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Strengthening Analytical Support in Agricultural Research

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ABSTRACT

The need for analytical support in agricultural research and development has long been recognized, especially for soil fertility evaluation and management, assessment of crop and food quality, and selection and breeding of nutritious food staples. In addition, the demand for analytical research support in the general areas of agriculture interfacing with human health and environmental quality has greatly increased in recent years. The trend for increased demand for analytical support will most likely continue in the future. To meet such diverse, increasing demands for analytical support, we need to upgrade infrastructure facilities and simultaneously teach and train students and young researchers in the use of modern analytical tools. This is prerequisite to providing timely, efficient, and effective analytical support, as such support is the key to monitoring, assessing, and maintaining soil, food, and environmental quality and to breeding nutritious food staples.

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Introduction

In the history of progress of agricultural research and development, the role of analytical support has long been recognized and appreciated. Analytical support has played a critical role at least in four areas of agricultural and interfacing research. They include (i) soil fertility evaluation and management in the context of augmenting soil fertility through the input of plant nutrients from external sources including mineral and organic fertilizers (Dahnke and Olson 1990; Black 1993; Mills and Jones 1996; Sahrawat and Wani 2013); (ii) monitoring and assessment of crop, food, and other natural resources' base quality(Chaney 2012; Sahrawat et al. 2010; Sahrawat and Wani 2013); (iii) selection and breeding of nutritious food crops (Graham et al. 2007; Ashok Kumar et al. 2013); and (iv) interfacing of human health and environmental quality (WHO 2002; Johnson et al. 2007; Chaney 2012; Christou et al. 2014; Sahrawat 2013; Wright et al. 2010), which has greatly increased in recent years.

This increasing demand for diverse analytical research support in countries such as India warrants the availability of well-trained analysts in the use of modern analytical tools. Simultaneously, there is an urgent need to upgrade the infrastructure (establishing state-of-the-art laboratory facilities to provide analytical research support) to meet the increasing demand on a timely basis. Also it is important to make an overview of the various analytical research needs that especially need strengthening.

The objective of this communication therefore is to present a brief overview of the general areas of agricultural research, and agricultural research interfacing human health and environmental quality, where analytical support needs to be strengthened to face the diverse challenges of twenty-first-century agriculture. The need to strengthen analytical support is most acute in some of the developing nations of the world.

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Soil fertility evaluation and management

For soil fertility evaluation and management, soil and plant testing have had been used; and they remain the obvious tools for diagnosing nutrient problems and for recommending nutrient application through fertilization. This process of soil and plant testing was understandably slow in the initial stage of the development of various techniques and methodology for assessing soil fertility status. However, over time, there have been tremendous developments and advances in the area of instrumentation, which at the present time make it conveniently feasible to conduct high-volume analyses of soil and plant materials and provide timely quality analytical support to serve practical agriculture (Sahrawat and Wani 2013).

Equally importantly, it is known that soils differ in their capacity to supply nutrients (major, secondary, and micronutrient elements) to plants growing on them. From this, it follows that different soils will require different amounts of plant nutrient elements as inputs from outside sources mostly through mineral and organic fertilizers to achieve a target yield (Black 1993; Dahnke and Olson 1990; Mills and Jones 1996; Reuter and Robinson 1997; Sahrawat and Wani 2013).

Moreover, fertilizers are becoming increasingly expensive and for the rational and judicious use of nutrients added as amendments from outside sources should obviously be based on the nutrient-supplying capacity of the soil relative to individual nutrients. As necessity is the mother of invention, techniques and methods were developed to assess soil quality. Initially, soil quality tests were developed for soil organic matter and potentially available major nutrients [nitrogen (N), phosphorus (P), and potassium (K)] as they were considered as the foundation of soil quality especially organic matter status, which is considered the dominant determinant of soil fertility. However, with time, the deficiencies of secondary nutrients [sulfur (S), calcium (Ca), and magnesium (Mg)] and micronutrients [iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), molybdenum (Mo) and boron (B)] became apparent; and their use became as essential as those of major nutrients for maintaining or enhancing productivity and crop quality (Dahnke and Olson 1990; Black 1993; Sahrawat and Wani 2013). Before the advent of chemical or mineral fertilizers, organic matter in various forms (e.g., as farmyard manure, green manure, crop residues, and diverse waste and by-products) was the sole source of plant nutrients (Sahrawat and Wani 2013).

