

APPENDIX 1

CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE LIMES COLLECTED

Ref no	Trial no	Ca %	Mg %	CCE HCl %	RH-value %	Sieve Fraction Analysis (% passing)				Lime type
						SF<1.7mm	SF<1.0mm	SF<0.25mm	SF<0.106mm	
K001*	1	17.20	11.23	83.00	75.83	98.52	96.89	91.66	84.13	Dolomitic
K002*+	2	30.02	7.37	95.48	49.67	95.53	87.93	67.45	39.90	Slag
K003*+	3	31.06	5.57	84.98	64.57	99.36	92.01	64.98	42.48	Dolomitic
K004*	4	37.76	0.95	98.04	91.72	99.90	99.80	98.90	98.13	Paper mill waste
K005		28.36	8.59	97.30	55.63	99.28	91.32	63.90	44.80	Slag
K006		18.74	12.49	87.31	47.02	94.06	80.83	47.78	34.00	Dolomitic
K007		18.86	11.62	84.84	72.19	99.80	99.56	99.44	94.58	Dolomitic
K008		32.08	4.61	93.75	53.31	99.43	92.10	61.67	39.90	Slag
K009		40.43	4.95	104.28	76.16	99.53	99.13	89.73	61.53	Slag
K010		17.54	10.56	79.35	72.19	99.55	99.00	87.30	73.60	Dolomitic
K011*	5	16.27	14.63	85.75	59.60	97.70	88.35	66.20	59.80	Dolomitic
K012		29.51	7.24	95.53	45.36	88.11	82.56	61.10	31.40	Slag
K013*+	6	27.02	9.32	95.88	59.60	99.59	91.21	59.58	37.25	Slag
K014		1.43	14.68	50.83	10.93	88.19	75.24	48.61	37.68	Magnesite mine by-product
K015*	7	37.30	1.18	98.54	87.75	99.96	99.86	98.48	94.88	Paper mill waste
K016		26.51	4.85	89.79	33.77	76.88	61.18	35.43	24.15	Slag
K017*	8	16.64	14.68	88.38	54.97	87.04	72.46	50.73	43.75	Dolomitic
K018		35.08	0.94	85.38	75.17	99.15	98.65	96.90	96.25	Sugar industry by-product
K019		19.04	14.32	95.31	67.55	99.18	96.83	77.53	57.60	Dolomitic
K020		32.81	1.69	86.65	50.99	99.94	99.84	52.46	37.18	Calcitic
K021*	9	18.20	11.99	87.98	77.48	99.71	98.46	57.13	29.00	Dolomitic
K022*	10	19.95	12.11	91.40	54.64	99.68	99.30	73.58	67.56	Dolomitic
K023*+	11	40.43	4.95	104.28	76.16	99.53	99.13	89.73	61.53	Slag
K024*	12	26.02	5.55	74.90	46.59	97.67	80.77	43.57	22.87	Slag

* Limes selected for Trial 1

+ Limes selected for Trial 2

APPENDIX 2

TEST RESULTS OF METALS NOT INCLUDED IN STUDY

1. Copper

TABLE 1. Copper content of limes and amounts of lime and Co added per pot.

Lime no	Rate	Cu Content of Lime (mg.kg ⁻¹)	Lime added per pot (g)	Equivalence in Ton/ha	Concentration increase in the soil (mg.kg ⁻¹)
1	1	23.03*	5.94	3.60	0.02
	2		15.16	9.10	0.05
	3		24.38	14.60	0.07
2	1	32.30 (14.00)**	6.89	4.10	0.03
	2		17.59	10.60	0.08
	3		28.30	17.00	0.12
3	1	43.73 (40.00)	5.41	3.20	0.03
	2		13.81	8.30	0.08
	3		22.22	13.30	0.13
4	1	7.34	3.60	2.20	0.00
	2		9.20	5.50	0.01
	3		14.80	8.90	0.01
5	1	5.77	6.95	4.20	0.01
	2		17.74	10.70	0.01
	3		28.54	17.10	0.02
6	1	35.98 (36.00)	5.91	3.50	0.03
	2		15.09	9.10	0.07
	3		24.26	14.60	0.12
7	1	5.40	3.79	2.30	0.00
	2		9.68	5.80	0.01
	3		15.56	9.30	0.01
8	1	4.06	7.43	4.50	0.00
	2		18.98	11.40	0.01
	3		30.52	18.30	0.02
9	1	11.76	5.47	3.30	0.01
	2		13.97	8.40	0.02
	3		22.47	13.50	0.04
10	1	10.37	7.30	4.40	0.01
	2		18.65	11.20	0.03
	3		30.00	18.00	0.04
11	1	47.50 (109.00)	3.70	2.20	0.02
	2		9.45	5.70	0.06
	3		15.21	9.10	0.10
12	1	140.95	8.70	5.20	0.16
	2		22.21	13.30	0.42
	3		35.73	21.50	0.67

* Semi-quantitative determination by ICP MS-scan

** Quantitative determination by ICP MS

TABLE 2. Copper content (mg.kg⁻¹) of spinach leaves and pH of the growth medium.

Lime no	Rate	Spinach dry mass (g)	Cu (mg.kg ⁻¹)	pH
1	1	4.33	12	6.35
	2	4.71	6	6.91
	3	8.96	4.5	7.29
2	1	5.2	7.5	6.05
	2	8.86	7.5	7.27
	3	10.67	10.5	7.88
3	1	5.93	6	6.33
	2	6.42	4.5	7.42
	3	9.26	10.5	7.61
4	1	5.68	13.5	6.05
	2	9.16	7.5	6.55
	3	9.38	7.5	7.34
5	1	6.16	6	6.15
	2	6.89	3	7.11
	3	8.49	4.5	7.54
6	1	5.19	9	6.22
	2	7.35	6	7.18
	3	7.2	10.5	7.60
7	1	8.33	6	6.19
	2	12.84	13.5	7.02
	3	14.66	12	7.86
8	1	3.26	6	6.58
	2	6.85	3	7.18
	3	7.94	4.5	7.53
9	1	5.98	4.5	6.37
	2	9.32	7.5	6.95
	3	9.94	12	7.43
10	1	5.5	6	6.25
	2	7.44	6	6.79
	3	11.04	10.5	7.21
11	1	5.51	6	5.91
	2	8.03	4.5	6.78
	3	9.79	9	7.27
12	1	3.19	3	6.12
	2	8.75	7.5	6.78
	3	9.66	7.5	7.60

2. Zinc

TABLE 3. Zinc content of limes and amounts of lime and Zn added per pot.

Lime no	Rate	Zn Content of Lime (mg.kg ⁻¹)	Lime added per pot (g)	Equivalence in Ton/ha	Concentration increase in the soil (mg.kg ⁻¹)
1	1	27.48*	5.94	3.60	0.0218
	2		15.16	9.10	0.0555
	3		24.38	14.60	0.0893
2	1	42.94 (31.00)**	6.89	4.10	0.0285
	2		17.59	10.60	0.0727
	3		28.30	17.00	0.1170
3	1	30.49 (49.00)	5.41	3.20	0.0353
	2		13.81	8.30	0.0902
	3		22.22	13.30	0.1452
4	1	8.68	3.60	2.20	0.0042
	2		9.20	5.50	0.0106
	3		14.80	8.90	0.0171
5	1	5.68	6.95	4.20	0.0053
	2		17.74	10.70	0.0134
	3		28.54	17.10	0.0216
6	1	25.74 (54.00)	5.91	3.50	0.0426
	2		15.09	9.10	0.1086
	3		24.26	14.60	0.1747
7	1	6.12	3.79	2.30	0.0031
	2		9.68	5.80	0.0079
	3		15.56	9.30	0.0127
8	1	4.19	7.43	4.50	0.0042
	2		18.98	11.40	0.0106
	3		30.52	18.30	0.0171
9	1	11.91	5.47	3.30	0.0087
	2		13.97	8.40	0.0222
	3		22.47	13.50	0.0357
10	1	4.33	7.30	4.40	0.0042
	2		18.65	11.20	0.0108
	3		30.00	18.00	0.0173
11	1	64.22 (202)	3.70	2.20	0.0997
	2		9.45	5.70	0.2545
	3		15.21	9.10	0.4097
12	1	281.41	8.70	5.20	0.3264
	2		22.21	13.30	0.8333
	3		35.73	21.50	1.3406

* Semi-quantitative determination by ICP MS-scan

** Quantitative determination by ICP MS

TABLE 4. Zinc content (mg.kg^{-1}) of spinach leaves and pH of the growth medium.

Lime no	Rate	Spinach dry mass (g)	Zn (mg.kg^{-1})	pH
1	1	4.33	228	6.35
	2	4.71	136	6.91
	3	8.96	123	7.29
2	1	5.2	162	6.05
	2	8.86	123	7.27
	3	10.67	88	7.88
3	1	5.93	194	6.33
	2	6.42	124	7.42
	3	9.26	146	7.61
4	1	5.68	201	6.05
	2	9.16	148	6.55
	3	9.38	112	7.34
5	1	6.16	200	6.15
	2	6.89	120	7.11
	3	8.49	136	7.54
6	1	5.19	172	6.22
	2	7.35	92	7.18
	3	7.2	96	7.60
7	1	8.33	194	6.19
	2	12.84	164	7.02
	3	14.66	132	7.86
8	1	3.26	184	6.58
	2	6.85	128	7.18
	3	7.94	117	7.53
9	1	5.98	189	6.37
	2	9.32	158	6.95
	3	9.94	132	7.43
10	1	5.5	186	6.25
	2	7.44	144	6.79
	3	11.04	150	7.21
11	1	5.51	178	5.91
	2	8.03	141	6.78
	3	9.79	129	7.27
12	1	3.19	147	6.12
	2	8.75	124	6.78
	3	9.66	111	7.60

3. Barium

TABLE 5. Barium content of limes and amounts of lime and Ba added per pot.

Lime no	Rate	Ba Content of Lime (mg.kg ⁻¹)	Lime added per pot (g)	Equivalence in Ton/ha	Concentration increase in the soil (mg.kg ⁻¹)
2	1	114.20* (106.14)**	6.89	4.10	0.10
	2		17.59	10.60	0.27
	3		28.30	17.00	0.43
3	2	65.57	13.81	8.30	0.12
	3		22.22	13.30	0.19
4	1	143.42	3.60	2.20	0.07
	2		9.20	5.50	0.18
	3		14.80	8.90	0.28
10	1	15.80 (14.20)	7.30	4.40	0.02
	2		18.65	11.20	0.04
	3		30.00	18.00	0.06
11	1	185.87 (147.27)	3.70	2.20	0.09
	2		9.45	5.70	0.23
	3		15.21	9.10	0.38
12	1	481.21	8.70	5.20	0.56
	2		22.21	13.30	1.43
	3		35.73	21.50	2.29

* Semi-quantitative determination by ICP MS-scan

** Quantitative determination by ICP MS

TABLE 6. Barium content (mg.kg⁻¹) of spinach leaves and pH of the growth medium.

Lime no	Rate	Spinach dry mass (g)	Ba (mg.kg ⁻¹)	pH
2	1	5.2	28.06	6.05
	2	8.86	7.20	7.27
	3	10.67	0.06	7.88
3	2	6.42	14.55	7.42
	3	9.26	6.99	7.61
4	1	5.68	58.76	6.05
	2	9.16	25.75	6.55
	3	9.38	25.22	7.34
10	1	5.5	45.52	6.25
	2	7.44	30.29	6.79
	3	11.04	20.73	7.21
11	1	5.51	40.52	5.91
	2	8.03	17.37	6.78
	3	9.79	4.56	7.27
12	1	3.19	44.18	6.12
	2	8.75	10.44	6.78
	3	9.66	8.08	7.60



TABLE 7. NH₄-EDTA extraction (Ba) on soil from lime 11.

Rate	NH ₄ -EDTA extractable Ba (mg.kg ⁻¹)
Control	4.416
1	5.026
2	4.779
3	4.840

4. Molybdenum

TABLE 8. Molybdenum content of limes and amounts of lime and Mo added per pot.

Lime no	Rate	Mo Content of Lime (mg.kg ⁻¹)	Lime added per pot (g)	Equivalence in Ton/ha	Concentration increase in the soil (mg.kg ⁻¹)
2	1	40.11* (28.85)**	6.89	4.10	0.0368
	2		17.59	10.60	0.0941
	3		28.30	17.00	0.1513
3	1	2.44 (0.82)	5.41	3.20	0.0018
	2		13.81	8.30	0.0045
	3		22.22	13.30	0.0072
5	1	0 (0)	6.95	4.20	0.0000
	2		17.74	10.70	0.0000
	3		28.54	17.10	0.0000
8	1	0 (0)	7.43	4.50	0.0000
	2		18.98	11.40	0.0000
	3		30.52	18.30	0.0000
11	1	14.84	3.70	2.20	0.0073
	2		9.45	5.70	0.0187
	3		15.21	9.10	0.0301

* Semi-quantitative determination by ICP MS-scan

** Quantitative determination by ICP MS

TABLE 9. Molybdenum content (mg.kg⁻¹) of spinach leaves and pH of the growth medium.

