Role of phosphorus in the suppression of Poa annua on bentgrass putting greens

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Summary and recommendations

The five-year-old A4 greens at Talega suggest that low soil phosphorus might play a role in limiting invasion by poa. This report summarizes the findings of a study conducted by George Kenny at Talega that reveals the approximate minimum level of phosphorus that is needed to maintain healthy bentgrass with the target of suppressing poa invasion. The target value is between 20 and 30 ppm based upon the observations below. However, it is possible that the addition of phosphorus to the surface of an established green will reverse the benefits of the low soil phosphorus that was observed during the first five years of bentgrass growth when the bentgrass was able mine phosphorus from deep soil profiles where poa roots can not reach. Once the original phosphorus was depleted and additional phosphorus is applied, the low phosphorus strategy may be broken. There currently is no practical method of placing phosphorus deep into the soil, below the poa roots where the bentgrass has access but the poa does not.

- In order to continue the poa control strategy of low phosphorus management, do not apply excessive phosphorus. The target is between 20 and 30 ppm Mehlich III P to maintain adequate bentgrass growth at the lowest phosphorus levels possible. For increased accuracy in phosphorus testing, use the Olsen test for phosphorus and target a minimum of 5 ppm in the soil for adequate growth of bentgrass. Olsen P values above 5 ppm may be needed if iron levels are increased or the turf begins to display the purple symptoms of phosphorus deficiency.

- Do not apply more than ½ lb P2O5/1000 sq ft in a single application. MAP is a good source but monopotassium phosphate 0-52-34 will also do a good job while applying potassium at the same time without the added nitrogen.

- Apply 2 lbs 0-0-50/1000 sq ft monthly throughout the year to provide needed potassium. Irrigate following application.

Background

Suppression of Poa annua (poa) invasion into bentgrass greens has always been a controversial topic. In the past when arsenic was used as a poa specific herbicide on bentgrass greens, low soil phosphorus levels were needed for full herbicidal activity of the arsenic. This led to the belief that poa was a phosphorus-loving weed that might be suppressed by low phosphorus soil conditions. However, once arsenic was no longer used, low phosphorus was no longer essential. Furthermore, experience in research trials where poa invades different varieties of bentgrass indicates that the highest quality bentgrass varieties are most capable of resisting poa invasion. The most robust and healthiest bentgrass provides the greatest defense against poa invasion. This result would suggest that low phosphorus levels might result in less aggressive bentgrass growth and more poa invasion. The opposite was observed at Talega Golf Club – low phosphorus containing greens had very little poa invasion with abundant poa population being present in the collars.

Materials and Methods

Soil phosphorus evalutions: Soil phosphorus levels were determined via Olsen, Bray II and Mehlich III extractions run by Brookside Laboratories (New Knoxville, OH). To compare the soil phosphorus levels between treated and non-treated areas, cup cutter samples were collected from treated and non-treated areas of the practice green (two treated and two non-treated samples), green 12 (one treated and one non-treated) and two samples from the poa infested collar and green 14 (one treated and one non-treated sample) and two samples from the poa infested collar. The top 3 inches of soil were removed from each cup cutter sample and the soils were analyzed. In addition to the soil samples from greens, two cup cutter samples were collected from the surrounds of green 12 and 14 were poa invasion was severe.

Diagnostic tests: The A4 greens at Telaga were planted in 2000. Poa invasion was extremely limited as of May, 2005. Bensulide pre-emergent herbicide was applied in March of most years to suppress poa invasion. No phosphorus was applied to greens between 2000 and April of 2005 with the goal of suppressing poa using low soil phosphorus as a strategy. The ryegrass overseeded bermudagrass collars were thoroughly invaded by poa (Photos 1 and 2).

The lack of poa invasion into greens is not the result of a lack of poa seeds. The collars at Talega are heavily infested with poa (Photo 2). The bermudagrass collars are overseeded every year with ryegrass and the lack of effective poa-selective herbicides results in heavy poa invasion. Poa-

selective herbicides introduced in 2005 will help reduce poa invasion in collars in the future but these herbicides were only available for a few weeks at the time this report was written. In preparation for overseeding and to stimulate overseeded ryegrass growth and development, one pound of phosphate is applied every year as a 0-25-25 starter fertilizer. Phosphate is also applied to the collars and greens surrounds in a 29-6-3 sulfur coated urea product. The collars report about 40 ppm phosphorus – slightly lower than our general recommendation for sufficient phosphorus of 50 ppm.

The greens at Talega exhibited classical symptoms of phosphorus deficiency when observed on May 3, 2005. This was the first year that dramatic phosphorus deficiency was observed even though soil tests revealed low phosphorus in 2004 – in the range of about 40 ppm. Severe deficiency symptoms did not show up until soil phosphorus levels dropped below 20 ppm. Although rapid blight was previously diagnosed from Talega, it was not observed in the symptomatic plants. The general and widespread distribution of the discolored plants also did not match the typical distribution of rapid blight. However, to be cautious, an application of Insignia (0.9 oz/1000 sq ft) was evaluated along with application of phosphorus as mono ammonium phosphate (MAP 11-48-0). The areas treated with Insignia alone remained discolored and did not recover. Only the areas treated with MAP began to recover dramatically. The strategy was to apply as little phosphorus as possible to maintain the low phosphorus poa-suppression strategy while providing sufficient phosphorus to maintain the bentgrass in a reasonably healthy condition.

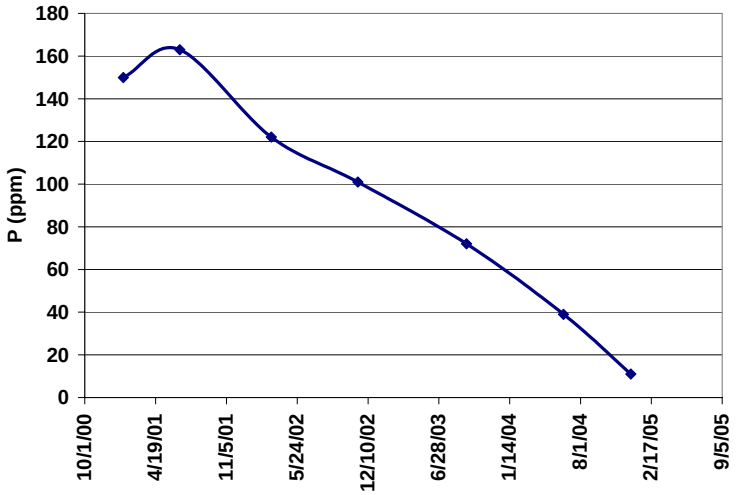
To carry out the test, plywood boards 2'x3' were placed on the practice green, green 12 and green 14 prior to application of Insignia (0.9 oz/1000 sq ft) or application of 1/2 lb P2O5/1000 sq ft using monoammonium phosphate (11-48-0). The boards act as a non-treated check area for each treatment – Insignia alone or MAP alone. A second application of MAP was applied about 14 days after the first application (First application of MAP 4/12 and second on 4/26).

Results and Discussion

Figure 1 illustrates the trend in soil phosphorus levels based upon the historical soil testing that was available. Note the steady decrease in soil phosphorus that reflects the low phosphorus strategy used to suppress poa. Some turf stress was observed in 2004 when soil phosphorus levels dropped below 50 ppm. The stress was observed as a light purple color in cold weather on some greens and lower than expected response to nitrogen fertilization. More severe deficiency was not clearly

identified until levels dropped below 20 ppm in 2005 and most of the greens revealed symptoms of phosphorus deficiency (Photos 3 and 4).

Figure 1. Trend in soil phosphorus levels at Talega Golf Club.



Photos 1 and 3 illustrates the appearance of the greens prior to treatment with either Insignia or MAP. Photo 5 illustrates the appearance of greens following MAP applications and the non-treated rectangle where no MAP was applied. The Insignia application had no effect on the performance of the turf – only the areas treated with MAP regained normal growth.