Because soil tests only indicate the status relative to potentially available nutrients, the availability and uptake by plants can only be ascertained by actually analyzing the plant tissue. Thus, the use of plant (grain or nongrain parts of plant) testing to complement soil testing was realized as soil testing alone was not sufficient to establish uptake of nutrient (s) in the plant. Moreover, for assessing crop quality as influenced by nutrient input management, the analysis of both nongrain and grain part of the crops is essential. Also, other biotic and abiotic stresses and interactions among them greatly influence the uptake and utilization of the soil and added nutrients by the growing plants (Mills and Jones 1996; Reuter and Robinson 1997; Sahrawat 2006).

Monitoring and assessing crop, food, and other natural resources' quality

The second major areas of agricultural research where the need for the use of analytical tools has long been felt pertains to soil, water, and crop and food quality for food safety relative to diverse pollutants that enter through the food chain during the implementation of various soil, water, and crop management practices (Adriano 2001; Arao et al. 2009; Chaney 2012; Ratna Kumari et al. 2012).

To ensure food safety, the soil health has to be ensured, as the ultimate source of all chemicals benign or polluting is via soil. However, soil can also be polluted through the use of poor-quality surface or ground waters. In brief, there are food chain connections between soil health and human health via food quality. Thus to maintain food quality, there is need to monitor and assess not only the quality of food but also that of soil and irrigation water used in agriculture (Arao et al. 2009; Sahrawat et al. 2010; Christou et al. 2014).

Selecting and breeding nutritious food and feed crops

Another important area in which the provision of analytical support is of critical importance pertains to the selection and breeding nutritious food staples through biofortification. The aim of such research is to select and breed crop cultivars that are denser in micronutrients such as iron (Fe) and zinc (Zn), whose deficiencies are related to hidden hunger malnutrition in humans; moreover, biofortification has been suggested as the most economically viable means to mitigate Fe and Zn malnutrition (Graham et al. 2007; Dwivedi et al. 2012; Ashok Kumar et al. 2013; Govindaraj et al. 2013; Kanati et al. 2014).

Obviously, there will be increased need for analytical support not only to select and breed crops and cultivars denser in minerals associated with malnutrition but also to monitor and assess food quality on a continuing basis.

Agricultural production interfacing with human health and environmental quality

It is known that agricultural practices during food, fodder, and feed production influence environmental quality; and the influence could be positive, neutral, or negative. Here the environmental quality refers to the quality of soil, water, and products from production systems (Sahrawat et al. 2010). However, it is not necessary that agricultural production systems should have a negative influence on the environment. Implementation of best soil, water, and nutrient management practices enhances agricultural production without damaging environmental quality (Sahrawat et al. 2010; Sahrawat and Wani 2013). However, without proper investment in proper management of the natural resources, there is widespread degradation of agroecosystems and environmental quality (Wani, Chander, and Sahrawat 2014).

With time, the need for analytical support in the critical area of environmental (including contamination of soil, water, and production systems) quality, as influenced by agricultural production practices, has been increasing at a phenomenal rate. Indeed, environmentalists are driving the research on the pollution of natural resources, e.g., the contamination of soil and surface and ground water quality with various chemicals including fertilizers, heavy and trace metals, and pesticides (Galloway, Raghuram, and Abrol 2008; Okihashi et al. 2005; Sahrawat et al. 2010; Ratna Kumari et al. 2012; Shirisha et al. 2014).