Lime no	Rate	Spinach dry mass (g)	Mo (mg.kg ⁻¹)	pH
2	1	5.2	0.00	6.05
	2	8.86	0.34	7.27
	3	10.67	0.50	7.88
3	1	5.93	-	6.33
	2	6.42	0.50	7.42
	3	9.26	0.70	7.61
5	1	6.16	0.00	6.15
	2	6.89	0.29	7.11
	3	8.49	0.24	7.54
8	1	3.26	0.07	6.58
	2	6.85	0.26	7.18
	3	7.94	0.28	7.53
11	1	5.51	0.08	5.91
	2	8.03	0.37	6.78
	3	9.79	0.16	7.27

APPENDIX 3

pH RESULTS FOR TRIAL 1 AND TRIAL 2

Table 1 to 4 present the $pH_{(water)}$ and $pH_{(KCl)}$ results for Trial 1. Table 5 and 6 present the values for Trial 2.

TABLE 1. Trial 1 $pH_{(water)}$ values (first sampling) for twelve liming materials at three application rates.

Rate	Lime no.	pH (Replications)				Average
		1	2	3	4	
Control	Control	5.24	5.31	5.32	5.46	5.33
1	1	6.27	6.30	6.37	6.46	6.35
2	1	6.80	6.88	6.96	6.99	6.91
3	1	7.16	7.28	7.30	7.42	7.29
1	2	5.78	5.87	6.06	6.50	6.05
2	2	7.09	7.25	7.32	7.41	7.27
3	2	7.76	7.81	7.93	8.03	7.88
1	3	6.21	6.29	6.32	6.50	6.33
2	3	7.29	7.41	7.42	7.57	7.42
3	3	7.52	7.57	7.60	7.74	7.61
1	4	5.74	5.95	6.08	6.41	6.05
2	4	6.10	6.60	6.64	6.86	6.55
3	4	7.15	7.23	7.30	7.69	7.34
1	5	5.87	6.08	6.09	6.55	6.15
2	5	6.67	7.13	7.27	7.35	7.11
3	5	7.37	7.55	7.59	7.65	7.54
1	6	6.10	6.20	6.23	6.36	6.22
2	6	7.09	7.18	7.19	7.27	7.18
3	6	7.26	7.65	7.73	7.74	7.60
1	7	6.01	6.14	6.22	6.40	6.19
2	7	6.30	6.96	7.10	7.73	7.02
3	7	7.77	7.84	7.90	7.93	7.86
1	8	6.48	6.58	6.6	6.67	6.58
2	8	6.71	7.20	7.35	7.47	7.18
3	8	7.31	7.53	7.55	7.74	7.53
1	9	6.09	6.21	6.41	6.76	6.37
2	9	6.82	6.96	6.98	7.05	6.95
3	9	7.19	7.43	7.48	7.60	7.43
1	10	6.08	6.18	6.35	6.38	6.25
2	10	6.49	6.80	6.89	6.99	6.79
3	10	7.10	7.11	7.29	7.32	7.21
1	11	5.67	5.95	6.00	6.01	5.91
2	11	6.52	6.74	6.91	6.93	6.78
3	11	7.04	7.20	7.36	7.47	7.27
1	12	5.77	5.93	6.22	6.54	6.12
2	12	6.56	6.63	6.92	7.02	6.78
3	12	7.49	7.60	7.60	7.72	7.60

TABLE 2. Trial 1 pH_(Water) values (second sampling) for twelve liming materials at three application rates.

Rate	Lime no.	pH (Replications)				Average
		1	2	3	4	
Control	Control	4.90	5.16	5.05	5.14	5.06
1	1	6.08	6.05	6.24	5.70	6.02
2	1	6.56	6.13	6.89	6.81	6.60
3	1	7.20	7.28	7.30	7.41	7.30
1	2	6.36	6.75	6.40	5.77	6.32
2	2	7.58	7.75	7.14	7.33	7.45
3	2	8.22	7.97	8.16	7.95	8.08
1	3	6.13	6.08	5.64	6.12	5.99
2	3	6.82	7.23	7.15	7.20	7.10
3	3	7.56	7.46	7.47	7.29	7.45
1	4	5.35	5.37	5.02	5.90	5.41
2	4	6.23	6.73	7.02	6.77	6.69
3	4	6.68	7.24	6.86	7.06	6.96
1	5	6.66	6.24	5.88	6.28	6.27
2	5	6.88	7.10	7.28	7.30	7.14
3	5	7.32	7.38	7.57	7.52	7.45
1	6	6.02	6.10	6.25	5.62	6.00
2	6	7.02	6.96	7.58	7.33	7.22
3	6	7.75	7.52	8.06	7.77	7.78
1	7	6.32	6.39	6.05	5.77	6.13
2	7	6.69	7.58	7.24	7.32	7.21
3	7	7.54	7.75	7.66	7.98	7.73
1	8	5.90	6.28	6.39	6.34	6.23
2	8	6.54	7.10	6.94	6.90	6.87
3	8	7.32	7.44	7.35	7.33	7.36
1	9	4.97	5.86	6.03	5.77	5.66
2	9	6.81	6.77	7.03	6.80	6.85
3	9	7.34	7.22	7.04	7.32	7.23
1	10	6.01	5.92	5.76	6.11	5.95
2	10	6.71	6.75	7.16	5.56	6.55
3	10	7.25	7.37	7.57	7.36	7.39
1	11	5.87	5.65	5.48	5.60	5.65
2	11	6.32	6.60	6.69	6.93	6.64
3	11	7.33	7.23	7.37	7.53	7.37
1	12	5.40	5.75	5.76	5.72	5.66
2	12	6.47	6.61	6.88	6.99	6.74
3	12	7.50	7.69	7.35	7.65	7.55

TABLE 3. Trial 1 pH_(KCl) values (first sampling) for twelve liming materials at three application rates.

Rate	Lime no.	pH (Replications)				Average
		1	2	3	4	
Control	Control	4.17	4.21	4.24	4.26	4.22
1	1	5.08	5.01	5.71	5.38	5.30
2	1	6.07	6.11	6.03	5.58	5.95
3	1	6.40	6.46	6.33	6.40	6.40
1	2	4.69	4.85	5.17	4.95	4.92
2	2	6.80	6.61	6.63	6.46	6.63
3	2	6.63	7.12	7.32	7.03	7.03
1	3	5.63	5.04	4.77	5.06	5.13
2	3	6.77	6.22	5.97	5.99	6.24
3	3	6.72	6.77	6.75	6.58	6.71
1	4	4.40	4.68	5.00	4.54	4.66
2	4	5.47	5.04	5.76	5.73	5.50
3	4	5.56	6.08	5.94	6.45	6.01
1	5	4.65	4.72	4.89	5.01	4.82
2	5	5.94	6.14	6.47	6.57	6.28
3	5	6.58	6.86	6.84	6.91	6.80
1	6	4.71	4.77	4.86	5.12	4.87
2	6	6.23	6.18	6.27	6.12	6.20
3	6	6.21	6.81	6.77	6.89	6.67
1	7	4.87	4.96	4.63	4.92	4.85
2	7	6.34	5.90	6.40	5.16	5.95
3	7	6.47	6.46	6.86	6.89	6.67
1	8	4.64	4.99	5.17	4.88	4.92
2	8	6.20	6.38	5.72	6.27	6.14
3	8	6.47	6.61	6.47	6.76	6.58
1	9	5.09	5.90	4.78	4.81	5.15
2	9	5.70	5.51	5.59	5.63	5.61
3	9	6.27	6.77	6.75	6.58	6.59
1	10	4.90	5.01	5.06	4.77	4.94
2	10	5.39	5.82	6.14	5.79	5.79
3	10	6.18	6.19	6.18	6.32	6.22
1	11	4.64	4.83	4.56	4.50	4.63
2	11	6.22	5.45	5.77	5.15	5.65
3	11	5.96	6.40	6.01	6.60	6.24
1	12	5.06	4.71	4.56	5.53	4.97
2	12	5.86	5.66	6.13	6.24	5.97
3	12	6.52	6.79	6.42	6.90	6.66

TABLE 4. Trial 1 pH_(KCl) values (second sampling) for twelve liming materials at three application rates.

Rate	Lime no.	pH (Replications)				Average
		1	2	3	4	
Control	Control	4.17	4.28	4.17	4.28	4.23
1	1	4.67	4.91	4.99	5.13	4.93
2	1	6.00	6.03	6.09	5.90	6.01
3	1	6.33	6.39	6.48	6.47	6.42
1	2	5.01	5.13	5.84	5.14	5.28
2	2	6.51	6.63	6.01	6.40	6.39
3	2	7.10	7.06	7.18	7.07	7.10
1	3	5.25	4.83	4.81	5.30	5.05
2	3	6.32	6.37	6.33	6.11	6.28
3	3	7.08	6.86	6.91	7.25	7.03
1	4	5.02	4.62	4.50	4.84	4.75
2	4	5.38	5.88	5.86	5.71	5.71
3	4	5.55	6.25	5.85	6.21	5.97
1	5	5.01	5.28	4.89	5.20	5.10
2	5	6.20	6.21	6.24	6.51	6.29
3	5	6.70	6.55	6.65	6.90	6.70
1	6	4.93	5.32	5.01	4.55	4.95
2	6	6.11	6.16	6.62	6.58	6.37
3	6	6.74	6.71	7.03	6.80	6.82
1	7	4.93	5.21	4.78	4.92	4.96
2	7	5.78	6.81	6.14	6.55	6.32
3	7	6.54	6.95	6.72	6.94	6.79
1	8	4.98	5.18	5.33	5.29	5.20
2	8	5.94	6.33	6.28	6.15	6.18
3	8	6.42	6.63	6.55	6.64	6.56
1	9	4.65	4.64	4.85	4.99	4.78
2	9	6.16	5.76	6.13	5.95	6.00
3	9	6.53	6.33	6.48	6.60	6.49
1	10	4.97	4.84	5.17	4.61	4.90
2	10	5.35	6.13	5.71	5.45	5.66
3	10	6.68	5.61	6.58	6.45	6.33
1	11	4.71	4.53	4.95	4.61	4.70
2	11	5.30	5.76	5.59	5.94	5.65
3	11	6.35	6.36	6.46	6.69	6.47
1	12	4.39	5.18	4.96	4.82	4.84
2	12	6.20	6.20	6.33	6.37	6.28
3	12	6.64	6.90	6.75	6.83	6.78

TABLE 5. Trial 2 $pH_{(Water)}$ values for four slags and one laboratory reagent at three application rates.

Rate	Lime no.	pH (Replications)				Average
		1	2	3	4	
Control	Control	4.08	3.97	4.02	4.03	4.03
1	2	6.65	6.53	6.51	6.35	6.51
2	2	7.18	6.82	6.80	6.67	6.87
3	2	6.98	7.21	7.19	7.30	7.17
1	3	6.13	5.77	5.98	5.55	5.86
2	3	5.75	6.25	6.33	6.01	6.09
3	3	6.84	6.71	6.54	6.60	6.67
1	6	5.35	5.86	5.66	5.51	5.60
2	6	5.90	5.48	6.21	6.20	5.95
3	6	6.51	6.49	6.67	6.69	6.59
1	11	4.91	4.98	4.95	4.94	4.95
2	11	5.23	4.73	5.20	4.98	5.04
3	11	5.68	5.14	5.40	5.89	5.53
1	Lab R	4.66	5.09	5.14	5.27	5.04
2	Lab R	5.40	5.11	5.58	5.62	5.43
3	Lab R	5.65	5.65	5.78	5.99	5.77

TABLE 6. Trial 2 $pH_{(KCl)}$ values for four slags and one laboratory reagent at three application rates.

Rate	Lime no.	pH (Replications)				Average
		1	2	3	4	
Control	Control	3.63	3.61	3.60	3.63	3.62
1	2	5.88	5.85	5.98	5.70	5.85
2	2	6.42	6.03	6.08	5.84	6.09
3	2	6.40	6.43	6.44	6.45	6.43
1	3	4.50	5.09	4.66	5.12	4.84
2	3	4.91	5.22	5.42	5.54	5.27
3	3	5.62	5.58	5.68	5.67	5.64
1	6	4.80	5.12	5.09	4.87	4.97
2	6	5.46	5.88	4.87	5.58	5.45
3	6	5.77	5.80	6.04	6.07	5.92
1	11	4.34	4.35	4.33	4.37	4.35
2	11	4.58	4.18	4.59	4.45	4.45
3	11	4.76	4.51	4.71	5.14	4.78
1	Lab R	4.03	4.39	4.25	4.32	4.25
2	Lab R	4.80	4.89	4.85	4.35	4.72
3	Lab R	4.83	5.29	5.16	5.11	5.10

APPENDIX 4

LIME INCUBATION CURVES

1. Incubation Curves

Figures 1 to 12 indicate the average value of four $\text{pH}_{(\text{Water})}$ and $\text{pH}_{(\text{KCl})}$ replicates for each lime. The figure number corresponds with the lime number. The results of each lime were used to calculate the correlation coefficient between the pH and lime requirement as well as regression equation.

