Title Relationship of soil K fixation and other soil properties to fertilizer K rate requirement

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CDFA Funding Request/Other Funding

	CDFA request	UC (10% P.L. salary/benefit match)	Total
2011	48,176	28,000	76,176
2012	49,998	28,000	77,998
2013	49,903	28,000	77,903
3-yr total	**$148,077**	**$84,000**	**$232,077**

B. Executive Summary

Soils of the Central Valley and bordering uplands display a wide range in the properties that determine K fertilization requirements. Soil K fixation, which is associated with persistent crop K deficiencies, is due to the presence of vermiculite, found in soils derived from granitic parent material, which in California occur mainly on the east side of the Central Valley. Vermiculite is a weathering product of biotite mica that can occur in the clay-, silt-, and fine sand-size fractions of soil.

During the past 40 years, UC researchers have demonstrated the significance of K fixation for cotton and processing tomato production in the Central Valley. In a field experiment, UC Davis researchers reported that 86% of the 1540 lb K_2O/acre applied in a 3-yr period was fixed beyond extraction by NH_4^+, and cotton plants remained marginally deficient. More recently, we have identified soils with high K fixation potential in a number of vineyards in the Lodi winegrape district. A result of our work is development of a regional-scale model that predicts the location of K fixing soils. This work is not complete, but it may be useful to winegrape growers in selecting rootstocks (which are known to control K supply to the scion), in delineating nutrient management or plant/soil sampling zones, and in avoiding over-fertilization with K, which can affect juice quality.

There is still a need to develop procedures for determining the K fertilizer requirements of K-fixing soils. A soil test for estimating K soil fixation potential that is suitable for commercial analytical laboratory usage was developed in our laboratory. However, this has not been correlated to K fertilization requirement. A second test that has been used by researchers to quantify the portion of fixed K that may be plant-available is the sodium tetraphenyl boron ($NaPh_4B$) test. We propose to use our large collection of well-characterized soils from San Joaquin Valley winegrape vineyards and cotton fields (>750 soil samples) to determine whether our regional model categories are informative with respect to K fertilizer requirement and whether the two analytical procedures mentioned here are predictive of the rate of K required to achieve sufficiency levels. We will select profiles to a 1 meter depth or more from fixing and non-fixing soils covering a range of soil textures, soil mineralogies, and degree of soil weathering. Samples will be amended with a range of rates of K fertilizer and incubated while subjected to wet-dry cycling. Following the incubation, samples will be analyzed for total K, ammonium acetate K, $NaPh_4B$ test K, and K fixation potential by our 1-hour procedure. A separate set of soil samples will be used in a greenhouse pot study to determine K uptake by annual ryegrass clipped several times. Also, to assess the implications for crops with different rooting patterns, we will compare the K fertilizer response profiles using different weightings of the soil layers.

The information from this project will be useful to growers of cotton, processing tomato, and grapes. Crop consultants and advisers (Certified Crop Advisers, licensed Pest Control Advisers) and analytical laboratory operators serving growers with crops on K-fixing soils will gain an increased understanding of the phenomenon of K fixation, and our research will provide them with soil testing tools to make more accurate recommendations for crop management. We will extend the project results through a series of conferences, trade journal articles, and extension publications.

C. Justification

Soils of the Central Valley and bordering uplands display a wide range in the properties that determine K fertilization requirements. Soil K fixation, which is associated with persistent crop K deficiencies, is found in some soils derived from granitic parent material on the east side of the Central Valley. UC scientists first identified K fixation in the 1940s. Subsequently, the role of vermiculite – a weathering product of biotite mica– was elucidated (e.g., Cassman et al., 1989; Page et al., 1967; Shaviv et al., 1985; Sparks, 1987; Stromberg, 1960).

