

Southern Regional Fact Sheet



June, 2007, SERA-IEG-8*

REPLACING ADAMS-EVANS BUFFER WITH MOORE-SIKORA BUFFER FOR DETERMINING LIME REQUIREMENT OF SOIL

Lime requirement is vital information provided by soil test laboratories to improve the soil's ability to maximize crop productivity. To avoid time consuming procedures such as CaCO_3 incubation or $\text{Ca}(\text{OH})_2$ titration of soil, buffers have been developed for a quick assessment of lime requirement. Buffer methods recognized in the four USA regional soil test procedure publications include Shoemaker, McLean and Pratt (SMP), Adams-Evans, Mehlich, and Woodruff (Isaac and Donohue, 1983; Sims and Wolf, 1995; Brown, 1998; Gavlak et al., 2003). In the 2006 fourth quarter report of the North American Proficiency Testing (NAPT) program, 54, 12, 17 and 4 laboratories reported a buffer pH value using SMP, AE, Mehlich and Woodruff buffers, respectively (Kotuby-Amacher, 2007).

The Woodruff buffer was the first of the four developed (Woodruff, 1948). Shoemaker, McLean and Pratt (1961) observed the Woodruff buffer underestimated lime requirement on soils with high extractable Al and therefore developed the SMP buffer for Ohio soils. McLean et al. (1966) further showed applicability on a broad range of USA soils. The SMP buffer works well for soils containing high extractable Al with lime requirement greater than 4.48 Mg ha^{-1} , soil pH less than 5.8, and organic matter less than 10% (McLean et al., 1978). The Woodruff buffer overestimates lime requirement on coarse-textured soils with low lime requirements in the Piedmont and Coastal Plain physiographic regions in the Southeastern USA (Adams and Evans, 1962, McLean et al., 1966, Follett and Follet, 1983). Excessive liming of soil in these regions poses crop damage risks from micronutrient deficiencies at high pH (Brady and Weil, 1996, Clemson University, 2001). To avoid the overliming issue with the Woodruff buffer, the

AE buffer was developed to estimate lime requirement for Ultisols in Alabama (Adams and Evans, 1962). These soils have cation exchange capacities generally less than 13 cmol kg⁻¹ and lime requirements generally less than 6.8 Mg ha⁻¹. The Mehlich buffer was developed later to estimate unbuffered salt-exchangeable acidity in soil (Mehlich, 1976).

Toxicity of chemical components was not considered at the time the buffers were developed. Toxic components include p-nitrophenol in the Woodruff, SMP, and AE buffers, chromium in the SMP buffer, and barium in the Mehlich buffer. Since the buffers were developed, these chemicals have been classified as hazardous wastes due to their toxicity (USEPA, 1980). To avoid dealing with hazardous chemicals, soil testing laboratories have been developing buffer solutions with nonhazardous chemicals to determine soil lime requirements. Vaughan (2004) suggested replacing chromate with citric acid or succinic acid and p-nitrophenol with ethylenediamine or imidazole in the SMP buffer. Wolf and Beegle (2005) compared the SMP buffer to a modified Mehlich buffer using CaCl₂ instead of BaCl₂. Sikora (2006) developed a buffer which duplicates the SMP buffer pH values and is free of hazardous constituents. Huluka (2005) modified the AE buffer by replacing the p-nitrophenol with potassium phosphate where the phosphate buffers pH similarly to p-nitrophenol. The University of Georgia eliminated the AE buffer by implementing direct titration of soil with calcium hydroxide (Liu et al., 2004, 2005).

The Clemson University soil testing laboratory used the AE buffer and desired an alternative buffer without p-nitrophenol but producing the same soil-buffer pH. The alternative buffer would have the advantage of not being a hazardous waste and the same lime requirement (LR) interpretation could be made from the soil-buffer pH. The buffer developed by Huluka (2005) is free of p-nitrophenol and produces soil-buffer pH similar to the AE buffer. However, there was considerable variation in a comparison between the two buffers. The Moore-Sikora (MS) buffer was developed to more closely mimic the AE soil-buffer pH and is currently used for lime requirement determination at Clemson University. This fact sheet summarizes the results on the MS buffer.