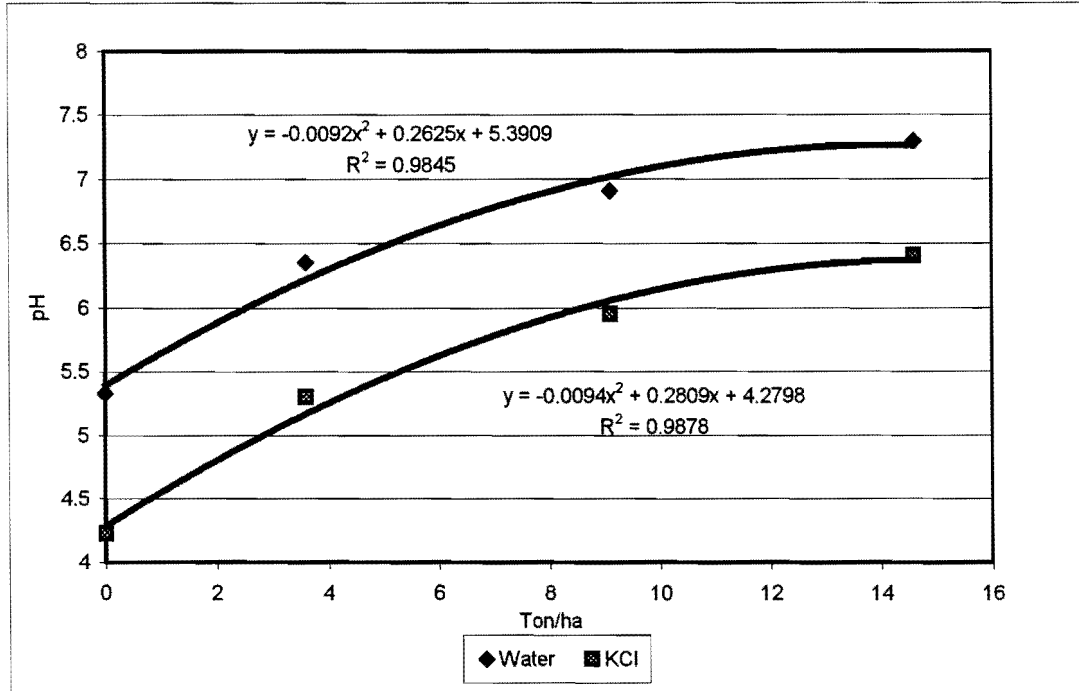


Figure 1. The relationship of the $pH_{(Water \text{ and } KCl)}$ after a three month incubation period for Lime 1 with corresponding regression equation and coefficient of determination.

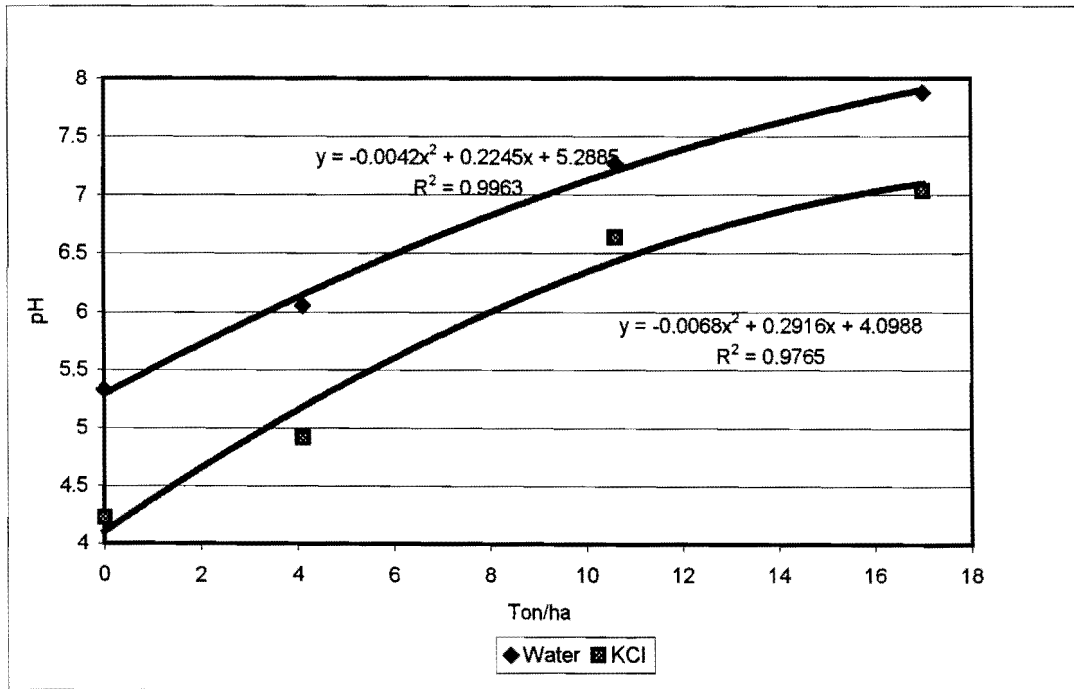


Figure 2. The relationship of the $pH_{(Water \text{ and } KCl)}$ after a three month incubation period for Lime 2 with corresponding regression equation and coefficient of determination.

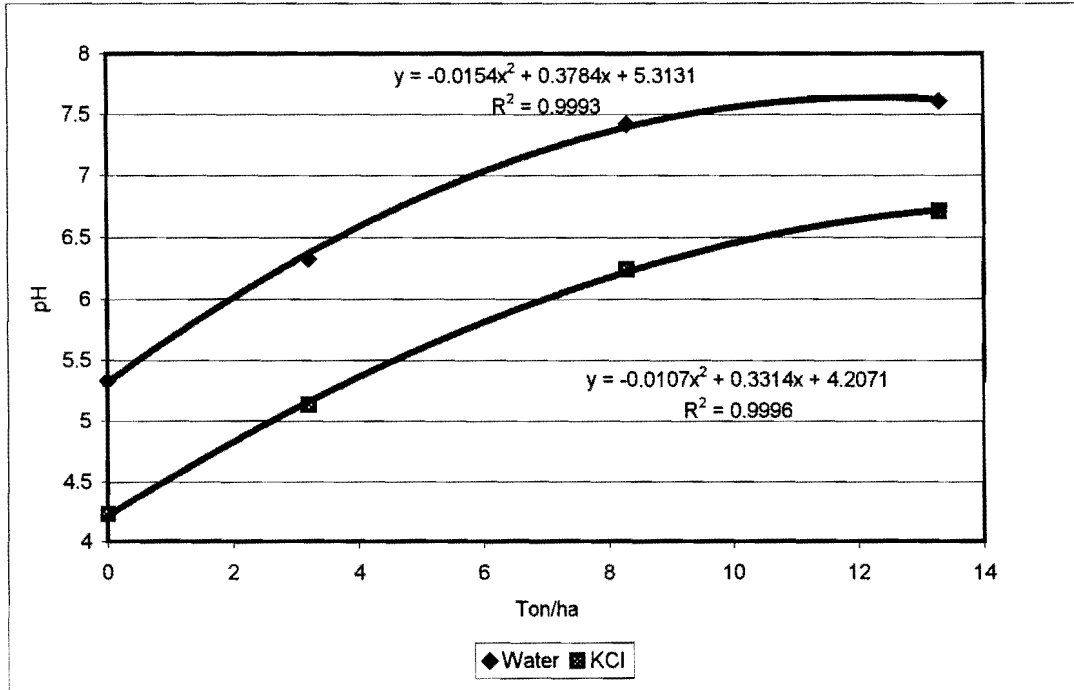


Figure 3. The relationship of the $pH_{(Water \text{ and } KCl)}$ after a three month incubation period for Lime 3 with corresponding regression equation and coefficient of determination.

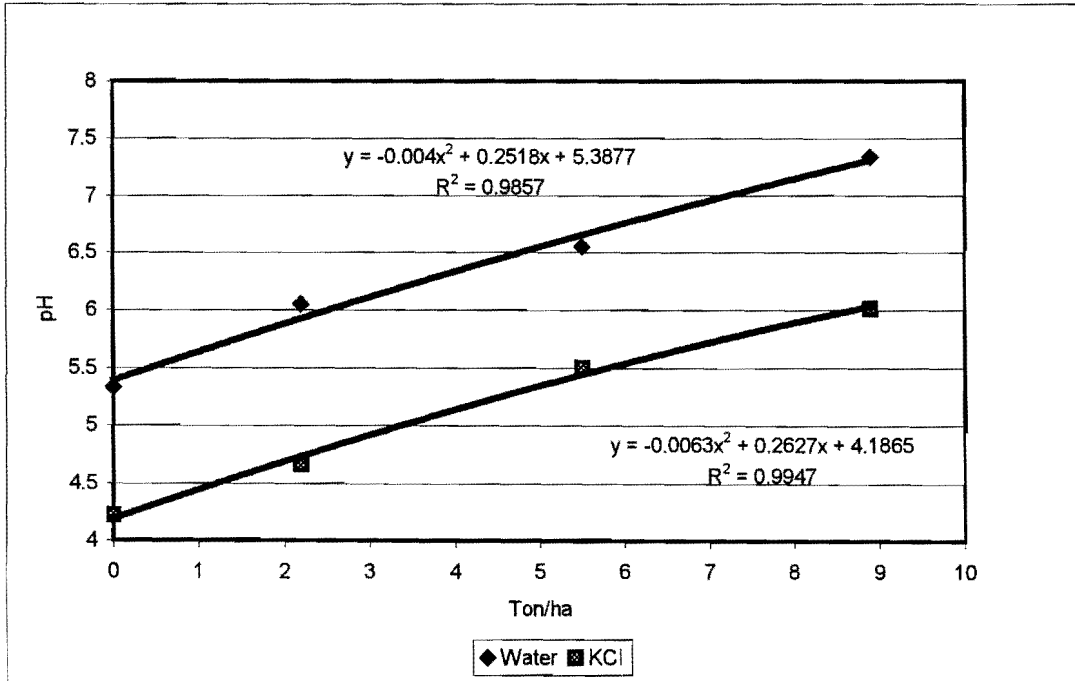


Figure 4. The relationship of the $pH_{(Water \text{ and } KCl)}$ after a three month incubation period for Lime 4 with corresponding regression equation and coefficient of determination.

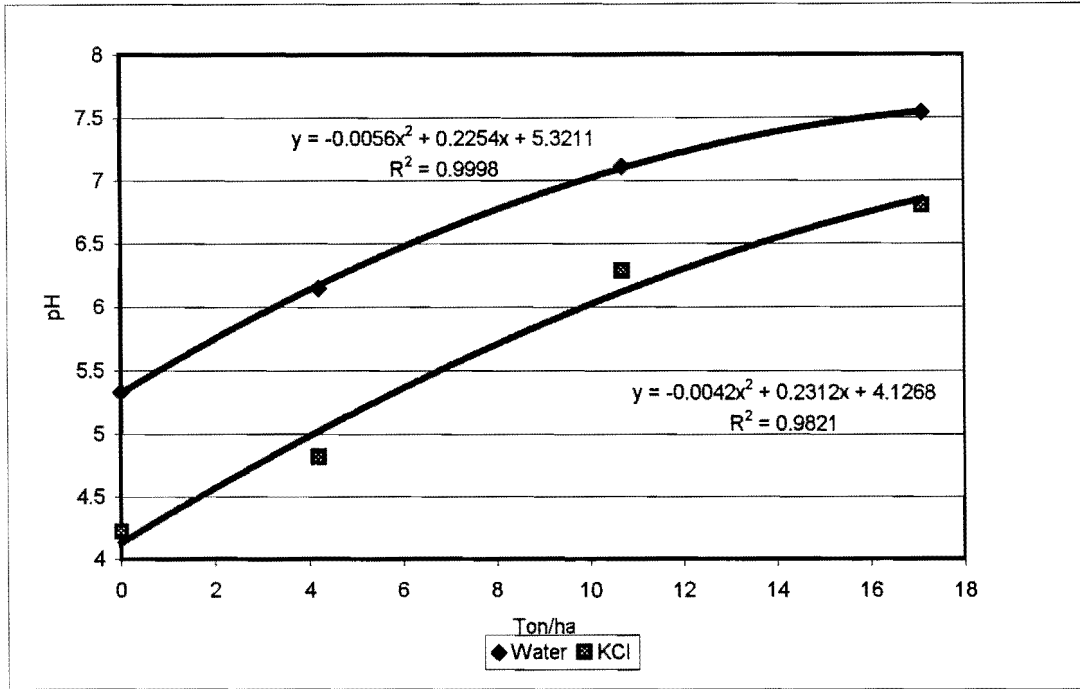


Figure 5. The relationship of the $pH_{(Water\ and\ KCl)}$ after a three month incubation period for Lime 5 with corresponding regression equation and coefficient of determination.

