Effects of Sugarbeet Processing Precipitated Calcium Carbonate on Crop Production and Soil Properties

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ABSTRACT

Precipitated calcium carbonate (PCC) lime is a byproduct of sucrose extraction from sugarbeet processing factories in Idaho. Each year 351,000 Mg PCC is produced and stockpiled at sugarbeet factories in Idaho. There currently are no large-scale disposal strategies for the PCC and these stockpiles continue to grow each year. The simplest solution would be to apply more of the PCC directly to agricultural fields each year, however the effects of PCC on high pH soils and southern Idaho crop rotations are not well understood. A study was conducted at the USDA-ARS laboratory in Kimberly, ID to determine the effects of PCC application to an alkaline silt loam soil on sugarbeet, dry bean and barley production and soil properties. Three PCC treatments (rate and timing) and an untreated control were compared. The PCC had no effects on crop production factors and most soil properties. The only significant effect of PCC treatments was an increase in soil phosphorus (P) concentrations compared to the control. This indicates the PCC can serve as a P fertilizer. For all three crops in this study, PCC was applied at rates that resulted in applied P levels that were 1.6 to 5.3 times greater than even the highest published recommended P rates. Compared to the control, bicarbonate soil P concentrations increased by 25% and 73% for the final PCC application amounts of 26.9 Mg ha^{-1} (6.7A treatment) and 89.7 Mg ha^{-1} (6.7A and 89.7T treatments), respectively. The

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PCC used in this study can safely be applied (at rates up to 87.9 Mg ha^{-1}) to heavier textured alkaline soils in the local growing area. Disposing of PCC in this way represents a viable strategy for reducing PCC stockpiles.

Additional Keywords: precipitated calcium carbonate, spent lime, lime, sugarbeet, sugar beet, Beta vulgaris, pH, phosphorus

Abbreviations: PCC = precipitated calcium carbonate

Precipitated calcium carbonate (PCC) is a byproduct of sucrose extraction from sugarbeet (*Beta vulgaris* L.). Other commonly used terms for PCC are beet lime and spend lime. The PCC is the by-product formed as a result of impurity removal during the purification of the sucrose. Impurities that need to be removed include organic molecules, phosphorus, magnesium, calcium, potassium and sodium (Hergert et al. 2017). To remove impurities from the sugarbeet sucrose liquid juice stream, calcium oxide and carbon dioxide are added to the stream to form calcium carbonate ($CaCO_3$) that precipitates out of the liquid juice stream with the impurities. The combination of the $CaCO_3$ and impurities form the PCC which is removed from the juice stream as a solid material.

Lime materials (PCC, calcium oxide, calcium hydroxide, calcium and magnesium carbonates, marl, blast-furnace slag, fly ash, and wastewater treatment sludge) are often used in agriculture to ameliorate the negative effects of soil acidification on crop production (Havlin et. al, 1999). These effects include Al and/or Mn toxicity, H ion toxicity, decreased bioavailability of some plant nutrients (Mg, Ca, K, P, and Mo), and inhibition of root growth (Marschner, 1995). An estimated 25 to 30% of world soils are acidic (Havlin et. al, 1999). In 1999, over 6.7 million Mg of agricultural lime was applied to acid soils in the U.S. (USGS, 2022). In agroecosystems, soil acidification is mainly attributed to the nitrification process (Tarkalson et al., 2006) and is enhanced by leaching of basic cations and conjugate bases such as nitrate ions and the removal of bases in harvested crops (Barak et al., 1997; Bouman et al., 1995; Dick, 1983; Heenan and Taylor, 1995; Juo et al., 1995; Lilienfein et al., 2000; Tarkalson et al., 2006). The incomplete return of neutralizing anions when nitrates are taken up by plants also contributes to soil acidification (Tarkalson et al., 2006). Soil acidification is common in areas with excess water leaching through soils due to higher rainfall amounts (typically >500 mm/yr) and lower soil base content (Miller and Gardiner, 2001). Periodic application of liming materials is often used on these soils to increase or maintain their productivity.

