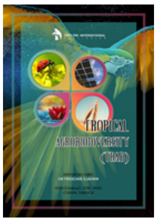
Tropical Agrobiodiversity (TRAB)

DOI: http://doi.org/10.26480/trab.01.2020.18.23

ISSN: 2716-7046 (Online)
CODEN: TARGCA



RESEARCH ARTICLE

ROLE OF NUTRIENTS IN WHEAT: A REVIEW

Meena Pandey[a]*, Jiban Shrestha[b], Subash Subedi[c], Kabita Kumari Shah[d]

[a]Institute of Agriculture and Animal Science, Paklihawa Campus, Tribhuwan University, Rupandehi, Nepal
[b]Nepal Agricultural Research Council (NARC), Agriculture Botany Division, Khumaltar, Lalitpur, Nepal,
[c]National Maize Research Program, NARC, Rampur, Chitwan, Nepal
[d]Gokuleshwor Agriculture and Animal Science College (GAASC), Tribhuwan University, Baitadi, Nepal
****Corresponding author email: pandeymeena999@gmail.com***

ARTICLE DETAILS

Article History:

Received 28 May 2020
Accepted 15 June 2020
Available online 18 June 2020

ABSTRACT

Wheat (*Triticum aestivum* L.) is an important cereal crop that provides ample nutritious calories for humans and animals. The nutrient plays a vital role in the production of wheat. In this review, previous works were evaluated to investigate the role of nutrients, nutrient deficiency and toxicity in wheat. Both macro and micronutrients are necessary for wheat plants. Every nutrient has its own character and is involved in different metabolic processes of plant life. Nutrient deficiency and toxicity conditions inhibit normal plant growth and exhibit characteristic symptoms. For optimal growth, development, and production, plants need all the necessary nutrients in balance. A balanced application of the primary nutrients (N, P, K), secondary nutrient (S) and some other micronutrients (Zn, B) are needed to enhance wheat production. The soil tests and the demand for crop nutrients should be assessed to identify the quantity of fertilizer recommended for the crop. This study would be a valuable means to wheat growers and researchers for sustainable and higher wheat production.

KEYWORDS

Wheat, nutrients, deficiency, toxicity

1. INTRODUCTION

Wheat (*Triticum aestivum* L.), a member of the Poaceae family, is one of the second main grain crops in the world. It is the important staple food of the world which meets most of the protein requirement of the people. In 2017/2018, wheat output exceeded 761.7 million tonnes, and in 2019/2020, global demand was projected to reach 762.4 million tonnes (FAO, 2020). The wide uses of wheat gluten are mainly baked breakfast, and analog meat products (Sarkki, 1979). Wheat is often commonly used for crumpets, cookies, flake, chapatis, bread, biscuits, noodles, flour, and grain to livestock, sales, roasted grain, and so forth. As the population increases exponentially, the production of wheat needs to be increased in order to fix the gap between growth and consumption.

Wheat is subjected to many biotic and abiotic pressures regardless of their poor productivity. In addition, there is inconsistency and improper use of fertilizers, lack of information on variants, edaphic features, mismanagement of farmers' field operations, and technology (Ali et al., 2018; Kumar et al., 2005; Meena et al., 2013). The requirement for wheat fertilizer depends on the accessibility of the crops to the soil (Krentos and Orphanos, 1979). Before using fertilizer, it is essential to recognize the condition of the soil's nutritional condition and plant nutrient uptake. Crops cannot respond well to fertilizer present in soil under inadequate moisture and humidity. Plants under fertilization require additional moisture than plants which are not in fertilization (Ralph and Ridgman, 1981). Besides, the water, nutrient absorption, and the stress response differ from the plant species and their genotypes. A cultivar that performs best in one type of soil can perform poorly in the other type of soil, and vice versa (Adhikari et al., 2019).

The organic manure alone cannot satisfy the nutrient demand, the wheat plant generates low yield (Sheoran et al., 2017). Application of chemical fertilizers to wheat in a timely manner and consequently increases the production of wheat (Lewis et al., 1938). A report that the optimal use of mineral fertilizers and organic manures increases plant inputs, crop field, and water use efficiency (Zhang et al., 2016). The growth character of wheat is evolving dramatically in the inoculation of biological fertilizers in wheat (Ahmed et al., 2011). It enhances the survival of tiller until harvest (Singh and Turkhede, 1986).

There are different methods to apply the micronutrients such as seed priming, soil application and fortification but the foliar application is more beneficial. A group researchers stated that spraying micronutrients root growth in wheat can be improved which increases in uptake of macro and micronutrients (Bameri et al., 2012). Micronutrients promote the good, strong and steady growth of plants that produce higher yields and increase the harvest of produce. Deficiency of micronutrients such as iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), boron (B), molybdenum (Mo) increased in crops worldwide in recent years.

Many factors which cause deficiency problems are intensification in the cropping system, chemical fertilizers (NPK), over liming of acid soils, and the increased demand of high-yielding varieties to feed the global population (Fageria et al., 2007). Ziaeian and Malakouti observed that fertilization of Fe, Mn, Zn and Cu significantly increased grain and straw yield, test weight, and the number of grains per spikelet (Ziaeian and Malakouti, 2001). In other studies, the scientist observed that when micronutrients (Fe, Mn, Zn, Cu and B) applied at different growth stages of wheat by foliar application significantly increased the plants' height,

Quick Response Code	Access this article online	
	Website: www.trab.org.my	**DOI:** 10.26480/trab.01.2020.18.23

Cite the Article: Meena Pandey, Jiban Shrestha, Subash Subedi, Kabita Kumari Shah (2020). Role of Nutrients in Wheat: A Review. *Tropical Agrobiodiversity, 1(1): 18-23.*

grains per spike, test, weight, biological yield, harvest index, straw and grain yield etc (Khan et al., 2010).