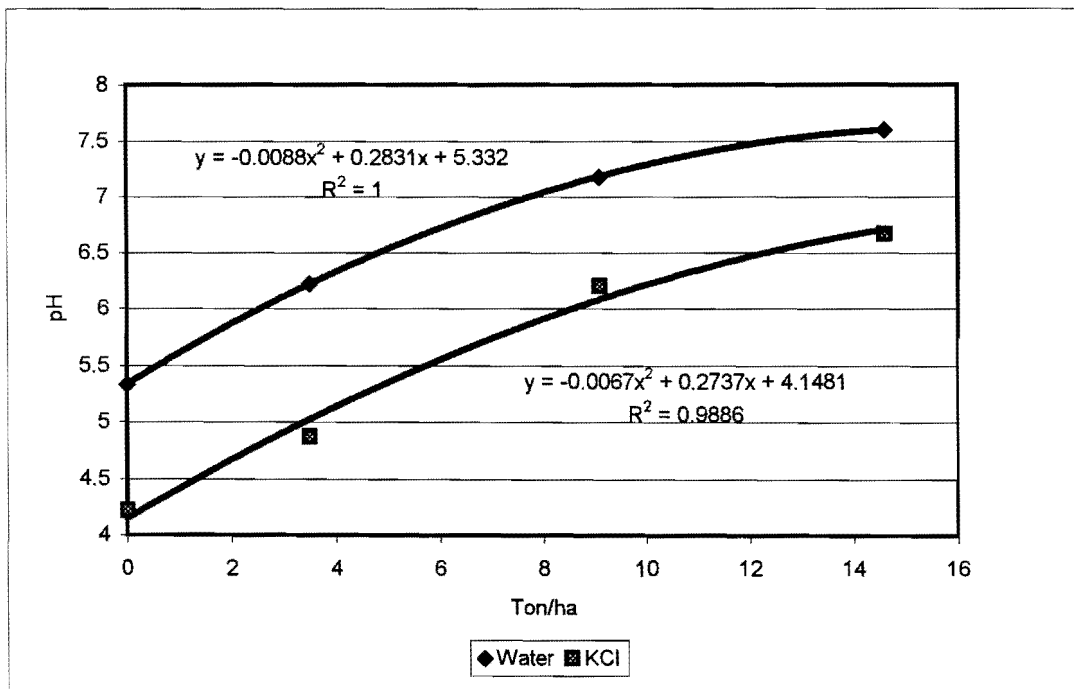


Figure 6. The relationship of the $pH_{(Water\ and\ KCl)}$ after a three month incubation period for Lime 6 with corresponding regression equation and coefficient of determination.

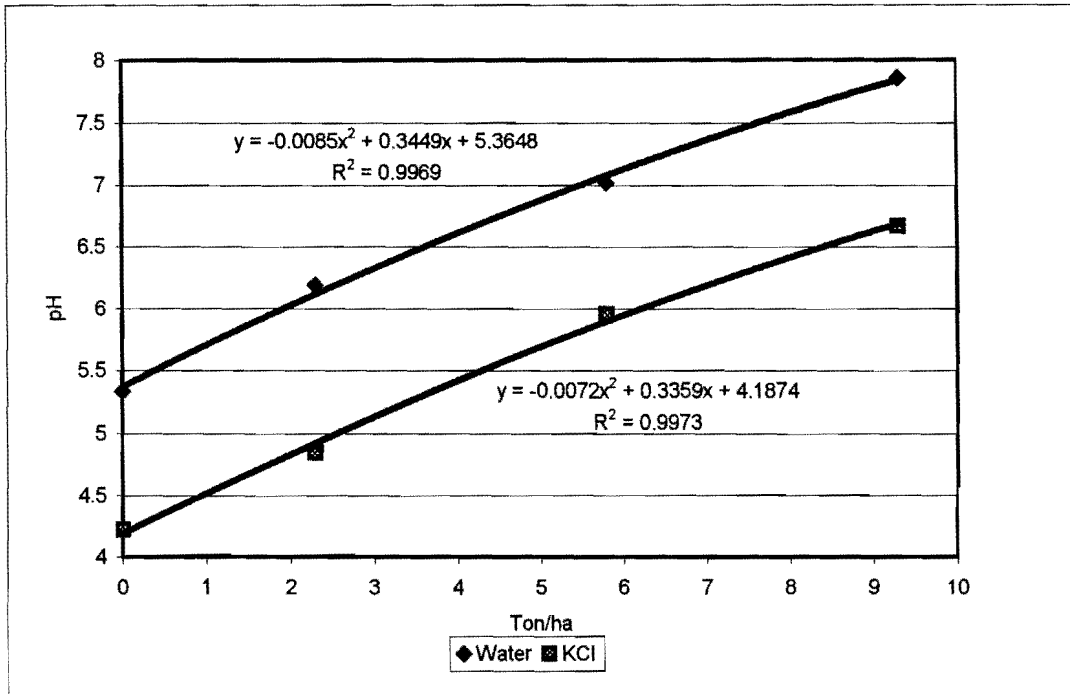


Figure 7. The relationship of the $pH_{(Water\ and\ KCl)}$ after a three month incubation period for Lime 7 with corresponding regression equation and coefficient of determination.

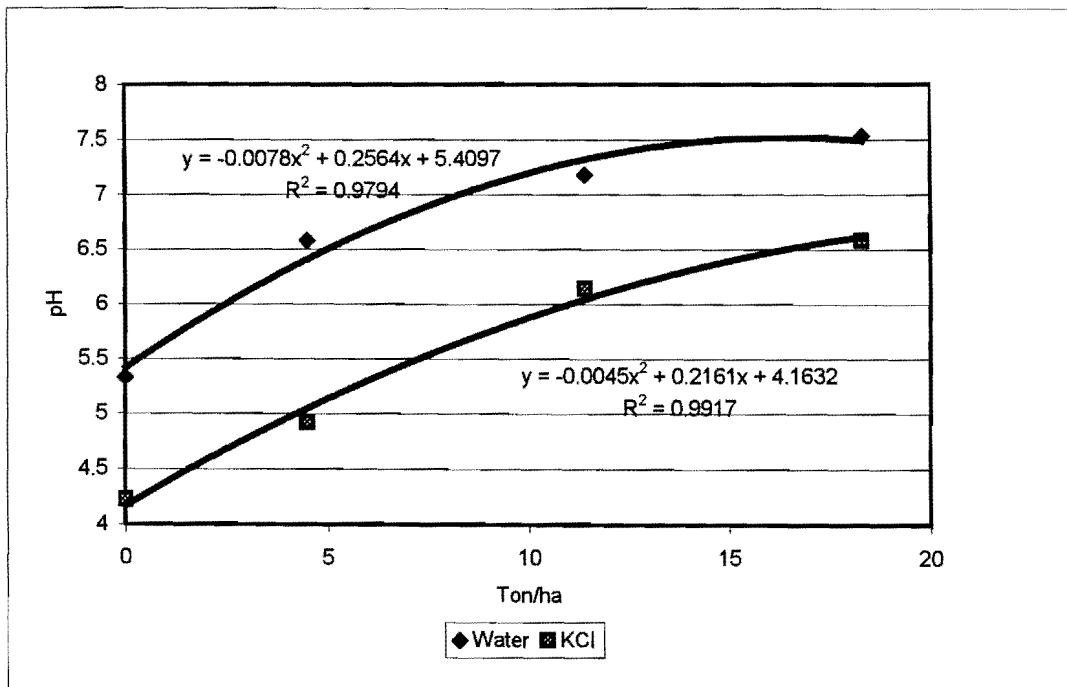


Figure 8. The relationship of the $pH_{(Water\ and\ KCl)}$ after a three month incubation period for Lime 8 with corresponding regression equation and coefficient of determination.

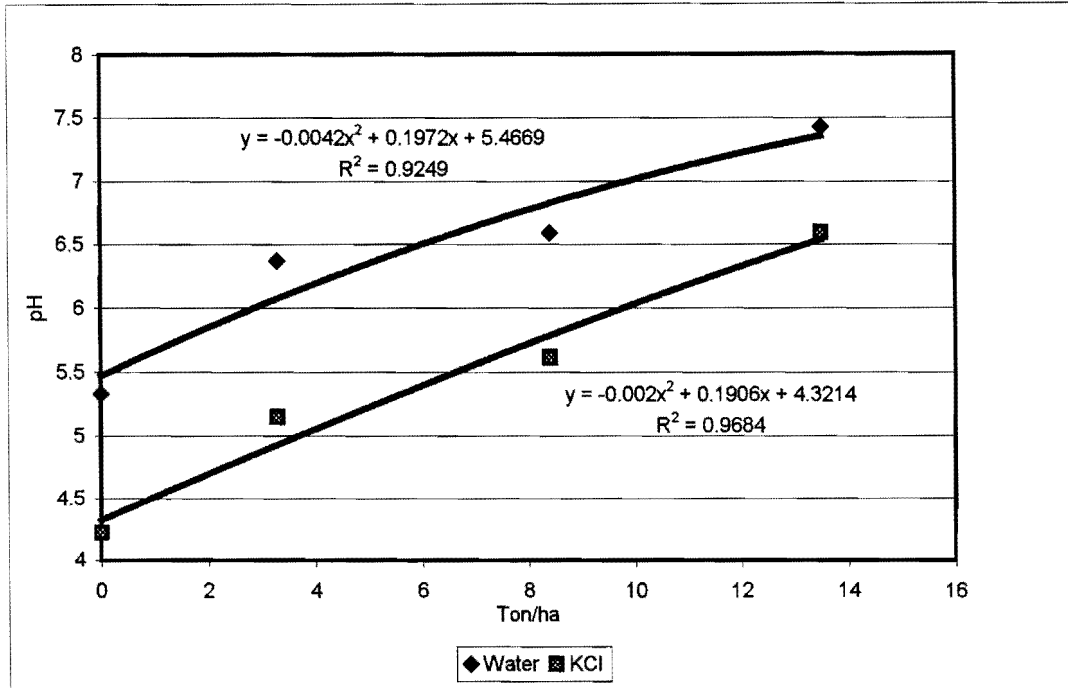


Figure 9. The relationship of the pH_(Water and KCl) after a three month incubation period for Lime 9 with corresponding regression equation and coefficient of determination.

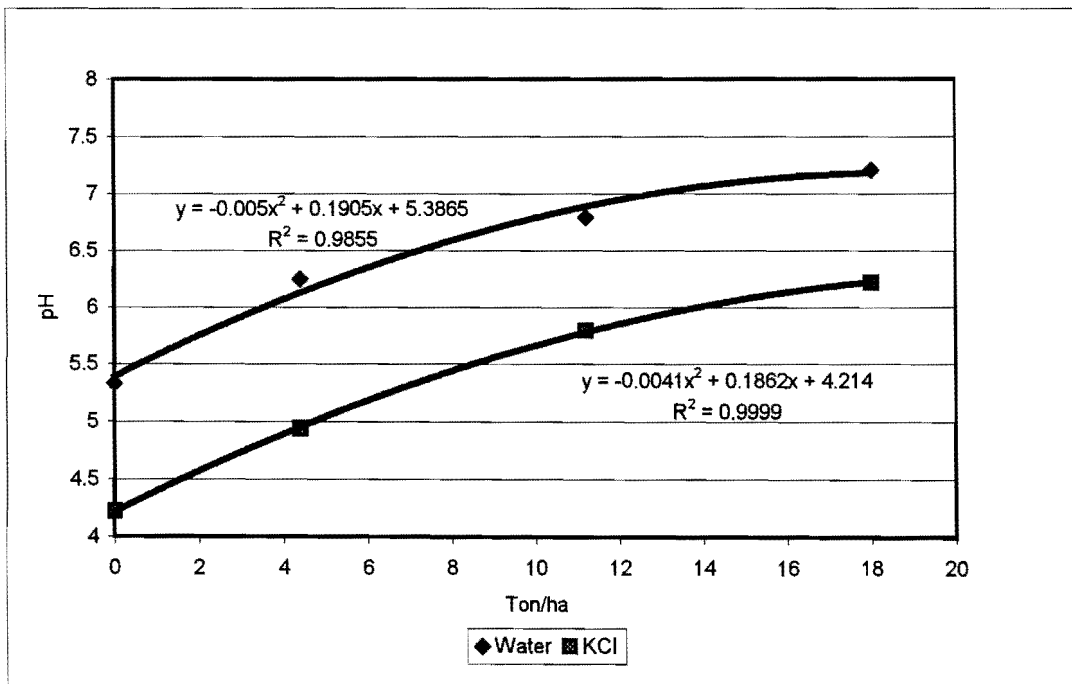


Figure 10. The relationship of the pH_(Water and KCl) after a three month incubation period for Lime 10 with corresponding regression equation and coefficient of determination.

