Plant Sci. Arc.
Plant Science Archives
An International Journal of Plant Biology

Review Article
ISSN 2518-6965
Journal Homepage: www.plantarc.com

Integrated Nutrient Management in Wheat (*Triticum aestivum* L.)

Khuma Kumari Bhusal

Department of Agronomy, Horticulture and Plant Science, South Dakota State University, Brookings, SD, 57007, United States

Citation: Khuma Kumari Bhusal (2025). Integrated Nutrient Management in Wheat (*Triticum aestivum* L.). *Plant Science Archives.*
DOI: https://doi.org/10.51470/PSA.2025.10.1.13

Corresponding Author: **Khuma Kumari Bhusal** | E-Mail: **(bhusalkhuma2@gmail.com)**

Received 29 October 2024 | Revised 30 November 2024 | Accepted 30 December 2024 | Available Online 24 January 2025

ABSTRACT

Wheat (Triticum aestivum L.) is one of the principal cereal crops grown worldwide which also has significance as the second-most staple food of the world after rice. Wheat is also a major crop grown in South Dakota. Being a rich source of energy and protein, it is consumed by a great deal of people around the world by making many different cuisines from it. Despite its huge demand in the food industry, its production has not escalated in recent years. One of the major constraints in wheat production is the sole application of chemical fertilizers to fulfill the nutritional requirement of wheat crop. Though NPK are the primary nutrients required for wheat crops, other essential nutrients are also equally significant to obtain optimum yield. Chemical fertilizers have adverse effect on the environment as well as long-term soil health. The imbalance use of nutrients results in unsustainable production. Integrated Nutrient Management (INM) system emphasizes the use of organic manures along with chemical fertilizers and it is a good approach to minimize losses in crop production and crop quality which would otherwise be caused by inappropriate use of fertilizers. This article reviews the literature pertaining to the research in fertilizers used in wheat production along with emphasizing the need for integrated nutrient management in wheat production.

Keywords: *wheat, integrated nutrient management, chemical fertilizers, organic manures*

Introduction

Wheat (*Triticum aestivum L.*), a member of the Poaceae Family, is one of the principal cereal crops grown worldwide. Wheat is considered to be the second-most staple food of the world following rice that has an association with some of the earliest and important civilizations of the world [1]. Originating in the Middle East or Eastern Mediterranean region of Eurasia, wheat is widely recognized as the primary grain for agriculture which grows best in places where the topsoil is exposed and heavily disturbed [2]. It is an annual grass growing up to a half-inch-tall and has 2-3 leafy green culms that can be single or tufted. The culms are upright, light green, terete, glabrous, and occasionally glaucous. Every culm terminates in an upright flower spike that is around 2-4 inches in length. These flower spikes have profound markings and are greyish or bluish-green in color. Meanwhile, the central stalk of each floral spike, known as the rachis, is nearly erect and bears many overlapping spikelets crowded against it [2].

Providing 40% of energy calories and 20% of protein to the world's population, wheat is the most significant grain crop [3]. Because it includes substantial amounts of other essential nutrients including proteins and dietary fiber, along with lower levels of lipids, terpenoids, vitamins, minerals, and phytochemicals, wheat is a great source of nutrition [4]. Usually, dried wheat is ground into flour, which is then used to make a wide variety of flour-based food items, including cereal, bread, pasta, and a number of others. As per the US Department of Agriculture Survey 2024, the wheat yield in the US was recorded to be 48.6 bushels per acre in the year 2023 [5]. Inorganic fertilizers are being applied to the agricultural fields so as to maximize production to meet the increasing food demand of growing world population. However, this practice has adverse effect not only on environmental quality, but also causes pollution in surface and sub-surface water levels due to the leaching of nutrients [6].

Because of the imbalance application of fertilizers like NPK and some essential micro-nutrients, many agricultural crop yields have been reported to be affected adversely and wheat is one of them. Apart from influencing crop yields and quality, improper use of fertilizers contributes largely for reducing agricultural sustainability and causing environmental pollution. Providing soil with excessive synthetic chemical fertilizers causes loss of soil fertility eventually leading to reduced agricultural productivity. Chemicals are responsible for destroying physical properties of the soil making it unsuitable for growing healthy crops. Poor Nutrient Use Efficiency (NUE) of the applied fertilizers is also the result of haphazard fertilizer application. NUE is the indication of how effectively the crop transforms available nutrients into grain yield which also depends on the factors like different agronomic practices, the ratio between nutrient uptake and nutrient applied [7].