In the North Central U.S. sugarbeet producing area soils are often acidic and PCC is used to raise soil pH as well as to suppress *Aphanomyces cochliodes,* a pathogenic oomycete that causes sugarbeet root damage (dampening off and rot) (Olsson et al., 2019; Lien et al., 2016; Brantner et al., 2015; Windels et al., 2008). Although, PCC has been applied to alkaline soils in the region without negative effects on crop production (Christenson et al., 2000). In Michigan, sugar beet growers apply approximately 220,000 tons of PCC annually (Clark et. al, 2015). Because PCC has value as an ameliorator of low pH soils, it is widely used (Barber, 1984). This prevents the kind of accumulation of PCC at North Central U.S. sugarbeet factories that is so common, and problematic, in the Pacific Northwest growing area (Clark et. al, 2015). In one study in Minnesota, PCC applied at rates ranging from 6 to 23.8 Mg ha^{-1} increased soil pH from 6.5 to 7.5 and sugar beet sucrose yield from 4,400 to 10,300 kg ha^{-1}, respectively. This increase in yield was attributed to ameliorating negative effects associated with low soil pH. In soils with high *Aphanomyces cochliodes* disease pressure, PCC applications have been shown to ameliorate root damage and yield losses (Lien et al., 2016; Brantner et al., 2015).

In the Amalgamated Sugar Company growing area in Idaho, Oregon and Washington calcareous soils prevail. High in base cations, these soils typically have pH's in the range 7.5-8.5. These soils do not cause the same negative effects on crop production as those associated with acidic soils and therefore do not require lime applications to adjust soil pH. The soil pathogen *Aphanomyces cochliodes* is also present in this growing region and PCC is often applied to reduce its damaging effects, however this accounts for a very small proportion of overall PCC production each year and is not in itself a solution for reducing the ever-growing stockpiles of PCC at the factories. Additional uses for PCC are required.

The simplest way to dispose of the PCC is to apply it each year to the agricultural soils within an economically feasible proximity to the sugarbeet factories. This could only be considered if there was confidence that the PCC caused no harm either to the soil chemical /physical properties, to sugarbeet productivity, or to the other crops commonly grown in rotation with sugarbeet. Additional questions regarding lime source applications to soils are potential negative effects from added salts and metals. The main soluble salts in the soil are composed of the combinations of the cations sodium (Na^{+}), calcium (Ca^{+2}), magnesium (Mg^{+2}), ammonium (NH_4^{+}), and potassium (K^{+}), and the anions chloride (Cl^{-}), sulfate (SO_4^{-2}), bicarbonate (HCO_3^{-}), carbonate (CO_2^{-2}), and nitrate (NO_3^{-}) (Miller and Gardiner, 2001). High soluble salts concentrations lower the osmotic water potential in soil resulting in plants being unable to draw water into the roots, resulting in water deficiencies in plants. Additionally, high soluble salts in the root zone can compromise sugarbeet seed germination and emergence resulting in poor stand counts (Walter et al., 1951). Preliminary research on the effects of PCC applied to arid alkaline soils (Scottsbluff NE, Ft. Morgan CO, and Torrington WY) showed no negative effects on the emergence of sugarbeet (Hergert et al., 2017). Hergert et al. (2017) stated that additional research was needed to evaluate the effects of PCC on soil characteristics and plant growth under field conditions. In addition, when land applying amendments, concentrations of potentially toxic metals need to be considered. Some common metals that can be toxic to plants if soluble concentrations in soils are high enough are Al, Cu, Zn, Cd, and Pb (Angulo-Bejarano et al., 2021).

The Amalgamated Sugar Company LLC's major sugarbeet processing factories (Paul, ID; Twin Falls, ID; and Nampa, ID) produce approximately 351,000 Mg of PCC annually (Amalgamated Sugar Company LLC, personal conversation). In 2018, PCC stockpiles at these factories totaled approximately 11.4 million Mg. Without an offsite beneficial use or disposal method for the PCC, the stockpiles will continue to grow. The difficulty in finding more land to stockpile PCC due to availability issues and high land prices, and potential environmental issues have resulted in the need for Amalgamated Sugar Company LLC to find more offsite beneficial use or disposal methods

The objective of the study was to assess the effects of added PCC to a common alkaline soil on a sugarbeet-dry bean-barley rotation yields and soil chemical properties. The data will be used to determine if PCC can be land applied on high pH soils.