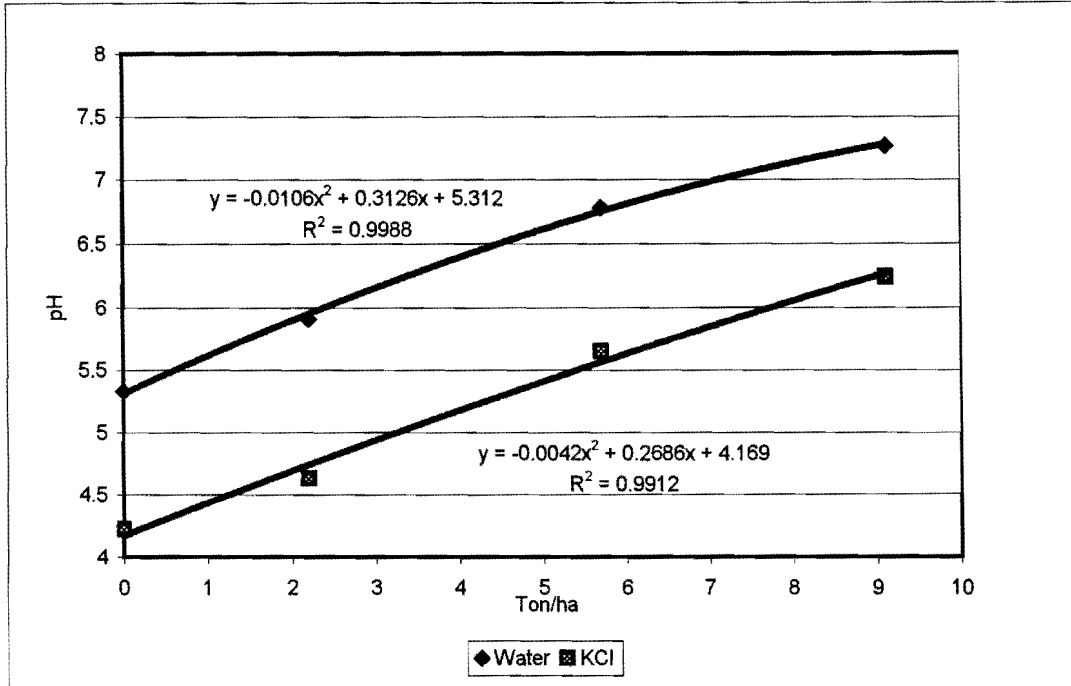


Figure 11. The relationship of the $\text{pH}_{(\text{Water and KCl})}$ after a three month incubation period for Lime 11 with corresponding regression equation and coefficient of determination.

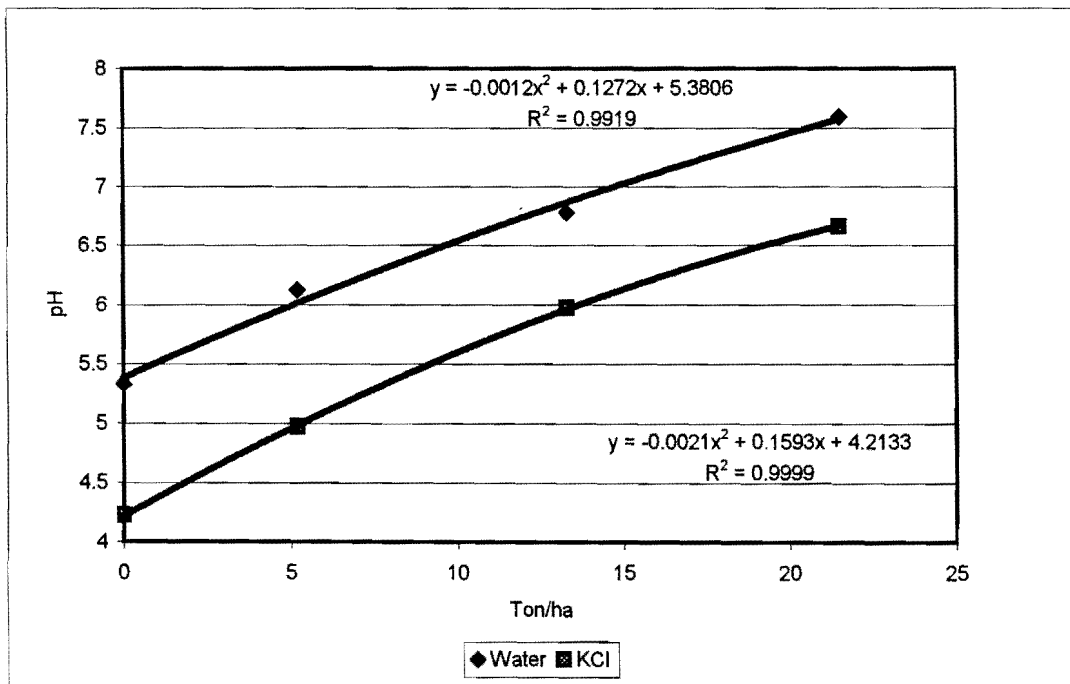


Figure 12. The relationship of the $\text{pH}_{(\text{Water and KCl})}$ after a three month incubation period for Lime 12 with corresponding regression equation and coefficient of determination.

APPENDIX 5

MODELING OF pH RESULTS

1. Correction Factors

Correction factors according to the CCE HCl as well as RH-values were calculated for each lime to correct the lime required to 100% reactivity. The value multiplied by the factor yields 100.

TABLE 1. Calculated factors to obtain 100% reactivity for different limes.

Lime no.	CCE HCl %	Factor 1	RH-value %	Factor 2
1	83.00	1.20	75.83	1.32
2	95.48	1.05	49.67	2.01
3	84.98	1.18	64.57	1.55
4	98.04	1.02	91.72	1.09
5	85.75	1.17	59.60	1.68
6	95.88	1.04	59.60	1.68
7	98.54	1.01	87.75	1.14
8	88.38	1.13	54.97	1.82
9	87.98	1.14	77.48	1.29
10	91.40	1.09	54.64	1.83
11	104.28	0.96	76.16	1.31
12	74.90	1.34	46.59	2.15

2. Lime Requirement

In Table 2 the amounts of pure CaCO_3 needed to attain the specific target pH values as calculated from the different buffer solution ratios are listed.

TABLE 2. Amount of pure CaCO_3 needed ($\text{ton}\cdot\text{ha}^{-1}$) to change the soil pH to the desired target, as calculated from the regression equation in Fig. 4.1.

Target pH	Soil to Solution Ratio (Time of Determination)		
	Ratio 1:1 (Before)	Ratio 1:1 (After)	Ratio 1:2.5 (After)
5.8	1.91 $\text{ton}\cdot\text{ha}^{-1}$	1.47 $\text{ton}\cdot\text{ha}^{-1}$	0.74 $\text{ton}\cdot\text{ha}^{-1}$
6.8	4.90 $\text{ton}\cdot\text{ha}^{-1}$	3.69 $\text{ton}\cdot\text{ha}^{-1}$	3.87 $\text{ton}\cdot\text{ha}^{-1}$
7.8	7.88 $\text{ton}\cdot\text{ha}^{-1}$	5.91 $\text{ton}\cdot\text{ha}^{-1}$	7.01 $\text{ton}\cdot\text{ha}^{-1}$

3. Lime Recommendation

In Tables 3 to 5 the lime recommendation values as calculated by the different methods, using the data from Tables 1 and 2, are presented for each target pH-value respectively.

TABLE 3. Lime recommendation values ($\text{ton}\cdot\text{ha}^{-1}$) as calculated from different methods for target pH 5.8.

Lime no.	Ratio 1:1 (Before)		Ratio 1:1 (After)		Ratio 1:2.5 (After)	
	RH-Value	CCE HCl	RH-Value	CCE HCl	RH-Value	CCE HCl
1	2.52	2.31	1.93	1.77	0.97	0.89
2	3.85	2.00	2.95	1.54	1.49	0.77
3	2.96	2.25	2.27	1.72	1.14	0.87
4	2.09	1.95	1.60	1.49	0.81	0.75
5	3.21	2.23	2.46	1.71	1.24	0.86
6	3.21	2.00	2.46	1.53	1.24	0.77
7	2.18	1.94	1.67	1.49	0.84	0.75
8	3.48	2.17	2.67	1.66	1.34	0.84
9	2.47	2.18	1.89	1.67	0.95	0.84
10	3.50	2.09	2.68	1.60	1.35	0.81
11	2.51	1.84	1.92	1.41	0.97	0.71
12	4.11	2.56	3.15	1.96	1.59	0.99

TABLE 4. Lime recommendation values (ton.ha⁻¹) as calculated from different methods for target pH 6.8.

Lime no.	Ratio 1:1 (Before)		Ratio 1:1 (After)		Ratio 1:2.5 (After)	
	RH-Value	CCE HCl	RH-Value	CCE HCl	RH-Value	CCE HCl
1	6.46	5.90	4.86	4.44	5.11	4.67
2	9.89	5.13	7.42	3.86	7.80	4.06
3	7.58	5.76	5.71	4.34	6.00	4.56
4	5.34	4.99	4.02	3.76	4.22	3.95
5	8.22	5.71	6.19	4.30	6.50	4.52
6	8.22	5.11	6.19	3.84	6.50	4.04
7	5.58	4.97	4.20	3.74	4.42	3.93
8	8.91	5.54	6.71	4.17	7.05	4.38
9	6.32	5.57	4.76	4.19	5.00	4.40
10	8.96	5.36	6.75	4.03	7.09	4.24
11	6.43	4.70	4.84	3.54	5.09	3.72
12	10.51	6.54	7.91	4.92	8.32	5.17

TABLE 5. Lime recommendation values (ton.ha⁻¹) as calculated from different methods for target pH 7.8.

Lime no.	Ratio 1:1 (Before)		Ratio 1:1 (After)		Ratio 1:2.5 (After)	
	RH-Value	CCE HCl	RH-Value	CCE HCl	RH-Value	CCE HCl
1	10.39	9.49	7.79	7.12	9.24	8.45
2	15.86	8.25	11.89	6.19	14.11	7.34
3	12.20	9.27	9.15	6.95	10.86	8.25
4	8.59	8.04	6.44	6.03	7.64	7.15
5	13.22	9.19	9.91	6.89	11.76	8.18
6	13.22	8.22	9.91	6.16	11.76	7.31
7	8.98	8.00	6.73	5.99	7.99	7.11
8	14.33	8.92	10.75	6.68	12.75	7.93
9	10.17	8.96	7.62	6.71	9.05	7.97
10	14.42	8.62	10.81	6.46	12.83	7.67
11	10.35	7.56	7.76	5.66	9.20	6.72
12	16.91	10.52	12.68	7.89	15.05	9.36

4. Resultant pH-values

The resultant $pH_{(Water)}$ -values as calculated from the incubation curves (Appendix 2) and the different methods are presented in Tables 6 to 8 for each target value respectively, and in Tables 9 to 11 for $pH_{(KCl)}$ -values for each target value respectively.

TABLE 6. Resultant $pH_{(Water)}$ values calculated from lime incubation curves for the different methods (target pH 5.8).

Lime no.	Ratio 1:1 (Before)		Ratio 1:1 (After)		Ratio 1:2.5 (After)	
	RH-Value	CCE HCl	RH-Value	CCE HCl	RH-Value	CCE HCl
1	5.99	5.95	5.86	5.83	5.64	5.62
2	6.09	5.72	5.91	5.62	5.61	5.46
3	6.30	6.09	6.09	5.92	5.73	5.63
4	5.90	5.86	5.78	5.76	5.59	5.58
5	5.99	5.80	5.84	5.69	5.59	5.51
6	6.15	5.86	5.97	5.74	5.67	5.54
7	6.08	6.00	5.92	5.86	5.65	5.62
8	6.21	5.93	6.04	5.81	5.74	5.62
9	5.93	5.88	5.82	5.78	5.65	5.63
10	5.99	5.76	5.86	5.68	5.63	5.54
11	6.03	5.85	5.87	5.73	5.61	5.53
12	5.88	5.70	5.77	5.62	5.58	5.50
Average	6.04	5.87	5.90	5.75	5.64	5.56

TABLE 7. Resultant $pH_{(Water)}$ values calculated from lime incubation curves for the different methods (target pH 6.8).

