Effect of Macro and Micronutrients on Growth of Wheat Crop- A Review

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Abstract **- Wheat is an important cereal crop and various macro and micronutrients have significant impacts on related systems and their processes. Numerous experiments helped us understand the role of every nutrient in wheat. Nitrogen experiments proved to us that it is the predominant macronutrient required. Apart from these, various other experiments were taken into consideration in this review paper and the paper tries to establish the role and functions of the nutrients in wheat. The review paper also tries to establish the correlation between various nutrients such as Calcium and Sulfur. At last, a suitable conclusion is drawn rationally and required suggestions were given to improve the experimentation and research topics that can be explored in near future.**

Index Terms **- Wheat, Macronutrients, Micronutrients and Growth**

INTRODUCTION

Wheat (Triticum aestivum) & (Triticum vulgare) is an important major cereal crop that serves as a staple crop in many places in the Indian Subcontinent and other parts of the world. The Macronutrients are Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus, Potassium, Calcium, Sulphur, and Magnesium. These nutrients have various effects on wheat growth. For instance, Nitrogen when provided through irrigation helps in leaf photosynthesis and other physiological activities. Nitrogen also helps in higher yields when it is applied in the form of chemical fertilizer. High yielding varieties also of the wheat show an increase in yield with increasing levels of Nitrogen application.

Potassium is significant for biochemical functions of the wheat-like activating enzymes, along with increased protein, carbohydrates, and fat concentration. The crop also shows greater drought, frost resistance along with disease resistance (Marschner). Phosphorus stimulates seed formation and germination, and the deficiency of potassium is `a direct result in 1000 grain's weight reduction in the wheat plant. Carbon is the building block of the plant (wheat) and oxygen is for photosynthesis. Along with hydrogen, oxygen is available in the form of water. Calcium is a part of cell wall synthesis and particularly in wheat, it helps increase the dry matter of the plant along with the leaf area. The NPK is the general form factor in which macronutrients are given to wheat. (Malghani) The macronutrients hence are needed the most for the plant (wheat) in large quantities.

The micronutrients are Zinc, Manganese, Boron, Iron, Copper, and Molybdenum are known to be the most important micronutrients for higher plants. Apart from the nutritional needs, the micronutrients also help in soil productivity. Liew (1988) also mentioned that micronutrients as macronutrients help in yield production. Zinc is having an important role as a metal component of enzymes or it acts as a functional, structural, or regulatory cofactor of a large number of enzymes in wheat. The pH of soil, carbonate content, organic matter, soil texture is affected due to the interaction between zinc and other microelements, such as iron. The study by Malakouti (2000), specifies that the combination of Iron, Zinc, Boron, and Copper to NPK fertilizer increase grain yield. Iron plays a crucial role in the net assimilation and enzymatic pathway and metabolism (Sultana et.al.2001).

In many areas, wheat has a reduced yield due to poor iron availability. The Manganese helps in yield production. Boron when applied at the booting stage gives us higher grain yield in Wheat. The recent entry into the club of nutrients is Nickel where it is a heavy metal that is needed at the micro-level and needed especially for the Urease availability in the wheat plant. In this review paper, we will discuss the individual effects of these nutrients in various aspects.

WHEAT AND ITS GROWTH STAGES

Wheat is the staple crop for many nations and is an important part of the cereal family. The wheat is one of the foremost cereals cultivated by mankind. The crop's main economic part is grain by which it is used for various purposes. The wheat crop requires micro and macronutrients at different stages of its growth period. The stages of wheat growth can be described by using different scales of growth. Generally, there are 3 main types of scales used in measuring the growth parameters of the wheat. They are:

a) Zadoks scale b) Feeks scale c) Haun scale

Of which Zadoks scale is used most prominently in the field of input application. (Table.1)

By this, we can understand that the growth stages in wheat can be broadly classified as

a) Seedling growth
b) Stem elongation
c) Ear emergence
d) Flowering
e) Dough development
f) Ripening

Now we will analyze the effect of micro and macronutrients in these stages of wheat growth.

EFFECT OF MACRONUTRIENTS ON WHEAT GROWTH

Macronutrients as discussed in the introduction are the nutrients that are required in large quantities. These macronutrients are again further divided into the following based on their origin.

a. Macronutrients (derived from air and water)- C, H, O
b. Macronutrients (Primary)- N, P, K
c. Macronutrients (Secondary)- S, Ca, Mg

The first category essentially derives from air and water, the primary and secondary types are given to plant by soil amendments, foliar applications, seed treatments, etc. with soil amendment being the major method of application as these are required in greater amounts.

