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Productivity and Quality of Wheat as Affected by Long-Term Addition of Fertilizers and Amendments: A Review

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A B S T R A C T

Wheat (*Triticum aestivum* L.) is the most widely produced cereal and one of the most important staple cereal crop for the majority of the world's population. Wheat grains are important source of protein and wheat flour has unique dough forming properties. The quality of wheat flour can be measured by parameters such as protein, moisture, gluten, fat, ash, carbohydrates and mineral nutrients. *Chapatti* is the major wheat product consumed in India. However, due to urbanization and industrialization, the demand for bread, biscuit and other related products is increasing whose quality is governed by unique properties of dough formed from the wheat flour with optimized grain protein content and other quality constituents. Therefore, it is important to combine the high grain yields with better grain quality to meet the twin challenges of nutritionally superior and high quality wheat products. This paper reviews about the productivity and quality of wheat as affected by addition of fertilizers and manures.

Introduction

Wheat is the second most important cereal after rice. It is one of the most staple food crops consumed by more than one third of the world population due to the presence of high calories. Wheat is not only a nutritious grain, but is also a rich source of proteins, minerals and dietary fibre (Oluwatoyin *et al.*, 2015). Wheat is also used in brewing for the production of ethanol and wheat beer, as a raw material for cosmetics, wheat protein as a substitute for meat, to make wheat straw composites and also as fodder for domestic animals (Leo *et al.*, 2012).

The nutritional value of wheat is extremely important as it takes an important place among the few crop species being extensively grown as staple food sources. The importance of wheat is mainly due to the fact that its seed can be ground into flour, semolina, etc.,

which form the basic ingredients of bread and other bakery products, as well as pastas, and thus it presents the main source of nutrients to the most of the world population (Sramkovaa *et al.,* 2009). The grain quality depends on the content of organic compounds (protein and its fractions, carbohydrates, and fat), mineral nutrients (phosphorus, calcium, potassium, magnesium, and microelements), vitamins, antioxidants, and antinutritional compounds (Mallick *et al.,* 2013; Poudel and Bhatta 2017).

The content and the properties of starch are very important, including the basic components of amylase and amylopectin. They determine the technological and nutrition quality of grains (Zhang *et al.,* 2017). A special biological and performance function is played by protein, especially the gluten fraction. Gliadin and glutenin ensure dough elasticity and extensibility (Singh and Khatkar 2005). Gluten determines softness, elasticity, and cohesion of bread both fresh and after storage (Curti *et al.,* 2014).

Nutrient balance is one of the key components to increase crop productivity and quality. Excess and imbalanced use of nutrients have caused nutrient mining, declined crop productivity and ultimately deteriorated the soil health which is also reflected in the quality of the produce. Replenishment of these nutrients through organics and a combination of organics and inorganics has a direct impact on soil health and crop productivity. Continuous use of inorganic fertilizers in imbalanced manner leads to deterioration in soil physical, chemical and biological properties and ultimately the soil health.

The deteriorating soil health, declining soil organic matter content and increasing micronutrient deficiencies have put a big question mark on the sustainability of wheat production. However, contribution of chemical fertilizers towards an increase in agricultural production is well known. But, their injudicious use exhibits a detrimental effect on soil health. Long-term use of FYM with inorganic fertilizers is a good management system in accumulating soil organic carbon, sustaining yield and enhancing soil quality for increasing crop production. This paper reviews about the productivity and quality of wheat as affected by long-term addition of fertilizers and manures.

Brief resume of research work pertinent to the investigation entitled, "Productivity and quality of wheat as affected by long-term addition of fertilizers and amendments" has been reviewed in under the following heads:

I. Effect of fertilizers and amendments on wheat productivity
II. Effect of fertilizers and amendments on wheat quality

Effect of fertilizers and amendments on wheat productivity

Tiwari *et al.,* (2002) studied the long-term influence of organic and inorganic fertilization on productivity of soybean-wheat system in *Typic Haplusterts* of Jabalpur (Madhya Pradesh) and concluded that application of recommended dose of inorganic fertilizer along with manure at the rate of 15 t ha^{-1} helped in sustaining the yields of soybean and wheat. While studying the effect of continuous application of chemical fertilizers with and without farmyard manure (FYM) and lime on maize – wheat productivity, Subehia *et al.,* (2005) found that continuous addition of 100 per cent N alone (urea) caused maximum damage and not even a single grain of maize or wheat could be harvested in that treatment whereas, application of FYM and lime along with NPK sustained higher grain yields as compared to sole use of inorganic fertilizers.