During the past 40 years, UC researchers have demonstrated the significance of K fixation for cotton and processing tomato production in the Central Valley (Miller et al, 1997; Hartz et al., 2008). In one field experiment (Cassman et. al, 1989), 86% of the 1540 lb K_2O/acre applied in a 3-yr period was fixed beyond extraction by NH_4^+, and cotton plants remained marginally deficient. We expanded on that previous work by investigating more thoroughly the relationship between soil mineralogy and K-fixation behavior in San Joaquin Valley soils used primarily for cotton production. Major outcomes of that work were the development of a 1-hour incubation method for measuring K-fixation potential (Murashkina et al., 2007a), documentation of the dominant role of silt and fine sand fractions in K-fixation in most of the SJV soils formed from Sierran granites we studied (Murashkina et al., 2007b), and the observation that some soils that contain little vermiculite fix K, probably due to tetrahedrally substituted smectite (Murashkina et al., 2008). More recently, we have identified soils with high K fixation potential in a number of winegrape vineyards in the Lodi district. A concern with winegrapes is the potentially deleterious effect of excess K on fruit and wine quality, and therefore some caution is needed in applying K fertilizers to overcome soil K fixation. In 2009 and 2010 with support of the Lodi Winegrape Commission, we established K fertilizer experiments on K-fixing and non K-fixing soils to determine the implications of soil K fixation on winegrape nutrient management.

The key soil factors predicting K fixation are parent mineralogy and degree of weathering. Non K-fixing soils in the Central Valley and bordering uplands are dominated by smectitic or kaolinitic mineralogy, but mixed mineralogy is common in the region, making it difficult to predict which soils have the capacity to fix K. Recently, we have developed a regional-scale model of K fixation potential and related properties for the Lodi winegrape district (O'Geen et al., 2008). Soils in the model are grouped by a combination of landscape, geology, and soil taxonomy. This model when validated will aid grape growers and crop consultants in selecting rootstocks (which are known to control K supply to the scion), in delineating nutrient management zones and in designing plant/soil sampling strategies.

Although several UC researchers have examined K fertilizer responsiveness in K-fixing and non K-fixing soils (e.g., Cassman et al., 1990; Cassman et al., 1992; Christensen et al., 1978; Gulick et al., 1989) there is still a need to develop clearer procedures for determining the K fertilizer requirements of such soils. Our 1-hour K-fixation potential method (Murashkina et al., 2007a) has not been calibrated to K-fertilization requirements. Another procedure that has been used by researchers to quantify the portion of fixed K that may be plant-available is the sodium tetraphenyl boron ($NaBPh_4$) test (Cox et al., 1999). To be useful to growers, this test also needs to be compared to K fertilization requirements. We propose to use our large collection of well-characterized soils from the Lodi wine district project and earlier research on San Joaquin Valley cotton soils to determine whether our regional model categories are informative with respect to K fertilizer requirement and whether the two analytical procedures mentioned above predict the rate of K required to achieve sufficiency levels.

D. Objectives

1. Determine the rate of K fertilizer required to achieve sufficiency levels (yield not K limited) in both K-fixing and non K-fixing soils.
2. Relate K fertilizer responsiveness of soil profiles for regional model categories (O'Geen et al., 2008). The model groups soils by K fixation potential, landscape location, and geology.
3. Test the 1-hour K-fixation potential method with lab experiments to determine the effect of wetting and drying and sequential K-additions on amounts of K fixed.
4. Provide research summaries and K fertilization recommendations for K-fixing soils to crop management professionals, analytical laboratories, and growers.

E. Workplan and Methods

1. Determine rate of K fertilizer required to establish sufficiency in K-fixing soils
We will select one representative soil profile (5-7 horizons/depth increments to a depth of 100-120 cm) from each of the following seven categories. Soil materials will be collected from pits or by auger from sites we have already studied. We anticipate that this work will take place during Year 1 and Year 2.