The organic manures have been used in farming since the beginning of human civilization. Those, in combination with each other and synthetic fertilizers have a great beneficial effect on plant growth and development [8]. The increasing adverse impacts of chemicals on soil coupled with their escalating price cannot be overlooked. Continuous application of chemical fertilizers is likely to impact the soil health even if used in balanced proportion [9]. This demands the incorporation of organic manure as a renewable source of nutrient. Non-chemical fertilizers like Farm Yard Manure (FYM), poultry manure, sheep manure and cow manure can be used as fertilizers to substitute the greater portion of chemical fertilizers in today's farming system. An adequate balance of organic and inorganic fertilizers is important not only for plant wellness and yield, but also for sustaining soil health through improved soil physical properties, nutrient availability, and soil organic carbon content [10]. Hence, an integrated approach of nutrient management in wheat is required to produce healthy wheat crops along with maintaining agricultural sustainability.

The concept of Integrated Nutrient Management (INM) focuses on incorporating manures along with the chemical fertilizers creating a balance of required crop nutrients which is important for better crop productivity and quality [11]. The possible antagonistic effects due to some hidden nutrient deficiency and imbalance can be minimized by providing the crop with balanced nutrition through INM approach. In this way, the amount of chemicals going into the soil reduces significantly improving the soil health in long term.

Nutritional Requirements of Wheat

Wheat crop requires around 17 different essential nutrients. They are available to plants in two forms: non-mineral and mineral nutrients. The non-mineral nutrients are Carbon (C), Hydrogen (H) and Oxygen (O) which are largely fulfilled by means of atmospheric air and water. Besides these, 14 other mineral nutrients need to be extracted from the soil by plant roots which are classified as macro and micro-nutrients on the basis of their quantity needed for sound growth of the crop. They have to be provided either by soil or in the form of manures so that the plant can use them for its proper growth and development. Macro-nutrients include Nitrogen (N), Phosphorous (P), Potassium (K), Sulphur (S), Calcium (Ca), and Magnesium (Mg). NPK are the primary macro-nutrients that are required in relatively large quantity.

Nitrogen (N): Wheat is more sensitive to Nitrogen than any other essential elements that are absorbed from the soil. N uptake starts in wheat as the roots begin to operate and continue until the plant is fully mature and no longer requires nutrients. Research shows that Nitrogen fertilization increases the flour protein content in wheat [12]. The early growth stage has been recorded with the highest amount of N, taking into account the future need of plant, that will be translocated to different parts of the plant when required and stored in kernels, leaves, and stem. In general, 70% of the N is stored in kernels and the remaining 30% is stored in culms [13].

Phosphorous (P): Phosphorous is a crucial element to carryout metabolic functions in plants. It also stimulates root development in the young plants and promotes early fruiting. Phosphorous is a component of Adenosine Triphosphate (ATP) which is often required as a source of energy in the synthesis of new molecules as well as uptake and transport of nutrients within the plant [14]. P is mostly stored in seeds to ensure proper germination and early growth before heavy root growth occurs.

Potassium (K): Potassium not only promotes the optimum growth and development in wheat crop; but also ensures better quality of the crop due to increased water use efficiency, improved photosynthetic efficiency and increased disease resistance. It is found abundantly in soil minerals and adsorbed to the soil particles and organic matter as K^+ ion. These ions are taken up by the plant roots, often through the process of osmosis. Unlike N and P, K can be combined into organic compounds in the plant tissues, however, remains in ionic form within the cells. After wheat is harvested and the straw is incorporated into the soil, a good amount (75%) of K is released back into the soil which can later be used by the crops [13].

The secondary macro-nutrients include Sulphur (S), Calcium (Ca) and Magnesium (Mg) which are required in less amount, but equally important to the growth of the plant. Sulphur is usually found in soil organic matter and clay minerals. It is a basic component of protein and helps the plant to form chlorophyll. Ca and Mg are present in soil and plant roots conveniently capture them as cations (Ca^{++} and Mg^{++}). Ca is the structural component of cell walls and plant tissues, while Mg has a significant role in the formation of chlorophyll molecules.

Micro-nutrients are also as important as the macro-nutrients for the optimum growth of crops. They include Manganese (Mn), Boron (B), Zinc (Zn), Iron (Fe), Nickle (Ni), Chloride (Cl), Molybdenum (Mo) and Copper (Cu). The only difference is that they are needed in comparatively low quantities. If a single nutrient is deficient or if any of the nutrients is not properly balanced with another, there is always some adverse effect or delay in the wheat crop's growth and development [13]. Therefore, proper nutritional balance should be of great concern to the wheat growers.