There was no significant difference in the phosphorus values in the MAP treated and non-treated samples when the Mehlich III extraction or Bray II extraction was used for analysis. However, use of the Olsen method of phosphorus analysis indicates that there is a significant difference between the treated and non-treated areas (Figure 3). The Olsen test is an old test that was developed for phosphorus analysis in high pH soils. The expected increase in soil phosphorus was about 5 ppm in the top 3 inches. The Olsen P test indicates that the average increase in soil P was about 2 ppm. This is a small but significant increase was enough to improve turf performance.

The correlation between the Olsen P and easily extractable Mehlich III phosphorus test is strong ($r^2 = 0.71$, $p<0.001$). Because the Olsen P test is more expensive than the Mehlich III test and most of the major laboratories use the Mehlich III extraction, a conversion has been used to provide an idea of what Mehlich III value would correlate to the minimum desired value on the olsen test of 4.5 ppm. The conversion equation is:

Easily extractable Mehlich III P = 19 + 4.5 x Olsen P

The minimum easily extractable Mehlich III P soil test for adequate growth of bentgrass at Talega is 21 ppm. This value is consistent with the observation that turf performance was reduced in 2004 when soil phosphorus levels dropped below 40 ppm with severe phosphorus deficiency at 11 ppm by the Mehlich III soil test. However, with the knowledge that the Olsen test is more representative of plant responses, it is recommended that soil P levels be evaluated using the Olsen test if the low P strategy is used in the future.

There were no significant differences in soil nitrate or ammonium nitrogen levels in treated and non-treated areas. There was, however a significant difference in the nitrate:ammonium ratio with a NO3:NH4 ratio of 1.2 in the non-treated plots and a NO3:NH4 ratio of 0.6 in the treated plots ($p<0.05$) reflecting the ammonium added by the MAP. The alleviation of typical phosphorus symptoms points toward an increase in plant phosphorus levels rather than a nitrogen response. Tissue chemical analysis were not conducted.

The unfortunate reality of applying phosphorus to the surface of the green is that the highest concentration of phosphorus will occur near the surface of the green and not deep in the soil profile. Once the sub-soil has been depleted of phosphorus as happened in 2005, it may not be possible to maintain a poa suppressive environment at the surface where poa invades. This factor may contribute to the invasion of bentgrass greens that is typically observed after 5 – 7 years.

Figure 2. Easily extractable phosphorus (Mehlich III) for the treated, non-treated and poa infested collars. Note that the treated areas do not report significantly more phosphorus compared to the non-treated areas. The poa infested collars report significantly more phosphorus compared to either the MAP treated or non-treated areas. Collar represents the average of the samples from the poa infested collars of green 12 and 14. The vertical bar represents the standard error of the mean. Non refers to the average of the non-treated samples and treated refers to the MAP treated soils.

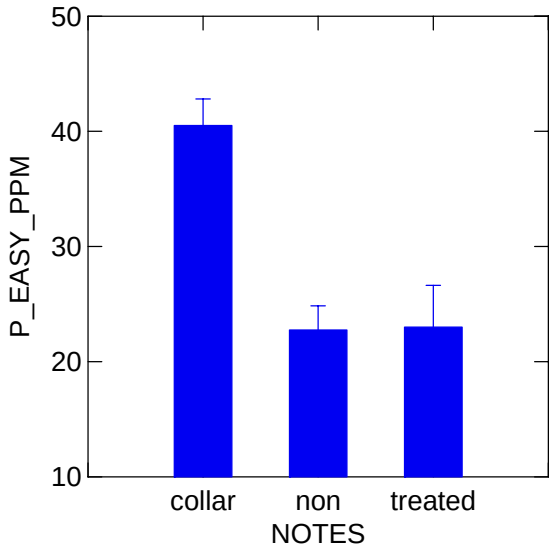


Figure 3. Olsen phosphorus for the treated, non-treated and poa infested collars. Olsen phosphorus test are frequently used for high pH soils. The Olsen P test correlates well with Mehlich III P but only the Olsen P test picked up the small but significant difference between the treated and non-treated areas when the Mehlich III test could not resolve the small difference.

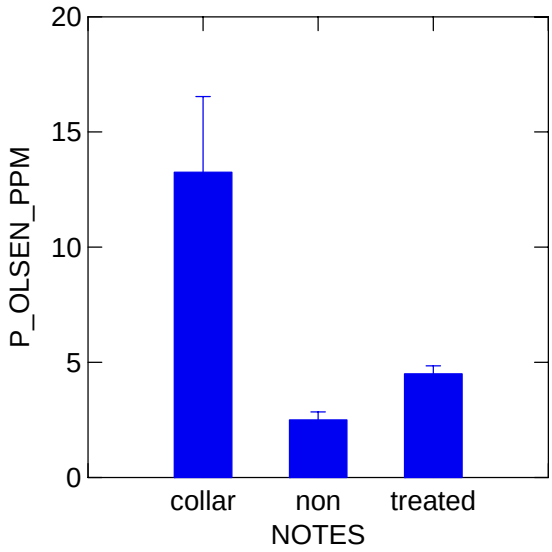


Table 1. Nutritional deficits, pH and EC.

05052001 Talega Golf Club

		Ca lb/M	Mg lb/M	K2O lb/M	P2O5 lb/M	Mn lb/M	Fe lb/M	pH	EC dS/m
c 12a	poa	0	1	5	1	0.0	1.0	7.40	1.09
c 12b	poa	0	0	3	2	0.0	0.7	7.40	0.94
c 14a	poa	0	0	6	0	0.0	0.0	7.50	0.90
c 14b	poa	0	0	6	0	0.0	0.6	7.50	0.88
g 12n	non	0	1	4	3	0.0	1.5	7.60	0.92
g 12t	treated	0	1	4	2	0.0	0.9	7.50	1.05
g 14n	non	0	0	5	2	0.0	1.0	7.60	0.81
g 14t	treated	0	0	4	3	0.0	0.6	7.60	0.84
g pg01n	non	1	0	1	4	0.0	0.0	7.30	0.81
g pg01t	treated	2	0	3	4	0.0	0.1	7.50	0.77
g pg02n	non	0	0	3	4	0.0	0.0	7.00	0.81
g pg02t	treated	3	0	2	3	0.0	0.0	7.40	0.86

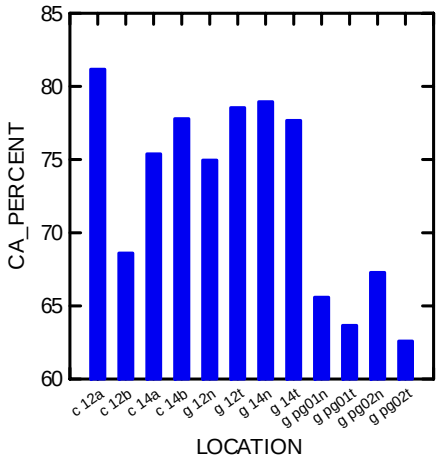
Photos 1 (left) and 2 (right). Symptoms before treatment.

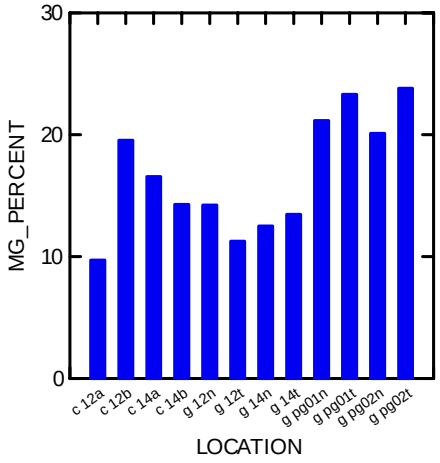
The entire green was discolored prior to application of MAP (photo 1 left). Notice the poa invasion in the collars (photo 2 right).

