AGRONOMIC POTENTIAL AND LIMITATIONS OF USING PRECIPITATED CALCIUM CARBONATE IN THE HIGH PLAINS

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Introduction and Objectives:

Precipitated Calcium Carbonate (PCC) is a by-product of the sugar purification process. Calcium oxide and carbon dioxide from calcium carbonate are injected into juice and calcium carbonate reforms precipitating impurities to produce the thin juice from which sugar is extracted. Western Sugar factories at Fort Morgan, CO, Scottsbluff, NE and Torrington, WY currently produce approximately 105,000 tons per year plus about 15,000 tons of coal ash. Historically, PCC has been stockpiled near the factory sites and the amount and storage area continue to increase. PCC piles can be a management problem because they will grow weeds and can produce lime dust during wind storms. This is a concern with pending EPA regulations on agricultural dust.

Research in the Red River Valley (RRV) has evaluated PCC both as a fertilizer source and as a soil amendment. Some soils in the RRV region are acidic and PCC is an effective source for liming. However, soils of the High Plains are different than the soils in the RRV. Most soils in the Western Sugar areas contain low to high levels of residual lime and most pH levels are above 7.3. Due to the encouraging results from research done in the RRV area the potential for agricultural uses for this by-product could exist.

The main objective of the study is to evaluate PCC as a soil amendment and its possible agronomic benefits including added nutrients and its ability to affect disease, weed and insect pests. A secondary objective is to determine that there are no short or long term detrimental effects on crop production. To fulfill these objectives, several laboratory, greenhouse, growth chamber and field studies were conducted at different locations in Nebraska, Wyoming, and Colorado during 2011-2012.

Methods:

This experiment consisted of two phases: 1) greenhouse, growth chamber and laboratory research and 2) field plot research. Soil samples were collected from 10 different locations near Western Sugar factories at Scottsbluff NE, Torrington WY, and Ft. Morgan CO during late 2011. Greenhouse and growth chamber experiments were started in January, 2012.

Greenhouse Experiment 1:

A greenhouse experiment was conducted to determine the effect of different PCC rates on soil characteristics and the dry weight of sugar beet, corn, and dry bean. Soils from the 10 sites were analyzed for chemical properties and nutrient status. The collected soils were air dried and mixed with PCC at different rates (0, 5, 10, 15 and 20 tons/acre) for a greenhouse experiment in January, 2012. The experimental design was a randomized complete block design

with 3 replications. Three crops were planted in mid-February, 2012 and grown for 6-8 weeks. Plant biomass and soil samples were taken at the end of the experiment to determine effects of PCC on plant growth and chemical properties of the soil.

Growth Chamber Experiments:

To determine the sensitivity of kochia at 3 different PCC locations, an experiment was conducted under controlled conditions using four herbicide treatments at 6 different rates. Kochia seeds were collected in the fall of 2011 from plants growing on lime piles at the sugar factories located at Fort Morgan, CO, Scottsbluff, NE and Torrington, WY. Four-inch square plastic pots were filled with potting mix and 15 kochia seeds were planted per pot. The pots were transferred to a growth chamber and maintained at optimum conditions for seed germination. After the kochia seeds germinated, the seedlings were thinned to three plants per pot. When the average seedling height was 3 to 4 inches (approximately 15 days after planting), the pots were removed from the growth chamber and the plants were treated with different rates of herbicide.

The experimental design was a randomized complete block with three locations (Fort Morgan, Scottsbluff, and Torrington) and three herbicides (Roundup, atrazine, and Clarity) applied at six rates. Each treatment was repeated 6 times. The experiment was repeated twice. In the second run, atrazine was replaced with UpBeet. After treatment, plants were returned to the growth chamber and allowed to grow for 15 days. Seven days after herbicide application, kochia injury from herbicides was evaluated on a scale from 0 to 100 with 0 equal to no injury and 100 equal to death of the plant. Kochia plants were clipped at the base 15 days after treatment, put in a paper sack, placed in a dryer set at 100 F for 24 hours, after which the dry weight was recorded.