These are required in large amounts in comparison to the micronutrients. When we look into all of these, the Air and water derived macronutrients include Carbon, Hydrogen, and Oxygen.

a) Macronutrients (derived from air and water)

- Carbon dioxide (the source of carbon and oxygen)

The carbon and oxygen are taken by crops through carbon dioxide. CO_2 is a photosynthetic input for not only wheat but every plant. Extensive research done in the 1990s makes us understand the effect of the CO_2 in the wheat plant. CO_2 increased concentrations also result in stomatal conductance being lowered (Cure and Acock, 1986). This helps in water use efficiency in the later growth stages of the wheat crop like ripening and dough development. The CO_2 has an implicating effect on the dates of germination, and mid- anthesis. During these days, the natural availability of CO_2 is increasing day by day. A 3-year long experiment on increasing CO_2 on the Wheat plant was conducted. The experiment concluded that increased CO_2 only resulted in varying yield with an increasing margin of yield along with implicating effects on flag leaf area, stomatal conductance, and water use efficiency [Pleijel, Håkan.et.al.2000]. This makes us understand that CO_2 is important in the stages of germination, stem elongation, ripening, and harvesting stages of the wheat crop. (Table.2)

- Hydrogen (available through the water in combination with oxygen)

The hydrogen is one of the main important macronutrients required by the wheat during its initial seed germination stages and also pollen viability. Hydrogen is primarily available in the form of water and the hydrogen when applied externally in the form of H_2O_2 resulted in severe effects on wheat's pollen viability and seed setting stages of wheat. The H_2O_2 also has a role of regulation in controlling the proteins under abiotic stress. It is also helpful in regulating antioxidant enzymes. The hydrogen in the form of water helps in reducing droughts and in the form of H_2O_2 results in enzymatic regulation and also affects pollen viability and also in the germination of seed. The H_2O_2 is toxic at high levels which can severely affect the growth of wheat. The H_2O_2 has the main role in proline accumulation in cells and also cell membrane integrity [Kumar, Ranjeet Ranjan, et al., 2012].

- Oxygen (available through air and water)

The oxygen is the main requirement for the respiration in wheat. The respiration process itself helps in energy assimilation in wheat. The oxygen is required in the growth of wheat in all stages. The oxygen is also the product of photosynthesis. This shows us the dual role of Oxygen as a requirement and also as a product of photosynthesis. The main requirement of oxygen

comes from respiration as described before. A comparative study on varying oxygen tensions in two important cereal crops wheat and rice shed some light on the role of oxygen in the growth stages of wheat. The experiment was conducted with an oxygen tension of 0.0 – 20.8 %. The results make us understand that the unavailability of O_2 germination never occurred in the wheat. The rate of germination was severely affected by the availability and concentration of oxygen. The low availability of oxygen also resulted in the inhibition of root growth. The experiment also indicated that the rice has a superior edge in germination in deprived oxygen conditions when compared to wheat. This implies that wheat germination is largely dependent on oxygen concentrations. The oxygen hence plays a vital role in wheat growth [Taylor, David L., 1942]. (Fig.1)

b) Macronutrients (Primary)

Primary macronutrients are the nutrients that are needed most for the crop. They include Nitrogen, Phosphorus, and Potassium. The following will make us understand their role in wheat growth.

- Nitrogen (The major macronutrient)

Nitrogen is required for all major life processes in not only wheat crops but also every plant. The nitrogen helps in various biochemical processes of wheat and also a major constituent of proteins and amino acids. Simply nitrogen is the required input for the protein which in turn are the building blocks of the plant (wheat). Various experiments have shown that irrigation and nitrogen fertilizer application go hand in hand. Careful application of nitrogen results in a positive amount of wheat crop. Nitrogen's application is in the form of chemical fertilizer (mostly Urea) [D.K.Das, and T.V. Rao (1993)]. The application of nitrogen is directly proportional to yield and yield components (for high yielding varieties). It is also applied in the form of NPK fertilizer. Coming to the dosage of nitrogen, it is applied in split doses generally, but this does not compile to it being the only method.