The knowledge of micronutrient status and relationship with other soil properties is vital to the management strategies to be adopted for sustainability and improve crop production. Assessment of soil fertility status at production fields can help draw sound nutrient management. The amounts of nutrients required can be derived from soil testing and nutrient removal by grains and straw. The nutrient requirement varies considerably depending on soil fertility, climate conditions, cultivar characteristics, and yields. The balanced use of macronutrients and micronutrients is vital role in crop nutrition for improved yield and quality (Saeed et al., 2012). Balanced application of micronutrient application will significantly improve the yield attributes of wheat crop such as leaf area index (LAI), leaf area duration, crop growth rate, net assimilation rate, relative growth rate plant height, spike length, spikelet's/ spike, grains/spike, test weight, tillers per square meter, grain yield, chlorophyll content, biological yield as well as harvest index etc.

The balanced application of fertilizers increases the efficiency of fertilizer use and increases the physical, chemical, and biological environment of the soil, which leads to an increase in crop yield. The main objective of this study was to provide the information on the role of different nutrients on the growth and productivity of wheat.

2. ROLE OF NUTRIENTS IN WHEAT

2.1 Nitrogen (N)

Nitrogen is part of an essential component in cells, including amino acids, nucleic acid, photosynthetic pigment, protein, and enzymes. (Bungard et al., 1999). The use of nitrogen enhances photosynthesis accumulation (Lawlor et al., 1989). Nitrogen needs for cereals vary from different growth phases (Akhter et al., 2016; Biljana and Aca, 2009; Tranaviciene et al., 2008).

The content of chlorophyll dictates the amount of nitrogen the plants require. The amount of chlorophyll was significantly linked to the concentration of nitrogen in the wheat plant and the leaves (Akhter et al., 2016; Schlichting et al., 2015). Using the appropriate nitrogen sum at the proper moment will help us achieve the estimated wheat production. A significant increase in grain and straw is also accomplished through the application of nitrogen fertilizers for wheat. Nitrogen is normally added to the soil at three splits.

One-third of nitrogen was utilized during the sowing cycle and the other one third was during the first irrigation. Also, the remaining application of nitrogen was done after second irrigation. Various areas of studies have suggested that the implementation of the varying rates of nitrogen fertilizers at various times with diverse application techniques enhanced the wheat production (Long and Sherbakoff, 1951; Wahhab and Hussain, 1957). For irrigated areas, the output of wheat to nitrogen is greater than unirrigated.

Nitrogen absorption in the wheat plants is enhanced from emergence to tillage. Nitrogen treatment enhances the wheat production added at seeding or throughout the early season despite influencing the protein quality of the wheat.

The usage of nitrogen above 151 kg ha^{-1}, when the field is insufficient with N, is not advantageous (Gasser and Thorburn, 1972). Elevated N rates significantly increase the risk of lodging and disease, and although increasing the production of protein, grain protein. The number of kernels per spike, number of spikes per head, and test weight did not impact the germination due to nitrogen.

The number of plant tilers, mature heads, and weight of the tests are enhanced by nitrogen (Camberato and Bock, 1990; Wahhab and Hussain, 1957). The production of the semi-dwarf varieties are somewhat reduced, despite extra nitrogen (Pearman et al., 1978). The capacity and the meteorological state of the wheat field dictates how much nitrogen is absorbed by the wheat plants. The 90 kg N ha^{-1} the formulation in granulated form improved the yield of grain protein 13.0% and 33.7%, and yield by 12.4% and 6.1% respectively for irrigated and non-irrigated area (Pushman and Bingham, 1976).

In the availability of nitrification inhibitors such as EAS (enhanced ammonium supply), the grain dry matter enhances with the proportion of nitrogen as NH4 (Camberato and Bock, 1990). The nitrogen source does not significantly impact the row length of tillers but increased tiller length and plant height (Sharma et al., 2016).

The wheat grains were significantly increased when nitrogen was incorporated to over 40 kg ha^{-1} to 80 kg ha^{-1}. The usage of wheat has been declining by weight from 0 to 80 kg N ha^{-1} of 1000 grams of wheat (Sharma et al., 2016). Treatment with Nitrification Inhibitors can focus on improving vegetative tiller per plant (Camberato and Bock, 1990).

2.2 Phosphorous (P)

Phosphorus is an essential part of numerous physiological functions such as energy accumulation and transmission, photosynthesis, respiration, cell differentiation, and cell expansion, which implies energy-rich phosphate compound synthesis as ATP, ADP. Phosphoproteins, nucleic acids, nucleotides, phospholipids, are also essential components (Anwar, 2016).

The central component in plant metabolism is phosphorus. Throughout the plant's initial developmental process, the necessity for phosphorous is paramount. The slight mottling of the oldest leaves in P has a deficient plant and the leaves appear to be dark green. P deficit leaves are more coiling than younger leaves, also sometimes found on older leaves are covered with young leaves, and lately the maturity of plants with little heads.

The plant takes up P easily after irrigation 3-4 weeks following germination (Iqbal et al., 2003). The amount of phosphorus from wheat is not impaired by the fertilizers containing phosphates. The plants will persist in adverse environmental effects with Phosphorous (Jamal and Fawad, 2019). Required plant phosphorus, seed moisture, and corresponding precipitation enhance phosphorus fertilizer heat yield (Power et al., 1961). When NP fertilizer is applied, phosphorous composition in wheat is significantly higher than phosphate alone.