Greenhouse Experiment 2:

After determining the optimum PCC rate for plant growth, another greenhouse experiment was conducted to investigate the interaction between root aphid infestation and PCC. A soil mixture of 50% Tripp very fine sandy loam and 50% peat moss was used for this study. The PCC was from Western Sugar at Scottsbluff, NE. Four different rates of lime (0, 4, 8 12 tons/A) were blended with this soil mixture and tested. A sugar beet root aphid susceptible variety (HM3035RZ) was used in this study, with ten replicated plantings into 3½ inch pots for each lime rate. Each pot or plant was infested with 10 aphids. Aphids were allowed to multiply for three weeks, and then the study was evaluated. Root aphid number and root mass were evaluated by a visual rating.

Field Experiments:

Field experiments were also conducted at ten locations in NE, CO, and WY during 2012 to determine the effect of PCC on plant growth, yield, and quality of sugar beet, corn, and dry bean. Soil samples were collected from each individual field. The PCC was applied at the rates of 0, 4, 8, 12 tons per acre. Plot size was 25 feet long by six rows, depending on the producer planter row width. The experiment was designed as a Latin-square with four replications. At the end of the season, plots were harvested to determine yield and quality parameters.

Results and Discussion:

Greenhouse Experiment 1: PCC rate effect on soil characteristics and dry weight of sugar beet, corn, and dry bean

The chemical characteristics of PCC collected at different locations are shown in the Table 1. The chemical analysis of PCC (100%) from the three different locations suggested that PCC provides some nitrogen, phosphorus, and minor quantities of essential micronutrients such as iron, manganese, and copper. The analysis also suggested that nutrient status of PCC varied with the level of impurities precipitated during the reformation of $CaCO_3$. On average, 1 ton of 100% PCC provides 1.3 pounds of nitrate-N and 0.5 pounds of phosphorus. Large quantities of PCC would be required to improve the nutrient status of soil.

Table 1: Chemical characteristics of Precipitated Calcium Carbonate (PCC) used in the greenhouse and field studies obtained from three sugar factories.

Location	pH	Nitrate-N	P	K	Zn	Fe	Mn	Cu		ECC†	Moisture (%)
		ppm									
Scottsbluff, NE	8.4	160	175	34	1.6	62	6.5	0.22		72.3	15.3
Torrington, WY	7.8	1281	285	37	2.1	66	8.6	0.11		70.3	8.2
Ft. Morgan, CO	7.9	535	257	9.1	1.6	61	10.7	0.38		69.4	14.1

†Effective Calcium Carbonate percent

The soil texture of the soils used in this study ranged from sandy loam to clay. The pH ranged from slightly acidic to alkaline. The pH of most of the soils in the study was slightly alkaline and was similar to the average pH of PCC. The soil pH was not influenced by the rate of PCC (data not shown). The amount of PCC added to the soil was not large enough to make a difference in the pH of these soils, also similar results were observed with CEC and soluble salts. However, some sandy soils seemed to have lower soluble salts after PCC application. This may be due to the leaching of salts from irrigation of the pots.

The results also indicated that there were no negative effects of PCC observed on the plant growth and dry matter accumulation of sugar beet (Table 2), corn, and dry bean (data not shown). However, the significant rate effect on dry weight of sugar beet in some soils was evident in the results but, in general, the effect seemed to have no apparent trend or was completely random. Since all of the soils were alkaline, the PCC did not create a significant effect on the availability of nutrients, especially iron. The PCC rates used were not high enough to provide significant nutrients to create yield improvement even at the maximum rate of 20 tons/a.

In summary, the application of different PCC rates had no significant effect on either chemical characteristics of the soil (pH, CEC, soluble salts) or plant dry matter accumulation of the sugar beet. Based on the greenhouse work and considering what equipment might be used to spread PCC and what might be considered economically feasible rates, the PCC rates for the field work were established at 0, 4, 8 and 12 tons per acre.