Lime no.	Ratio 1:1 (Before)		Ratio 1:1 (After)		Ratio 1:2.5 (After)	
	RH-Value	CCE HCl	RH-Value	CCE HCl	RH-Value	CCE HCl
1	6.70	6.62	6.45	6.38	6.49	6.42
2	7.09	6.33	6.72	6.09	6.78	6.13
3	7.30	6.98	6.97	6.66	7.03	6.72
4	6.62	6.55	6.34	6.28	6.38	6.32
5	6.79	6.43	6.50	6.19	6.55	6.23
6	7.06	6.55	6.75	6.29	6.80	6.33
7	7.02	6.87	6.66	6.54	6.72	6.59
8	7.07	6.59	6.78	6.34	6.83	6.38
9	6.55	6.43	6.31	6.22	6.35	6.25
10	6.69	6.26	6.44	6.07	6.49	6.10
11	6.88	6.55	6.58	6.28	6.63	6.33
12	6.58	6.16	6.31	5.98	6.36	6.01
Average	6.86	6.53	6.57	6.28	6.62	6.32

TABLE 8. Resultant $pH_{(Water)}$ values calculated from lime incubation curves for the different methods (target pH 7.8).

Lime no.	Ratio 1:1 (Before)		Ratio 1:1 (After)		Ratio 1:2.5 (After)	
	RH-Value	CCE HCl	RH-Value	CCE HCl	RH-Value	CCE HCl
1	7.13	7.05	6.88	6.79	7.03	6.95
2	7.79	6.86	7.36	6.52	7.62	6.71
3	7.64	7.50	7.49	7.20	7.61	7.39
4	7.26	7.15	6.84	6.76	7.08	6.98
5	7.32	6.92	7.01	6.61	7.20	6.79
6	7.54	7.06	7.27	6.74	7.44	6.93
7	7.78	7.58	7.30	7.13	7.58	7.39
8	7.48	7.08	7.26	6.77	7.41	6.95
9	6.90	7.22	6.60	6.89	6.77	7.08
10	7.09	6.66	6.86	6.41	7.01	6.55
11	7.41	7.07	7.10	6.74	7.29	6.93
12	7.19	6.59	6.80	6.31	7.02	6.47
Average	7.39	7.03	7.08	6.72	7.27	6.90

TABLE 9. Resultant $pH_{(KCl)}$ values calculated from lime incubation curves for the different methods (target $pH_{(Water)}$ 5.8).

Lime no.	Ratio 1:1 (Before)		Ratio 1:1 (After)		Ratio 1:2.5 (After)	
	RH-Value	CCE HCl	RH-Value	CCE HCl	RH-Value	CCE HCl
1	5.16	5.09	4.97	4.92	4.65	4.62
2	5.19	4.69	4.95	4.56	4.55	4.34
3	5.17	4.96	4.96	4.79	4.60	4.51
4	4.72	4.69	4.60	4.58	4.40	4.39
5	5.02	4.76	4.82	4.62	4.49	4.38
6	5.03	4.72	4.84	4.59	4.51	4.38
7	4.91	4.84	4.75	4.69	4.48	4.44
8	5.04	4.73	4.85	4.60	4.52	4.39
9	4.92	4.85	4.79	4.73	4.56	4.53
10	4.95	4.67	4.79	4.57	4.52	4.40
11	4.74	4.59	4.61	4.50	4.40	4.34
12	4.99	4.71	4.81	4.60	4.52	4.41

TABLE 10. Resultant $pH_{(KCl)}$ values calculated from lime incubation curves for the different methods (target $pH_{(Water)}$ 6.8).

Lime no.	Ratio 1:1 (Before)		Ratio 1:1 (After)		Ratio 1:2.5 (After)	
	RH-Value	CCE HCl	RH-Value	CCE HCl	RH-Value	CCE HCl
1	6.06	5.96	5.76	5.67	5.81	5.72
2	6.42	5.49	5.99	5.19	6.06	5.24
3	6.22	5.87	5.86	5.54	5.92	5.59
4	5.44	5.37	5.17	5.11	5.21	5.15
5	6.11	5.61	5.71	5.28	5.77	5.34
6	6.08	5.47	5.70	5.19	5.76	5.23
7	5.89	5.73	5.52	5.38	5.58	5.44
8	6.04	5.47	5.68	5.19	5.74	5.23
9	5.78	5.62	5.44	5.32	5.50	5.37
10	5.78	5.28	5.49	5.05	5.54	5.08
11	5.56	5.21	5.24	4.97	5.29	5.00
12	5.96	5.39	5.60	5.13	5.66	5.17

TABLE 11. Resultant $pH_{(KCl)}$ values calculated from lime incubation curves for the different methods (target $pH_{(Water)}$ 7.8).

Lime no.	Ratio 1:1 (Before)		Ratio 1:1 (After)		Ratio 1:2.5 (After)	
	RH-Value	CCE HCl	RH-Value	CCE HCl	RH-Value	CCE HCl
1	6.38	6.35	6.23	6.15	6.34	6.29
2	7.09	6.14	6.71	5.73	6.95	5.97
3	6.72	6.47	6.45	6.11	6.63	6.32
4	6.02	5.93	5.66	5.58	5.87	5.78
5	6.85	6.28	6.40	5.85	6.67	6.10
6	6.71	6.08	6.34	5.70	6.57	5.92
7	6.70	6.48	6.19	6.00	6.48	6.28
8	6.61	6.04	6.28	5.68	6.49	5.89
9	6.53	6.30	6.04	5.86	6.32	6.11
10	6.24	5.74	5.98	5.45	6.14	5.62
11	6.27	5.77	5.81	5.41	6.07	5.61
12	6.66	5.96	6.23	5.60	6.49	5.81

Figures 1 through 12 indicate the predicted pH values for each lime as calculated above.

Note: The second lime requirement in the 1:1 soil to solution ratio (RH and HCl) is not indicated in the figures.

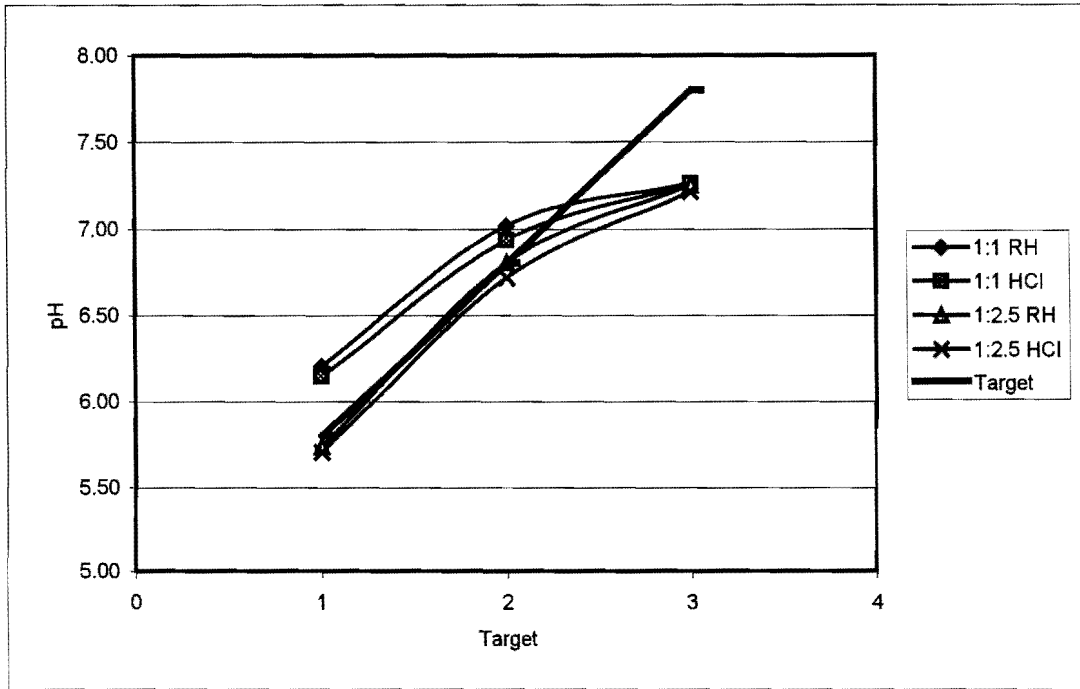


Figure 1. Predicted pH values for Lime 1 from calculated lime recommendations.

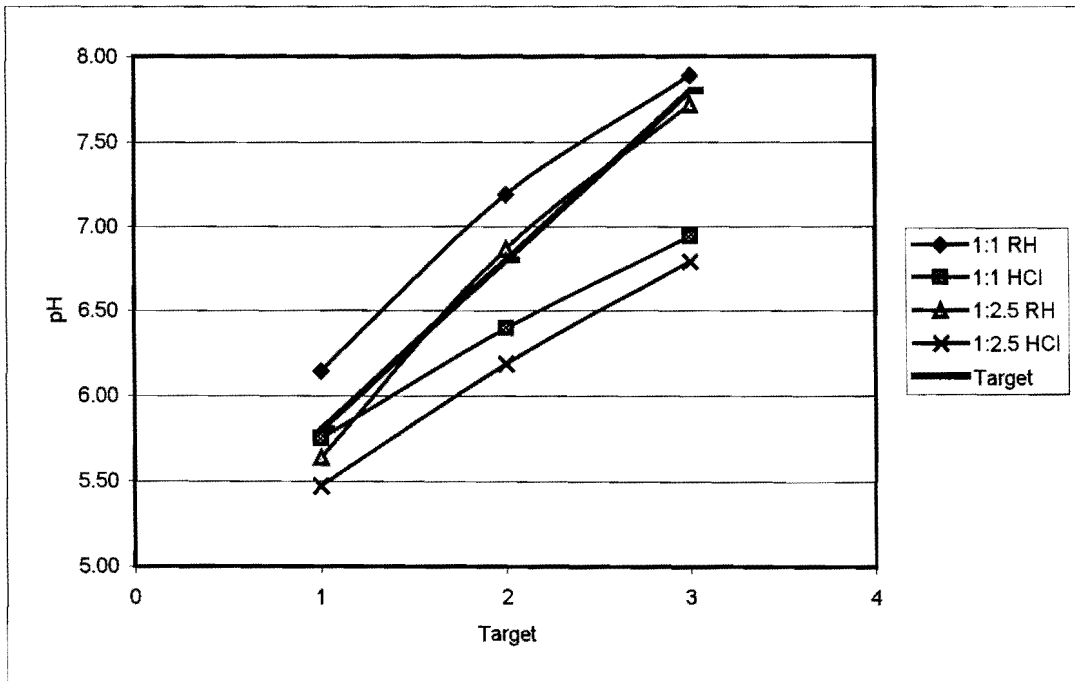


Figure 2. Predicted pH values for Lime 2 from calculated lime recommendations.

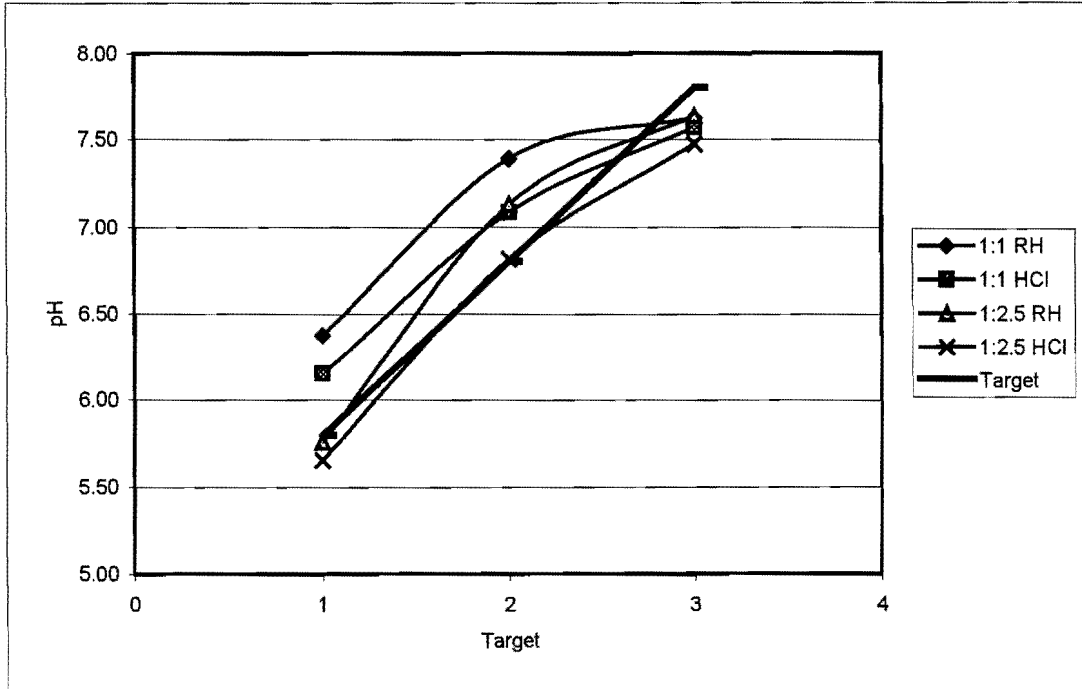


Figure 3. Predicted pH values for Lime 3 from calculated lime recommendations.