Photos 3 (left) and 4 (right). Practice green illustrating phosphorus deficiency.
The purple color of the practice green is characteristic of phosphorus deficiency. The close-up on the right illustrates the deposition of purple colored anthocyanins in the bottom of the leaves.


Photos 5. Comparison between treated and non-treated (rectangle) area.
Non-treated rectangular area where MAP was not applied. The surrounding area was treated two times using ½ lbs P2O5/1000 sq ft.

Figure 4. Soil cations reported in percentage of total extractable cations.
Desired values are: Calcium (Ca) 68%, Magnesium (Mg) 12 - 20%, sodium (Na) less than 3%.





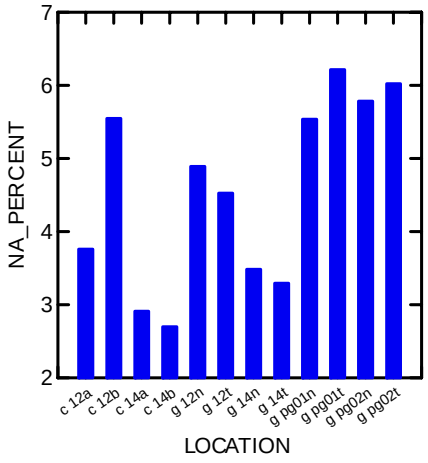
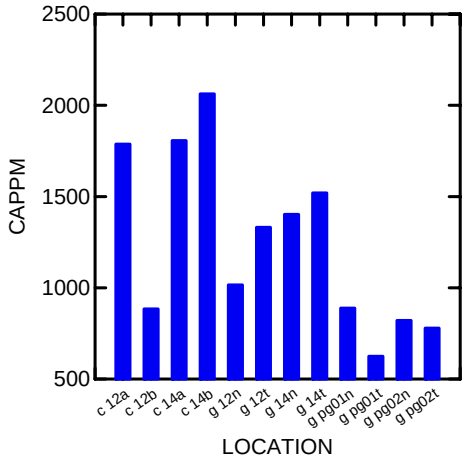
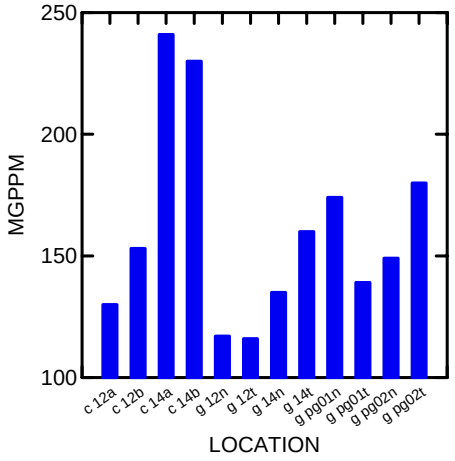


Figure 5. Soil cations reported in parts per million (ppm).
Desired values are calcium (Ca) greater than 750 ppm, magnesium (Mg) greater than 140 ppm, and sodium (Na) less than 110 ppm.





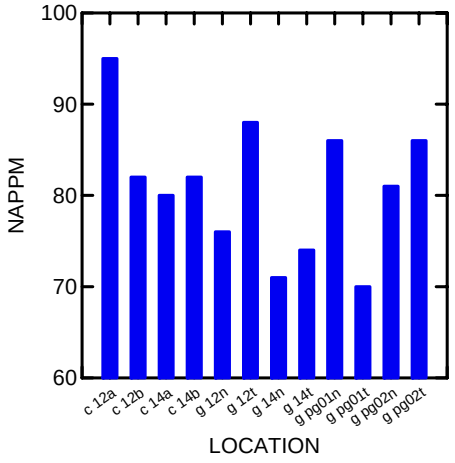


Figure 6. Soil plant available nitrogen values reported in parts per million (ppm), potassium (K ppm and K%) and phosphorus (P2O5).
Desired values are: Nitrate (NO_3) between 3 and 20 ppm, ammonium (NH_4) less than 7 ppm, nitrate:ammonium (NO_3NH_4) ratio greater than 3:1, and total plant available nitrogen less than 20 ppm. Potassium levels above 110 ppm are desired and phosphorus (BrayIIP) above 50 ppm is optimal.

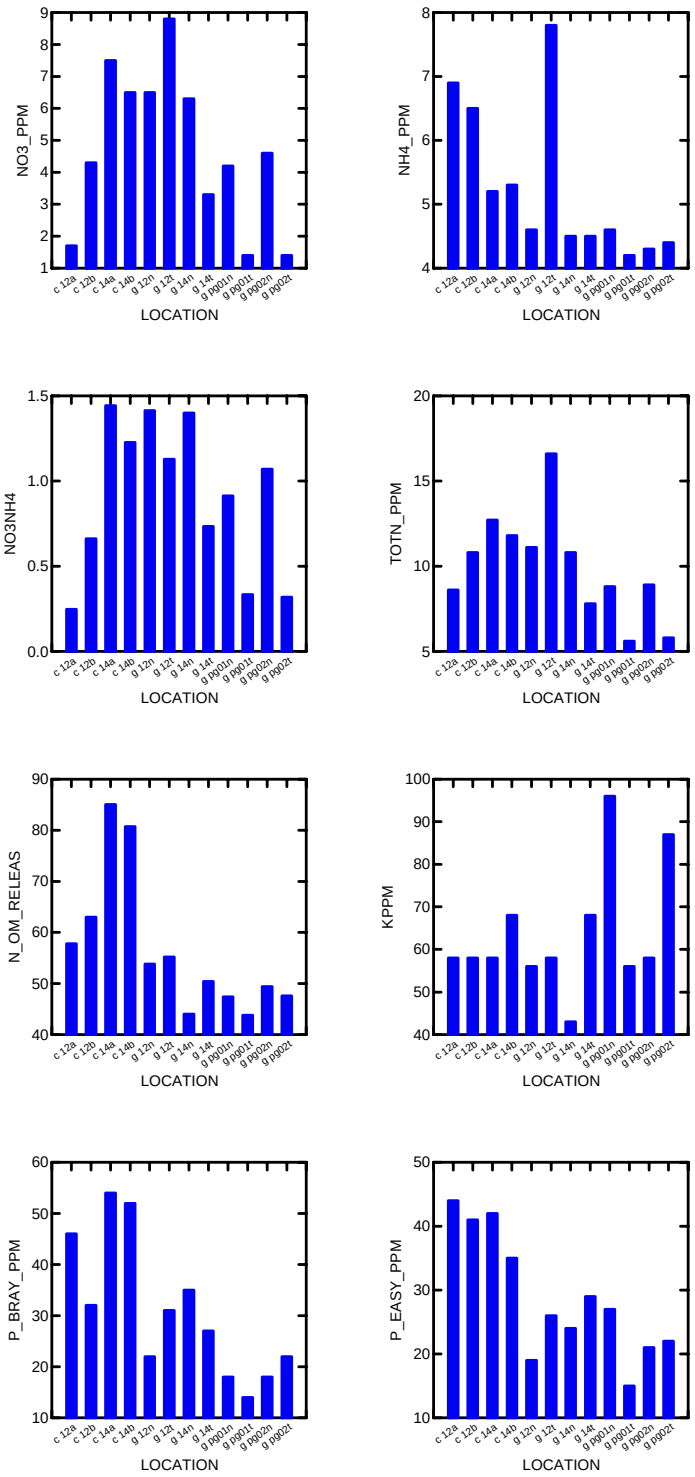


Figure 7. Soil pH, sulfate (ppm), organic matter (percentage) and electrical conductivity (EC dS/m).