<u>K-fixing</u>

1. Coarse- or medium-textured young alluvium from fans or floodplain (e.g., Armona , Columbia, or Sailboat soil)
2. Fine-textured alluvium on fans (e.g., Dierssen, Guard, or Hollenbeck soil)
3. Coarse- or medium-textured, low terrace weathered soils (e.g., San Joaquin soil)

<u>Non K-fixing</u>

4. Coarse or medium-textured young alluvium on fans or floodplain (e.g., Acampo, Kimberlina, or Tokay soil)
5. Fine-textured alluvium on fans (e.g., Clearlake or Archerdale soil)
6. High terrace weathered alluvium (e.g., Redding soil)
7. Volcanic uplands (e.g., Pentz soil)

These will be chosen from materials sampled from our cotton project (12 profiles) and winegrape project (140 profiles from 36 vineyards), which encompass a wide range of K soil test levels, K fixation potential, textures, and CEC values. We will also collect soil materials from soils formed from basaltic Cascade Range alluvium. These soils are used extensively for tree crop production in the eastern Sacramento Valley. The basalt has low native K content, and weathers to clay minerals that do not fix K. These soils will allow us to compare K fixation and fertilizer requirements on low K soils (Cascades) and high K soils (volcanic uplands, above).

We will apply a range of rates of K fertilizer (0-48 mmoles K/kg soil) to each sample and incubate for 6 days, then measure the change in plant-available K by two methods: (1) Modified sodium tetraphenyl boron ($NaBPh_4$) method (Cox et al., 1999) and (2) greenhouse pot studies with wheat or ryegrass in which K harvest removal by plants in multiple clippings will be measured. The $NaBPh_4$ procedure measures exchangeable K and a plant-available portion of fixed K. No critical value has been established in the literature, but we will compare individual values to an average relationship with the standard NH_4OAc extraction method (Soil Survey Staff, 2004) in non K-fixing soils. Also we will calculate K by $NaBPH_4$ procedure as a percentage of CEC, for which there is some literature support. These methods ($NaBPh_4$ and greenhouse cropping study) will give us two independent methods for estimating the rate of K fertilizer required to achieve sufficiency levels, and this will be compared to our 1-hr K fixation potential method value (Murashkina et al., 2007a) and CEC.

2. **Estimate K fertilizer requirements for model soil profiles representing the categories in our landscape soil K supply model**

Our previous work has shown that surface horizons of most of the soils we have studied do not fix K (instead release K during the 1-hour fixation test), and the subsoils fix varying amounts of K depending on soil mineralogy and texture. The proposed work will attempt to estimate K uptake and supply in the rooting zone of annual and perennial crops. We will calculate profile K fertilizer requirements based on the measurements from objective 1 and integrating over the profile by three methods: (1) Annual crop root zone (0-60 cm) by depth weighting, (2) Perennial crop root zone (0-100 cm) by depth weighting, and (3) Perennial crop root zone (0-100 cm) with depth weighting modified for a rooting pattern that decreases with depth. Our modeling efforts will be guided by previously published studies of root distribution and nutrient and soil solution uptake (e.g., Barber and Cushman, 1981; Smart et al., 2005; Vrugt et al., 2001) in a variety of cropping systems.

The timeline for this objective will include Year 2 and Year 3.

3. **Test the 1-hour K-fixation potential method with lab experiments to determine the effect of wetting and drying and sequential K-additions on amounts of K fixed.**

Our K-fixation test measures the ability of air-dried soil material to retain added K against removal by ammonium. Previous work suggests that soil wetting and drying may have a significant impact on soil K dynamics (Sparks, 1987). K-fixation potential of un-dried (field moist) soils will be measured on a subset of the soils analyzed for objective 1 and compared with values from air-dried soils. Also, the effect of repeated wetting and drying on the K-fixation potential will be measured to simulate effects of irrigation and field drying cycles.

At present, our K-fixation method yields results that indicate how much added K can be fixed by a soil. We will test these results by adding that amount of K to the soil and repeating the K-fixation test to see if K-fixation potential has been satisfied. We anticipate that some of the soils we have worked with will fix additional K, in particular if the soils are allowed to wet and dry, which could expose additional mineral surfaces for K sorption.