Materials and Methods

This study was conducted from 2014 to 2020 at the USDA-ARS Northwest Irrigation & Soils Research Lab in Kimberly, ID on a Portneuf silt loam (coarse-silty mixed superactive, mesic Durixerollic Xeric Haplocalcids). The treatments included four PCC (obtained from the Twin Falls Idaho factory) application rate/timings. Table 1 outlines the treatments application details. The treatments included:

- 0 Mg PCC ha^{-1} (control)
- 7 Mg PCC ha^{-1} fall applied in 2014, 2015, 2016, and 2017
- 4 3 Mg PCC ha^{-1} fall applied in 2014, 2015, 2016, and 2017
- 7 Mg ha^{-1} applied in the fall of 2014.

Treatments 3 and 4 contained the same cumulative rate of 89.7 Mg ha^{-1} (Table 1). The treatments were arranged in a randomized block design and each treatment was replicated four times. Each plot was 6.7 m wide and 18.3 m long. Soils were sampled in the spring and fall of each year. Samples were collected from 0 to 0.3 m depth. In the fall of each year the soil sampling was done before PCC application. Soil sampling dates are in Table 1. The soil samples were analyzed for pH (Kalra, 1995), electrical conductivity (EC) (Rhoades, 1996), bicarbonate extractable P (Olsen et al., 1954), NO_3-N and NH_4-N (Mulvaney, 1996), Total C and N using a FlashEA1112 CN analyzer (CE, Elantech, Lakewood, NJ), and total elements (P, K, Ca, Na, Al, Cu, Zn, Cd, Pb) with ICP-OES detection (U.S. Environmental Protection Agency, 1996). Due to the significant concentration of P in the PCC (Tables 2 and 3) and the marginal crop requirement concentrations in the soil over the study area (site bicarbonate extractable P average = 18.1 mg kg^{-1}), to eliminate the crop productivity responses to P, in spring 2015, 450 kg P_2O_5 ha^{-1} (mono ammonium phosphate fertilizer) was applied over the entire study area. Soil fertilizer recommendations were determined each year based on University of Idaho recommendations for sugarbeet (Walsh et al., 2019; 168 kg N ha^{-1} and 224 kg K_2O ha^{-1} in 2015, and 78 kg N ha^{-1} in 2018), dry bean (Moore et al., 2012; no fertilizer recommended), and barley (Robertson and Stark, 2003; 168 kg N ha^{-1}).

Table 1. For each year of the study, precipitated calcium carbonate (PCC) treatment annual rates and cumulative total amounts applied (in parentheses), crop grown, soil sample date, and lime application date in Idaho.

Year	2014	2015	2016	2017	2018	2019	2020
Crop	—	Sugarbeet	Dry Bean	Barley	Sugarbeet	Dry Bean	Barley
	———————————————-Mg ha^{-1}———————————————-						
Control	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
6.7A	6.7 (6.7)	6.7 (13.5)	6.7 (20.2)	6.7 (26.9)	0 (26.9)	0 (26.9)	0 (26.9)
22.4A	22.4 (22.4)	22.4 (44.8)	22.4 (67.3)	22.4 (89.7)	0 (89.7)	0 (89.7)	0 (89.7)
89.7T	89.7 (89.7)	0 (89.7)	0 (89.7)	0 (89.7)	0 (89.7)	0 (89.7)	0 (89.7)
Soil Sample Date	Oct. 29	Nov. 17	Nov. 15	Oct. 25	Nov. 14	Oct. 24	Oct. 16
Lime Application Date	Oct. 30	Nov. 18	Nov. 30	Oct. 31	—	—	—

Table 2. Selected average chemical characteristics and constituent contents of the PCC used in this study.

CCE (%)	81
pH	8.4
EC (µS cm^{-1})	2280
NO_3-N (mg kg^{-1})	183.8
NH_4-N (mg kg^{-1})	8.5
P (mg kg^{-1})	6559
K (mg kg^{-1})	1008
Ca (mg kg^{-1})	289069
Na (mg kg^{-1})	453.2
Al (mg kg^{-1})	3636
Cu (mg kg^{-1})	16.3
Zn (mg kg^{-1})	36.2
Cd (mg kg^{-1})	0.40
Pb (mg kg^{-1})	0.92

Table 3. Total rates of selected constituents applied from the PCC treatments. Rates are based on total lime applied for each treatment: 26.9, 89.7, and 89.7 Mg ha^{-1} for the 6.7A, 22.4A, 89.7T treatments, respectively.