COMPOSITION AND PREPARATION OF THE MOORE-SIKORA BUFFER

For every liter of solution, the following quantities of chemicals are dissolved.
MES (2-(N-morpholino)ethanesulfonic acid hydrate (C₆H₁₃NO₄S·xH₂O, fw with x of 1 = 213.25)): 7.43 g
MOPS (3-(N-Morpholino) propanesulfonic acid (C₇H₁₅NO₄S, fw=209.26)): 27.4 g
Boric Acid (H₃BO₃, fw=61.83): 13.1 g
Potassium Chloride (KCl, fw=74.56): 74.0 g
Potassium Hydroxide (KOH, fw=56.11): 11.2 g

Add 400 mL deionized water to a 1 L volumetric flask, and then quantitatively add each component above to the flask. Use deionized water to rinse out the weighing containers into the flask. Add deionized water to 80% of the final intended volume and stir the

solution overnight. Dilute the solution with deionized water to the intended final volume and mix thoroughly.

Add twenty mL of deionized water to a 20 mL aliquot of the buffer solution. The pH of the 1:1 mixture should be 8.00 ± 0.01 . If the pH is not 8.00 ± 0.01 , the pH of the original solution is adjusted using dropwise additions of concentrated KOH or HCl until the pH of the 1:1 mixture of the buffer with water is at the desired pH of 8.00 ± 0.01 .

Soil pH is determined by stirring 16 mL (assumed 20 g) of soil with 20 mL of water using a stirring rod, letting the slurry stand for 1 hour, and then measuring the pH of the slurry. After determining the soil pH, 20 mL of the Moore-Sikora buffer is added, and then the sample is stirred vigorously and allowed to set for 30 minutes. The sample is stirred again prior to the buffer pH measurement.

RESULTS WITH THE MOORE-SIKORA BUFFER

The study included 222 soils routinely submitted to the Clemson University soil testing laboratory in South Carolina in the fall of 2005. Major physiographic regions within South Carolina include Piedmont, Sandhills, and Coastal Plain. Soils within these regions consist of Ultisols with coarse texture and CEC less than 13 cmol kg^{-1} . Soils were selected with a wide range in AE soil-buffer pH. The 1:1 soil-water pH of the all the soils had a median of 6.0 and ranged from 4.6 to 7.1.

Soils from the North American Proficiency Testing (NAPT) program were also included in the study (Soil and Plant Analysis Council, 2000) to evaluate the analytical proficiency of the MS buffer to mimic the soil-buffer pH obtained with the AE buffer. The NAPT program soils were selected from 2002 through 2005 circulated samples (Miller and Kotuby, 2005). The 41 selected soils included 7 mollisols, 6 entisols, 5 aridisols, 3 alfisols, 3 ultisols, 1 spodosol, and 1 entisol. Fifteen soils did not have soil order identified. Duplicate samples submitted in the program were not included. The median 1:1 soil-water pH values of the soils reported from the participating laboratories had a median of 6.5 and ranged from 4.6 to 8.5. The median cation exchange capacities reported from the participating laboratories was 16 cmol kg^{-1} and ranged from 1 to 43 cmol kg^{-1} . Most of the NAPT soils are not suited for AE lime requirements to be determined since it was calibrated on Ultisols in Alabama with CEC ranging from 1 to 13 cmol kg^{-1} (Adams and Evans, 1962). Therefore, lime requirements determined with the MS and AE buffers may not represent actual lime requirements for those samples.

Soil-buffer pH was determined on paired soil samples with one sample receiving AE buffer and the other sample receiving MS buffer. The samples were prepared as stated earlier for soil-water pH determination; however instead of reading the pH after setting for 1 hr, the respective buffer solutions were added. The samples were tested in batches of approximately 40. The batches were scooped in duplicate sets with 20 mL of the MS buffer being added to one set and 20 mL of the AE Buffer being added to the second set. After buffer solution addition, the samples were vigorously stirred. The samples were

vigorously stirred two more times after 10 and 20 minutes. After 30 minutes, pH was determined by hand using an Orion meter and Accumet electrode calibrated with buffer solutions of pH 7.00 and pH 4.00. A buffer solution of pH 10.00 was checked for accuracy. Each sample was stirred vigorously again prior to reading and the meter was allowed to stabilize for each reading. The pH values of the 1:1 mixtures of water:AE buffer and water:MS buffer (20 mL buffer plus 20 mL water for each mixture) were verified to read 8.00 ± 0.01 at the beginning of the run and after every 10 samples.