In an Alfisol of Ranchi (Jharkhand), Mishra *et al.,* (2008) found that the highest grain yields of wheat (3.28 t ha^{-1}) was obtained with the application of 100 per cent NPK + lime which was at par with the yield obtained in 100 per cent NPK + FYM. Addition of FYM or lime along with inorganic fertilizer sustained higher crop yield and also improved the soil quality. Whereas, imbalance use of inorganic fertilizer (100% N) reduced crop productivity and nutrient uptake.

To assess the changes in soil fertility after 31 years of fertilizer use, a study was conducted by Behera and Singh (2009) at Delhi and they found that the grain and straw yields of wheat under 100 per cent NPK + FYM and 100 per cent NPK + Zn were at par and higher as compared to other treatments. The long-term effect of nutrient management on productivity of rice (*Oryza sativa*) - wheat (*Triticum aestivum*) system was studied by Yadav and Kumar (2009) at Faizabad (Uttar Pradesh). They reported that the addition of organic manures along with chemical fertilizers sustained the wheat yield by increasing nutrients availability and nutrient use efficiency.

Verma *et al.,* (2012) studied the changes in soil fertility status of maize-wheat system due to long-term use of chemical fertilizers and amendments in acid Alfisol of Palampur (Himachal Pradesh). They reported that the use of either FYM or lime along with 100 per cent NPK sustained the crop productivity and imbalanced use of nutrients i.e. NP or N alone adversely affected the fertility of soil by aggravating the problem of soil acidity.

In permanent manurial trial (PMT) initiated in 1956, in an Alfisol of Ranchi (Jharkhand), Kumari *et al.,* (2013) studied the long-term effect of fertilizers, manure and lime on yield sustainability under maize-wheat cropping system. The highest grain yield of wheat (3.27 t ha^{-1}) was recorded in lime amended treatment and the reduction in grain yield of wheat over the years was noticed due to imbalanced application of fertilizers. Maximum reduction in grain yield was recorded in 100 per cent N followed by 100 per cent NP over 100 per cent NPK. Yang *et al.,* (2015) examined crop yields after 22 years of long-term fertilizer experiment and they found that combination of inorganic and organic fertilizer substantially increased crop yields and it further increased with increasing the amount of fertilizer.

While studying the wheat yield trend in long-term rice-wheat cropping system in silt loam soil of Bhairahawa (Nepal), Rawal *et al.,* (2015) reported that yields were consistently higher in NPK and FYM treatments than the treatments where one or more nutrients were lacking. They concluded that the productivity of the wheat can be increased and sustained by supplementing the nutrient through the integrated long-term use of organic and inorganic source. In Mollisol of Pantnagar (Uttrakhand), Bhatt *et al.,* (2016) found that long-term integrated use of 100 per cent NPK with FYM sustained the yields under rice-wheat cropping system. Hand weeding and application of Zn along with 100 per cent NPK was found to be superior over 100 per cent NPK in increasing rice and wheat productivity.

Over 41 years of study in silty clay loam soil of Pantnagar (Uttrakhand), Ram *et al.,* (2016) reported that long-term integrated use of inorganic fertilizers and organic manure (FYM) was found superior in comparison with sole application of inorganic fertilizers in sustaining the crop productivity and soil fertility to enhance the soil quality in rice-wheat cropping system. In an acid Alfisol of Palampur (Himachal Pradesh), Meena *et al.,* (2017) conducted an experiment to study the effect of continuous application of fertilizers, farmyard manure and lime on soil fertility and productivity of the maize-wheat system and