Absorption of N may proceed until the soft dough, though P is restrictive. When both Na and P are restricted, N soil absorption proceeds until the plants mature (Boatwright and Haas, 1961). The agricultural dimensions such as plant height, grain number per spike, grain weight, and test weight dramatically improved with treatments of 180 kg of N ha^{-1} and 90 kg of P_2O_5 (Ibtida, 2010).

When wheat was provided P at 90 kg ha^{-1}, the production of wheat was substantially enhanced from 2920 kg ha^{-1} up to 3560 kg ha^{-1}; the yield was increased by 22% and the number of lengths, tillers, spikes, and wheat plants was substantially higher (Khan et al., 2007).

The experiment performed during the Rawalpindi season demonstrated better outcomes of wheat than triple superphosphate (TPS), nitrophos, diammonium, and phosphate (DAP) when P was used at the rate of 80 kg P ha^{-1} as single superphosphates (SSP) (Khan et al., 2010). Applied phosphorus to 90 kg of P_2O_5 ha^{-1}, the largest amount was obtained with tillers per square meter (558) and spike per meter square (388) and length of the spike (11.2 cm) and its height (106.6 cm). P toxic effects cause mottled chlorosis on the margin of the leaf as well as on the end of the oldest leaf that becomes necrotic. The leaf is chlorosis and transforms into a glossy yellow on the bottom, but the core of the plants remains green (Snowball and Robson, 1991).

2.3 Potassium (K)

For plants including osmoregulatory, cellular extension, stomach regulation, enzyme activation, protein synthesis, photosynthesis, phloem loading, and transport and uptake, potassium is indispensable for plants in various phenomena (Pushman and Bingham, 1976). The K absorption by plants is significantly impacted by growth rate and plant composition. The concentration of K at the root and the plant surface determines K demand (Barnes et al., 1976). K can significantly reduce the region of the upper leaves, depending on environmental factors and culture. In the ears and upper internodes, it may also decline the dry matter, the number of grains per unit surface, and grain size (Ralph and Ridgman, 1981). Until going for wheat the strongest demand is for potassium (Gasser and Thorburn, 1972).

As we incorporated 90 kg K_2O and the maximum grain production on the application of 30 kg ha^{-1} K_2O, the highest spike length was achieved. The production of wheat grain was documented to be enhanced respectively by 27.34% and 30.03% with 60 and 90 kg ha^{-1} K_2O applications (Brhane and Mamo, 2017). No mechanism has been reported to stimulate the production of wheat by the insufficiency of potassium content in the soil (Ralph and Ridgman, 1981).

2.4 Sulfur (S)

Sulfur is a building block of protein and a key ingredient in the formation of chlorophyll. Without adequate Sulfur, crops cannot possibly reach their full potential in terms of yield or protein content. S is important in plants because it contributes to the synthesis of amino acids and the production of secondary metabolites. In wheat plant S deficit is not thoroughly explored as an assessment is conducted in the absence of NPK. Owing to major declines in atmospheric, S deficit in cereal crops and Brassica became triggered (Zhao et al., 1999).

The application of Sulfur is not negatively impacted by wheat yield and protein concentration (Karamanos et al., 2013). For optimized growth, the demand for wheat is approximately 15-20 kg ha^{-1}. The usage of 25 kg S ha^{-1} did not impede the production of wheat grain and protein but the improved output of (80-100 kg N ha^{-1}) by the usage of when used with the addition of Sulfur (Karamanos et al., 2013). In winter, S intakes vary from 15 to 25 kg ha^{-1} in the non-deficient condition while total absorption in S deficit soil becomes less than 15 kg ha^{-1} (Zhao et al., 1999). As atmosphere sulfur fulfills its plant requirements, Sulfur additions to wheat and crop plants were not of a complaint. Conversely, the demand for S nutrient in the plant has intensified because of the impact of acid on the natural environment (Zhao et al., 1997).

2.5 Boron (B)

Marschner reported that Boron is essential for cell division and elongation in meristematic tissues, floral organs and for flower male fertility, pollen tube germination along with its elongation and seed/fruit formation (Marschner, 1995). In addition, in Boron deficient soil seeds generate abnormal seedlings. Boron has a low demand for wheat. Yet wheat is vulnerable to Boron deficiency (Martens and Westermann, 2018). The prime area in which B-deficiency of wheat has been identified is adjacent to eastern Nepal, northwest Bangladesh, northeast India, and south-west China (Rerkasem and Jamjod, 2004). The Boron deficit in higher plants allows the root elongation to be abandoned (Gupta, 1983).

Boron deficiency induces a longitudinal differentiation of younger leaves near the midrib in a young wheat field, and sawtooth results grow at the edge of young leaves (Dell and Robinson, 1993). During the anthesis, the first sign of a plant with B defect can be identified (Rerkasem and Jamjod, 2004). The paucity of B provokes wheat sterility; male sterility and wheat have minimal demands at vegetative period than reproductive prerequisites for B.

The B deficit also influences the germination of pollen and processes of fertilization (Cheng and Rerkasem, 1993). Both Bangladesh and Nepal, the prevalence of wheat sterility due to boron deficiency has often been considered to be significantly dynamic (Saifuzzaman and Meisner, 1996; Sthapit, 1988).

The dry matter production of wheat in all implemented Zn levels is reduced significantly by excess boron (Singh et al., 1990). Abundance B disrupts plant biochemical processes, triggering changes in metabolism and also negatively impacting photosynthesis processes, which significantly reduces the division of root cells (Cervilla et al., 2009; Metwally et al., 2016). Abundance Boron also impairs photo-oxidant distress resistance (Cervilla et al., 2009).