The soil-buffer pH values from the AE buffer and MS buffer were plotted on an x-y plot and compared to a 1:1 line in Fig 1. Regression analysis was performed on the data with slope, intercept and coefficient of determination (r^2) evaluated. The scatter of the data was compared to boundaries around the 1:1 line defined by interlaboratory error of AE soil-buffer pH values according to the NAPT program definition of interlaboratory error as a median absolute deviation (MAD) value (Miller and Kotuby-Amacher, 2005).

The MS buffer produced a soil-buffer pH slightly less than the soil-buffer pH using AE buffer as indicated by the majority of the data being lower than the 1:1 line in Fig. 1. A t-test evaluation indicated the MS buffer pH was 0.03 lower than the AE buffer pH for both South Carolina and NAPT soils. Even though the MS buffer pH values were slightly less they still fell within NAPT warning limits defined by interlaboratory variation. There was a good closeness of fit with r^2 values greater than 0.98 (Fig. 1).

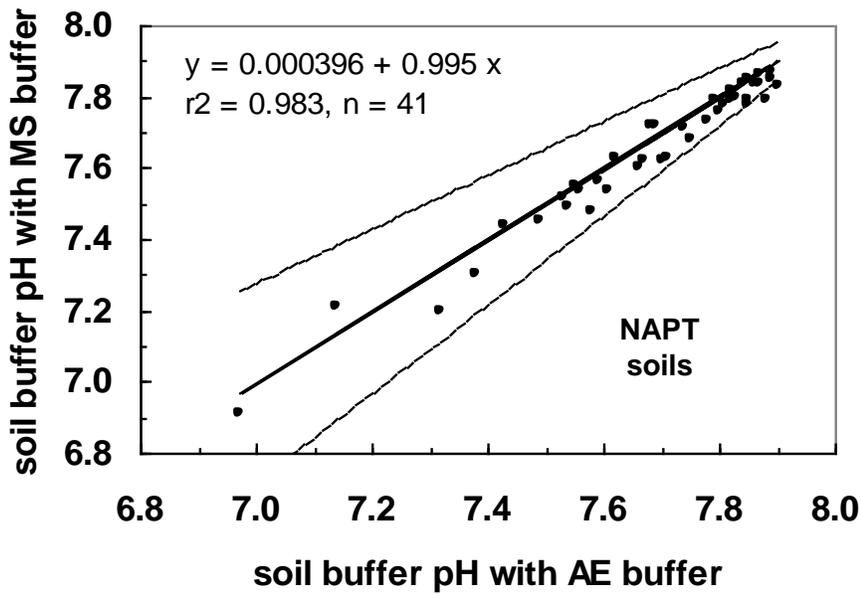
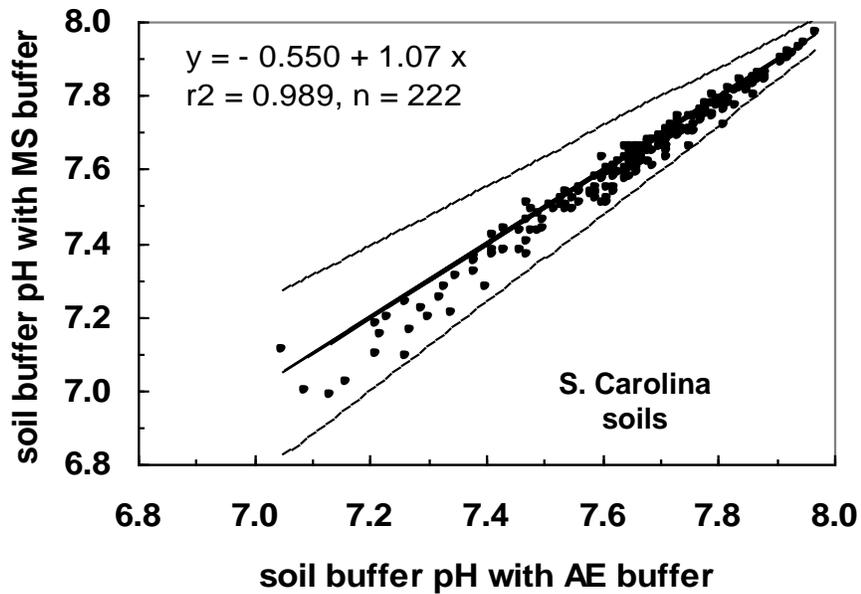