Desired values are: pH between 6.2 and 7.4, sulfate between 15 and 200 ppm, organic matter less than 2% for greens and less than 4% for fairways, electrical conductivity less than 3 dS/m for poa greens, less than 4 dS/m for bentgrass greens, less than 6 dS/m for ryegrass and tall fescue, less than 8 dS/m for bermuda and less than 12 dS/m for paspalum.

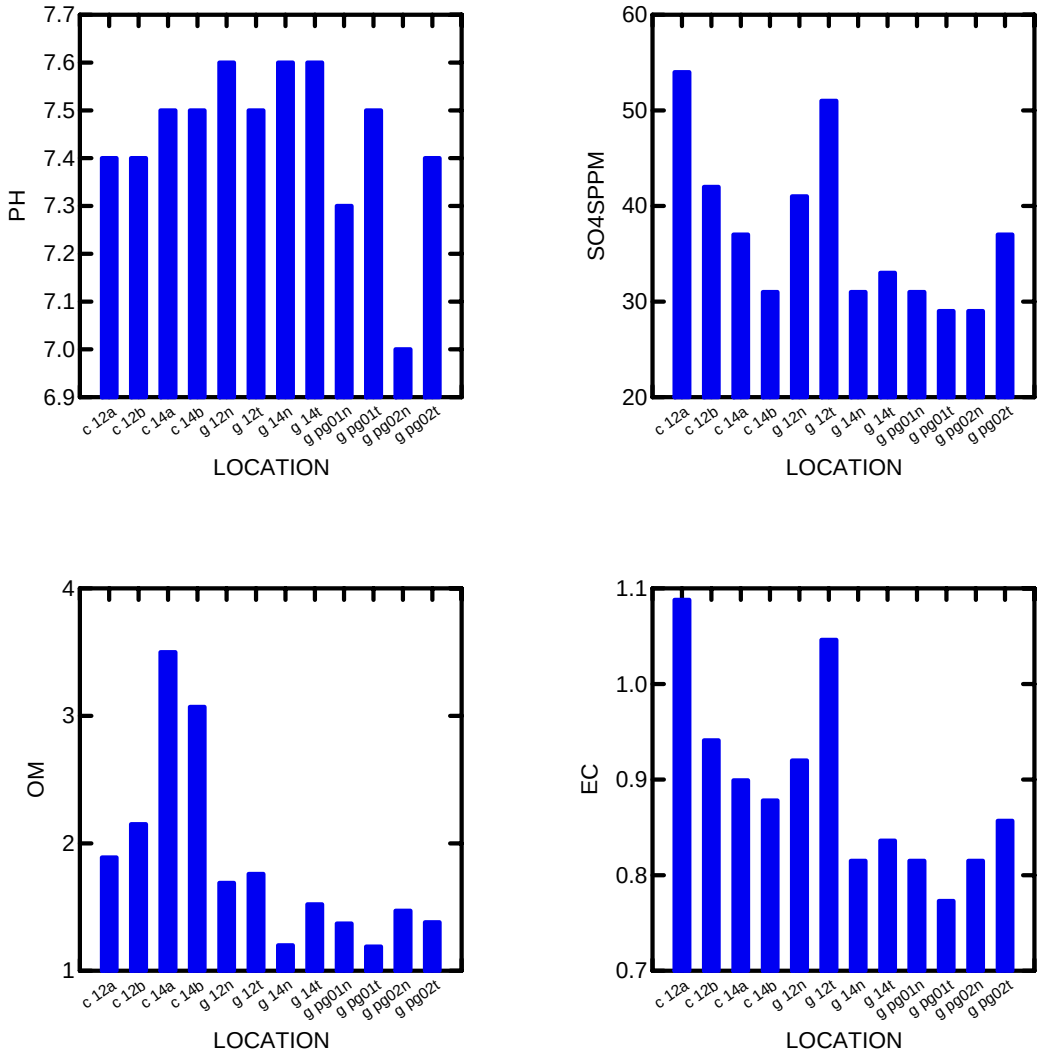
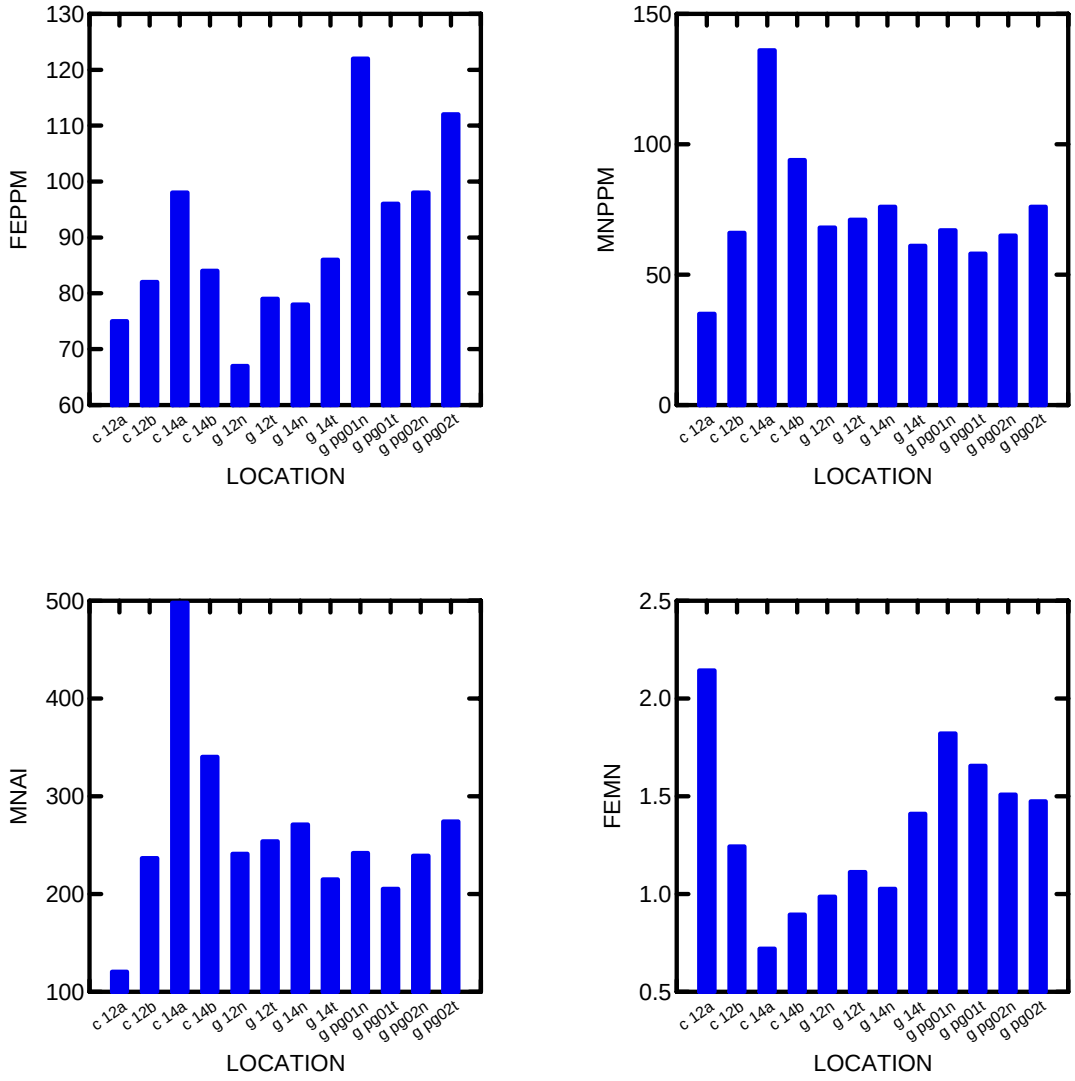


Figure 8. Iron and manganese relationships.

