36,062 plants/acre in 2016. On June 22, corn populations averaged 26,250 plants/acre between systems (Table 2). Early grass weed populations were equivalent in conventional plots where multiple herbicides were applied, and in the C-S-C-O/A rotation (Table 1), but higher in the other organic C-S-O/A and C-S-O/A-A rotations, which averaged 14 weeds/m^2. Broadleaf weeds, averaging 3 weeds/m^2, were similar in both conventional and organic plots. At the later sampling, the same pattern remained, with less grass weeds in the conventional and C-S-C-O/A rotations compared to an average of 4 weeds/m^2 in the other organic rotations (Table 2). Broadleaf weeds were similar between rotations, averaging 1 weed/m^2.

Soybean plant populations were greatest in the C-S-C-O/A rotation, and averaged 95,500 plants/acre on June 2 (Table 3), compared to an average of 106,833 plants/acre in 2016. Conventional and the other organic C-S-O/A and C-S-O/A-A rotations were lower, at an average of 77,417 plants/acre. Usually, with a population of at least 74,000 plants/acre, the expense of re-planting is not warranted. At the June 22 sampling date, there was no difference between organic and conventional soybean stands, which were reduced to an average of 65,167 plants/acre (Table 4). At the early sampling, grass weeds averaged 3 weeds/m^2, with no difference between rotations (Table 3). Broadleaf weeds were also similar between conventional and organic soybean plots, averaging 6 weeds/m^2 compared to previous years where conventional soybean plots typically had less weeds than organic plots. At the second sampling, the early pattern remained, with equivalent grass weeds (averaging 1 weed/m^2) and broadleaf weeds (averaging 4 weeds/m^2) in both conventional and organic systems. As in recent years, many broadleaf weeds remained in conventional plots, even after multiple herbicide applications.

No corn borers (CB) were detected in corn plants on July 18, but CB damage was observed in equivalent, low numbers, averaging less than 1%, across all plots (Table 5). SPAD readings, signifying chlorophyll content, were similar between rotations, averaging 59 across all plots (Table 5). Corn stalk nitrate levels were also equivalent between systems, averaging 942 ppm nitrate-N (Table 6). The rotation with the greatest stalk nitrate levels (C-S-O/A-A) did have the highest yields in 2017 (Table 9).

Soybean insect pest levels were low in 2017, with no difference in pest insects between conventional and organic soybeans (Table 7). Aphids averaged 1 aphid/20 sweeps and bean leaf beetles averaged 6 beetles/20 sweeps. Corn rootworm beetles were observed at the highest levels ever recorded, averaging 11 beetles/20 sweeps, which had not been observed previously in soybean plots. Thrips also averaged 11 thrips/20 sweeps, but this level was not damaging. Beneficial insects in the soybean plots, including minute pirate bugs and green lacewings, did not differ between rotations (Table 7). Soybean cyst nematodes averaged 9 eggs per 75 cc of soil, with no differences between systems (Table 8). Stained soybeans (from insect-vectored diseases or other pathogens) averaged 1.6%, signifying low populations of damage.

Oat yields were impacted by wet weather, with yields of 73 bu/acre in the three-year rotation, and 92 bu/acre in the four-year rotation (Table 10), although the county average was only 77 bu/acre. Alfalfa yields were excellent, at 4.1 tons/acre over the entire season, similar to the 4.6 tons/acre yields in 2014 and 2015. The June harvest was the highest, with the July and August cuttings suffering from dry weather.

Organic corn yield in the C-S-O/A-A plots (151 bu/acre) was statistically greater than the conventional corn yield, which averaged 134 bu/acre (Table 9). The other organic corn yields were statistically similar to the conventional corn yield, but numerically higher, at 151 bu/acre in the three-year rotation, and 136 bu/acre in the rotation with the reduced rate of compost (C-S-C-O/A).

Despite insufficient mechanical weed management in organic soybean plots due to weather impacting field operations, the subsequent high weed populations in the organic soybeans were managed through manual removal ("walking") and yields were high. The average organic soybean yield (47 bu/acre) was equivalent to the conventional soybean yield (45 bu/acre), which received multiple herbicides (Table 9).

If crops were sold as certified organic, as they were in previous years (and can continue to be, since the fields are certified every year), premium organic corn prices would have brought in $1,359/acre in the C-S-O/A-A rotation, compared to $422/acre for conventional corn. Organic soybeans could have been sold for $852/acre in the same rotation, compared to $415/acre for conventional soybeans.