they found that continuous application of chemical fertilizers along with farmyard manure (FYM) or lime significantly influenced the yield and the uptake of nutrients by maize and wheat. Imbalanced use of fertilizers led to a significant reduction in the productivity and also depleted the soil fertility. From a similar study conducted by Rajneesh *et al.,* (2017) on long-term effect of fertilizers and amendments in an acid Alfisol of North Western Himalayas, it was concluded that the application of 100 per cent NPK along with amendments (FYM/lime) recorded significantly higher NPK uptake over other treatments and imbalanced use of nutrients led to the reduction in the uptake of N, P and K. The impact of 21 years of continuous application of inorganic fertilizers and organic manure on sustainability of soybean-wheat cropping system, was studied by Choudhary *et al.,* (2018) at Hawalbagh (Uttrakhand) and they reported that combined application of NPK + FYM resulted in significantly higher grain yield of soybean and wheat.

Effect of fertilizers and amendments on wheat quality

In acidic red soil of Ranchi (Jharkhand), the long-term effect of organic manures and fertilizers on quality of wheat was studied by Singh and Prasad (1977) and they found that potassium application decreased the calcium, phosphorus and boron contents of wheat grain, but increased the zinc content. Supplementing organic manures with phosphate fertilizers resulted in increase of calcium and phosphorus content of the grains.

Nedelciuc *et al.,* (1995) studied the effect of fertilizers on protein content of wheat in chernozem soil of Romania and they reported that the grain crude protein content increased with increase in N rate, whereas, P fertilizer had no effect on protein content. Effect of organic and inorganic fertilization on wheat quality was studied by Ragasits *et al.,* (2000) in Hungary and they reported that N fertilizer application (0-200 kg N ha^{-1}) influenced quality of wheat substantially and simultaneous application of FYM along with fertilizer increased the gluten content and its quality.

Singh *et al.,* (2002) reported that the protein content of wheat grain increased significantly by 1.48 per cent with the application of farmyard manure @ 10 tonnes ha^{-1} and also enhanced the NPK content in wheat grain over control. In *Typic Ustochrept* of Kanpur, Dwivedi *et al.,* (2002) found that the protein content increased significantly with increased use of S and Zn over control. Positive effects of application of FYM along with NPK on the protein and gluten content of grain were also reported by Blecharczyk and Malecka (2004) in Poland.

Long-term effect of NPK fertilizers on grain quality in winter wheat was studied by Dong *et al.,* (2004) in China and they reported that the grain protein content decreased with the combined application of N and P fertilizers as compared to sole application of nitrogen. Gluten and grain protein increased with the application of N and K fertilizers, indicating the importance of balanced nutrition in soil. In a long-term field experiment at Beijing (China), the effect of long-term fertilizer use on the quality of wheat was studied by Huan *et al.,* (2004) in grey desert soil of China and they reported that application of N, NP, NK and NPK increased the grain quality as compared to control. Omission of N reduced the contents of crude protein, essential amino acids and deteriorated flour and dough quality. Sahay *et al.,* (2005) studied the long-term effect of manuring and fertilization on S, N and protein content of wheat at Ranchi (Jharkhand) and they found that continuous use of manure enhanced the S content both in

grain and straw. Higher protein content (13.15%) was observed with half dose of FYM along with chemical fertilizers.

Pepo *et al.,* (2005) also studied the baking quality parameters in long-term fertilizer experiment in chernozem soil in Hungary and they found that N fertilization increased the wet gluten content. Mars *et al.,* (2006) evaluated the effect of S fertilizer on the quality (gluten and protein content) of wheat and they found that application of S fertilizer had no significant effect on quality. Baking quality parameters especially dough formation was better in treatments where S was added as compared to control.