The Split doses of nitrogen have no significant effect on the yield but affect the number of spikelets. The recommended dosage of Nitrogen fertilizer stands at 120kg/ha. An experiment was conducted to get the importance of Nitrogen fertilizer and irrigation timings on wheat growth. With the nitrogen application of 150 kg/ha and irrigation water application on 15 Days of Germination, the wheat showed a significant increase in plant height (96.6cm and 79.54cm respectively). The nitrogen levels also show an effect on the number of spikelets per spike. The other growth parameters affected by nitrogen application are no. of grains/spike and also 1000 grain-weight. Where the positive application of Nitrogen fertilizer affected in direct and significant growth of the above growth parameters. The excess amount of fertilizer showed negative impacts on wheat growth economically and biologically. It also creates environmental issues [Yousaf, M. et.al, 2014].

- Phosphorus (The energy making macronutrient)

Phosphorus is an important part of ATP in plants (wheat). In the subject, there is less available data regarding the in-depth role of phosphorus in yield improvements of wheat. Phosphorus is needed the most during the 5-6 days of rooting and tillering stages of wheat. An experiment showed with the increase in Phosphorus as a starter there is a significant impact on the emergence and tillers growth in the wheat plant (spring wheat). Phosphorus also has a great impact on tiller initiation. The minimal dosage of Phosphorus varies from crop to crop but as it is immobile it needs to be placed in the root zone. Low amounts of Phosphorus are required and is generally placed directly with the seed (< 20-30 lb. P2O5/ac). The phosphorus deficiency is generally seen in lower leaves which are seen on ridges of the field [Goos.R and Johnson.B (1996-2001)].

- Potassium (The enzymatic macronutrient)

Potassium is required for photosynthesis and protein formation in wheat crops. Potassium is involved in sugar transport. Potassium helps in maintaining the cellular organization. An experiment conducted to draw some results on the effect of potassium on the growth of wheat which concluded that the growth parameters of plant height, no. of ear/head, etc. are affected by the rate of potassium application. In the experiment when 80 K_2O ha^{-1} is applied, it resulted in maximum plant height, no. of ear/head, and dry and wet matter along with the number of tillers. This result is similar to the standard application of 60 K2O ha^{-1}. The yield parameters were also at a positive rate with the application of 80 K_2O ha^{-1} to the wheat [Prakash Maurya et.al, 2014] (Table.3)

C) Macronutrients (Secondary)

Secondary macronutrients are those which are required next to that of primary macronutrients. These include Sulfur, Calcium, and Magnesium. In the below, we will discuss the role of these macronutrients in the growth of the wheat plant.

- Sulfur

Sulfur in wheat is required for the synthesis of protein and as well as the synthesis of Chlorophyll. An experiment conducted on wheat in calcareous soil showed a significant increase in the leaf area, fresh weight at tillering, and ear numbers/plant at heading. Sulfur, however, has a residual effect. In the second season of the experiment, there is an increase in tillering along with stem diameter and other growth parameters, especially in the heading stage. Many researchers claim that the role of Sulphur is very low. But several experiments have shown that it is indeed required for various growth parameters. An experiment showed that the pre-application of Sulphur with the amount equaling to 50kg ha^{-1} along with 80kgha^{-1} of nitrogen gave an optimal grain yield. The results also proved that Sulphur is indeed required for efficient wheat growth [Hanna Klikocka et.al, 2018].

- Calcium

Calcium is a very important macronutrient that is involved in the composition of the cell wall and also plays a crucial role in the photosynthesis of Wheat growth. It also affects the soil structure. As calcium is immobile, it is required in large amounts. A combined form of Sulphur and calcium have a great impact on the growth parameters of the wheat plant. An experiment was conducted with different levels of $CaSO_4$ on wheat to understand the effect of calcium and sulfur on the growth of wheat and their correlation. It had a positive impact on the growth and yield parameters of wheat. The highest value of plant height, spike length, grains/spike, etc., are obtained when 150 kg $CaSO_4$/ha is applied.100 and 200 kg $CaSO_4$ /ha application also showed a positive impact. [Muhammad Arshadullah et.al, 2009-10]. (Table.4)

- Magnesium

Magnesium is the last of macronutrients and also plays an important role in the structure of chlorophyll and various other metabolic activities. The magnesium's main role in wheat includes root formation, photosynthesis along with chlorophyll as discussed. Magnesium has an impact on other micronutrient's impact on wheat also, especially on manganese. Apart from this magnesium's role is discussed in an experiment in Egypt recently. Magnesium was given in the form of $MgSO_4$ was given in pot treatments as soil amendments as well as a foliar application. The quantities are of 60 kg/ha as a soil amendment or 5 g/l foliar application showed a significant impact on plant height and dry biomass which showed a positive growth rate. The deficiency of magnesium chlorosis and necrosis of leaves in wheat along with the significant impact on the uptake of micronutrients. The experiment also concluded that soil amendments must be preferred over the foliar application as it replenishes soil health but in deficiency cases, the foliar application is a must. [El-Zanaty A.A. Abou El-Nour and Mahmoud M. Shaaban, 2012] (Table.5)