2.6 Zinc (Zn)

Zn is important for plant growth, as plants require a proper balance of all the essential nutrients for normal growth and optimum yield. It contributes to stronger emergence, faster stand establishment, healthier root growth, greater plant vigor and increased yield. Boron absorption enhances plants that have toxic effects in wheat if there is a Zinc deficit (Singh et al., 1990). Likewise, the deficiency in Zn stimulates the uptake of phosphorous into older leaves up to toxicity (Webb and Loneragan, 1988).

The minimum straw yield of 3,436 kg ha^{-1} and a minimal harvest yield of 39% of lowest production was observed in adding zinc in a pace of 15 kg ha-1, the maximum proportion of tillers was 335 m^2, the highest production of 3354 kg ha-1 and the highest plant height was 85 cm, maximum straw production was 4307 kg ha-1 with a maximum biological production of 7785 kg ha^{-1}, the largest yield of 43% and the highest height of 78 cm. In the index of the leaf region, zinc has no measurable effect (Jan et al., 2013). The nutrients and their functions in wheat plant is given in Table 1.

Table 1: Nutrients and their functions in wheat

SN	Nutrient	Functions	References
1	Nitrogen (N)	The plant height and the number of tillers are enhanced. The synthesis of enzymes, nucleic acids (DNA, RNA), proteins, hormones, vitamins, alkaloids, and so on has a significant role to play.	(Agrinfobank, 2019)
2	Phosphorus (P)	Energy and protein metabolism transport has a critical part to play. Sugar Phosphates, phospholipids, co-enzymes, Nucleotides, and nucleic acids are essential to this field.	(Agrinfobank, 2019)
3	Potassium (K)	It tends to make ionic control and osmotic easier and necessitates a co-factor or activator of over 40 enzymes. This offers disease tolerance and drought protection.	(Agrinfobank, 2019)
4	Sulfur (S)	Bonds that are vital for sustaining the protein structure in wheat and also help sustain the viscoelastic properties of wheat gluten are the production of sulfhydryl (S-H).	(Naeem and MacRitchie, 2003)
5	Boron (B)	This is regarded as critical plant meristem cells to grow and develop. The formation of flowers, pollen germination, and cation absorption are essential	(Agrinfobank, 2019)
6	Zinc (Zn)	It is an integral part of several enzyme processes (for example dehydrogenase, carbon dioxide, protease, peptidase, and dehydrogenase of alcohol).	(Agrinfobank, 2019)

3. NUTRIENT INTERACTION AND DEFICIENCY

Awareness of the interaction between nutrients can prompt fertilization studies and optimize fertilization approaches for higher returns and high output in nutrient use (Rietra et al., 2017). Nutrient interactions take place when a nutrient's supply influences the absorption, dispersion, or function of some other nutrient. The relationship will affect plant growth and yield depending on nutrient availability. The relationship seen between the availability of nutrients and the accumulation of nutrients inside the plant and the correlation between the production of nutrients and plant growth can be assessed (Robson and Pitman, 1983). Antagonistic (detrimental) nutrient associations should be reduced in the production with fertilizers of the correct nutritional content thus optimizing synergistic (significant) nutrient interactions to maximize nutrient usage effectiveness. Such practices include an effective understanding of potential detrimental and significant nutrient associations (Rietra et al., 2017). The antagonistic interactions of nutrients are given in Table 2.

Interaction between nutrients in crop plants occurs when the supply of one nutrient affects the absorption and utilization of other nutrients. Nutrient interaction was shown in Table 3.

Table 2: Antagonistic interaction of nutrients

SN	Excess element	Nutrients affected
1	Nitrogen	Potassium, calcium,
2	Potassium	Nitrogen, calcium, magnesium,
3	Phosphorus	Zinc, copper, iron,
4	Iron	Manganese
5	Magnesium	Calcium, potassium
6	Sodium	Potassium, magnesium, calcium,
7	Copper	Molybdenum, manganese, zinc, iron
8	Calcium	phosphorus, magnesium, Boron
9	Molybdenum	Iron, copper
10	Zinc	Manganese, Iron
11	Sulfur	Zinc, manganese, iron, molybdenum

(Source: Rietra et al., 2015; Rx Green Technologies, 2020)

Cite the Article: Meena Pandey, Jiban Shrestha, Subash Subedi, Kabita Kumari Shah (2020). Role of Nutrients in Wheat: A Review.
Tropical Agrobiodiversity, 1(1): 18-23.

Table 3: Nutrient Interaction and Plant Nutrition

SN	Nutrient Interaction
1	The low levels of N, S and Mg showed high absorption of Mn and low uptake of Fe.
2	Zn deficiency is most common under excess P conditions
3	Excess Zn may induce Fe deficiency
4	Excess P indirectly affects plant growth by reducing Fe, Mn and Zn uptake;
5	Use of K reduces Mn and Fe levels in a rice plant
6	Increasing the pH value by applying lime reduces the availability of Zn for plants.
7	Iron toxicity occurs in acidic soils
8	A high iron content in the soil inhibits the absorption of copper
9	Zn application inhibits extractable Fe
10	Zinc deficiency occurs in normal and saline-sodic soils

(Source: Das, 2014; McCauley, 2011).

Deficiencies of zinc, iron, phosphorus and sometimes calcium, potassium and magnesium when soil pH is greater than 8.0. At soil pH greater than 8.0, the toxicity of Boron and sodium occur (Marschner, 1995). At soil pH 7.5-8.5, deficiency of iron, zinc, phosphorus and sometimes manganese occur (Marschner, 1995). Due to nitrogen deficiency plants become pale green to yellow with chlorosis beginning on lower leaves and progressing upwards as the deficiency intensifies; plants have spindly stems and growth is slow. Plants with a phosphorous deficiency may remain darker green than normal plants and develop purple discoloration first on the underside and later throughout. When P deficiency is severe, leaf tips may die back. Plants grow slowly, stems are thin and shortened and maturity is delayed. P deficient plants also exhibit poor tillering.