Organic corn grain quality was exceptionally high in 2017. Protein levels, averaging 9.1%, were equal to conventional corn, at 8.7% (Table 11). The longer period between corn crops in the organic system lent an additional 0.35% in protein content, as evidenced by the 8.88% protein in the corn-intensive C-S-C-O/A rotation compared to 9.23% in the C-S-O/A-A rotation. Corn density was greater in the organic system, at 1.3%. Moisture was equivalent between systems, averaging 17%. Corn starch was also equivalent in both systems, averaging 72%. Oil content was similar between conventional and organic corn, averaging 4.2%.

Soybean moisture levels were equivalent between systems, averaging 10.5% (Table 12). Protein levels were greater in the organic soybeans, averaging at 38.7%, compared to 36.4% in conventional soybeans. Protein levels in the C-S-C-O/A rotation (39.2%) were greater than the conventional and C-S-O/A-A rotation (38.1%). Soybean carbohydrate levels were greater in the conventional C-S rotation (22.7%) compared to the organic rotations, which averaged 21.6%. Oil levels were also greater in the conventional C-S rotation (18.2%) compared to the organic rotations, which averaged 17.2%. Fiber content in the conventional soybeans (4.7%) was greater than the organic rotations, which averaged 4.6% (Table 12).

Soil quality determinations at the LTAR site, by Dr. Cynthia Cambardella, Soil Scientist, USDA-ARS (Ames, IA), were found to be consistently higher in the organic rotations relative to the conventionally managed corn-soybean rotation. In 2015 and 2016, soil quality the organic soils had more microbial biomass C and N, higher P, K, Mg and Ca concentrations, and lower soil acidity than conventional soils. The long-term 4-yr organic rotation had more microbial biomass C and stable macroaggregates than the 3-yr organic rotation in the fall of 2016 (Table 13) which suggests that the extra year of alfalfa enhances soil structural stabilization and microbial activity. Soil quality enhancement was particularly evident for labile soil C and N pools, such as N mineralization potential and particulate organic matter, which are critical for maintenance of N fertility and efficient carbon cycling in organic systems, and for basic cation concentrations, which control nutrient availability through the relationship with cation exchange capacity (CEC).

In the soil microbial community structure analysis of LTAR soils, data suggested that bacterial communities in the organic soil differed from conventional soils. Since the organic soils were shown to have significantly higher microbial biomass C and N and more biologically active organic matter than the conventional soil, this suggests that organic management provides a rich resource of food for the soil microbes, which fuels microbial growth, and subsequently increases microbial biomass.

Acknowledgments

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Table 1. Corn and weed populations in the LTAR experiment, Neely-Kinyon Farm, Greenfield, IA, 6/2/17.

Treatment	Plant population (plants/acre)	Grass weeds (plants/m^2)	Broadleaf weeds (plants/m^2)
Conventional C-SB[x]	24,000	0.17b	2.33
Org. C-SB-O/A	24,833	14.83a	4.67
Org. C-SB-O/A-A	24,250	13.00a	0.17
Org. C-SB-C-O/A	25,417	8.67ab	3.00
$LSD_{0.05}$	NS[y]	8.66	NS
p value (α=0.05)	0.6274	0.0067	0.0620

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 2. Corn and weed populations in the LTAR experiment, Neely-Kinyon Farm, Greenfield, IA, 6/22/17.

Treatment	Stand (plants/acre)	Grass (plants/acre)	Broadleaf (plants/acre)
Conventional C-SB[x]	24,667	0.17b	1.33
Org. C-SB-O/A	27,083	5.33a	2.83
Org. C-SB-O/A-A	24,917	6.00a	0.33
Org. C-SB-C-O/A	28,333	1.33b	1.17
$LSD_{0.05}$	NS[y]	3.35	NS
p value (α=0.05)	0.2650	0.0015	0.0753

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 3. Soybean plant and weed populations in the LTAR experiment, Neely-Kinyon Farm, Greenfield, IA, 6/2/17.