Constituent	6.7A	22.4A	89.7T
	——————Total kg ha^{-1}——————		
NO_3-N	4.9	16.5	16.5
NH_4-N	0.23	0.76	0.76
P	176	588	588
P_2O_5	404	1347	1347
K	27.1	90.4	90.4
K_2O	32.5	108	108
Ca	7776	25930	25930
Na	12.2	40.7	40.7
Al	98	326	326
Cu	0.4	1.5	1.5
Zn	1.0	3.2	3.2
Cd	0.011	0.036	0.036
Pb	0.025	0.083	0.083

The PCC was uniformly surface broadcast using a manure spreader. Following PCC applications each fall the entire study area was disked, moldboard plowed, and roller harrowed. The study area was planted to sugarbeet (BTS 21RR25) in 2015 and 2018, dry beans (Ruby Small Red) in 2016 and 2019, and barley (Moravian 69) in 2017 and 2020. The crops were furrow irrigated to meet estimated crop evapotranspiration (ET_c) rates (Wright, 1982). The harvest areas within each plot for each crop were 18.7, 25.5, and 25.5 m^2 for sugarbeet, dry bean, and barley, respectively. Sugarbeets were harvested using a custom 2 row (1.1176 m) research harvester attached to a New Holland (Turin, Italy) TM90 tractor. Sugarbeets from the plots harvest areas were removed from the soil and placed onto a load cell platform where each plot weights were measured, and two 8 beet subsamples were collected. Subsamples were sent to the Amalgamated Sugar Company tare lab for analysis of percent sugar and quality parameters (conductivity and nitrates). Percent sugar was determined using an Autopol 880 polarimeter (Rudolph Research Analytical, Hackettstown, NJ), a half-normal weight sample dilution, and aluminum sulfate clarification method [ICUMSA Method GS6-3 1994] (Bartens, 2005).

Conductivity was measured using a Foxboro conductivity meter Model 871EC (Foxboro, Foxboro, MA) and nitrate was measured using a Denver Instruments Model 250 multimeter (Denver Instruments, Denver, CO) with Orion probes 900200 and 9300 BNWP (Krackler Scientific, Inc., Albany, NY). Recoverable sucrose yield per ton of roots was estimated by: [(extraction)(0.01)(gross sucrose/ha)]/(t/ha), where extraction = 250 + [[(1255.2)(conductivity) – (15000)(percent sucrose – 6185)]/[(percent sucrose)(98.66 – [(7.845)(conductivity)])]] and gross sucrose = (t/ha)(percent sucrose)(0.01)(1000 kg/t). Dry bean and barley were harvested with an Almaco (Nevada, Iowa, U.S.) PMC20 Plot Master Combine with a 1.524 m wide cutting head, The harvested grain and beans were collected in sacks, weighed, and yield determined.

Analysis of variance was determined for treatment main effects for production factors (sugarbeet root yield, sugarbeet ERS yield, sugarbeet root sucrose concentration, sugarbeet root brei nitrate concentration, barley grain yield, and dry bean yield) using a randomized block design model in Statistix 8.2 (Analytical Software, Tallahassee, FL). For significant (0.05 probability level) main effects, the LSD mean separation method were used to determine treatment differences.

Results and Discussion

There were no significant impacts of PCC on sugarbeet, dry bean, and barley crop yields in years 2015, 2016, 2017, 2019, and 2020. (Table 4). However, in 2018, sugarbeet root yield was lower for the control treatment compared to the 22.4A treatment (Table 4) but there was no difference between the control and the remaining two PCC treatments (6.7A and 89.7T) or between the 22.4A treatment and the other two PCC treatments. This significant difference was not easily interpreted according to PCC application rates and timings, thus any negative or positive effects associated with PCC could not be determined. In 2018, both the 22.4A and 89.7T treatments had the same total lime application rate of 89.7 kg ha^{-1} (Table 1). In both sugarbeet crop years (2015 and 2018) PCC had no significant effect on sucrose concentration, sugar quality indicators (conductivity and nitrates) (Table 4), or seed germination (data not shown). The average sugarbeet populations at harvest in 2015 and 2018 were 110,00 and 122,000 plants ha^{-1}, respectively. Plant populations were not determined for barley and dry beans.