Table 1: Common Fertilizers Applied to Soil in South Dakota

Form of Fertilizers	N %	P_2O_5 %	K_2O %
Solid	33	0	0
Ammonium Nitrate	18-21	46-53	0
Di-ammonium Phosphate (DAP)			
Mono-ammonium Phosphate (MAP)	11-13	48-55	0
Liquid	28-32	0	0
Urea-ammonium-nitrate (UAN)			
Ammonium Polyphosphate	10	34	0
Gas	82	0	0
Anhydrous Ammonia			

(Source: Clay and Carlson, 2011)

Different forms of fertilizers have different requirements in terms of method of application and dose calculation. While selecting a specific fertilizer, certain factors need to be taken into consideration such as type of fertilizer, market price, concentration of nutrient, potential ways of nutrient loss and special handling requirements if applicable [15]. The ideal recommended dose of nutrients for wheat crops is shown in Table 2.

Table 2: Recommended Dose of Nutrients for Wheat

Nutrients	Quantity	Unit
Nitrogen	150	Kg/ha
Phosphorous	120	Kg/ha
Potassium	60	Kg/ha

(Source: Rasul et al., 2015)

The organic fertilizers used in wheat fields include cow manure, poultry manure, and sheep manure. The organic manures applied in crop fields act as chelating agents (chemical compounds that react with metal ions to form a stable, water-soluble complex) which hold the mineral nutrients removed from the soil. Moreover, the acid produced from the decomposition of organic matter increases the availability of mineral nutrients in the soil that can be used by plants [16].

Table 3: Nutrient content in some organic manures

Organic Manures	N %	Available P ppm	Soluble K^+ meq/L	Soluble Na^+ meq/L
Cow Manure	1.17	448.85	25.38	23.38
Poultry Manure	1.72	451.61	117.95	117.95
Sheep Manure	1.48	273.43	12.05	12.05

(Source: Rasul et al., 2015)

Factors Affecting Wheat's Response to Applied Mineral Fertilizers

Mineral fertilizers have been a crucial component of farming since the green revolution. Yield in many crops has been evidenced to be escalated after the trend of applying NPK fertilizers [14]. The absorption of applied fertilizers has a great dependency on the availability of nutrients in the soil and their possible losses. Apart from this, there are some other factors that influence the crop's response to applied fertilizers.

1. Wheat Varieties

The high-yielding wheat varieties are usually more efficient in using applied mineral nutrients as compared to those having lower yield potential [13]. Wheat cultivars are categorized as nutrient-efficient and non-efficient on the basis of the wheat crop yield. The varieties that can better respond to the applied fertilizers have various advantages such as reduced rate of fertilizers, robust seedlings and better resistance to plant stress conditions. Therefore, considering the crop productivity and quality of the grains, nutrient-efficient varieties should be grown.

2. Time of Planting

Time of planting affects the crop yield. Early planting increases the incidence of disease and insect pests while delayed planting may result in less chances of crop survival and reduces crop productivity. Around a 34% decrease in wheat grain yield is evidenced when the wheat is sown 1 month later than the usual sowing date [17]. Thus, because of the lower yield potential, late-sown wheat crops do not exhibit good response to the applied fertilizers which can be a result of moisture/heat stress to the crop.

3. Available Soil Nutrients

While planting a crop, soil test is important to know the plant-available nutrients present in soil. If the soil has lower levels of available nutrients, there will be need of more mineral fertilizers and vice-versa [13]. In most cases, wheat growers have been focusing more on primary nutrients like Nitrogen which leads to the excessive application of N and losses through leaching causing environmental pollution and animal as well as human health hazards.

4. Soil Moisture Content and Irrigation

Water is essential for physiological development and metabolic functions in the wheat crop. The movement of nutrients applied to the soil depends on the frequency and amount of irrigation. The amount of irrigation and availability of Nitrogen are interdependent to each other. Soil moisture content influences the uptake of Nitrogen by wheat plant through mass flow and diffusion which is also accompanied indirectly by root interception. A study suggests that early irrigation when coupled with adequate Nitrogen application exhibits maximum rooting in wheat crops [18].

5. Soil Texture

The texture of the soil, although does not directly influence the release of mineral fertilizers, has more or less impact in soil moisture holding capacity and soil temperature. Clay soil has good nutrient holding capacity, while sandy soil possesses a risk of nutrient leaching. Similarly, loamy soils have better nutrient holding capacity as compared to other types of soil [19].