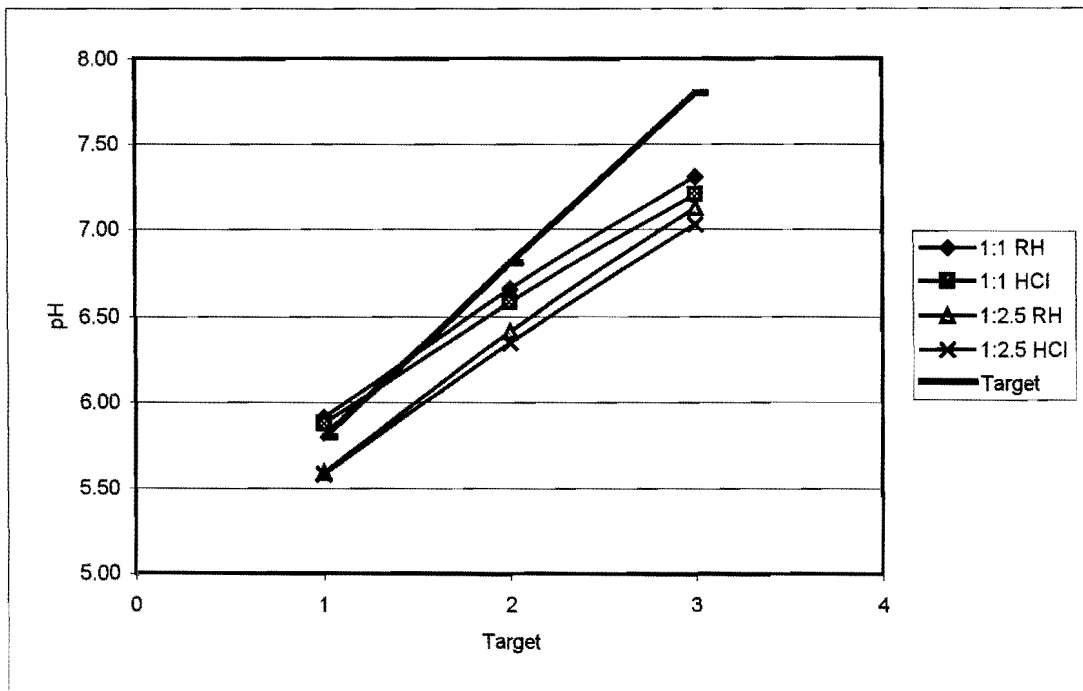


Figure 4. Predicted pH values for Lime 4 from calculated lime recommendations.

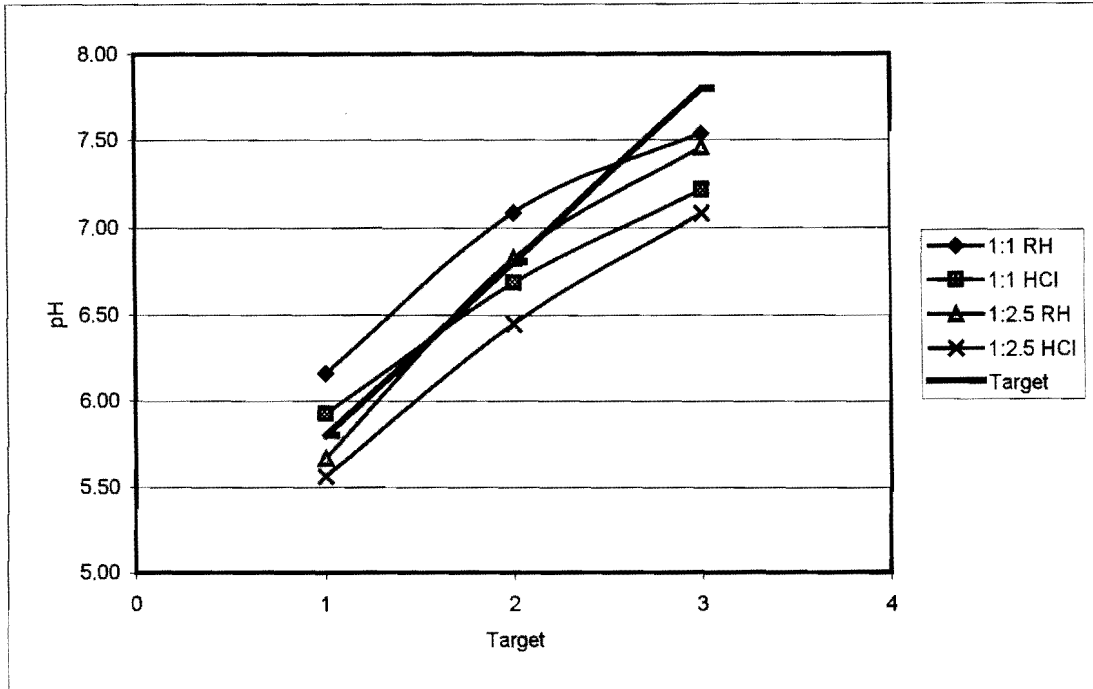


Figure 5. Predicted pH values for Lime 5 from calculated lime recommendations.

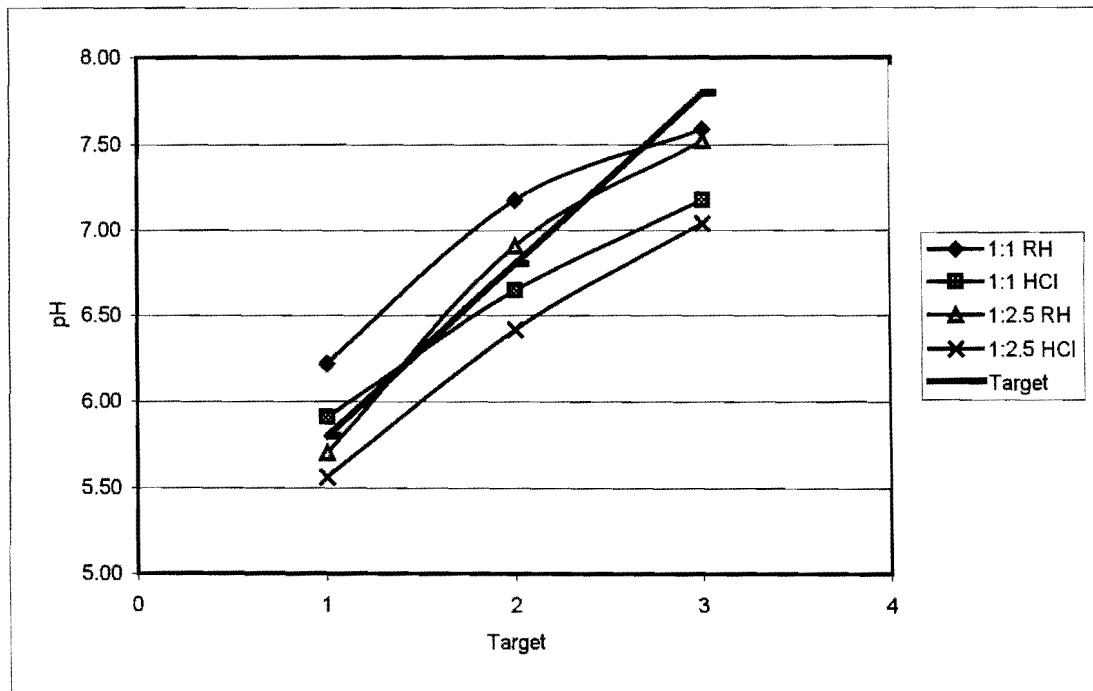


Figure 6. Predicted pH values for Lime 6 from calculated lime recommendations.

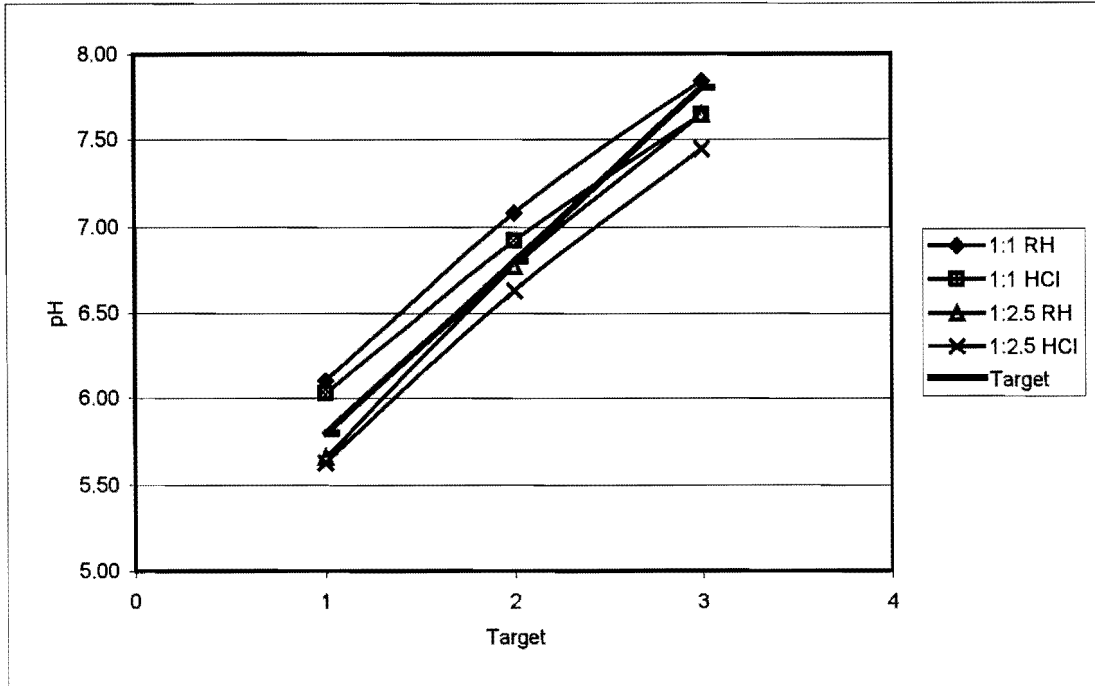


Figure 7. Predicted pH values for Lime 7 from calculated lime recommendations.

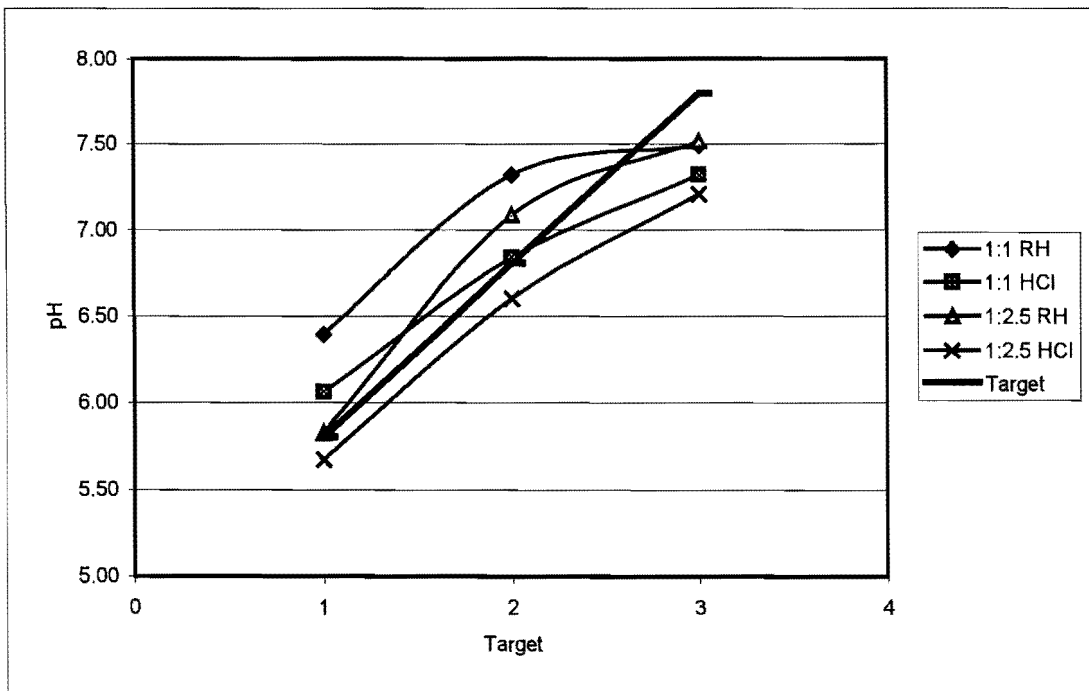


Figure 8. Predicted pH values for Lime 8 from calculated lime recommendations.