Figure 1. Comparison of soil buffer pH using the MS and AE buffers on South Carolina and NAPT soils. Center line is a 1:1 line bracketed by lines representing NAPT interlaboratory variation for AE buffer pH as 2.5 x MAD.

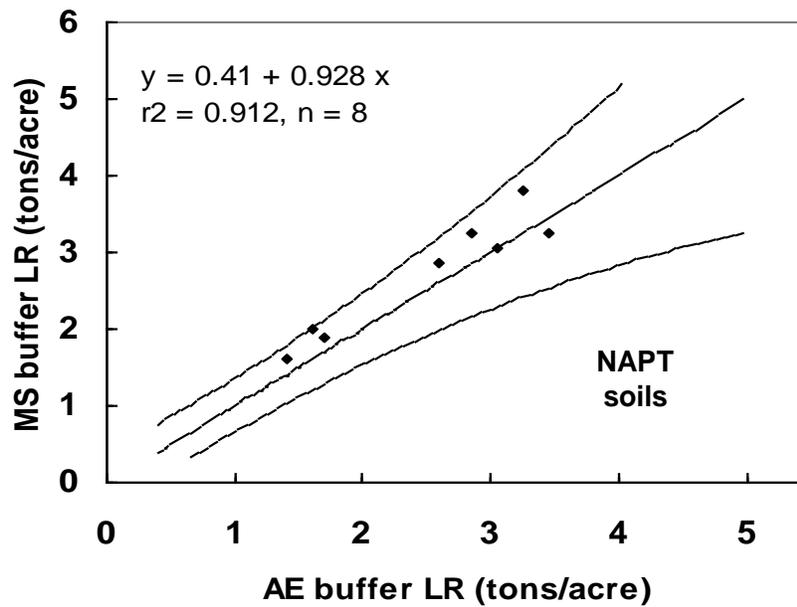
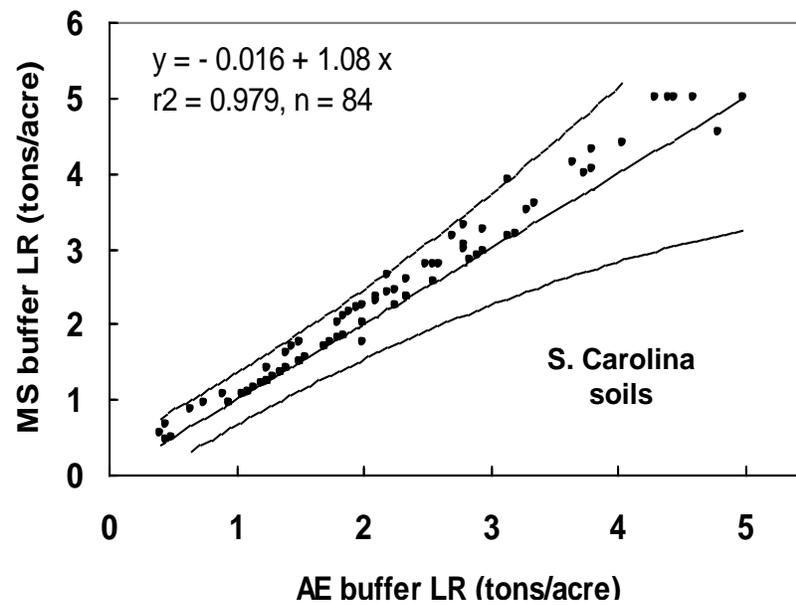


Figure 2. Comparison of Clemson University (2001) lime requirement (LR) determined with the MS buffer and AE buffer on South Carolina and NAPT soils with soil water pH values less than 5.8. Center line is a 1:1 line bracketed by lines representing LR determined from NAPT interlaboratory variation for AE buffer pH as 2.5 MAD.