Desired values are currently based upon manganese availability and iron levels needed to balance the iron:manganese ratio. Manganese availability index should exceed 110. Iron should be present at three times the manganese level resulting in a iron:manganese ratio of 3:1.



Soil appraisals

Talega Golf Club **c 12a**

05052001 Standard Extraction Methods poa
5/20/2005 Brookside 0171-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	46			
Phosphate P2O5 ppm:	105	120	29	1
Phosphorus Availablity Index:	0.39			
Sulfur (S) ppm:	54	15-40		
Calcium (Ca) ppm:	1787	1494	0	0
Magnesium (Mg) ppm:	130	158	56	1
Potassium (K) ppm:	58			
Potash (K2O) ppm:	70	183	226	5
Sodium (Na) ppm:	95	< 67		
Aluminum (Al) KCl extract ppm:	6			

Minor Elements	Observed	Desired	
Boron (B) ppm:	0.88	0.4 - 1.5	
Iron (Fe) ppm:	75.00	97	
Manganese (Mn) ppm:	35.00	32	Manganese Availability Index = 120.5
Copper (Cu) ppm:	1.76	0.6 - 2.0	
Zinc (Zn) ppm:	5.61	1.3 - 3.5	

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	83.9	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	10.17	10 - 20 (12 optimum)
Percent Potassium (% K)	1.4	1.5 - 10
Percent Sodium (%Na)	3.88	0.5 - 3

pH:	7.4	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.9	Nitrate (NO3)	1.7
Soluble Salts (SS) 1:2 (ppm):	179.2	Ammonium (NH4)	6.9
Electrical Conductivity (EC) 1:2 (dS/m)	0.3	Total available	8.6
SS estimated saturated paste (ppm)	696.3	NO3:NH4 ratio	0.2
EC estimated saturated paste (dS/m)	1.1	Organic N release	57.8
Total Extractable Cations (meq/100 g)	11.0		
Chloride Cl ppm	65.66		

Talega Golf Club **c 12b**

05052001 Standard Extraction Methods poa
5/20/2005 Brookside 0170-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	32			
Phosphate P2O5 ppm:	73	118	89	2
Phosphorus Availablity Index:	0.30			
Sulfur (S) ppm:	42	15-40		
Calcium (Ca) ppm:	884	875	0	0
Magnesium (Mg) ppm:	153	140	0	0
Potassium (K) ppm:	58			
Potash (K2O) ppm:	70	145	149	3
Sodium (Na) ppm:	82	< 67		
Aluminum (Al) KCl extract ppm:	3			

Minor Elements	Observed	Desired	
Boron (B) ppm:	1.24	0.4 - 1.5	
Iron (Fe) ppm:	82.00	97	
Manganese (Mn) ppm:	66.00	32	Manganese Availability Index = 236.7
Copper (Cu) ppm:	2.74	0.6 - 2.0	
Zinc (Zn) ppm:	10.02	1.3 - 3.5	

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	70.95	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	20.47	10 - 20 (12 optimum)
Percent Potassium (% K)	2.39	1.5 - 10
Percent Sodium (%Na)	5.72	0.5 - 3

pH:	7.4	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	2.2	Nitrate (NO3)	4.3
Soluble Salts (SS) 1:2 (ppm):	134.4	Ammonium (NH4)	6.5
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	10.8
SS estimated saturated paste (ppm)	602.2	NO3:NH4 ratio	0.7
EC estimated saturated paste (dS/m)	0.9	Organic N release	63
Total Extractable Cations (meq/100 g)	6.4		
Chloride Cl ppm	42.25		

Talega Golf Club **c 14a**

05052001 Standard Extraction Methods poa
5/20/2005 Brookside 0169-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	54			
Phosphate P2O5 ppm:	124	120	0	0
Phosphorus Availablity Index:	0.40			
Sulfur (S) ppm:	37	15-40		
Calcium (Ca) ppm:	1806	1626	0	0
Magnesium (Mg) ppm:	241	172	0	0
Potassium (K) ppm:	58			
Potash (K2O) ppm:	70	191	243	6
Sodium (Na) ppm:	80	< 67		
Aluminum (Al) KCl extract ppm:	5			

Minor Elements	Observed	Desired	
Boron (B) ppm:	1.09	0.4 - 1.5	
Iron (Fe) ppm:	98.00	98	
Manganese (Mn) ppm:	136.00	33	Manganese Availability Index = 497.7
Copper (Cu) ppm:	9.62	0.6 - 2.0	
Zinc (Zn) ppm:	52.98	1.3 - 3.5	

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	77.91	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	17.33	10 - 20 (12 optimum)
Percent Potassium (% K)	1.28	1.5 - 10
Percent Sodium (%Na)	3	0.5 - 3

pH:	7.5	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	3.5	Nitrate (NO3)	7.5
Soluble Salts (SS) 1:2 (ppm):	121.6	Ammonium (NH4)	5.2
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	12.7
SS estimated saturated paste (ppm)	575.4	NO3:NH4 ratio	1.4
EC estimated saturated paste (dS/m)	0.9	Organic N release	85
Total Extractable Cations (meq/100 g)	12.0		
Chloride Cl ppm	29.39		

Talega Golf Club **c 14b**

05052001 Standard Extraction Methods poa
5/20/2005 Brookside 0168-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	52			
Phosphate P2O5 ppm:	119	121	4	0
Phosphorus Availablity Index:	0.40			
Sulfur (S) ppm:	31	15-40		
Calcium (Ca) ppm:	2062	1799	0	0
Magnesium (Mg) ppm:	230	190	0	0
Potassium (K) ppm:	68			
Potash (K2O) ppm:	82	202	240	6
Sodium (Na) ppm:	82	< 67		
Aluminum (Al) KCl extract ppm:	8			

Minor Elements	Observed	Desired	
Boron (B) ppm:	1.01	0.4 - 1.5	
Iron (Fe) ppm:	84.00	98	
Manganese (Mn) ppm:	94.00	33	Manganese Availability Index = 340.2
Copper (Cu) ppm:	7.06	0.6 - 2.0	
Zinc (Zn) ppm:	40.90	1.3 - 3.5	

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	80.23	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	14.92	10 - 20 (12 optimum)
Percent Potassium (% K)	1.36	1.5 - 10
Percent Sodium (%Na)	2.77	0.5 - 3

pH:	7.5	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	3.1	Nitrate (NO3)	6.5
Soluble Salts (SS) 1:2 (ppm):	115.2	Ammonium (NH4)	5.3
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	11.8
SS estimated saturated paste (ppm)	561.9	NO3:NH4 ratio	1.2
EC estimated saturated paste (dS/m)	0.9	Organic N release	80.7
Total Extractable Cations (meq/100 g)	13.2		
Chloride Cl ppm	28.65		

Talega Golf Club **g 12n**

05052001 Standard Extraction Methods non
5/20/2005 Brookside 0165-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	22			
Phosphate P2O5 ppm:	50	118	135	3
Phosphorus Availablity Index:	0.15			
Sulfur (S) ppm:	41	15-40		
Calcium (Ca) ppm:	1015	919	0	0
Magnesium (Mg) ppm:	117	140	46	1
Potassium (K) ppm:	56			
Potash (K2O) ppm:	67	147	160	4
Sodium (Na) ppm:	76	< 67		
Aluminum (Al) KCl extract ppm:	6			

Minor Elements	Observed	Desired	
Boron (B) ppm:	1.05	0.4 - 1.5	
Iron (Fe) ppm:	67.00	99	
Manganese (Mn) ppm:	68.00	33	Manganese Availability Index = 241.2
Copper (Cu) ppm:	4.26	0.6 - 2.0	
Zinc (Zn) ppm:	14.66	1.3 - 3.5	