6. Temperature

Higher soil temperature increases the rate of nutrient release in soil. Soil temperature often depends on the type of soil, condition of soil (such as bare or mulched) which eventually has an impact in the release of mineral fertilizers in the soil. Variation in daytime temperature could also be a factor influencing the rate of soil mineral release [20].

7. Diseases

Crop health highly influences the uptake of nutrients and nutrient uptake also depends on the health of the crop. It is likely that diseased plants show less response to the applied fertilizers as compared to the healthier ones. Wheat crops are prone to root diseases when roots absorb excess of N in the form of NO_3, meanwhile it is better for the roots take up N in the form of NH_4 [13].

8. Weeds

Various weeds compete with wheat plants for nutrients, light and moisture. The application of fertilizers, specifically N, encourages the growth of weeds along with the wheat crop in the field. Therefore, weeds need to be controlled to eliminate them from competing with the wheat plants. There are various techniques and timing of fertilizers placement with the seed while planting that successfully suppress the weeds. Applying different quantities of fertilizers can adversely affect weed density and dry weight [21].

Need for Integrated Nutrient Management (INM) in Wheat Production

As the unsustainability in production is proven to be a great threat in modern agriculture system, the integrated nutrient management (INM) technique would best address this issue. Sustainability in production is possible by incorporating non-chemical fertilizers in crop fields where the application of only the synthetic fertilizers has been practiced for years. Combining organic manures with inorganic fertilizers has been reported to increase the efficiency of all fertilizers applied to wheat crop along with adding the organic matter content in soil which would improve the water holding capacity of the soil [22]. The continuous availability of organic manures in the fields also eradicate the deficiency of several secondary macro-nutrients and micro-nutrients [23]. It is evident from previous researches that the application of organic manures in conjunction with chemical fertilizers shows great influence in reducing nutrient losses to the environment by converting inorganic nitrogen into organic forms and thus contributes for minimizing the environmental issues that could have been observed [24].

The INM technique also aids in improving the quality of produced wheat kernels.

The sole use of chemical fertilizers improves the crop yield in short term but leaves behind hazardous effects by impairing soil characteristics and degrading environmental quality in long term which would take decades to be eradicated. Therefore, the balanced use of chemical fertilizers and organic manures is beneficial in order to maintain crop yield, soil fertility and environmental quality in the long-term.

Conclusion

Though NPK are the primary macro-nutrients needed for the proper growth and development of wheat, the importance of other macro and micro-nutrients can't be overlooked. The nutritional requirements of wheat crop should be fulfilled together by the use of organic and inorganic fertilizers to get the optimum yield. The uptake of applied mineral fertilizers is dependent on several factors including edaphic, environmental and cultural management factors. The adverse effect in soil health due to the sole application of chemical fertilizers can be minimized by the organic matter present in manures like cow manure, poultry manure, and sheep manure. In addition, organic manures are also active in holding nutrients in soil and increasing their availability to the crop which otherwise would be wasted. Hence, as emphasized by the INM technique, organic manures should be incorporated with chemical fertilizers while cultivating wheat crop to obtain sustainable wheat yield and improve soil fertility in long-term.

References

1. Farook, U. B., Khan, Z. H., Ahad, I., Maqbool, S., Yaqoob, M., Rafieq, I., ... & Sultan, N. (2019). A review on insect pest complex of wheat (Triticum aestivum L.). *Journal of Entomology and zoology studies*, *7*(1), 1292-1298.

2. Moshawih, S., Abdullah Juperi, R. A. N. A., Paneerselvam, G. S., Ming, L. C., Liew, K. B., Goh, B. H., ... & Kifli, N. (2022). General health benefits and pharmacological activities of Triticum aestivum L. *Molecules*, *27*(6), 1948.

3. Kumar, P., Sarangi, A., Singh, D. K., Parihar, S. S., & Sahoo, R. N. (2015). Simulation of salt dynamics in the root zone and yield of wheat crop under irrigated saline regimes using SWAP model. *Agricultural Water Management*, *148*, 72-83.

4. Adom, K. K., Sorrells, M. E., & Liu, R. H. (2003). Phytochemical profiles and antioxidant activity of wheat varieties. *Journal of agricultural and food chemistry*, *51*(26), 7825-7834.

5. US Department of Agricultural Survey, 2024.

6. Baker, J. L., & Johnson, H. P. (1981). *Nitrate-nitrogen in tile drainage as affected by fertilization* (Vol. 10, No. 4, pp. 519-522). American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

7. Salvagiotti, F., Castellarín, J. M., Miralles, D. J., & Pedrol, H. M. (2009). Sulfur fertilization improves nitrogen use efficiency in wheat by increasing nitrogen uptake. *Field Crops Research*, *113*(2), 170-177.