The calcium carbonate equivalency (CCE) is the acid neutralizing value of PCC compared to 100% calcium carbonate. The average CCE of PCC used in this study was 81%. This PCC is a good lime source compared to other by-product related lime sources. For example, Class C fly ash (by-product of subbituminous coal combustion) utilized in Nebraska as an agricultural lime source has an average CCE of 40-45% (Tarkalson et al., 2005; Yunusa et al., 2012). Despite PCC’s acid neutralizing value and at the high rates applied in this study, none of the PCC treatments caused significant increases in soil pH in any of the years measured (Table 5). The PCC pH (8.4) was not much higher than many alkaline soils in the arid western U.S. The research area for this study had control treatment (no PCC) pH levels ranging from 7.8 to 8.1 across sampling times (Table 5). The average EC value of the PCC was 2280 µS cm^{-1} (Table 2). Although this was much higher than the control soil (average 569 µS cm^{-1}) it did not result in any significant increase in soil EC even at the highest applied rate (Table 5). This could explain why sugarbeet sugar quality, which is negatively influenced by high salts, remained unaffected by any PCC treatment.

The PCC contained a significant amount of crop nutrients P and K (Table 2). The PCC additions increased soil bicarbonate extractable and total P concentrations (Table 5). Across all crops and PCC treatments, PCC applied between 1.6 and 5.3 times more P_2O_5 than the highest recommended rates for sugarbeet, barley and dry bean (Walsh et al., 2019; Moore et al., 2012; Robertson and Stark, 2003) (Table 3). Across all crops and PCC treatments, PCC applied between 0.07 and 0.42 times more K_2O than the highest recommended rate (Table 3). The PCC was not a significant source of available N (Table 2 and 3).

Comparisons between the soil in 2014 prior to PCC applications and the PCC material showed that PCC contained 6.6, 5.0, 1.8, and 1.2 times higher concentrations of P, Ca, Na, and Cu than the soil, respectively. At the rates of PCC applied in the study, the masses of Na and Cu added to the soil were minimal. Precipitated calcium carbonate applied at a cumulative amount of 26.9 kg ha^{-1} (6.7A treatment) increased total soil Na and Cu masses by 1.2% and 0.82% in the top 0.3 m of soil, respectively. Precipitated calcium carbonate applied at a cumulative amount of 89.7 kg ha^{-1} increased total soil Na and Cu masses by 3.9% and 2.7% in the top 0.3 m of soil, respectively. The only constituent that increased in concentration in the soil over time compared to the control was P (Table 5). All other measurements and constituent concentrations did not increase in the soil after lime applications across time. The soil (0-0.3 m) contains 3.5, 5.0, 1.8, 1.4, and 12.4-times higher concentrations of K, Al, Zn, Cd, and Pb than the PCC, respectively. Because the PCC was incorporated into the top 0.3 m layer, the addition of PCC cannot increase the total concentrations of K, Al, Zn, Cd and Pb in the soil. Overall, PCC additions at rates in this study only increased soil P concentrations thus serving as a P source. Compared to the control, the bicarbonate soil P concentrations increased by 25% and 73% for the final PCC application amounts of 26.9 kg ha^{-1} (6.7A treatment) and 89.7 kg ha^{-1} (6.7A and 89.7T treatments), respectively. The applied PCC at all rates did not negatively impact soil properties. Christenson et al. (2000) showed that PCC application rates up to 5.6 Mg ha^{-1} increased the concentrations of Mn and Zn in sugarbeet and soybean leaves but did not affect yields compared to no PCC. The concentrations of Mn and Zn in the PCC was not reported in the study (Christenson et al., 2000).

The elements Al, Cu, Zn, Cd and Pb when in sufficient plant available concentrations can be toxic to plants (Angulo-Bejarano et al., 2021). However, there were no negative impacts on crop production from these elements.

Table 4. Sugarbeet production factors and analysis of variance (ANOVA) for production factors (significance at p>f = 0.05). Bolded p>f values were significant at the 0.05 probability level. Within each production factor, study, and year values with the same letters are not different at the 0.05 probability level. Sugarbeet root yields are reported at approximately 77% water content. Barley and dry bean yields are reported based on dry matter.