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	77.01	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	14.8	10 - 20 (12 optimum)
Percent Potassium (% K)	2.18	1.5 - 10
Percent Sodium (%Na)	5.01	0.5 - 3

pH:	7.6	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.7	Nitrate (NO3)	6.5
Soluble Salts (SS) 1:2 (ppm):	128.0	Ammonium (NH4)	4.6
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	11.1
SS estimated saturated paste (ppm)	588.8	NO3:NH4 ratio	1.4
EC estimated saturated paste (dS/m)	0.9	Organic N release	53.8
Total Extractable Cations (meq/100 g)	6.8		
Chloride Cl ppm	39.16		

Talega Golf Club **g 12t**

05052001 Standard Extraction Methods treated
5/20/2005 Brookside 0164-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	31			
Phosphate P2O5 ppm:	71	119	95	2
Phosphorus Availablity Index:	0.20			
Sulfur (S) ppm:	51	15-40		
Calcium (Ca) ppm:	1331	1150	0	0
Magnesium (Mg) ppm:	116	140	48	1
Potassium (K) ppm:	58			
Potash (K2O) ppm:	70	162	184	4
Sodium (Na) ppm:	88	< 67		
Aluminum (Al) KCl extract ppm:	3			

Minor Elements	Observed	Desired	
Boron (B) ppm:	0.86	0.4 - 1.5	
Iron (Fe) ppm:	79.00	98	
Manganese (Mn) ppm:	71.00	33	Manganese Availability Index = 254.0
Copper (Cu) ppm:	3.70	0.6 - 2.0	
Zinc (Zn) ppm:	13.98	1.3 - 3.5	

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	81.26	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	11.8	10 - 20 (12 optimum)
Percent Potassium (% K)	1.82	1.5 - 10
Percent Sodium (%Na)	4.67	0.5 - 3

pH:	7.5	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.8	Nitrate (NO3)	8.8
Soluble Salts (SS) 1:2 (ppm):	166.4	Ammonium (NH4)	7.8
Electrical Conductivity (EC) 1:2 (dS/m)	0.3	Total available	16.6
SS estimated saturated paste (ppm)	669.4	NO3:NH4 ratio	1.1
EC estimated saturated paste (dS/m)	1.0	Organic N release	55.2
Total Extractable Cations (meq/100 g)	8.5		
Chloride Cl ppm	57.24		

Talega Golf Club **g 14n**

05052001 Standard Extraction Methods non
5/20/2005 Brookside 0167-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	35			
Phosphate P2O5 ppm:	80	119	77	2
Phosphorus Availablity Index:	0.24			
Sulfur (S) ppm:	31	15-40		
Calcium (Ca) ppm:	1402	1205	0	0
Magnesium (Mg) ppm:	135	140	10	0
Potassium (K) ppm:	43			
Potash (K2O) ppm:	52	165	227	5
Sodium (Na) ppm:	71	< 67		
Aluminum (Al) KCl extract ppm:	3			

Minor Elements	Observed	Desired	
Boron (B) ppm:	0.88	0.4 - 1.5	
Iron (Fe) ppm:	78.00	99	
Manganese (Mn) ppm:	76.00	33	Manganese Availability Index = 271.2
Copper (Cu) ppm:	4.60	0.6 - 2.0	
Zinc (Zn) ppm:	17.39	1.3 - 3.5	

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	81.61	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	13.1	10 - 20 (12 optimum)
Percent Potassium (% K)	1.28	1.5 - 10
Percent Sodium (%Na)	3.59	0.5 - 3

pH:	7.6	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.2	Nitrate (NO3)	6.3
Soluble Salts (SS) 1:2 (ppm):	96.0	Ammonium (NH4)	4.5
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	10.8
SS estimated saturated paste (ppm)	521.6	NO3:NH4 ratio	1.4
EC estimated saturated paste (dS/m)	0.8	Organic N release	44
Total Extractable Cations (meq/100 g)	8.9		
Chloride Cl ppm	25.82		

Talega Golf Club **g 14t**

05052001 Standard Extraction Methods treated
5/20/2005 Brookside 0166-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	27			
Phosphate P2O5 ppm:	62	119	115	3
Phosphorus Availablity Index:	0.19			
Sulfur (S) ppm:	33	15-40		
Calcium (Ca) ppm:	1520	1328	0	0
Magnesium (Mg) ppm:	160	141	0	0
Potassium (K) ppm:	68			
Potash (K2O) ppm:	82	173	182	4
Sodium (Na) ppm:	74	< 67		
Aluminum (Al) KCl extract ppm:	5			

Minor Elements	Observed	Desired	
Boron (B) ppm:	1.01	0.4 - 1.5	
Iron (Fe) ppm:	86.00	99	
Manganese (Mn) ppm:	61.00	33	Manganese Availability Index = 214.9
Copper (Cu) ppm:	4.18	0.6 - 2.0	
Zinc (Zn) ppm:	14.83	1.3 - 3.5	

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	80.17	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	14.06	10 - 20 (12 optimum)
Percent Potassium (% K)	1.84	1.5 - 10
Percent Sodium (%Na)	3.39	0.5 - 3

pH:	7.6	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.5	Nitrate (NO3)	3.3
Soluble Salts (SS) 1:2 (ppm):	102.4	Ammonium (NH4)	4.5
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	7.8
SS estimated saturated paste (ppm)	535.0	NO3:NH4 ratio	0.7
EC estimated saturated paste (dS/m)	0.8	Organic N release	50.4
Total Extractable Cations (meq/100 g)	9.8		
Chloride Cl ppm	32.7		

Talega Golf Club **g pg01n**

05052001 Standard Extraction Methods non
5/20/2005 Brookside 0160-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	18			
Phosphate P2O5 ppm:	41	118	153	4
Phosphorus Availablity Index:	0.11			
Sulfur (S) ppm:	31	15-40		
Calcium (Ca) ppm:	888	919	62	1
Magnesium (Mg) ppm:	174	140	0	0
Potassium (K) ppm:	96			
Potash (K2O) ppm:	116	147	63	1
Sodium (Na) ppm:	86	< 67		
Aluminum (Al) KCl extract ppm:	6			

Minor Elements	Observed	Desired	
Boron (B) ppm:	0.88	0.4 - 1.5	
Iron (Fe) ppm:	122.00	95	
Manganese (Mn) ppm:	67.00	32	Manganese Availability Index = 242.0
Copper (Cu) ppm:	2.10	0.6 - 2.0	
Zinc (Zn) ppm:	33.42	1.3 - 3.5	

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	67.48	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	22.04	10 - 20 (12 optimum)
Percent Potassium (% K)	3.74	1.5 - 10
Percent Sodium (%Na)	5.68	0.5 - 3

		Plant available soil nitrogen ppm	
pH:	7.3		
Percent Organic Matter (% OM):	1.4	Nitrate (NO3)	4.2
Soluble Salts (SS) 1:2 (ppm):	96.0	Ammonium (NH4)	4.6
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	8.8
SS estimated saturated paste (ppm)	521.6	NO3:NH4 ratio	0.9
EC estimated saturated paste (dS/m)	0.8	Organic N release	47.4
Total Extractable Cations (meq/100 g)	6.8		
Chloride Cl ppm	23.38		

Talega Golf Club **g pg01t**

05052001 Standard Extraction Methods treated
5/20/2005 Brookside 0162-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	14			
Phosphate P2O5 ppm:	32	117	170	4
Phosphorus Availablity Index:	0.09			
Sulfur (S) ppm:	29	15-40		
Calcium (Ca) ppm:	625	666	83	2
Magnesium (Mg) ppm:	139	140	2	0
Potassium (K) ppm:	56			
Potash (K2O) ppm:	67	132	128	3
Sodium (Na) ppm:	70	< 67		
Aluminum (Al) KCl extract ppm:	2			