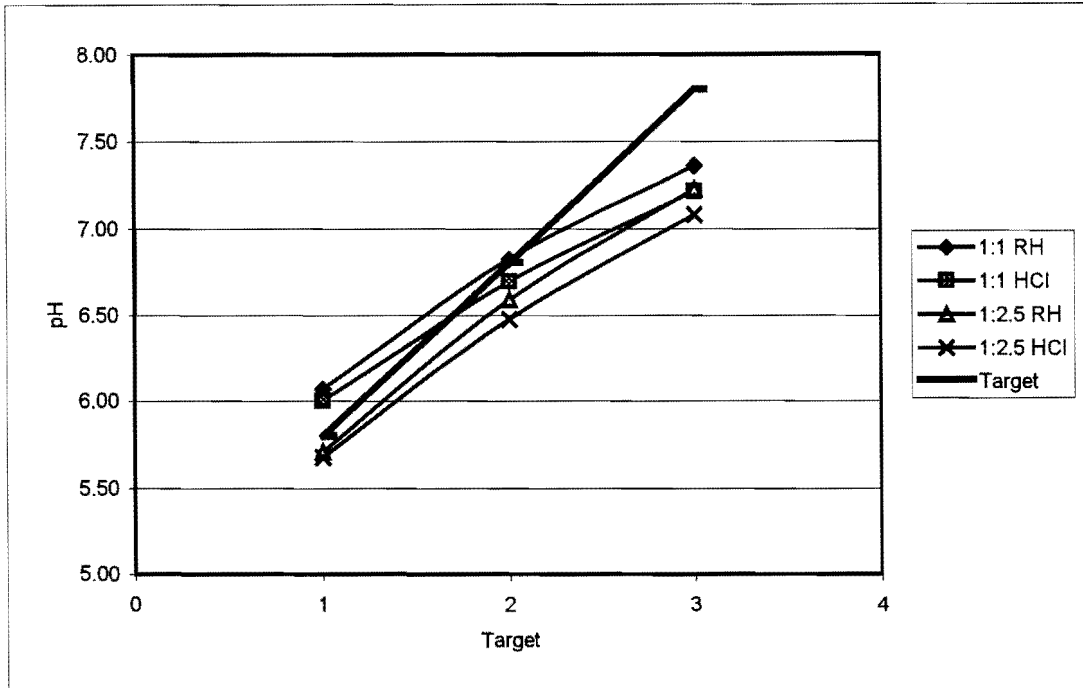


Figure 9. Predicted pH values for Lime 9 from calculated lime recommendations.

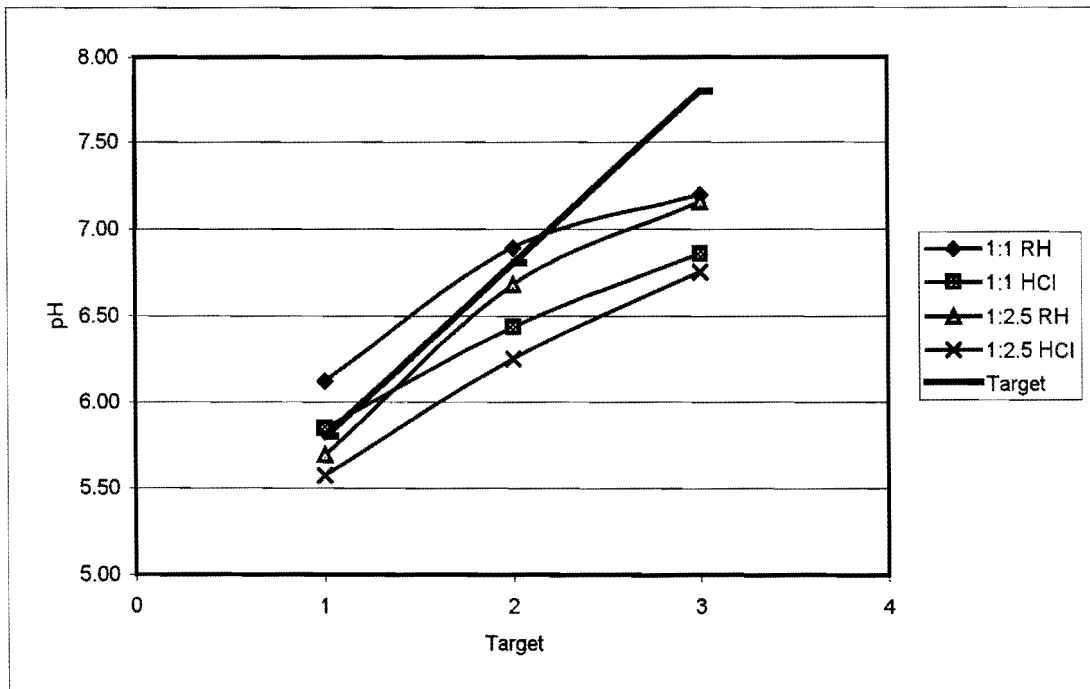


Figure 10. Predicted pH values for Lime 10 from calculated lime recommendations.

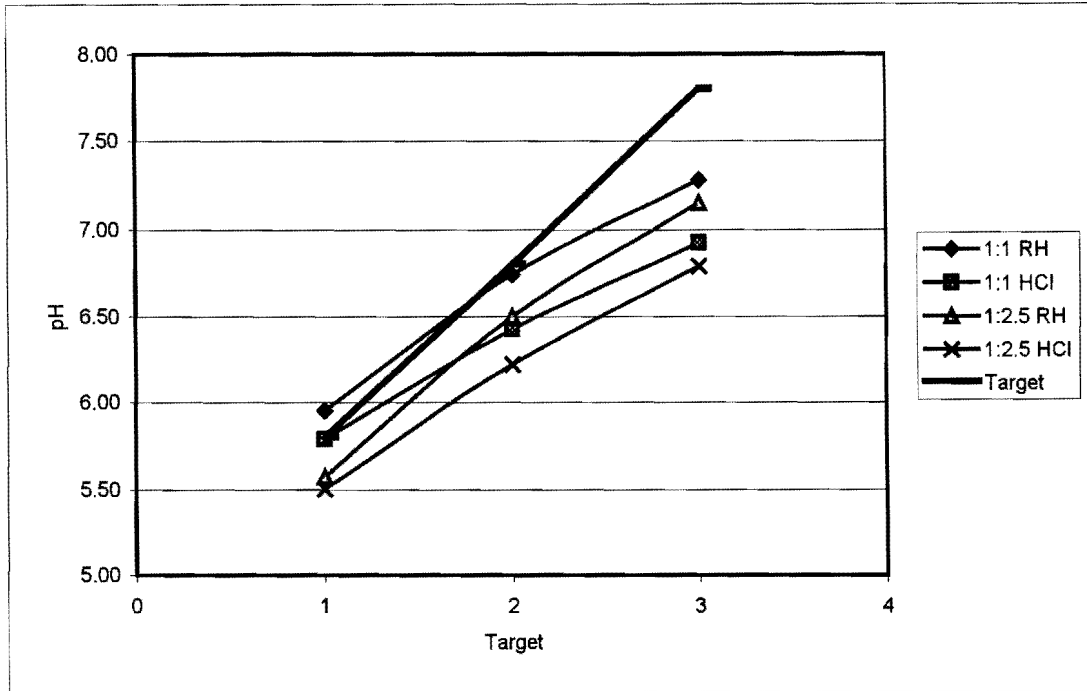


Figure 11. Predicted pH values for Lime 11 from calculated lime recommendations.

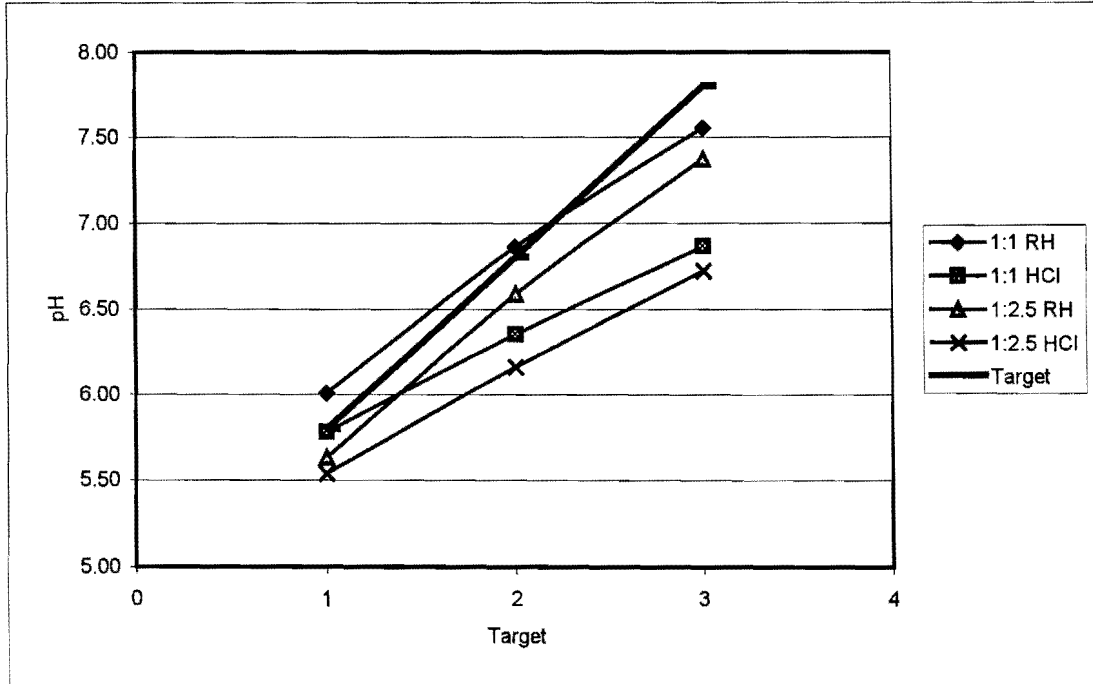


Figure 12. Predicted pH values for Lime 12 from calculated lime recommendations.

APPENDIX 6

YIELD OF WHEAT AND SPINACH

TABLE 1. Total wheat yield per rate of lime application.

Lime no.	Rate	Yield per four pots (g) First harvest	pH	Yield per four pots (g) Second harvest	pH
	Control	35.65	5.33	26.65	5.06
1	1	30.48	6.35	32.02	6.02
	2	26.70	6.91	46.03	6.60
	3	37.04	7.29	47.99	7.30
2	1	33.83	6.05	40.54	6.32
	2	41.14	7.27	43.67	7.45
	3	50.27	7.88	50.14	8.08
3	1	30.37	6.33	46.32	5.99
	2	33.30	7.42	45.07	7.10
	3	37.00	7.61	44.48	7.45
4	1	31.37	6.05	37.72	5.41
	2	32.68	6.55	30.21	6.69
	3	32.97	7.34	36.51	6.96
5	1	30.05	6.15	39.02	6.27
	2	35.55	7.11	42.62	7.14
	3	35.04	7.54	37.88	7.45
6	1	29.72	6.22	41.46	6.00
	2	40.10	7.18	46.52	7.22
	3	44.93	7.60	45.35	7.78
7	1	30.09	6.19	38.71	6.13
	2	34.01	7.02	53.54	7.21
	3	34.87	7.86	52.65	7.73
8	1	36.12	6.58	33.81	6.23
	2	38.51	7.18	44.77	6.87
	3	34.65	7.53	43.52	7.36
9	1	30.80	6.37	32.19	5.66
	2	31.75	6.95	44.19	6.85
	3	31.55	7.43	48.22	7.23
10	1	32.88	6.25	29.05	5.95
	2	30.46	6.79	51.84	6.55
	3	31.78	7.21	46.05	7.39
11	1	29.55	5.91	34.51	5.65
	2	34.27	6.78	39.07	6.64
	3	39.08	7.27	41.66	7.37
12	1	30.01	6.12	34.24	5.66
	2	26.85	6.78	44.63	6.74
	3	36.95	7.60	38.56	7.55



Table 2. Total spinach yield per rate of lime application.

Lime no.	Rate	Yield per four pots (g) First harvest	pH
	Control	0.29	5.33
1	1	4.33	6.35
	2	4.71	6.91
	3	8.96	7.29
2	1	5.2	6.05
	2	8.86	7.27
	3	10.67	7.88
3	1	5.93	6.33
	2	6.42	7.42
	3	9.26	7.61
4	1	5.68	6.05
	2	9.16	6.55
	3	9.38	7.34
5	1	6.16	6.15
	2	6.89	7.11
	3	8.49	7.54
6	1	5.19	6.22
	2	7.35	7.18
	3	7.2	7.60
7	1	8.33	6.19
	2	12.84	7.02
	3	14.66	7.86
8	1	3.26	6.58
	2	6.85	7.18
	3	7.94	7.53
9	1	5.98	6.37
	2	9.32	6.95
	3	9.94	7.43
10	1	5.5	6.25
	2	7.44	6.79
	3	11.04	7.21
11	1	5.51	5.91
	2	8.03	6.78
	3	9.79	7.27
12	1	3.19	6.12
	2	8.75	6.78
	3	9.66	7.60

Note: Due to poor growth no data exists for second spinach harvest