Year	Crop	Treatment	Cumulative Lime Applied Prior to Listed Year Crop (Mg ha^{-1})	————––-Production Measurements————–				
				Root Yield	Sucrose Yield	Sucrose	Root Nitrate	Root Conductivity
				Mg ha^{-1}	kg ha^{-1}	g kg^{-1}	mg kg^{-1}	mmhos
2015	Sugarbeet	Control	0	92.2	14024	17.8	140	0.70
		6.7A	6.7	87.8	13383	17.8	139	0.69
		22.4A	22.4	88.0	13310	17.7	140	0.70
		89.7T	89.7	91.8	13940	17.7	136	0.68
		Mean		**89.9**	**13664.4**	**17.7**	**138.9**	**0.70**
		p>f		*0.444*	*0.300*	*0.991*	*0.699*	*0.969*
2016	Dry Bean			No treatment yields measured due to significant crop damage from hailstorm in early June.				
				Yield				
				kg ha^{-1}				
2017	Barley	Control	0	5879				
		6.7A	20.2	5527				
		22.4A	67.3	5600				
		89.7T	89.7	5168				
		Mean		**5543**				
		p>f		*0.306*				
				Root Yield	Sucrose Yield	Sucrose	Root Nitrate	Root Conductivity
				Mg ha^{-1}	kg ha^{-1}	g kg^{-1}	mg kg^{-1}	mmhos
2018	Sugarbeet	Control	0	64.0 b	10697	19.3	84.0	0.64
		6.7A	26.9	73.5 ab	11871	18.9	90.2	0.75
		22.4A	89.7	83.6 a	13154	18.4	129.3	0.73
		89.7T	89.7	71.5 ab	11514	18.8	78.8	0.71
		Mean		**73.2**	**11809**	**18.8**	**95.6**	**0.70**
		p>f		***0.042***	*0.082*	*0.253*	*0.456*	*0.256*
				Yield				
				kg ha^{-1}				
2019	Dry Bean	Control	0	3635				
		6.7A	26.9	4079				
		22.4A	89.7	4041				
		89.7T	89.7	4130				
		Mean		**3971**				
		p>f		*0.317*				
				Yield				
				kg ha^{-1}				
2020	Barley	Control	0	7341				
		6.7A	26.9	7359				
		22.4A	89.7	7309				
		89.7T	89.7	7108				
		Mean		**7279**				
		p>f		*0.905*				

CONCLUSIONS

The PCC used in this study can safely be applied (at rates up to 89.7 kg ha^{-1}) to heavier textured alkaline soils in the local growing area. The application of PCC did not negatively affect sugarbeet, dry bean and barley yields in a silt loam soil. The PCC applied at rates up to 89.7 kg ha^{-1} was not a significant source of toxic elements to plants. Although the pH of PCC was higher than the soil, PCC rates application rates up to 89.7 kg ha^{-1} did not increase soil pH. The sugarbeet PCC used in this study could be used as a P fertilizer. In soils that have high soil P, PCC can potentially increase negative surface water impacts. The extent of the environmental impacts will vary based on management practices that affects the amount of runoff that enters off-site water streams. Practices that reduce runoff will reduce risks.

Table 5. Fall soil sample analysis and analysis of variance (significance at $p>f = 0.05$) for selected variables for treatments across years of the study. Bolded p>f values were significant at the 0.05 probability level.