EFFECT OF MICRONUTRIENTS ON WHEAT GROWTH

Micronutrients are the essential nutrients that are needed by the crop, here Wheat in fewer quantities. These nutrients are required compulsorily but their quantity hinders in comparison with the Macronutrients. The micronutrients in general help in the growth of the crop, but they also have an added role of increasing soil health. The main micronutrients are Zinc, Iron, Copper, Boron, Manganese, and Molybdenum. Also, along with this Nickel is considered to be a micronutrient with a specific role in plant growth. It is a recently added nutrient into the list.

- Zinc (The cofactor micronutrient)

Zinc is one of the most important micronutrients where its role in the plant is proven significantly. The micronutrient is responsible for various life processes like photosynthesis, nitrogen metabolism, stress resistance (Cakmak 2008), and cofactor to many enzymes in the crop (Grotz and Guerinot, 2006). An experiment to make us understand some important facts of Zinc on growth parameters and yield was conducted in water-stressed conditions and $ZnSO_4H_2O$ was used as zinc fertilizer. The crops experimented with normal irrigation and with 0.06% of foliar application gave maximum growth and yield. Whereas in water-stressed conditions at critical stages like crown root initiation has a very bad impact on growth. This makes us understand zinc importance.

The experiment concluded that 0.04% of zinc is ideal for growth [Sultana et.al, 2016]. The experiment on calcareous soils about the effect of zinc when applied to the soil in wheat concluded that the Zinc Sulfate (the fertilizer used for zinc application) increased various growth parameters like leaf area index, no. of spikelets/spike, no. of fertile tillers, spike length, the grain/ spike, and along with thousand-grain weight [Khan et al., 2005-2007]. The team also suggested that 5kg/ha of zinc sulfate at the time of sowing will yield maximum results. Thus, these are the effects of zinc on wheat growth.

- Iron

Iron as its co-nutrients is a very important micronutrient that is helpful in various physiological as well as biological functions of the crop. That includes thylakoid as well as chlorophyll synthesis and chloroplast development (Masoud et.al). An experiment was conducted to understand the effect of iron as a foliar application on the wheat crop alone and in combination with boron. The alone use of iron resulted in improved growth parameters like plant height, no. of leaves, no. of tillers, and root depth. All of these show maximum results when they are given in Iron and Boron combination (Fe 6% & B 17% as Fe-DTPA and Boric acid respectively).

The individual iron ration includes 1000ppm of Fe-DTPA (Fe 6%) in the experiment which yielded good results [Hamzeh Mohmmed Rawashdeh and Florin Sala, 2012-13]. An experiment conducted by the application of NPK fertilizer along with Iron concluded that with the application of 125 Kg ha^{-1} NPK (150:100:60) along with 12 Kg ha^{-1} showed maximum no. of tillers and maximum mean 1000-grain weight. The application of Fe with 16kg ha^{-1} showed a maximum spike length of 13.89 cm. (G.Abbas et.al, 2005-2007).

- Manganese

Manganese is a minor micronutrient that is useful as an auxiliary growth nutrient. The manganese yet has variable toxic effects on crops that have a direct or indirect impact on the uptake of certain nutrients. Its mutual antagonism with elements like Potassium, Sodium, Magnesium (McCool). But an experiment conducted on micronutrient effects on wheat plants gives us the idea of how manganese affects plant growth. The experiment dealt with manganese in Treatments $T_{10, 11, 12}$ with concentrations of 8, 12, 16 Kg ha^{-1} respectively. The results include a significant increase in the leaf area index (at 49 and 98 DAS) with a value of 3.21 which is on par with the maximum value obtained by boron application. But the crop growth rate (g m^{-2} day^{-1}) is the lowest for treatments with Manganese valuing in between 18-19. But the absolute growth indicator is Relative Growth Rate, where manganese in T_{11} treatment produced a satisfying RGR with a value of 82.10. The net assimilation rate is on par with the maximum results of the experiment when 16 kg ha^{-1} manganese is applied. Optimum growth parameters are observed when 16 kg ha^{-1} of Manganese is applied. [Muhammad Amjad Nadim et.al, 2009-10]

