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Different nutrient sources affect growth and yield of wheat crop

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Abstract

For organically grown produce has increased intensely over the past decade, most likely because of the professed welfares to the environment and human health. Providing organic sources of nutrients to endorse plant growth as well as endure soil quality is a major component of organic production. Organic nutrition of plants can present opportunities and challenges to the grower. To review scientifically based information dealing with the effects of organic nutrient sources on crop yields and quality, soil properties, and environmental risks is the primary objective of this article. Effects of organic nutrient sources are often evaluated by comparison with conventional production, but this approach can be problematic because nutrient source may be confounded with many other cropping system components. Even though these drawbacks, a careful examination of the literature suggests the following conclusions. Application of organic nutrient sources can generally improve soil health, but careful management is required to avoid environmental risks of nitrate (NO₃) leaching and phosphorus accumulation. Provided that nutrient supply is equal, yields with organic sources tend to be similar to those with inorganic sources. However, lack of available nitrogen (N) that is synchronous with plant demand often limits yields in organic cropping systems. Limited N availability and varied supply of other nutrients from organic sources may contribute to the differences sometimes observed in dry matter content, tissue NO₃ and mineral concentration, vitamin C and other phytochemicals, and taste. Phytonutrient content also may be affected by differences in pest control strategies among cropping systems regardless of nutrient source. There is a slight, but significantly, increased risk of produce contamination by *Escherichia coli* and other enteric bacteria contamination on produce when organic nutrient sources are used, but if proper guidelines are followed, contamination with the lethal serotype O157:H7 does not appear to be a major concern. Appropriate management of organic inputs is critical to achieving potential benefits for crop production and soil quality.

Keywords: Organic nutrient sources, soil quality, health benefits, environment

Introduction

To grow crops has gained in popularity from the use of organic farming techniques in recent years as a result of both an increase in consumer demand for organically grown produce and a genuine desire on the part of many growers to sustain or improve the soil (Dimitri and Greene, 2002) [2]. Now, organic produce generally commands a higher price than conventional produce (Oberholtzer *et al.*, 2005) [60], prompting producers to grow crops organically. The increased consumer demand appears to be driven primarily by the perception that organically grown produce is safer and more nutritious to eat than produce grown conventionally (Lockie *et al.*, 2002; Williams and Hammit, 2001) [43, 80]. Numerous problems exist when comparing nutrient sources in organic and conventional systems, mainly because of the difficulty in controlling all the variables involved (Hornick, 1992; Lester, 2006) [27, 41]. Controlling variables is difficult because organic production methods have a defined set of rules to follow [U.S. Department of Agriculture (USDA), 2000], meaning that differences between systems include more factors than just nutrient source. Unless experiments are designed carefully, comparing systems can lead to results in which nutrient source is confounded with: unequal rates or availability of the nutrient(s) in question, methods for controlling weeds, differences in crop rotations, insects and diseases, cultivar, climate, stage of harvest, and postharvest handling. From a practical or consumer standpoint, it may not matter what the exact causes of the differences are, but from a production or scientific standpoint, it is important to know what components of the system may exert an influence on crop and soil quality. The focus of this review is on organic nutrient sources used in organic production, but these sources can also be a component of conventional production.