The accumulation of various pollutants in the soil and ground water has implications for human health through the links between soil quality and food quality and between food quality and human health through the food chain (Okihashi et al. 2005; Galloway, Raghuram, and Abrol 2008; Ratna Kumari et al. 2012; Bolan et al. 2013; Sahrawat and Wani 2013; Shirisha et al. 2014). It is therefore not at all surprising that analytical support provided through plant testing and crop and food quality assessment has been receiving increasing attention in the past decades, and this trend will most likely continue in the future (Sahrawat 2013).

In addition, agriculture is also a major emitter of greenhouse gases [including carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_3)], which contribute to climate change and associated problems. There is need to mitigate climate change impact by reducing the emissions of greenhouse gases through proper management of soil, water, and nutrients. At the same time, agriculture has to provide food for an ever-growing population, especially in the regions of developing world (Johnson et al. 2007; Sahrawat 2004; Smith et al. 2008).

For climate change mitigation, there is need to monitor and assess greenhouse gas emissions to develop best management practices that reduce greenhouse gas emissions without affecting agricultural production (Smith et al. 2008). To ensure overall environmental quality, there is continuing need to monitor and assess the components of the environment—soil, water, and production systems—so that appropriate corrective management practices could be put in place in time to mitigate and or stop negative influences on the agroecosystem (Johnson et al. 2007; Sahrawat et al. 2010).

Perspectives

With the advances in instrumentation coupled with automation of methods used for analytical support, it has now become possible to provide high-throughput or large-volume chemical analyses of soil and plant materials for a range of plant nutrients and pollutants (chemicals such as nitrate, heavy metals, and pesticides) on a timely basis (Okihashi et al. 2005; Ratna Kumari et al. 2012; Sahrawat and Wani 2013; Shirisha et al. 2014).

The availability of timely quality analytical support service has greatly helped in making agricultural production more efficient without damaging the environmental quality. For example, use of fertilizer inputs using soil-test-based recommendations has not only helped smallholder farmers in rational and judicious use of plant nutrients from external sources but also has increased farm productivity and household incomes by exploiting synergy between soil water and fertility in rainfed farming systems (Sahrawat and Wani 2013; Wani et al. 2011, 2015).

Equally importantly, timely provision of high-throughput service in terms of analysis of grain samples for mineral content forms an integral component of research in the breeding and selection of crops and crop cultivars that are denser in minerals, especially in Fe, Zn, and carotenoids, as the deficiencies of these minerals are the major cause of malnutrition in humans, especially in the developing world (WHO 2002; Graham et al. 2007; Dwivedi et al. 2012; Ashok Kumar et al. 2013; Dwivedi et al. 2013; Govindaraj et al. 2013; Kanati et al. 2014).

In addition, the area in which the need for analytical support is phenomenally increasing is the area where agricultural production interfaces with human health and environmental quality. This is caused by the emissions of greenhouse gases and accumulation of pollutants in soil, water, and production systems, which directly affect environmental quality and through the food chain human and animal health. In fact, agriculture has the greatest impact on the environment, but it need not be negative and damaging to the environment and food quality. However, soil health has direct impact on food quality and a healthy soil produces healthy food (Adriano 2001; Okihashi et al. 2005; Graham et al. 2007; Galloway, Raghuram, and Abrol 2008; Smith et al. 2008; Sahrawat et al. 2010; Chaney 2012; Ratna Kumari et al. 2012; Christou et al. 2014).

However, to satisfactorily meet such diverse and increasing demands for analytical support service in agricultural research and development, there is an obvious need to put appropriate stress on the teaching and training of students and young researchers and prepare them in the use of modern analytical research support tools (Sahrawat and Wani 2013). With the ever-increasing demand for such service in developing nations such as India, we should not be inadequately providing needed analytical support, which is the backbone for monitoring, assessing, and maintaining soil, food, and environmental quality for human health. Simultaneously, there is need to upgrade and strengthen the infrastructure facilities such as state-of-the-art laboratory facilities for training, capacity building, and carrying out the actual analytical work.

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