Potassium deficiency is initially manifested as chlorosis on the older leaves and progresses upwards as the deficiency intensifies. Deficiency symptoms can occur in young leaves of some fast-maturing high-yielding varieties. Because of K deficiency, the leaves eventually become streaked and take on a scorched appearance along the leaf margins. Chlorotic areas may develop throughout the leaf. Stems of deficient plants are weak and tend to lodge. The deficiency of K resulted in decrease in yield (Ali et al., 2005). In wheat Zinc deficiency appears as interveinal chlorosis on the most recently developed leaves; plants are stunted and produce few tillers; if the deficiency is severe the leaves may turn white and die. Zinc deficiency symptoms are reductions in plant height and leaf size. These symptoms are followed by the development of whitish-brown necrotic spots on middle-aged leaves.

As the severity of zinc deficiency intensifies, the necrotic spots spread on top leaves, and the middle parts of the leaves are often collapsed, showing a “scorched” appearance. Crops are grown on zinc-deficient soils exhibit chlorotic or necrotic spots on leaves, the short stature of plants, uneven crop stand, delayed maturity, improperly developed fruits, decreased yield and low nutritional quality (Broadley et al., 2007; Alloway, 2008). The effects of low B reducing male fertility by impairing microsporogenesis and pollen tube growth are well known in wheat (Dell and Huang, 1997). Deficiency of B reduces grain set resulting in an increased number of open spikelets and decreased number of grains per spike (Rerkasem and Jamjod, 1997). Sulfur is an essential plant nutrient for crop production required for protein and enzyme synthesis as well it is a constituent of the some of the amino acids (Scherer, 2001). So an insufficient S supply can affect both the yield and quality of the crops. The diagnostic key for identifying nutrient deficiency in wheat is given in Figure 1.

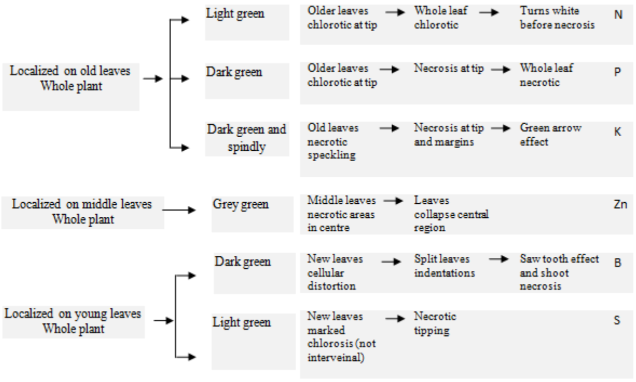


Figure 1: Diagnostic key for identifying nutrient deficiency in wheat (Source: Snowball and Robson, 1991)

4. CONCLUSION

Wheat is the important staple food and meets most of the protein requirement of the globe. The multiple nutrient deficiencies are the key factors that reduce the yield and profit. Wheat crop requires nitrogen, phosphorous, potassium, sulfur, boron, iron and zinc for its proper growth and development. The proper management of nutrients is necessary for a successful crop production. Nutrient deficiencies and toxicities decrease crop health and productivity. The cautious nutrient supply at the right time, right rate and right place have a tremendous effects on wheat yield. The appropriate dosage of nutrients in balance manner helps to increase the crop yield and ensure the health and consistency of soils and the environment.

CONFLICT OF INTEREST

The authors declared that they have no conflicts of interest.

ACKNOWLEDGMENT

The authors received no specific financial support for the reviewing, authorship, and/or publication of this article.

REFERENCES

Adhikari, M., Adhikari, N., Sharma, S., Gairhe, J., Bhandari, R., Paudel, S., 2019. Evaluation of Drought Tolerant Rice Cultivars Using Drought Tolerant Indices under Water Stress and Irrigated Condition. American Journal of Climate Change, 8, Pp. 228-236.

Agrinfobank., 2019. Micronutrients and Macronutrients in Rice Production. *https://agrinfobank.com.pk/micronutrients-and-macronutrients-in-rice-production/*

Ahmed, M.A., Amal, G.A., Magda, H.M., Tawfik, M.M., 2011. Integrated effect of organic and biofertilizers on wheat productivity in new reclaimed sandy soil. Res. J. Agric. and Biol Sci., 7 (1), Pp. 105–114.

Akhter, M.M., Hossain, A., Timsina, J., Teixeira da Silva, J.A., Islam, M.S., 2016. Chlorophyll meter-A decision-making tool for nitrogen application in wheat under light soils. International Journal of Plant Production, 10 (3), Pp. 289–302. DOI: https://doi.org/10.22069/ijpp.2016.2898

Ali, H., Ahmad, S., Ali, H., Hassan, F.S., 2005. Impact of nitrogen application on growth and productivity of wheat (*Triticum aestivum* L.). J. Agric. and Soc. Sci., 1 (3), Pp. 216-218.

Ali, N., Durrani, S., Adeel Shabaz, M., Hafeez, A., Ameer, H., Ishfaq, M., Fayyaz, M.R., Rehman, A., Waheed, A., 2018. Effect of different nitrogen levels on growth, yield and yield contributing attributes of wheat. International Journal of Scientific and Engineering Research, 9 (9), Pp. 595–602. DOI: https://doi.org/10.14299/ijser.2018.09.01

Alloway, B.J., 2008. Zinc in soils and crop nutrition. 2nd ed. International Zinc Association, Brussels; International Fertilizer Industry Association, Paris.