Year	Treatment	Cumulative Lime Applied Prior to Soil Sample	pH	EC	Bicarbonate P	Total Inorganic N	Total P	Total K	Total Ca	Total Na	Total Al	Total Cu	Total Zn	Total Cd	Total Pb
		Mg ha^{-1}		µS cm^{-1}	————————————————————————mg kg^{-1}————————————————————————										
2014	Control	0	7.9	409	20.0	12.6	975	3421	64734	290.6	17766	12.6	64.3	0.54	11.8
	6.7A	0	7.8	412	22.3	11.3	1004	3552	55531	243.1	18356	13.5	66.5	0.55	11.7
	22.4A	0	7.8	393	14.2	10.6	968	3593	55675	249.3	18521	13.6	65.2	0.54	11.2
	89.7T	0	7.8	425	17.4	12.3	987	3532	54459	249.6	18355	13.6	64.7	0.54	11.1
	p>f		*0.903*	*0.693*	*0.381*	*0.412*	*0.717*	*0.575*	*0.662*	*0.314*	*0.404*	*0.662*	*0.850*	*0.804*	*0.611*
2015	Control	0	7.8	708	23.5b	25.5	1018b	3362	62567	261.0	17836	12.5	67.6	0.62	11.3
	6.7A	6.7	7.8	475	28.1b	29.7	1035b	3709	53458	272.0	18992	13.6	71.4	0.64	11.8
	22.4A	22.4	7.9	668	29.3b	21.9	1067b	3534	58949	263.5	18549	13.0	68.6	0.64	11.5
	89.7T	89.7	7.9	732	45.8a	23.4	1139a	3582	57703	278.3	18599	13.5	70.4	0.64	11.5
	p>f		*0.434*	*0.070*	***0.020***	*0.801*	***0.008***	*0.267*	*0.836*	*0.515*	*0.220*	*0.645*	*0.693*	*0.599*	*0.756*
2016	Control	0	7.8	498	27.7b	19.8	1082b	3812	60310	268.0	19010	12.8	76.4	0.61	12.4
	6.7A	20.2	7.8	533	37.5ab	22.6	1117ab	4182	51918	269.5	20397	13.5	69.6	0.58	11.9
	22.4A	67.3	7.8	547	43.3a	20.5	1090b	4071	56805	267.8	19754	13.0	66.7	0.60	11.8
	89.7T	89.7	7.9	590	48.7a	24.6	1158a	3942	54630	270.7	19326	13.4	66.7	0.60	11.8
	p>f		*0.152*	*0.074*	***0.015***	*0.161*	***0.044***	*0.362*	*0.839*	*0.998*	*0.322*	*0.869*	*0.135*	*0.756*	*0.851*
2017	Control	0	8.1	578	26.1c	35.4	1055	3639	60024	252.6	18385	12.9	403.0	0.66	11.4
	6.7A	26.9	8.1	543	35.6b	25.4	1067	4075	51641	230.9	19864	13.8	106.1	0.63	12.4
	22.4A	89.7	8.1	557	49.5a	32.3	1131	3909	55584	250.7	19252	13.7	270.4	0.65	9.5
	89.7T	89.7	8.1	454	45.6a	33.3	1123	3880	56154	308.8	19044	13.5	388.9	0.63	9.5
	p>f		*0.711*	*0.721*	***0.001***	*0.527*	*0.098*	*0.195*	*0.815*	*0.185*	*0.231*	*0.816*	*0.801*	*0.679*	*0.062*
2018	Control	0	8.1	596	29.7c	28.5	1016	3615	57880	246.1	18334	13.3	374.5	0.56	10.3
	6.7A	26.9	8.1	636	40.2b	46.0	997	3358	51561	294.1	16895	12.9	345.7	0.53	9.6
	22.4A	89.7	8.2	627	53.3a	30.8	1129	3755	64397	285.9	18822	13.6	115.0	0.59	11.8
	89.7T	89.7	8.1	621	44.0ab	27.7	1142	3791	62528	353.6	19044	14.4	127.5	0.59	11.1
	p>f		*0.384*	*0.819*	***0.005***	*0.307*	*0.092*	*0.517*	*0.626*	*0.334*	*0.366*	*0.578*	*0.261*	*0.289*	*0.370*
2019	Control	0	8.0	697	28.1c	50.3	1053	3625	62728	285.8	18455	13.5	63.0	0.60	12.8
	6.7A	26.9	8.1	594	35.8b	37.3	1053	3798	53345	263.1	19026	13.9	64.0	0.60	12.9
	22.4A	89.7	8.2	596	47.0a	34.6	1136	3625	60103	280.7	18407	13.9	63.6	0.62	12.4
	89.7T	89.7	8.1	706	43.3a	48.5	1141	3502	57258	272.7	17903	13.9	63.4	0.58	12.8
	p>f		*0.236*	*0.583*	***0.001***	*0.596*	*0.061*	*0.780*	*0.776*	*0.525*	*0.783*	*0.952*	*0.991*	*0.530*	*0.788*
2020	Control	0	8.1	502	22.0c	18.8	1030c	3454	60787	258.2	17730	12.9	63.3	0.63	12.4
	6.7A	26.9	8.1	467	30.8b	16.9	1060bc	3663	55792	260.1	18561	13.5	64.9	0.65	12.7
	22.4A	89.7	8.1	494	44.1a	13.8	1128a	3634	61948	277.9	18549	13.1	62.4	0.63	12.6
	89.7T	89.7	8.1	458	37.9a	15.2	1104ab	3615	54092	249.6	18470	13.7	65.6	0.64	12.9
	p>f		*0.617*	*0.743*	***<0.001***	*0.5237*	***0.019***	*0.442*	*0.802*	*0.501*	*0.321*	*0.802*	*0.602*	*0.771*	*0.861*

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