Table 2: Effect of Precipitated Calcium Carbonate (PCC), mixed with ten different soils, on sugar beet dry weight.

Location	Soil type	PCC rate (tons/acre)				
		0	5	10	15	20
		Average Dry Weight (grams/plant)				
Scottsbluff, NE	Tripp very fine sandy loam	1.37 a*	1.77 a	1.06 a	1.26 a	1.34 a
	Otero-Bayard fine sandy loams	1.95 a	1.74 ab	1.63 ab	1.15 b	2.02 a
	Mitchell silt loam	1.82 a	2.27 a	1.76 a	2.05 a	1.71 a
	Alliance loam	1.59 a	1.02 b	1.26 ab	1.03 b	1.23 ab
Torrington, WY	Bankard loamy fine sand	1.53 a	1.86 a	1.98 a	1.40 a	1.88 a
	Mitchell silt loam	1.80 a	1.77 a	1.92 a	1.93 a	1.72 a
	Kim clay loam, alkali	1.65 a	1.30 ab	1.07 bc	0.85 c	1.37 ab
Ft. Morgan, CO	Deep clayey soils: Heldt-Limon	3.29 a	4.39 a	3.30 a	2.93 a	3.19 a
	Rago and kuma silt loams	3.84 a	3.58 a	2.76 a	2.51 a	2.91 a
	Weld silt loam	2.02 ab	2.38 ab	2.60 ab	1.83 b	2.84

*Values followed by the same letter are not significantly different at the 5% level.

Growth Chamber: Sensitivity of kochia growing on PCC piles to different herbicides.

The results from the two growth chamber experiments were similar. The physical appearance of kochia plants grown from seed collected at Fort Morgan were different from plants grown from seed collected at Scottsbluff or Torrington. Leaf arrangement and leaf size provided the most contrast. Kochia collected at Scottsbluff were 4 to 5% more tolerant to all herbicides than those collected at Fort Morgan or Torrington.

Results from the first experiment showed that kochia plants differed in their response to herbicides. When averaged over the three seed sampling sites, the quantity of herbicide required to reduce kochia growth by 50% (LD 50) (average of LD 50 calculated from visual evaluation and percent reduction of dry weight) was 0.6 ounces for atrazine, 26 ounces for Roundup and 6.3 ounces for Clarity. Results from the second experiment showed that kochia plants were not responsive to UpBeet and were suspected to be sulfonylurea resistant. The LD 50 for Roundup during the second run of the experiment was 31.5 ounces and 8.8 ounces for Clarity.

In summary the kochia populations growing on PCC piles at Fort Morgan, Scottsbluff, and Torrington did not exhibit herbicide resistance and were controlled with atrazine, Roundup, and Clarity.

Effect of PCC on root aphid population.

Root area generally was greater in lime-amended treatments which was most evident at the final evaluation (Fig. 1). PCC also suppressed root aphid production (Fig. 2). All rates of lime significantly reduced root aphid numbers as compared to the untreated control. No differences were found between the tested rates of lime; however, there could be a rate response

a low lime rates. To date, we have only completed one experiment; however, additional experiments currently underway (at time of writing) confirm the findings.

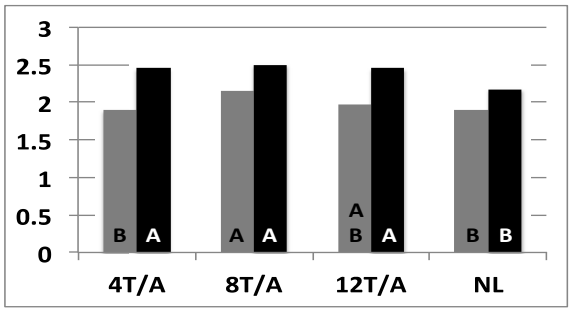

Figure 1. Mean root area rating of beets exposed to 3 rates of PCC or no lime at 3 weeks (gray bars) and 6 weeks (black bars) post seeding. Estimates with similar letters are not significantly different at the 5% level of probability.