Treatment	Stand (plants/acre)	Grass weeds (plants/m^2)	Broadleaf weeds (plants/m^2)
Conventional C-SB[x]	77,750bc[y]	3.17	4.50
Org. C-SB-O/A	72,500c	2.17	6.83
Org. C-SB-O/A-A	82,000b	2.67	4.83
Org. C-SB-C-O/A	95,500a	4.00	6.50
$LSD_{0.05}$	9.33	NS	NS
p value (α=0.05)	<0.0001	0.8018	0.7157

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 4. Soybean and weed populations in the LTAR experiment, Neely-Kinyon Farm, Greenfield, IA, 6/22/17.

Treatment	Plant population (plants/acre)	Grass weeds (plants/m^2)	Broadleaf weeds (plants/m^2)
Conventional C-SB[x]	70,000	0.33	2.67
Org. C-SB-O/A	67,000	2.00	7.00
Org. C-SB-O/A-A	63,833	1.67	3.33
Org. C-SB-C-O/A	59,833	0.50	4.67
$LSD_{0.05}$	NS[y]	NS	NS
p value (α=0.05)	0.3281	0.2942	0.0940

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 5. Corn borer populations and SPAD readings in the LTAR experiment, Neely-Kinyon Farm, Greenfield, IA, 7/18/17.

Treatment	Corn borer presence (insect/plant)	Corn borer damage (0 or 1)	SPAD reading
Conventional C-SB[x]	0	0.08	60.60
Org. C-SB-O/A	0	0.00	57.80
Org. C-SB-O/A-A	0	0.00	58.85
Org. C-SB-C-O/A	0	0.08	57.68
$LSD_{0.05}$	NS[y]	NS	NS
p value (α=0.05)	-	0.5770	0.1429

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa
[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 6. Corn stalk nitrate in the LTAR experiment, Neely-Kinyon Farm, Greenfield, IA, 9/30/17.

Treatment	NO_3^--N (mg/kg)
Conventional C-SB[x]	543
Org. C-SB-O/A	1,008
Org. C-SB-O/A-A	1,469
Org. C-SB-C-O/A	348
$LSD_{0.05}$	NS[y]
p value (α=0.05)	0.4608

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa
[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 7. Soybean insect populations in the LTAR experiment, Neely-Kinyon Farm, Greenfield, IA, 2017 (number per 20 sweeps).

Treatment	Ants	Aphids	Bean leaf beetles	Caterpillars	Corn rootworms	Crickets	Flea beetles	Whiteflies
Conventional C-SB[x]	0.00	0.75	3.50	0.50	9.75	0.00	0.50	0.00
Org. C-SB-O/A	0.25	1.50	5.25	1.00	10.00	0.00	0.25	0.00
Org. C-SB-O/A-A	0.25	2.25	10.25	0.75	6.25	0.00	0.25	0.25
Org. C-S-C-O/A	0.00	0.25	5.25	0.50	16.75	0.25	0.00	2.25
LSD$_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS
p value (α=0.05)	0.5885	0.6495	0.2369	0.8836	0.5827	0.4262	0.7256	0.0963

Grass-hoppers	Green lace-wings	Leaf-hoppers	Minute pirate bugs	Moths	Spiders	Stink-bugs	Tarnished plant bugs	Thrips	Parasitoid wasps	Mites
0.75	0.25	0.00	0.50	0.00	1.00	0.00	0.25	8.75	0.25	0.25
0.75	0.00	0.75	0.50	0.00	0.00	0.25	0.25	13.50	0.25	0.00
0.50	0.00	0.00	1.50	0.50	0.00	0.75	0.25	14.25	0.25	0.50
0.25	0.25	0.25	0.75	0.00	0.00	0.75	0.00	8.25	0.00	0.75
NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
0.8637	0.5885	0.5174	0.5796	0.4262	0.1678	0.3945	0.8015	0.9138	0.8015	0.7047

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 8. Soybean cyst nematode populations and stained soybeans in the LTAR experiment, Neely-Kinyon Farm, Greenfield, IA, 2017.

Treatment	Eggs/75cc soil	Stained soybeans (%)
Conventional C-SB[x]	0.00	0.96
Org. C-SB-O/A	0.00	1.35
Org. C-SB-O/A-A	0.00	1.90
Org. C-SB-C-O/A	37.50	2.35
$LSD_{0.05}$	NS[y]	NS
p value (α=0.05)	0.1134	0.3818

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa

[y]Means followed by the same letter down the column are not significantly different (S) at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 9. Corn and soybean yields in the LTAR experiment, Neely-Kinyon Farm, Greenfield, IA, 2017.