Anwar, S., 2016. Nitrogen and phosphorus fertilization of improved varieties for enhancing yield and yield components of wheat. Pure and Applied Biology, 5 (4), Pp. 727–737. DOI: https://doi.org/10.19045/bspab.2016.50091

Bameri, M., Abdolshahi, R., Mohammadi-Nejad, G., Yousefi, K., Tabatabaie, S.M., 2012. Effect of different microelement treatment on wheat (Triticum aestivum) growth and yield. Intl. Res. J. Appl. Basic. Sci., 3 (1), Pp. 219-223.

Barnes, A., Greenwood, D.J., Cleaver, T.J., 1976. A dynamic model for the effects of potassium and nitrogen fertilizers on the growth and nutrient uptake of crops. The Journal of Agricultural Science, 86 (2), Pp. 225–244. DOI: https://doi.org/10.1017/S002185960005468X

Biljana, B., Aca, M., 2009. Correlation between nitrogen and chlorophyll conent in wheat (*Triticum aestivum* L.). Kragujevac Journal of Science, 31, Pp. 69–74.

Boatwright, G.O., Haas, H.J., 1961. Development and Composition of Spring Wheat as Influenced by Nitrogen and Phosphorus Fertilization 1 . Agronomy Journal, 53 (1), Pp. 33–36. https://doi.org/10.2134/agronj1961.00021962005300010012x

Brhane, H., Mamo, T., Teka, K., 2017. Potassium Fertilization and its Level on Wheat (*Triticum aestivum*) Yield in Shallow Depth Soils of Northern Ethiopia. Journal of Fertilizers and Pesticides, 08 (02), Pp. 8–10. DOI: https://doi.org/10.4172/2471-2728.1000182

Broadley, M.R., White, P.J., Hammond, J.P., Zelko, L., Lux, A., 2007. Zinc in plants. New Phytologist, 173, Pp. 677-702.

Bungard, R.A., Wingler, A., Morton, J.D., Andrews, M., Press M.C., Scholes, J.D., 1999. Ammonium can stimulate nitrate and nitrite reductase in the absence of nitrate in Clematis vitalba. Plant, Cell and Environment, 22, Pp. 859–866.

Camberato, J.J., Bock, B.R., 1990. Spring Wheat Response to Enhanced Ammonium Supply: II. Tillering. Agronomy Journal, 82 (3), Pp. 467–473. DOI: https://doi.org/10.2134/agronj1990.00021962008200030005x

Cervilla, L.M., Blasco, B., Ríos, J.J., Rosales, M.A., Rubio-Wilhelmi, M.M., Sánchez-Rodríguez, E., Romero, L., Ruiz, J.M., 2009. Response of nitrogen metabolism to boron toxicity in tomato plants. Plant Biology (Stuttgart, Germany), 11 (5), Pp. 671–677. DOI: https://doi.org/10.1111/j.1438-8677.2008.00167.x

Cheng, C., Rerkasem, B., 1993. Effects of boron on pollen viability in wheat. Plant and Soil, 155-156 (1), Pp. 313–315. DOI: https://doi.org/10.1007/BF00025045

Das, S., 2014. Role of Micronutrient in Rice Cultivation and Management Strategy in Organic Agriculture-A Reappraisal. Agricultural Sciences, 5, Pp. 765-769.

Dell, B., Huang, L.B., 1997. Physiological response of plants to low boron. Plant and Soil, 193, Pp. 103-120.

Dell, B., Robinson, J.M., 1993. Symptoms of mineral nutrient deficiencies and the nutrient concentration ranges in seedlings of Eucalyptus maculata Hook. Plant and Soil, 155-156 (1), Pp. 255–261. DOI: https://doi.org/10.1007/BF00025032

Fageria, N.K., 2007. Soil fertility and plant nutrition research under field conditions: Basic principles and methodology. Journal of Plant Nutrition, 30 (2), Pp. 203-223.

FAO. 2020. Cereal_supply_and_demand_data_may. http://www.fao.org/fileadmin/templates/worldfood/Reports_and_docs/Cereal_supply_and_demand_data_may.xls

Gasser, J.K.R., Thorburn, M.A.P., 1972. The growth, composition and nutrient uptake of spring wheat. The Journal of Agricultural Science, 78 (3), Pp. 393–404. DOI: https://doi.org/10.1017/S0021859600026307

Gupta, U.C., 1983. Boron Deficiency And Toxicity Symptoms For Several Crops As Related To Tissue Boron Levels. Journal of Plant Nutrition, 6 (5), Pp. 387–395. DOI: https://doi.org/10.1080/01904168309363098

Ibtida, R., 2010. Effect of different phosphatic fertilizers on growth attributes of wheat (*Triticum aestivum* L.) Muhammad. Journal of American Science, 9 (1), Pp. 76–99. DOI: https://doi.org/10.1558/jsrnc.v4il.24

Jamal, A., Fawad, M., 2019. Effectiveness of Phosphorous Fertilizers in Wheat Crop Production in Pakistan. Journal of Horticulture and Plant Research, 5, Pp. 25–29. DOI: https://doi.org/10.18052/www.scipress.com/jhpr.5.25

Jan, A., Wasim, M., Amanullah, Jr., 2013. Interactive effects of zinc and nitrogen application on wheat growth and grain yield. Journal of Plant Nutrition, 36 (10), Pp. 1506–1520. DOI: https://doi.org/10.1080/01904167.2013.799181

Karamanos, R.E., Harapiak, J.T., Flore, N.A., 2013. Sulfur application does not improve wheat yield and protein concentration. Canadian Journal of Soil Science, 93 (2), Pp. 223–228. DOI: https://doi.org/10.4141/CJSS2012-068.