About one-third of the South Carolina soils (84 out of 222) and one-fifth of the NAPT soils (8 out of 41) had soil with pH values less than 5.8 indicating a need for lime application. Because of the difference in soil-buffer pH values between the MS buffer and the AE buffer, there was a slight difference in lime requirement from the two buffers (Fig. 2). Lime requirements with the MS buffer were slightly greater than LRs with AE buffer indicated by the data in Fig. 2. A t-test evaluation of the data indicated the MS buffer lime requirement was about 400 lbs/acre greater than the AE buffer lime requirement. Even with the slight difference in lime requirements with the MS buffer, the differences were not greater than the range of lime requirements considering the interlaboratory variation in AE buffer pH which are shown as the outer boundary lines in Fig. 2.

COST DIFFERENCES BETWEEN THE MOORE-SIKORA AND ADAMS-EVANS BUFFERS

The cost of the chemicals in the Moore-Sikora buffer is greater than the cost of chemicals in the Adams-Evans buffer (Table 1). The Adams-Evans buffer costs about 4 cents a sample where the Moore-Sikora costs about 23 cents a sample using a 20 mL aliquot. However, the laboratory at Clemson has reduced the cost from 23 cents to 17 cents by using a 15 mL aliquot instead of a 20 mL aliquot. The pH scoop size was reduced from 16 mL (assumed 20 g) to 12 mL (assumed 15 g) and the water and buffer amounts have each been reduced to 15 mL. The amount of soil, water, and buffer needed could even be reduced to a 10:10:10 ratio depending on the individual lab set up. That would reduce the cost per sample to 11 cents. More importantly, the health hazards from handling p-nitrophenol and the hazardous waste disposal procedures have been eliminated.

Table 1. Cost of Adams-Evans and Moore-Sikora buffers required for each soil test based on cost of individual chemical components.

Chemical	Needed for 1 L (g)	Quantity Purchased (g)	Price^a (\$)	Price/g (\$)	Cost per 20 mL (\$)
<i>Adams-Evans</i>					
KCl	74	10,000	105.44	0.011	0.016
KOH	10.5	10,000	122.60	0.012	0.003
p-nitrophenol	20	4,000	177.17	0.044	0.018
Boric acid	15	10,000	156.92	0.016	0.005
Total					0.042
<i>Moore-Sikora</i>					
Boric Acid	13.1	10,000	156.92	0.016	0.004
MES	7.43	500	229.91	0.460	0.068
MOPS	27.4	3,000	738.81	0.246	0.135
KCl	74	10,000	105.44	0.011	0.016
KOH	11.2	10,000	122.60	0.012	0.003
Total					0.226

^aFisher Scientific prices with Clemson University contractual agreement.

SUMMARY

A new buffer has been developed to replace the Adams-Evans buffer. The pH values of the new Moore-Sikora buffer were an average of 0.03 units lower than the pH values of the Adams-Evans buffer, however, they were still within the NAPT warning limits (Fig. 1). There was a slight difference in comparing the lime requirements from the Moore-Sikora buffer to the lime requirements from the Adams-Evans buffer, however the differences were within the interlaboratory variation boundary lines (Fig. 2).

The cost of the Moore-Sikora buffer is greater than the cost of the Adams-Evans buffer, however, the health hazards and waste disposal procedures associated with handling p-nitrophenol have been eliminated.