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We define, but do not limit, organic nutrient sources acceptable for organic production as natural, carbon (C)-containing, free from prohibited substances, nonsynthetic materials such as fresh or composted plant and animal material and green manures or cover crops grown in place. Nonsynthetic inorganic materials that have not been processed chemically such as crushed rock phosphate, limestone, various potassium (K) minerals, and other rock or mineral products may also qualify as nutrient sources acceptable for organic production. Not surprisingly, most of the research reported in the literature compares manures or composts and legume-based cropping systems with conventional fertilizer systems. The overall findings of the study indicate that the integrated use of chemical fertilizer and manure is important for sustainable crop yield. The integrated use of fertilizers and manure resulted in considerable improvement in soil health by increasing organic matter, available P, and S contents of soils (Ali *et al.*, 2009). Assessment of yield as affected by organic-nutrient sources can be problematic because these sources are complex compounds with varying degrees of nutrient availability and unpredictable release rates. Better characterization of organic input chemical constituents may help predict short-term mineralization rates (Palm *et al.*, 2001; Vanlauwe *et al.*, 2005) [61, 77], but the process will still vary with weather conditions such as rainfall and temperature. Based on the long-term evaluation of 14 sites receiving either manure or fertilizer, yields obtained with manure were generally similar to those obtained with conventional fertilizer except for one site where yields were higher with manure (Edmeades, 2003) [18]. Despite the beneficial effects of manure on soil quality noted previously, use of conventional fertilizer can apparently compensate for less desirable soil conditions such as lower organic matter. Provided that nutrient supply is equal or at adequate levels to support growth, yields with organic sources tend to be similar to those with inorganic sources. N availability was often the most important factor limiting yield in organic tomato (*Solanum lycopersicum*) systems; although, by including proper cover crops and using composts, comparable yield could be achieved (Clark *et al.* (1999) [12]. In cases in which deficiency was noted, a lack of synchrony between N release from organic sources and demand by the crop is the probable cause (Kirchmann and Ryan, 2004; Pang and Letey, 2000) [35, 62]. High-value horticultural crops may allow the purchase of more readily mineralizable forms of organic N sources or, if available, the use of more land to grow green manure crops to ensure that N is not lacking. However, there is potential for higher N losses and soil phosphorus (P) loading when more readily available N sources such as manure are used. Environmental consequences of high N availability and management practices to reduce the potential losses are discussed in a later section. In general, tissue dry matter content was reported to be higher in organically grown leafy vegetables, but not in fruit (Magkos *et al.*, 2003; Woese *et al.*, 1997) [50, 81]. Heaton (2001) reported that 10 of 19 studies showed that dry matter of produce from organic systems was higher than in conventionally grown produce. Increasing N rate (either from manure or synthetic fertilizers) generally promotes higher yield and dry matter accumulation on a per-plant basis (Stanford and Legg, 1984) [70]. However, as a result of limited N availability, Leclerc *et al.* (1991) [40] reported that organically grown produce weighed less on a per-plant basis than conventionally grown produce but had higher dry matter content and less water. High rates of K fertilization have been

reported to reduce dry matter content in some crops (Allison *et al.*, 2001) [1]. It is likely that lower plant weight and higher dry matter content in some organically grown plants is related to lower soil N and possibly lower soil K availability than with conventional systems. Of the organic constituents measured in plant tissue, ascorbic acid (vitamin C) has frequently been reported, on average, to be higher in organically grown plants than with plants grown conventionally (Chen, 2005; Heaton, 2001; Williams, 2002; Woese *et al.*, 1997; Worthington, 2001) [104, 10, 79, 84]. However, studies could be found in which there were no differences resulting from source (Brandt and Beeson, 1951; Lombardi-Boccia *et al.*, 2004; Nilsson, 1979) [5, 58], or in some cases, ascorbic acid was lower in produce grown with organic sources (Lester, 2006; Montagu and Goh, 1990) [41, 54]. Factors affecting ascorbic content include cultivar, N rate, environmental factors (especially light), stage of growth, and storage (Dumas *et al.*, 2003; Hamner *et al.*, 1945) [17, 23]. Oxidative stresses such as drought, full sunlight, and low N availability also have been reported to increase ascorbic acid content (Brandt and Molgaard, 2001) [6]. Degradation in soil health has emerged as a major factor responsible for stagnation in agricultural production. The maintenance of good soil health needs balanced fertilization, which includes application of all the required plant nutrients in proper amount and form. Long-term studies revealed that crop productivity is declining even after applying recommended doses of NPK fertilizers. Responses to N reduced greatly in rice and almost zero in wheat (*Triticumaestivum* L. emend. Firori&Paol.) In the absence of P fertilizer over 20 years. But the responses to P and K emerged after 8–10 and 20–22 years respectively, when their availability in soil reached below the critical limits. The response (kg grain/kg nutrients applied) to N was higher in rice (*Oryza sativa* L.) than in wheat, while that to P and K was higher in wheat than in rice. Amongst the nutrients, maximum response was noted with P followed by N and K. Experiments conducted on farmers' fields revealed that 8–12% of the total increase in grain yield of various crops could be attributed to K application only. Application of zinc to both rice and wheat was found more beneficial than its application to any single crop. The results of site-specific nutrient-management experiments indicated that maximum grain and economic yields can be achieved by applying all the required nutrients including micro and macro-nutrients (N₁₅₀ P₆₀ K₁₂₀ S₄₀ B₅ Mn₂₀ Zn₂₅) based on soil-test values. Trends in organic farming revealed that the yield gaps between chemical fertilizers and organic manures reduced with time. Organic inputs take time to be apparently responsive in terms of productivity and soil health. The system of integrated plant-nutrient supply is emerging as the most logical concept for managing long-term soil fertility and productivity. Addition of organic manures along with chemical fertilizers sustained the yield through increased nutrients availability and nutrient-use efficiency. The combined use of organic manures and chemical fertilizers improves the physical condition of soil more effectively than continuous addition of chemical fertilizers alone.