Khan, Q.U., Khan, M.J., Rehman, S., Ullah, S., 2010. Comparison of different models for phosphate adsorption in salt inherent soil series of Dera Ismail Khan. Soil and Environment, 29 (1), Pp. 11–14.

Khan, R., Gurmani, A.R., Gurmani, A.H., Zia, M.S., 2007. Effect of phosphorus application on wheat and rice yield under wheat- rice system. Sarhad Journal Agriculture, 23 (4), Pp. 851–856.

Khan, S., Mirza, K.J., Anwar, F., Abdin, M.Z., 2010. Development of RAPD markers for authentication of Piper nigrum. Environment and International Journal of Science and Technology, 5, Pp. 53-62.

Krentos, V.D., Orphanos, P.I., 1979. Nitrogen And Phosphorus Fertilizers For Wheat And Barley In A Semi-Arid Region. The Journal of Agricultural Science, 93 (3), Pp. 711–717. DOI: https://doi.org/10.1017/S0021859600039125

Kumar, P., Sarangi, A., Singh, D.K., Parihar, S.S., 2005. Wheat Performance as influenced by Saline Irrigation Regimes and Cultivars, 1 (2), Pp. 66–72.

Lawlor, D.W., Kontturi, M., Young, A.T., 1989. Photosynthesis by flag leaves of wheat in relation to protein, ribulose Awphosphate carboxylase activity and nitrogen supply. Journal of Experimental Botany, 40, Pp. 43-52

Lewis, A.H., Procter, J., Trevains, D., 1938. The effect of time and rate of application of nitrogen fertilizers on the yield of wheat. The Journal of Agricultural Science, 28 (4), Pp. 618–629. DOI: https://doi.org/10.1017/S0021859600051029

Long, O.H., Sherbakoff, C.D., 1951. Effect of Nitrogen on Yield and Quality of Wheat1. Agronomy Journal, 43 (7), Pp. 320. DOI: https://doi.org/10.2134/agronj1951.00021962004300070005x

Marschner, H., 1995. Mineral nutrition of higher plants. 2nd Ed. New York: Academic Press, Pp. 889.

Martens, D.C., Westermann, D.T., 2018. Fertilizer Applications for Correcting Micronutrient Deficiencies. In: Micronutrients in Agriculture (2nd Edition). SSSA Book Series, No. 4. Pp. 549-592. SSSA, 677 S. Segoe Rd., Madison, WI 53711. DOI: https://doi.org/10.2136/sssabookser4.2ed.c15

McCauley, A., 2011. Module 9. Plant Nutrient Functions and Deficiency and Toxicity Symptoms. http://landresources.montana.edu/nm/documents/NM9.pdf

Meena, B.L., Singh, A.K., Phogat, B.S., Sharma, H.B., 2013. Effects of nutrient management and planting systems on root phenology and grain yield of wheat (*Triticum aestivum* L.). Indian Journal of Agricultural Sciences, 83 (6), Pp. 627-632.

Metwally, A., El-Shazoly, R., Hamada, A., 2016. Physiological responses to excess boron in wheat cultivars. European Journal of Biological Research, 7 (1), Pp. 1–8. DOI: https://doi.org/10.5281/zenodo.200373

Naeem, H.A., MacRitchie, F., 2003. Effect of Sulfur Nutrition on Agronomic and Quality Attributes of Wheat. Sulfur in Plants (Abrol, Y.P., Ahmad, A., Eds.). Pp. 305–322 305–322. DOI: https://doi.org/10.1007/978-94-017-0289-8_17

Pearman, I., Thomas, S.M., Thorne, G.N., 1978. Effect of nitrogen fertilizer on growth and yield of semi-dwarf and tall varieties of winter wheat. The Journal of Agricultural Science, 91 (1), Pp. 31–45. DOI: https://doi.org/10.1017/S0021859600056604

Pushman, F.M., Bingham, J., 1976. The effects of a granular nitrogen fertilizer and a foliar spray of urea on the yield and bread-making quality of ten winter wheats. The Journal of Agricultural Science, 87 (2), Pp. 281–292. DOI: https://doi.org/10.1017/S0021859600027556

Ralph, R.L., Ridgman, W.J., 1981. A study of the effects of potassium fertilizer with special reference to wheat on boulder-clay soils. The Journal of Agricultural Science, 97 (2), Pp. 261–296. DOI: https://doi.org/10.1017/S0021859600040697

Rerkasem, B., Jamjod, S., 2004. Boron deficiency in wheat: A review. Field Crops Research, 89 (2-3), Pp. 173-186. DOI: https://doi.org/10.1016/j.fcr.2004.01.022

Rietra, R.P.J.J., Heinen, M., Dimkpa, C., Bindraban, P.S., 2015. Effects of nutrient antagonism and synergism on fertilizer use efficiency. VFRC Report 2015/5. Virtual Fertilizer Research Center, Washington, D.C., Pp. 42.

Rietra, R.P.J.J., Heinen, M., Dimkpa, C.O., Bindraban, P.S., 2017. Effects of Nutrient Antagonism and Synergism on Yield and Fertilizer Use Efficiency. Communications in Soil Science and Plant Analysis, 48 (16), Pp. 1895-1920. DOI: 10.1080/00103624.2017.1407429

Robson, A.D., Pitman, M.G., 1983. Interactions Between Nutrients in Higher Plants. *Inorganic* Plant Nutrition, Lindsay, 1978, Pp. 147–180. DOI: https://doi.org/10.1007/978-3-642-68885-0_6

RX Green Technology., 2020. Nutrient antagonism. https://www.rxgreentechnologies.com/rxgt_papers/nutrient-antagonism/

Saeed, B., Gul, H., Khan, A.Z., Badshah, N.L., Parveen, L., Khan, A., 2012. Rates and methods of nitrogen and sulfur application influence and cost benefit analysis of wheat. Journal of Agricultural & Biological Science, 7 (2), Pp. 81-85.