On a small subset of samples, we will add rubidium as a trace cation proxy for K to determine where cations are being sorbed in mineral structures (e.g., Murashkina et al., 2008). Rb exchange will be followed by electron microprobe analysis, which allows for elemental mapping of soil minerals (Schiffman and Southard, 1996).

The timeline for this objective is Year 2 and 3.

4. Provide research summaries and K fertilization recommendations for K-fixing soils to crop management professionals, analytical laboratories, and growers.
See Section F.

F. Project Management, Evaluation, Outreach

1. Management. The research will be carried out by a team consisting of the two project leaders (Stuart Pettygrove and Randy Southard), a graduate student in Soil Science (Gordon Reese), and a Staff Research Associate (Jiayou Deng). The project leaders will provide guidance and oversight as well as laboratory space. Pettygrove will serve as project leader responsible for reports and project deliverables. Southard will serve as major professor for the graduate student. J. Deng will provide oversight to the graduate student in use of instrumentation, soil and plant grinders, etc. We will rent space in the campus greenhouse facility. As part of the rental fee, care of plants (watering, light and temperature control) is provided by greenhouse staff, but the graduate student will be responsible for setting up the experiment, monitoring plants during the experiment, and collection of all data and samples.
2. Evaluation. Progress of this project will consist of technical reports with data being submitted annually to the CDFA. These reports will document completion of work according to the timeline in section E. An objective of the project is to produce recommendations for soil analytical procedures that can be used to evaluate the K fertilizer requirement in K-fixing soils. The completion of the project will be marked by submission of a research manuscript to an appropriate peer-reviewed journal – e.g., Soil Science Society of America Journal or Communications in Soil and Plant Analysis. To promote the adoption of soil analytical procedures by commercial laboratories, we will recruit two commercial analytical laboratories in California to offer these soil analytical procedures to the public. The "one-hour K fixation potential" test procedure developed by Murashkina et al. is a more practical alternative to the 7-day procedure of Cassman et al., which has in past years been offered by two commercial laboratories.
3. Outreach. We will carry out the following eight outreach activities
   - October 2011 – poster presentation at the national Soil Science Society of America meeting in San Antonio TX. Audience is mainly professional researchers and cooperative extension specialists and university students in agriculture and environmental sciences
   - November-December 2011 – oral presentation and summary report for the FREP annual conference and associated Western Plant Health Association crop nutrition workshops. Audience is mainly Certified Crop Advisers, licensed Pest Control Advisers, UC Farm Advisors, USDA-NRCS staff, and research scientists/college students.
   - February 2012 – oral presentation and proceedings paper at the California Plant and Soil Conference sponsored by the California Chapter of the American Society of Agronomy. Audience is mainly Certified Crop Advisers and licensed Pest Control Advisers, UC Cooperative Extension county advisors and specialists, and growers.

- November-December 2012 – oral and/or summary report for the FREP annual conference and associated Western Plant Health Association crop nutrition workshops. Audience is mainly Certified Crop Advisers, licensed Pest Control Advisers, UC Farm Advisors, USDA-NRCS staff, and research scientists/college students.
- January-February 2013 – oral presentation and proceedings paper for Lodi Grape Day. Audience is mainly growers and crop consultants in wine grape production both inside the Lodi district and elsewhere in California.
- Summer 2013, submit article for publication in Better Crops, an English language trade journal published by the International Plant Nutrition Institute for crop management professionals, fertilizer industry technical personnel, and cooperative extensionists.
- 2013, prepare manuscript for California Agriculture, a publication of peer-reviewed papers and research briefs aimed at a professional non-academic audience both within and outside California.
- 2013, submit manuscript for publication in the peer-reviewed journal Soil Science Society of American Journal, or alternatively Communications in Soil and Plant Analysis. Readership is mainly professional researchers and students.
- 2013, prepare a UC extension downloadable peer-reviewed technical bulletin (8xxx series)

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