REFERENCES

- Adams, F. and C.E. Evans. 1962. A rapid method for measuring lime requirement of red-yellow podzolic soils. *Soil Sci. Soc. Amer. Proc.* 26: 355-357.
- Brady, N.C. and R.R. Weil. 1996. *The nature and properties of soils*, 11th ed. Prentice Hall, Upper Saddle River, NJ.
- Brown, J.R. (ed.) 1998. Recommended chemical soil test procedures for the north central region. North central regional research publication No. 221 (revised), Missouri Agricultural Experiment Station SB 1001.
- Clemson University. 2001. Nutrient management for South Carolina based on soil test results. EC 476. The Clemson University Cooperative Extension Service.
- Follett, R.H. and R.F. Follett. 1983. Soil and lime requirement test for the 50 states and Puerto Rico. *Journal of Agron. Educ.* 12:9-17.
- Gavlak, R.G., D.A. Horneck, R.O. Miller, and J. Kotuby-Amacher (eds.) 2003. *Soil, plant and water reference methods for the western region.*, 2nd ed. Western Coordinating Committee on Nutrient Management-103.
- Huluka, G. 2005. A modification to the Adams-Evans soil-buffer determination solution. *Commun. Soil Sci. Plant Anal.* 36:2005-2014.
- Isaac, R.A. and Donohue S. J. (eds.). 1983. Reference soil test methods for the southern region of the United States. Southern Cooperative Series Bulletin No. 289. University of Georgia, Georgia Agricultural Experiment Station, Athens, GA.
- Kotuby-Amacher, J. 2007. Results of 4th Quarter Exchange 2006. Memo to participants of the North American Proficiency Testing (NAPT) Program. Soil Science Society of America, Madison, WI.
- Liu, M., D.E. Kissel, M.L. Cabrera, and P.F. Vendrell. 2005. Soil lime requirement by direct titration with a single addition of calcium hydroxide. *Soil Sci. Soc. Am. J.* 69:522-530.
- Liu, M., D.E. Kissel, P.F. Vendrell, and M.L. Cabrera. 2004. Soil lime requirement by direct titration with calcium hydroxide. *Soil Sci. Soc. Am. J.* 68:1228-1233.
- McLean, E.O., S.W. Dumford, and F. Coronel. 1966. A comparison of several methods of determining lime requirements of soils. *Soil Sci. Soc. Amer. Proc.* 30:26-30.
- McLean, E.O., D.J. Eckert, G.Y Reddy, and J.F. Trierweiler. 1978. An improved SMP soil lime requirement method incorporating double-buffer and quick-test features. *Soil Sci. Soc. Am. J.* 42:311-316.

Mehlich, A. 1976. New buffer pH method for rapid estimation of exchangeable acidity and lime requirement of soils. *Commun. in Soil Sci. and Plant Anal.* 7(7): 637-652.

Miller, R.O. and J. Kotuby-Amacher. 2005. Results of 1st, 2nd, 3rd, and 4th Quarter Exchanges of 2003, 2004, and 2005. Memos to participants of the North American Proficiency Testing (NAPT) Program. Soil Science Society of America, Madison, WI.

Shoemaker, H.E., E.O. McLean, P.F. Pratt. 1961. Buffer methods for determining lime requirement of soils with appreciable amounts of extractable aluminum. *Soil Sci. Soc. Am. Proc.* 25: 274-277.

Sikora, F.J. 2006. A buffer that mimics the SMP buffer for determining lime requirement of soil. *Soil Sci. Soc. Am. J.* 70:474-486.

Sims, J.T. and A. Wolf. (eds.) 1995. Recommended soil testing procedures for the northeastern United States, 2nd ed. Northeastern regional publication No. 493, Northeast region coordinating committee on soil testing.

Soil and Plant Analysis Council. 2000. Soil analysis handbook of reference methods. CRC Press, Boca Raton, FL.

U.S. Environmental Protection Agency. 1980. Title 40, Protection of Environment, Part 261 – Identification and Listing of Hazardous Wastes. Washington: Government Printing Office, revised as of July 1, 2004.

Vaughan, B. 2004. Part 1: Review of buffer preparation and evaluation of commonly used buffers for determination of soil lime requirements. *The Soil-Plant Analysis Newsletter*, Summer 2004. Soil and Plant Analysis Council, Inc., Lincoln, NE.

Wolf, A.M. and D.B. Beegle. 2005. Comparison of SMP and Mehlich buffer tests for determining lime requirement. *The Soil-Plant Analysis Newsletter*, Winter 2005. Soil and Plant Analysis Council, Inc., Lincoln, NE.

Woodruff, C.M. 1948. Testing soils for lime requirement by means of a buffered solution and the glass electrode. *Soil Sci.* 66: 53-63.

K.P. Moore¹ and F.J. Sikora²

¹ **Clemson University**

² **University of Kentucky**