Minor Elements	Observed	Desired	
Boron (B) ppm:	1.09	0.4 - 1.5	
Iron (Fe) ppm:	96.00	98	
Manganese (Mn) ppm:	58.00	33	Manganese Availability Index = 205.2
Copper (Cu) ppm:	1.66	0.6 - 2.0	
Zinc (Zn) ppm:	22.01	1.3 - 3.5	

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	65.79	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	24.39	10 - 20 (12 optimum)
Percent Potassium (% K)	3.02	1.5 - 10
Percent Sodium (%Na)	6.41	0.5 - 3

		Plant available soil nitrogen ppm	
pH:	7.5		
Percent Organic Matter (% OM):	1.2	Nitrate (NO3)	1.4
Soluble Salts (SS) 1:2 (ppm):	83.2	Ammonium (NH4)	4.2
Electrical Conductivity (EC) 1:2 (dS/m)	0.1	Total available	5.6
SS estimated saturated paste (ppm)	494.7	NO3:NH4 ratio	0.3
EC estimated saturated paste (dS/m)	0.8	Organic N release	43.8
Total Extractable Cations (meq/100 g)	4.9		
Chloride Cl ppm	26.32		

Talega Golf Club **g pg02n**

05052001 Standard Extraction Methods non
5/20/2005 Brookside 0161-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	18			
Phosphate P2O5 ppm:	41	118	153	4
Phosphorus Availablity Index:	0.12			
Sulfur (S) ppm:	29	15-40		
Calcium (Ca) ppm:	821	828	14	0
Magnesium (Mg) ppm:	149	140	0	0
Potassium (K) ppm:	58			
Potash (K2O) ppm:	70	142	144	3
Sodium (Na) ppm:	81	< 67		
Aluminum (Al) KCl extract ppm:	4			

Minor Elements	Observed	Desired	
Boron (B) ppm:	0.88	0.4 - 1.5	
Iron (Fe) ppm:	98.00	92	
Manganese (Mn) ppm:	65.00	31	Manganese Availability Index = 239.1
Copper (Cu) ppm:	1.86	0.6 - 2.0	
Zinc (Zn) ppm:	28.29	1.3 - 3.5	

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	69.69	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	21.08	10 - 20 (12 optimum)
Percent Potassium (% K)	2.52	1.5 - 10
Percent Sodium (%Na)	5.98	0.5 - 3

pH:	7.0	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.5	Nitrate (NO3)	4.6
Soluble Salts (SS) 1:2 (ppm):	96.0	Ammonium (NH4)	4.3
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	8.9
SS estimated saturated paste (ppm)	521.6	NO3:NH4 ratio	1.1
EC estimated saturated paste (dS/m)	0.8	Organic N release	49.4
Total Extractable Cations (meq/100 g)	6.1		
Chloride Cl ppm	23.51		

Talega Golf Club **g pg02t**

05052001 Standard Extraction Methods treated
5/20/2005 Brookside 0163-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	22			
Phosphate P2O5 ppm:	50	118	134	3
Phosphorus Availablity Index:	0.10			
Sulfur (S) ppm:	37	15-40		
Calcium (Ca) ppm:	779	845	131	3
Magnesium (Mg) ppm:	180	140	0	0
Potassium (K) ppm:	87			
Potash (K2O) ppm:	105	143	76	2
Sodium (Na) ppm:	86	< 67		
Aluminum (Al) KCl extract ppm:	2			

Minor Elements	Observed	Desired	
Boron (B) ppm:	1.00	0.4 - 1.5	
Iron (Fe) ppm:	112.00	97	
Manganese (Mn) ppm:	76.00	32	Manganese Availability Index = 274.2
Copper (Cu) ppm:	2.58	0.6 - 2.0	
Zinc (Zn) ppm:	35.09	1.3 - 3.5	

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	64.81	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	24.96	10 - 20 (12 optimum)
Percent Potassium (% K)	3.71	1.5 - 10
Percent Sodium (%Na)	6.22	0.5 - 3

		Plant available soil nitrogen ppm	
pH:	7.4		
Percent Organic Matter (% OM):	1.4	Nitrate (NO3)	1.4
Soluble Salts (SS) 1:2 (ppm):	108.8	Ammonium (NH4)	4.4
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	5.8
SS estimated saturated paste (ppm)	548.5	NO3:NH4 ratio	0.3
EC estimated saturated paste (dS/m)	0.9	Organic N release	47.6
Total Extractable Cations (meq/100 g)	6.2		
Chloride Cl ppm	35.54		

Soil Summary Sheets

Talega Golf Club

Soil Summary

6/2/2005

Area	Hole	Date	TEC	pH	%OM		SO4	P	Ca	Mg	K	Na	Al KCl	Salt	B	Fe	Mn	Cu	Zn	Cl
c	12a	5/20/2005	10.65	7.4	1.89	PPM	54	46	1787	130	58	95	6	179.2	0.88	75	35	1.76	5.61	65.66
						%			83.9	10.17	1.4	3.88	0.63	Notes: poa				Docket #: 05052001		
c	12b	5/20/2005	6.23	7.4	2.15	PPM	42	32	884	153	58	82	3	134.4	1.24	82	66	2.74	10.02	42.25
						%			70.95	20.47	2.39	5.72	0.54	Notes: poa				Docket #: 05052001		
c	14a	5/20/2005	11.59	7.5	3.5	PPM	37	54	1806	241	58	80	5	121.6	1.09	98	136	9.62	52.98	29.39
						%			77.91	17.33	1.28	3	0.48	Notes: poa				Docket #: 05052001		
c	14b	5/20/2005	12.85	7.5	3.07	PPM	31	52	2062	230	68	82	8	115.2	1.01	84	94	7.06	40.9	28.65
						%			80.23	14.92	1.36	2.77	0.69	Notes: poa				Docket #: 05052001		

Talega Golf Club

Soil Summary

6/2/2005

Area	Hole	Date	TEC	pH	%OM		SO4	P	Ca	Mg	K	Na	Al KCl	Salt	B	Fe	Mn	Cu	Zn	Cl
g	0x	5/18/2001	3.99	7.4	0.54	PPM	26	44	541	94	63	41		108.8	1.07	55	14	0.37	2.41	
								%	67.79	19.63	4.05	4.47		Notes: poor				Docket #: 01051803		
g	12n	5/20/2005	6.59	7.6	1.69	PPM	41	22	1015	117	56	76	6	128	1.05	67	68	4.26	14.66	39.16
								%	77.01	14.8	2.18	5.01	1.01	Notes: non				Docket #: 05052001		
g	12t	5/20/2005	8.19	7.5	1.76	PPM	51	31	1331	116	58	88	3	166.4	0.86	79	71	3.7	13.98	57.24
								%	81.26	11.8	1.82	4.67	0.41	Notes: treated				Docket #: 05052001		
g	14n	5/20/2005	8.59	7.6	1.2	PPM	31	35	1402	135	43	71	3	96	0.88	78	76	4.6	17.39	25.82
								%	81.61	13.1	1.28	3.59	0.39	Notes: non				Docket #: 05052001		
g	14t	5/20/2005	9.48	7.6	1.52	PPM	33	27	1520	160	68	74	5	102.4	1.01	86	61	4.18	14.83	32.7
								%	80.17	14.06	1.84	3.39	0.59	Notes: treated				Docket #: 05052001		
g	pg01n	5/20/2005	6.58	7.3	1.37	PPM	31	18	888	174	96	86	6	96	0.88	122	67	2.1	33.42	23.38
								%	67.48	22.04	3.74	5.68	1.01	Notes: non				Docket #: 05052001		
g	pg01t	5/20/2005	4.75	7.5	1.19	PPM	29	14	625	139	56	70	2	83.2	1.09	96	58	1.66	22.01	26.32
								%	65.79	24.39	3.02	6.41	0.47	Notes: treated				Docket #: 05052001		
g	pg02n	5/20/2005	5.89	7	1.47	PPM	29	18	821	149	58	81	4	96	0.88	98	65	1.86	28.29	23.51
								%	69.69	21.08	2.52	5.98	0.75	Notes: non				Docket #: 05052001		
g	pg02t	5/20/2005	6.01	7.4	1.38	PPM	37	22	779	180	87	86	2	108.8	1	112	76	2.58	35.09	35.54
								%	64.81	24.96	3.71	6.22	0.37	Notes: treated				Docket #: 05052001		

Soil chemical guidelines - Melich III extraction

Table 1. Guidelines for iron and manganese, for soils at a range of different pHs. Note that the desired levels of micronutrients increases as soil pH increases. Maintaining higher levels of manganese and iron helps to overcome their tendency to become bound, and therefore unavailable, to the plant in more basic soils. We have paid special attention to these two micronutrients because plants are more likely to be deficient in iron than any other micronutrient. And higher levels of manganese appear to play a role in suppressing turf diseases caused by *Gaeumannomyces* such as bermudagrass decline, kikuyugrass decline, and take-all patch.