- Copper

Copper is the micronutrient that is required for various enzyme synthesis (here wheat). The lignin synthesis is one of the most important functions along with photosynthesis, respiration, and also various metabolisms. The effect of copper on the growth of wheat experimented was conducted in a pot with various copper levels. The plant height was maximum when 1.5 mg kg^{-1} of copper is applied. But the number of tillers was minimum at the same level. This experiment showed that the low levels of copper harm plant height, tillering, and also apical dominance. Hence Copper levels have a significant impact on the above growth parameters. The shoot dry and fresh matter was at the maximum at 1.5 mg kg^{-1} of copper application. So, the experiment concluded that 1.5 mg kg^{-1} of copper application resulted in positive growth parameters [Kumar et.al. 2006-2007]. The use of copper is also explained in the experiment where the Treatments $T_{4, 5, 6}$ with concentrations 6, 8, 10 kg ha^{-1}. The experiment concluded that the net assimilation rate in the wheat is highest with a value of 3.19 when copper is added in a concentration of 6 kg ha^{-1}. The tillers also increased with the copper (8 kg ha^{-1}). The Rate of Growth is on par with the application of copper at a rate of 6 kg ha^{-1}. This proves the role of copper in wheat growth.

- Boron

Boron is an important part of micronutrients and is required in various growth stages. Boron has an important role in spikelet formation and grains per spike. An experiment conducted with Boron

application at different growth stages of wheat showed that the application has a significant impact on the tillering, jolting, anthesis, and booting growth stages of wheat crop. The other growth parameters like a 1000-grain weight have increased at a positive rate with an application of 0.125ppm Boron. It also concluded that Boron is required the most in the reproductive stage rather than any growth stage in comparison [Tahir et al, 2006-07].

- Molybdenum

Molybdenum is a key micronutrient required for nitrogen species and plays a vital role in biological nitrogen fixation. The nutrient is also important in nitrogen assimilation (Taiz; Zeiger, 2004). Molybdenum hence is an inseparable micronutrient considering its role in nitrogen assimilation. To know about its role in wheat growth an experiment was conducted in no-till condition. Although there is no significant effect on growth parameters, there is an increase in the number of tillers when molybdenum was applied in the early tillering stage. Spikes per unit area has significantly increased on secondary application at the booting stage. The overall experiment resulted in increased yield with the application of molybdenum at the rate of 35 g ha^{-1} [Zoz, T. et al. 2008]. Similar results were obtained by Muhammad Amjad Nadim et.al.

- Nickel

Nickel as discussed is a recent entry into the micronutrient list as its use was discovered in recent times. Nickel is required in minute quantities but when we apply excess nickel it will result in toxicity levels that destroy photosynthesis and other vital plant processes. The effect of nickel on the wheat has experimented and plant height was significantly affected when 50 µg Ni L^{-1} was given to the plant. The nickel also harmed the chlorophyll content of the wheat especially at the level of 25µg Ni L^{-1}. So, nickel is required in minute quantities where a slight increase in its quantities result in drastic changes in the wheat crop [K. Uruc¸ Parlak, 2011].

CONCLUSION

Micro and Macronutrients play a vital role in wheat growth and development. They especially make the plant a working system by creating, supporting many life processes. Experiments in this review paper made us clear that the nutrients not only have an individual role but also affect the other nutrients such as Nitrogen, Nickel, and Molybdenum. The relation might be the protagonist or antagonistic. The Wheat crop showed various changes to many nutrients. Nitrogen played an important role in protein synthesis and photosynthesis. Oxygen is required for respiration. Zinc is important as a cofactor for many enzymes etc. Most of the experiments were conducted on the field before a decade. This may affect the present role of the macronutrients and micronutrients on Wheat. Comprehensive experimentation on nickel, copper, carbon dioxide, boron, manganese, and molybdenum are recommended.

The role of structural nutrients especially Carbon and Hydrogen can be taken as research goals and explored further. Their role is researched by few and has very little physical data. The planned and efficient use of all the nutrients will give positive results in the growth of wheat. Careful planning and execution are needed for effective and efficient use of micro and macronutrients in the same manner. Most of the macronutrients are required for the initial stages of growth whereas micronutrients are needed the most after initial germination and act as a supporting role to the macronutrients. So, these micro and macronutrients are called essential as their role in the crop or plant (wheat) is irreplaceable.

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