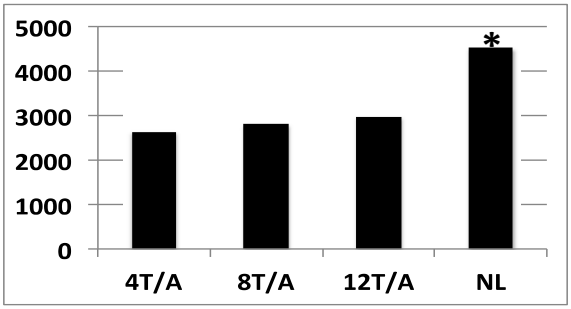

Figure 2. Mean number of root aphids exposed to 3 rates of PCC or no lime. Estimates with * is significantly different at the 5% level of probability.

Field Experiments: Effect of PCC on yield and quality of sugar beet, corn, and dry bean.

The field study showed that the yield and quality of sugar beet were not significantly affected by the application rates of PCC in almost all the locations (Table 3). There was no definite trend observed for yield and quality at different rates of PCC. The yield results are consistent with the biomass results of the greenhouse study. It was also observed that the application of PCC had no negative effect on sugar beet yield and quality across the 3 states and soil types.

Table 3: Effect of Precipitated Calcium Carbonate (PCC) on sugar beet yield and quality.

Location	Treatment	SLM	Yield (tons/acre)	Sucrose (lbs/acre)
Holyoke, CO	Check	1.32 a	48.4 a	17,175 a
	4 t/a	1.31 a	43.0 b	15,554 a
	8 t/a	1.27 a	45.5 ab	16,292 a
	12 t/a	1.34 a	45.4 ab	16,070 a
Yuma, CO	Check	1.78 a	41.5 a	14,106 a
	4 t/a	2.14 a	41.7 a	12,740 a
	8 t/a	2.19 a	42.7 a	13,511 a
	12 t/a	2.09 a	37.7 a	12,329 a

Torrington factory site, WY	Check	1.05 a	20.5 ab	6,569 ab
	4 t/a	0.97 a	19.4 b	6,217 b
	8 t/a	1.04 a	22.3 a	7,141 a
	12 t/a	0.97 a	21.4 ab	6,860 ab
Huntley, WY	Check	1.45 a	16.5 b	4,644 b
	4 t/a	1.42 a	17.5 b	5,278 ab
	8 t/a	1.38 a	18.9 ab	5,208 ab
	12 t/a	1.41 a	20.8 a	6,408 a
Mitchell (strip till), NE	Check	1.52 a	31.8 a	9,748 a
	4 t/a	1.51 a	32.7 a	10,126 a
	8 t/a	1.55 a	34.0 a	10,263 a
	12 t/a	1.55 a	33.1 a	9,911 a
Mitchell (plow), NE	Check	1.68 a	31.8 a	9,449 a
	4 t/a	1.64 a	30.4 a	9,491 a
	8 t/a	1.61 a	29.5 a	9,268 a
	12 t/a	1.74 a	29.2 a	8,955 a
Alliance, NE	Check	1.76 a	27.6 a	10,333 a
	4 t/a	1.80 a	25.7 a	9,765 a
	8 t/a	1.87 a	25.3 a	9,433 a
	12 t/a	1.91 a	25.6 a	9,765 a

The results for dry bean and corn were similar to sugar beet (data not shown). There was no significant yield increase or negative effects observed in the given soils as a result of the application of different rates of PCC.

In summary, the application of PCC, up to 12 tons per acre, had no consistent significant effect on yield or quality compared to checks in sugar beet, corn or dry bean. It was also evident that PCC had no adverse effect on yields of the three crops over a diverse range of soils in CO, WY and NE. Future field experiments will be done during 2013 and 2014 to provide more information. The plots will be followed for two cropping seasons to determine effects on subsequent crop yield, weed, disease and insect pressure. Greenhouse studies will be conducted to determine PCC effects on *Aphanomyces*. Once potential agronomic, economic and technical factors are known, agricultural applications of PCC may become an effective cultural practice.