	Desired soil concentrations (ppm) for pH 6 - 8.5 soils						**Average range for greens, tees & fairways (across all pHs)**
	6	**6.5**	**7**	**7.5**	**8**	**8.5**	
Iron (Fe)	**80**	**86**	**92**	**98**	**104**	**110**	**157-185**
Manganese (Mn)	**27**	**29**	**31**	**33**	**35**	**37**	**30-43**

Table 2. Soil nutritional guidelines. Iron and manganese values are reported in Table 1 above.

	Greens		**Tees**		**Fairways**	
Nutrient concentration (ppm)	Average	Desired	Average	Desired	Average	Desired
Nitrate (NO_3)	6.7	3-20	17.1	3-20	24.2	3-20
Ammonium (NH_4)	2.5	<7	4.2	<7	4.4	<7
NO_3 + NH_4	9.4	<20	21.3	<20	28.6	<20
Phosphorus (P)	99	51	92	40	101	44
Potassium (K)	156	144	135	174	235	229
Calcium (Ca)	1346	1327	1857	1916	2640	3043
Magnesium (Mg)	174	140	332	203	611	322
Sodium (Na)	174	<67	260	<67	584	<67
Sulfate (SO_4)	139	15 - 40	135	15 - 40	490	15 - 40
Boron (B)	1.0	0.4 - 1.5	1.2	0.4 - 1.5	1.7	0.4 - 1.5
Copper (Cu)	4.7	0.6 - 2.0	3.1	0.6 - 2.0	2.4	0.6 - 2.0
Iron (Fe)	185	See Table 1	175	See Table 1	157	See Table 1
Manganese (Mn)	30	See Table 1	30	See Table 1	43	See Table 1
Zinc (Zn)	18.9	1.3 - 3.5	13.9	1.3 - 3.5	8.4	1.3 - 3.5

	Greens		**Tees**		**Fairways**	
Other soil measurements	Average	Desired	Average	Desired	Average	Desired
pH	7.1	6.5 - 7.5	7.4	6.5 - 7.5	7.2	6.5 - 7.5
EC (dS/m)	3.2	<3.0	3.0	<3.0	6.4	<3.0
TEC (meq/100 g)	9.9	NA	14.5	NA	24	NA
OM%	2.0	NA	3.0	NA	4.4	NA
% Ca	69	68	66	68	59	68
% Mg	15	12-20	20	12-20	23	12-20
% K	4	4	3	4	3	4
%Na	8	<3	8	<3	11	<3
% H	0	10 - 15	0	10 - 15	0	10 - 15

These guidelines are based upon PACE data collected from golf course greens, tees and fairways. Soil analysis using Melich III extraction by Brookside Laboratories, New Knoxville, OH. This data can be used as an aid in developing turf fertility programs, but should always be used in conjunction with specific soil test results from your golf course.

Statistical analyses

```
The following results are for:
   NOTES$       = treated

                    P_EASY_PPM
  N of cases                 4
  Minimum             15.00000
  Maximum             29.00000
  Mean                23.00000
  Standard Dev         6.05530



The following results are for:
   NOTES$       = non

                    P_EASY_PPM
  N of cases                 4
  Minimum             19.00000
  Maximum             27.00000
  Mean                22.75000
  Standard Dev         3.50000



The following results are for:
   NOTES$       = collar

                    P_EASY_PPM
  N of cases                 4
  Minimum             35.00000
  Maximum             44.00000
  Mean                40.50000
  Standard Dev         3.87298

Durbin-Watson D Statistic        2.05313
First Order Autocorrelation     -0.08670
COL/
ROW NOTES$
  1  collar
  2  non
  3  treated
Using least squares means.
Post Hoc test of P_EASY_PPM

-------------------------------------------------------------------------------
Using model MSE of 21.306 with 9 df.

Matrix of pairwise mean differences:
                         1           2           3
             1         0.00000
             2       -17.75000     0.00000
             3       -17.50000     0.25000     0.00000


Fisher's Least-Significant-Difference Test.

Matrix of pairwise comparison probabilities:
                         1           2           3
             1         1.00000
             2         0.00041     1.00000
             3         0.00046     0.94062     1.00000
```

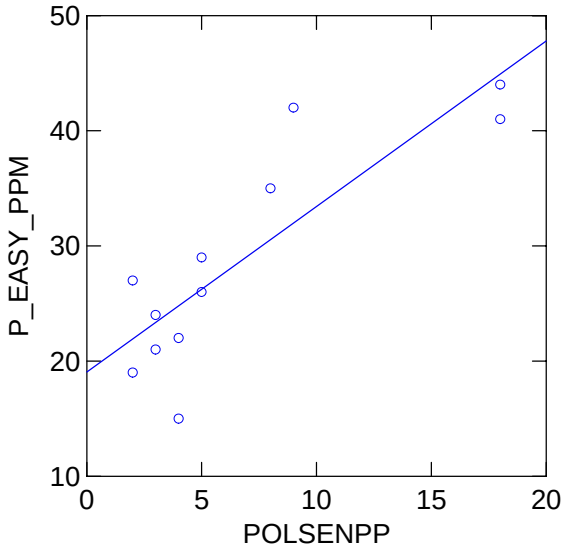
```
The following results are for:
   NOTES$       = non
Data for the following results were selected according to:
      (AREAGTF$<> "c")

                        NO3NH4
  N of cases                 4
  Minimum              0.91304
  Maximum              1.41304
  Mean                 1.19896
  Standard Dev         0.24812



The following results are for:
   NOTES$       = treated
Data for the following results were selected according to:
      (AREAGTF$<> "c")

                        NO3NH4
  N of cases                 4
  Minimum              0.31818
  Maximum              1.12821
  Mean                 0.62826
  Standard Dev         0.38476
```



Mehlich III = 1.4 x Olsen P + 19.0

Dep Var: P_EASY_PPM N: 12 Multiple R: 0.84708 Squared multiple R: 0.71754

Adjusted squared multiple R: 0.68929 Standard error of estimate: 5.36825

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	19.04658	2.47144	0.00000	.	7.70669	0.00002
POLSENPP	1.43754	0.28522	0.84708	1.00000	5.04015	0.00051

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	732.06934	1	732.06934	25.40314	0.00051
Residual	288.18066	10	28.81807		

Durbin-Watson D Statistic 1.59283
First Order Autocorrelation 0.15736

Data for the following results were selected according to:
(AREAGTF$<> "c")

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
NOTES$ (2 levels)
non, treated

Dep Var: P_OLSEN_PPM N: 8 Multiple R: 0.89443 Squared multiple R: 0.80000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
NOTES$	8.00000	1	8.00000	24.00000	0.00271
Error	2.00000	6	0.33333		