Effect of different nutrient source on wheat crop

Wheat (*Triticumaestivum* L.) is a staple food for more than one third of the world population (Anonymous, 2007-08). Cereal crops contribute about 80% to the total food coming from plants. Wheat contributes largest part among all cereals. Wheat is cultivated in 27 countries of the world (Stubbs *et al.*, 1986). It is the most important agricultural commodity and

plays a vital role in country's economy. To fulfill the demand of food, sustainable and high yielding crops have been grown which resulted in application of commercial inorganic fertilizers in larger amounts in the soils specially in case of the nitrogen fertilizers. These practices are not only the threats for environmental quality but also pollute the surface and sub-surface water reserves by leaching down into the soil (Avnimelech and Raveh, 1976; Baker and Johnson, 1981) ^[89, 90]. Continuous application of chemical fertilizers causes soil health problems even if applied in balanced proportion (Zia *et al.*, 2000) ^[91]. Ahmad *et al.* (2012) ^[92] reported that in wheat crop; Plant height, tillers/m², spike length (cm), no. of grains/spike, 1000 grain weight (grams) and grain yield t/ha have maximum results where NPK + press mud 500 kg/ acre are applied compared to other treatments ((NPK=150- 120-60,NPK+Poultry manure, NPK+City compost 300, NPK+Humic acid 4). It generally comprised of yard trimmings, food scraps, wood waste, and paper products and human, animals and birds wastes. On decomposition it turns into organic matter comprising of humus and humic acid. Recycling of organic material can be beneficial for human health, land, air, and water. Waste reduction and recycling prevents greenhouse gases (GHG) emissions, reduces pollutants, saves energy, conserves resources, and reduces the need for new disposal facilities. It has been established that organic material improves soil health and phyto-availability of the nutrients by increasing organic matter contents in the soil and improving the soil texture (Ibrahim *et al.*, 1992) ^[93]. Organic materials are present as farm waste, city waste, poultry litter and industrial wastes (food, sugar, and cotton and rice industry). There is no proper waste collection and disposal system. So, these wastes are polluting the environment badly (Economic Survey, 2001) ^[61]. Only the solution is to use these materials for agricultural lands. But organic nutrients alone could not be a perfect substitute for chemical fertilizers as these are not as much quick nutrient supplier as chemical fertilizers, so integrated use of organic nutrients along with chemical fertilizer has proved more beneficial (Nasir and Qureshi, 1999; Khanam *et al.*, 2001) ^[94, 95]. Regular use of a reasonable dose of organic manure, along with crop residue recycling, is known to cater the nutrient requirements of a low to medium intensity rice-wheat cropping system (Coventry *et al.*, 2011) ^[96]. However, most of the longterm INM field research in South Asia pertains to rice-wheat system (Kumar and Dhar, 2010) ^[97]. The integrated nutrient management helps to restore and sustain fertility and crop productivity. It may also help to check the emerging deficiency of nutrients other than N, P and K. Further, it brings economy and efficiency in fertilizers. The integrated nutrient management favorably affects the physical, chemical and biological environment of soil. Organic manure enhanced soil organic carbon (SOC) quality and quantity by an increased accumulation of various classes of organic compounds. Research on SOC following crop residue has been mainly focused on changes of bulk organic carbon (Sebastia *et al.*, 2007) ^[98]. The integrated use of concentrate organic materials and inorganic fertilizers has received considerable attention in the past with a hope of meeting the farmer's economic need as well as maintaining favorable ecological conditions on long-term basis (Kumar *et al.*, 2010) ^[97]. The grain yield of wheat was greatly influenced by treatments applied to preceding crop of pearl millet. The results are in closer conformity with Choudhary (2005) ^[99] and Choudhary and Gautam (2007) ^[100]. It can be concluded that different organic sources of nutrients had remarkable