The effect of NPK fertilization on quality parameters of winter wheat c.v. Zitarka in sandy loam soil of Donji Miholjac in eastern Croatia was studied by Hovart *et al.,* (2006) and they concluded that protein content increased significantly with the application of N @ 80, 120, 160 N ha^{-1} and wet gluten content was also significantly affected. Channabasanagowda *et al.,* (2008) evaluated the effect of organic manures on quality of wheat and recorded significantly higher protein content in treatment receiving vermicompost + poultry manure and recommended dose of fertilizers (13.23%). The increase in seed quality with application of vermicompost and poultry manure was attributed to better nutrient availability and its uptake by plant. The protein content of maize was significantly higher (9.94 %) in the chemical fertilized treatment at 100:50:30 kg ha^{-1} of N, P_2O_5 and K_2O as compared to other treatments and the lowest protein content of 8.58 per cent was noted under control (Ramesh *et al.,* 2008).

Influence of long-term N fertilization on micronutrient density of wheat grain was studied by Shi *et al.,* (2010) and they reported that N fertilization increased Fe, Zn and Cu density and protein concentration in wheat grain as compared to control but did not affect the Mn concentration. Vuscan (2010) reported that the lower potassium rates (K_{40} and K_{80}) influenced the dry gluten content of winter wheat positively in preluvo soil conditions of North-West part of Romania. The best value of the dry gluten content was obtained with $N_{160}P_{80}K_{80}$.

In Mollisol of Uttarakhand, a field experiment was conducted by Das *et al.,* (2012) to study the effect of long-term application of inorganic fertilizers and manure on grain quality of wheat under rice-wheat cropping system and they found that the application of optimal dose of NPK along with Zn (100% NPK + Zn) resulted in better grain quality in comparison to sole application of NPK fertilizers. Balanced application of fertilizer nutrients and combined use of inorganic fertilizers and manure enhanced the grain quality of wheat over sole use of NPK fertilizers.

In clay loam soil of Udaipur, Meena *et al.,* (2013) found significant increase in crude protein, HCN, crude fiber, fat and mineral ash contents of wheat under recommended dose of fertilizers through inorganic fertilizer + biofertilizer over control. In an experiment conducted to study the effect of zinc fertilization on quality of wheat grown in Jabalpur (Madhya Pradesh), Keram *et al.,* (2013) found that the quality parameters like crude protein, wet gluten and total carbohydrate in wheat grain were markedly improved by increasing level of Zn as compared to NPK alone. Application of Zn @ 10 kg ha^{-1} along with 100 per cent NPK maintained the quality of wheat grain.

Dhaliwal *et al.,* (2015) reported that the use of organic manures either alone or in combination with fertilizers improved all the quality parameters of wheat grain except the

protein content which was more in treatment receiving chemical fertilizers. A field experiment was conducted to study the effect of long-term fertilization and soil amendments on grain quality of wheat on acidic pseudogley of Kraljevo region (Serbia) by Jelic *et al.*, (2015) and they found that the combined use of NPK fertilizers (120:60:40), lime (5 t ha^{-1} $CaCO_3$) and manure (20 t ha^{-1}) positively affected grain quality in winter wheat.

Effect of zinc on yield and quality of wheat cultivars in Akola (Maharashtra) was studied by Bhujade *et al.*, (2016) and they reported that the protein content in wheat grain was significantly higher due to the soil application of $ZnSO_4$ @ 50 kg ha^{-1} along with two foliar sprays of $ZnSO_4$ @ 0.5 per cent. In a deep black soil of Dharwad (Karnataka), effect of soil and foliar application of zinc and iron on productivity and quality of wheat was studied by Pallavi and Sudha (2017) and they concluded that soil (20 kg ha^{-1}) and foliar application of zinc (0.5 %) at heading and milking stage was the best agronomic practice in order to obtain higher quality of crop.

Effect of different nutrient management practices on quality of wheat (*Triticum aestivum* L.) was studied by Akhtar *et al.*, (2018) in clayey soils of Junagarh (Gujrat) and they reported significantly higher protein content under the treatment 100 per cent NPK + $ZnSO_4$ @ 25 kg ha^{-1}.

The integration of chemical fertilizers with organics/lime resulted in the highest yield of wheat. Imbalanced use of fertilizers resulted in significant decline in yield of wheat. Wheat quality parameters improved with integrated use of organic and inorganic fertilizers. Also, the application of organics (FYM) enhanced all the quality parameters.

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