8. Channabasana Gowda, C. G., Patil, N. K. B., Patil, B. N., Awaknavar, J. S., Ninganur, B. T., & Ravi Hunje, R. H. (2008). Effect of organic manures on growth, seed yield and quality of wheat. *Karnataka Journal of Agricultural Sciences,* 21(3), 366-368.

9. Zia, M. S., Mann, R. A., Aslam, M., Khan, M. A., & Hussain, F. (2000, April). The role of green manuring in sustaining rice-wheat production. In *Proc. Symp."Integrated Plant Nutrition Management", NDFC, Islamabad, Pakistan* (pp. 130-149).

10. Weber, J., Karczewska, A., Drozd, J., Licznar, M., Licznar, S., Jamroz, E., & Kocowicz, A. (2007). Agricultural and ecological aspects of a sandy soil as affected by the application of municipal solid waste composts. *Soil biology and biochemistry*, *39*(6), 1294-1302.

11. Sachan, S., Singh, D., Kasera, S., Mishra, S. K., Tripathi, Y., Mishra, V., & Singh, R. K. (2017). Integrated nutrient management (INM) in Okra (Abelmoschus esculentus (L.) Moench) for better growth and higher yield. *Journal of Pharmacognosy and Phytochemistry*, *6*(5), 1854-1856.

12. Johansson, E., Prieto-Linde, M. L., & Svensson, G. (2004). Influence of nitrogen application rate and timing on grain protein composition and gluten strength in Swedish wheat cultivars. *Journal of Plant Nutrition and Soil Science*, *167*(3), 345-350.

13. Panhwar, Q. A., Ali, A., Naher, U. A., & Memon, M. Y. (2019). Fertilizer management strategies for enhancing nutrient use efficiency and sustainable wheat production. In *Organic farming* (pp. 17-39). Woodhead Publishing.

14. Brady, N. C., & Weil, R. R. (2008). Soil colloids: seat of soil chemical and physical acidity. *The Nature and Properties of Soils*, *5*(13), 311-358.

15. Clay, D.E., and C.G. Carlson. 2011. "Fertilizers used in wheat production." In Clay, D.E., C.G. Carlson, and K. Dalsted (eds). iGrow Wheat: Best Management Practices for Wheat Production in South Dakota. South Dakota State University, South Dakota Cooperative Extension Service, Brookings, SD.

16. Rasul, G. A. M., Ahmed, S., & Ahmed, M. Q. (2015). Influence of different organic fertilizers on growth and yield of wheat. *American-Eurasian Journal of Agriculture and Environmental Science*, *15*(6), 1123-1126.

17. El-Gizawy, N. K. B. (2009). Effect of planting date and fertilizer application on yield of wheat under no till system. *World J. Agric. Sci*, *5*(6), 777-783.

18. Gajri, P. R., Prihar, S. S., & Arora, V. K. (1989). Effects of nitrogen and early irrigation on root development and water use by wheat on two soils. *Field Crops Research*, *21*(2), 103-114.

19. Carson, L. C., & Ozores-Hampton, M. (2013). Factors affecting nutrient availability, placement, rate, and application timing of controlled-release fertilizers for Florida vegetable production using seepage irrigation. *HortTechnology*, *23*(5), 553-562.

20. Husby, C. E., Niemiera, A. X., Harris, J. R., & Wright, R. D. (2003). Influence of diurnal temperature on nutrient release patterns of three polymer-coated fertilizers.

21. Gerami, F., Aynehband, A., & Fateh, E. (2012). Weed suppression in wheat (Triticum aestivum L.) by legume and non-legume green manures along with different N fertilizer levels. *Intl J Agri Crop Sci*, *4*(9).

22. Hati, K.M., A. Swarup, A.K. Dwivedi, A.K. misra and K.K. Bandyopadhyay. 2006. Changes in soil physical properties and organic carbon status at the topsoil horizon of a vertisol of central India after 28 years of continuous cropping, fertilization and manuring. Agriculture, Ecosystem and Environment Doi: 10.1016/J. Agee. 2006.06.17.

23. Chand, S., Anwar, M., & Patra, D. D. (2006). Influence of long-term application of organic and inorganic fertilizer to build up soil fertility and nutrient uptake in mint-mustard cropping sequence. *Communications in Soil Science and Plant Analysis*, *37*(1-2), 63-76.

24. Chondie, Y. G. (2015). Effect of integrated nutrient management on wheat: A Review. *Journal of Biology, Agriculture and Healthcare*, *13*(5), 68-76.