Treatment	Corn yield (bu/acre)	Soybean yield (bu/acre)
Conventional C-SB[x]	133.58b[y]	44.81
Org. C-SB-O/A	139.71ab	48.97
Org. C-SB-O/A-A	151.22a	47.71
Org. C-SB-C-O/A	136.43b	44.88
$LSD_{0.05}$	12.67	NS
p value (α=0.05)	0.0479	0.3857

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 10. Oat and alfalfa yields in the LTAR experiment, Neely-Kinyon Farm, Greenfield, IA. 2017.

Treatment	Oats (bu/acre)	Alfalfa Harvest dates (tons/acre)			Alfalfa (seasonal total) 4.1 tons/acre
	7/21/17	6/5/17	7/7/17	8/8/17	
C-SB-O/A	72.56	--	--	--	
C-SB-O/A-A	91.93	2.36	1.17	0.57	

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa

Table 11. Corn grain quality in the LTAR experiment, Neely-Kinyon Farm, Greenfield, IA, 2017.

Treatment	Moisture (%)	Protein (%)	Oil (%)	Starch (%)	Density (g/cc)	Ethanol yield (gal/bu)
Conventional C-SB[x]	16.88	8.68	4.08	72.35	1.30b	2.81
Org. C-SB-O/A	16.83	9.15	4.25	71.90	1.32a	2.78
Org. C-SB-O/A-A	17.18	9.23	4.28	71.78	1.32a	2.78
Org. C-SB-C-O/A	16.88	8.88	4.15	72.20	1.31ab	2.80
$LSD_{0.05}$	NS	NS	NS	NS	0.009	NS
p value (α=0.05)	0.0566	0.2707	0.1533	0.2534	0.0261	0.3078

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa
[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 12. Soybean grain quality in the LTAR experiment, Neely-Kinyon Farm, Greenfield, IA, 2017.

Treatment	Moisture (%)	Protein (%)	Oil (%)	Fiber (%)	Carbohydrates (%)
Conventional C-SB[x]	10.15	36.38c	18.23a	4.70a	22.70a
Org. C-SB-O/A	10.68	38.75ab	17.20bc	4.53b	21.53bc
Org. C-SB-O/A-A	10.60	38.08b	17.53b	4.58b	21.85b
Org. C-SB-C-O/A	10.73	39.23a	16.95c	4.53b	21.33c
$LSD_{0.05}$	NS[y]	0.95	0.49	0.09	0.43
p value (α=0.05)	0.0720	0.0002b	0.0008	0.0039	<0.0001

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa
[y]Means followed by the same letter down the column are not significantly different (S) at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 13. Neely-Kinyon LTAR soil quality, Fall 2016 (depth 0-15 cm).

	SOC gkg^{-1}	TN gkg^{-1}	pomC gkg^{-1}	pomN gkg^{-1}	mbc $mgkg^{-1}$	mbn $mgkg^{-1}$	pminN $mgkg^{-1}$	no3N $mgkg^{-1}$	P $mgkg^{-1}$	K $mgkg^{-1}$	Mg $mgkg^{-1}$	Ca $mgkg^{-1}$	Ec $\mu S\ cm^{-1}$	ph	Aggs %	bd gcm^{-3}
Conv C-S	22.7b	2.3b	2.75b	0.23c	285c	15.4b	36.6b	10.7a	22.9c	252b	358c	3368b	161b	6.11c	23.1b	1.18
Organic C-S-O/A	24.5a	2.5a	3.62a	0.33a	334b	19.8ab	47.6a	10.5a	110.2a	357a	434ab	4271a	211a	7.19a	23.1b	1.16
Organic C-S-O/A-A	24.3a	2.6a	3.60a	0.34a	369a	20.5a	50.0a	11.6a	77.8ab	288b	428b	4157a	214a	6.93b	29.5a	1.16
Organic C-S-C-O/A	24.0ab	2.6a	3.11b	0.29b	343b	20.7a	46.4a	9.8a	45.0bc	254b	493a	4045a	200a	7.00b	30.8a	1.18
LSD $_{0.05}$	1.4	0.1	0.41	0.040	32	4.8	4.2	NS	35.6	37.5	60	243	36	0.13	5.4	NS

[x] C=corn, S=soybeans, O=oats, A=alfalfa

[y] Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ (Fisher's Protected LSD Test).