Saifuzzaman, M., Meisner, C.A., 1996. Wheat sterility in Bangladesh: an overview of the problem, research and possible solutions. In: Rawson, H.M., Subedi, K.D. (Eds.), Sterility in Wheat in Subtropical Asia: Extent, Causes and Solution, ACIAR Proceedings, 72, Pp. 104–108.

Sarkki, M.L., 1979. Food uses of wheat gluten. Journal of the American Oil Chemists' Society, 56 (3), Pp. 443-446. DOI: https://doi.org/10.1007/BF02671533

Scherer, H.W., 2001. Sulfur in crop production. Eu. J. Agron., 14, Pp. 81–111.

Schlichting, A.F., Bonfim-silva, E.M., Silva, M.D.C., Pietro-souza, W., Silva, T.J.A., Farias, L.N., 2015. Efficiency of portable chlorophyll meters in assessing the nutritional status of wheat plants. Rev. bras. eng. agríc. ambient., 19 (12). DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v19n12p1148-1151

Sharma, S., Singh, R., Singh, D., 2016. Effect of Balance Fertilizers application on Yield and Economics of Wheat. Journal of AgriSearch, 3 (2), Pp. 133–134. DOI: https://doi.org/10.21921/jas.v3i2.11276

Sheoran, S., Raj, D., Antil, R.S., Mor, V.S., Dahiya, D.S., 2017. Productivity, seed quality and nutrient use efficiency of wheat (*Triticum aestivum* L.) under organic, inorganic and integrated nutrient management practices after twenty years of fertilization. Cereal Research Communications, 45(2), Pp. 315-325. DOI: https://doi.org/10.1556/0806.45.2017.014

Singh, J.P., Dahiya, D.J., Narwal, R.P., 1990. Boron uptake and toxicity in wheat in relation to zinc supply. Fertilizer Research, 24 (2), Pp. 105–110. DOI: https://doi.org/10.1007/BF01073228

Singh, R.K., Turkhede, B.B., 1986. Effect of fertilizer placement and row arrangements on the yield of two varieties of wheat grown under dryland conditions. The Journal of Agricultural Science, 107(1), Pp. 113–118. DOI: https://doi.org/10.1017/S0021859600066855

Snowball, K., Robson, A.D., 1991. Nutrient Deficiencies and Toxicities in Wheat: A Guide for Field Identification. In Hettel GP. (ed.). Nutrient Deficiencies and Toxicities in Wheat. CIMMYT, Mexico.

Snowball, K., Robson, A.D., 1991. Symptoms of nutrient disorders: Faba beans and field peas. Grain legumes Research Council, Pp. 99.

Sthapit, B.R., 1988. Studies on wheat sterility problem in the Hills, Tar and Tarai of Nepal. Technical Report No. 16/88. Lumle Agricultural Research Centre, Pokhara, Kaski, Nepal.

Tranaviciene, T., Urbonaviciute, A., Samuoliene, G., Duchovskis, P., Vaguseviciene, I., Sliesaravicius, A., 2008. The effect of differential nitrogen fertilization on photosynthetic pigment and carbohydrate contents in the two winter wheat varieties. Agronomy Research, 6(2), Pp. 555–561.

Wahhab, A., Hussain, I., 1957. Effect of Nitrogen on Growth, Quality, and Yield of Irrigated Wheat in West Pakistan 1. Agronomy Journal, 49 (3), Pp. 116–119. DOI: https://doi.org/10.2134/agronj1957.00021962004900030003x

Webb, M.J., Loneragan, J.F., 1988. Effect of Zinc Deficiency on Growth, Phosphorus Concentration, and Phosphorus Toxicity of Wheat Plants. Soil Science Society of America Journal, 52 (6), Pp. 1676–1680. DOI: https://doi.org/10.2136/sssaj1988.03615995005200060032x

Zhang, H.Q., Yu, X.Y., Zhai, B.N., Jin, Z.Y., Wang, Z.H., 2016. Effect of manure under different nitrogen application rates on winter wheat production and soil fertility in dryland. IOP Conference Series: Earth and Environmental Science, 39 (1). DOI: https://doi.org/10.1088/1755-1315/39/1/012048

Zhao, F.J., Salmon, S.E., Withers, P.J.A., Evans, E.J., Monaghan, J.M., Shewry, P.R., McGrath, S.P., 1999. Responses of breadmaking quality to Sulfur in three wheat varieties. Journal of the Science of Food and Agriculture, 79, Pp. 1865–1874.

Zhao, F.J., Withers, P.J.A., Evans, E.J., Monaghan, J., Salmon, S.E., Shewry, P.R., McGrath, SP., 1997. Sulfur nutrition: An important factor for the quality of wheat and rapeseed. Soil Science and Plant Nutrition, 43 (SPEC. ISS.), Pp. 1137–1142. DOI: https://doi.org/10.1080/00380768.1997.11863731

Ziaeian, A. H., Malakouti, M.J., 2001. Effects of Fe, Mn, Zn and Cu fertilization on the yield and grain quality of wheat in the calcareous soils of Iran. Plant Nutrition, Pp. 840–841. DOI: https://doi.org/10.1007/0-306-47624-x_409