effect on growth, yield and quality of wheat. Integrated use of organic manures with optimal levels of NPK fertilizers is the need of the day that will not only improve the nutrient status and soil health but has also shown greater potential in stabilizing crop yields over a period of time. The integrated use of organics and chemical fertilizers at optimum levels as determined by soil tests in long-term fertilizer experiments indicate the build-up of micronutrient and secondary nutrient reserves such as Zn, Cu, Mn, Ca, Mg and S. Therefore, INM in sustainable rice-wheat cropping system is of paramount importance. It will also ensure increased crop productivity in an efficient and environmentally benign manner, without diminishing the capacity of the soil to produce for present and future generations. In other words, INM system is an ecologically, socially and economically viable approach, which on the whole is non-hazardous. The effect of different integrated nutrient management practices on soil organic carbon (SOC) stocks and its fractions, SOC sequestration potential as well as the sustainability of the rice-wheat system were evaluated in long term experiments at different agro-climatic zones of IGP. Application of NPK either through inorganic fertilizers or through combination of inorganic fertilizer and organics such as farm yard manure (FYM) or crop residue or green manure improved the SOC, particulate organic carbon (POC), microbial biomass carbon (MBC) concentration and their sequestration rate. Application of 50% NPK + 50% N through FYM in rice and 100% NPK in wheat, sequestered 0.39, 0.50, 0.51 and 0.62 Mg C ha⁻¹ yr⁻¹ over control (no N-P-K fertilizers or organics), respectively at Ludhiana, Kanpur, Sabour and Kalyani using the mass of SOC in the control treatment as reference point. Soil carbon sequestration with response to application of fertilizer partially substituted (50% on N basis) with organics were higher in Kalyani and Sabour lying in humid climate than Ludhiana and Kanpur lying in semiarid climate. The rice yield recorded a significant declining trend in Ludhiana and Kanpur whereas the yield trend was stable at Sabour and Kalyani under unfertilized control. The system productivity in N-P-K fertilized plots and NPK along with organics showed either an increasing trend or remained stable at all locations during last two and half decades of the experiment (Nayak *et al.*, 2011) ^[102]. The dramatic increase in worldwide agricultural production per unit area significantly reduced starvation rates in the developing world and enhanced the global food supply (Lal, 2009) ^[18]. During recent intensive farming systems, chemical fertilizers (consisting of N, P and K) are applied excessively to provide the nutrients for plants for increasing agricultural productivity. However, injudicious use of these fertilizers has caused pollution problems leading to public health hazards. Moreover, use of chemical fertilizers alone was not efficient in improving the nutrient status of soil (Kang *et al.*, 2005) ^[15] and integrated nutrient management system was found more appropriate to enhance soil fertility and plant growth. During last decades, it has been widely acknowledged that system oriented production research is needed to be strengthened as it is essential for maximizing land production per unit area, by harnessing synergies generated through microbial interactions in soil-crop-weather systems. Cropping systems approach of resource management was demonstrated to improve nutrient use efficiency. The decomposition and mineralization of added organic matter acted as a source of the nutrients, thereby creating a favorable environment for proliferation of microbes in the soil (Lal *et al.*, 2012) ^[17]. Thus, distinct organic amendments like manure, leguminous cover crops and composted materials were found to stimulate

microbial biomass differently through increased labile organic matter (Kallenbach and Grandy, 2011) [101]. Integrated use of chemical fertilizers and organic manure sources like FYM, wheat straw, Sesbania in pearl millet-wheat cropping system improved the viable counts of Azotobacter and PSB during both the years of the experiment. Enhanced microbial population in the soil may improve the soil fertility and crop productivity due to increased availability of utilizable nutrients for the plant growth. For obtaining optimum crop production the fertility of soil is very important and the absence of organic matter from soil results in unproductive soil. To supply essential plant nutrients in adequate amounts, huge quantity of organic material is needed. Slow release of plant nutrients after decomposition from organic material has been reported to promote crop growth (Goutami *et al.*, 2018) [8]. Organic sources when applied to preceding crop, leaves the residual effect and this benefit is harvested by the succeeding crop and system becomes sustainable through integrated use of crop residues, chemical fertilizers, green manure and FYM (farm yard manure) as a source of nutrients.

Conclusion

It can be concluded that different organic sources of nutrients had remarkable effect on growth, yield and quality of wheat. Integrated use of organic manures with optimal levels of NPK fertilizers is the need of the day that will not only improve the nutrient status and soil health but has also shown greater potential in stabilizing crop yields over a period of time. The integrated use of organics and chemical fertilizers at optimum levels as determined by soil tests in long-term fertilizer experiments indicate the build-up of micronutrient and secondary nutrient reserves such as Zn, Cu, Mn, Ca, Mg and S. Therefore, INM in sustainable rice-wheat cropping system is of paramount importance. It will also ensure increased crop productivity in an efficient and environmentally benign manner, without diminishing the capacity of the soil to produce for present and future generations. In other words, INM system is an ecologically, socially and economically viable approach, which on the whole is non-hazardous. The effect of different integrated nutrient management practices on soil organic carbon (SOC) stocks and its fractions, SOC sequestration potential as well as the sustainability of the rice-wheat system were evaluated in long term experiments at different agro-climatic zones of IGP.

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