International Journal of Environment and Climate Change

Volume 13, Issue 10, Page 1209-1221, 2023; Article no.IJECC.103817
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Effect of Phosphorus and Zinc on Fodder Yield and Quality of Leguminous Fodder: Berseem (*Trifolium alexandrinum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i102773

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/103817

Review Article

Received: 12/06/2023
Accepted: 17/08/2023
Published: 26/08/2023

ABSTRACT

The contribution of the livestock sector to the Indian Economy is 4.11% of its total GDP and it is nearly 25.6% for total agricultural GDP. Small and marginal farmers are mainly attached to the mixed farming of field crops and dairy animals. Farmers get regular income from their dairy unit and also use dairy animals as economic security. Though India comes under the highest livestock populated countries, the production of milk is lower than expected because of improper feeding quality. Through the last two decades, the demand and price of milk both increase gradually, and

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farmers are not getting that much profit because of their dependency on ready cattle food. The gross profit after the selling of milk is nearly equal to the feeding expenditure. For the use of paddy straw as dry fodder, the quality and quantity of milk production are decreased. So, green fodder is the best option for livestock as it contains adequate nutrients as well as crude fibre. Among the fodder and forage crops, berseem is the second maximum cultivated fodder crop which possesses a 2 million ha area of fodder crops in India. There are several advantages of berseem as a fodder crop such as a short-duration crop, multi-cut nature, the capability of higher biomass production, the presence of a good amount of crude protein, cellulose, total digestible nutrients and succulent nature. Though Phosphorus and zinc play an antagonistic effect on each other, both are required for the growth and development of berseem crops. From cellular respiration to enzymatic reactions, phosphorus is essential for completing several metabolic activities. Zinc is related to yield and fodder quality by completing plant metabolisms like carbohydrates and auxin production. Adequate management practice is required to maintain the concentration of both nutrients at an optimum level. In Indian soil, zinc is deficient and phosphorus is mostly present in organic form. So, the use of biofertilizers will be effective to convert those complex nutrients form into simple and available for the plant.

Keywords: Fodder; berseem; phosphorous; zinc; fodder quality.

1. INTRODUCTION

The agriculture sector's contribution to the Indian economy is about 17% of the total GDP. It is the biggest employment sector of the country by which nearly about 50 to 55% of the total population and greater than 70% of the rural population of India are connected [1]. In the agriculture sector, livestock is an undisputed part and plays an important role in the rural economy of India. The contribution of the livestock sector to the Indian economy is 4.11% of GDP and for total agriculture GDP, it is about 25.6% [2]. But most of the farmers in India are small and marginal. They practice a mixed farming method as they have less than 2 acres of small land holdings. In this farming system, they usually practised a combination method of livestock and crop for using the output from one sector as the input in another sector [3]. Farmers are served by livestock in different ways. Through livestock products, farmers maintain their earnings in crop losses years.

As per the 20th livestock census total livestock population in India is 535.38 million which is the largest in the world [4]. Though India stands among the highest livestock population country, productivity is low here due to improper feeding resources which can be identified as a major cause for not achieving the maximum desired potential [5]. So, in the current situation, there is a tremendous shortage of feed and fodder for the livestock. Suitable feeding and proper nutrition work as strategic factor for livestock, improving their qualitative and quantitative production on a sustainable base. Because of limited land resources and the substantially growing pressure of livestock in the country an enhancement or development is needed for fodder production [6].

As a leguminous fodder crop, berseem should have some vital quality parameters which will have economic importance in berseem such as crude protein, ether content, neutral detergent fibre, acid detergent fibre and acid detergent lignin [7]. The growth and development of berseem depend upon different Primary nutrients (like N, P, K) and micronutrients (Zn, B, Fe) [8]. For achieving maximum fodder production management of the proper application of primary, secondary and micronutrients can become a prospect to work out in a sustainable process.

Phosphorus and zinc are the two main important essential elements in the berseem crop. Phosphorus is one of the primary essential nutrients which needs the use of balanced fertilizers concentration with nitrogen and potassium. It is a vital element of several enzymes, phosphatides, phytin, nucleic acids and phosphatides. Phosphorus plays an important role in cellular respiration. Different metabolic activities such as enzymatic reaction, sugar metabolism and fixation of CO_2 can't be completed without phosphorus.

Being one of the essential micronutrients, zinc plays an important role in the growth and development of plants and living organisms. Though the requirement of zinc for its function in plant or living bodies is minimum, its deficiency causes effective yield losses and quality degradation. Several plant metabolisms such as carbohydrates and auxin are dependent on zinc [9]. Though sometimes zinc acts as an antioxidant, it also develops resistance to biotic and abiotic stresses.

After analysing the importance of these two essential elements in the berseem crop, the availability and uptake of these nutrients should be managed in a balanced way. Though phosphorus and zinc play an antagonistic effect on each other, the concentration of both nutrients in soil solution must have to analyse for adequate management practices. In Indian soils, the presence of phosphorus is sufficient but mostly in organic form which is unavailable to plants. But in the case of zinc, Indian soils are deficient in zinc content and zinc deficiency is mostly found among the other micronutrient in plants. They are mainly flocculated with oxides and hydroxides of iron, aluminium and manganese [10]. In most of the places in India, there are the availability of phosphorus and zinc is medium to low and the potential of increasing the fodder crop yield through a suitable application of phosphorus and zinc is remarkable in Indian soil. The use of biofertilizers like phosphorus-solubilizing bacteria and zinc-solubilizing bacteria will be handy to convert these nutrients from their organic form to inorganic form for increasing their availability to plants [11].

For the last two decades, biofertilizers are the most useful ones in the Indian agriculture system for reclaiming different nutrient deficiencies [12]. Their contribution to increasing productivity, effectiveness to minimize the cost of cultivation, nature of sustainability and eco-friendly uses are the main principles or objectives of their frequent uses. In an integrated nutrient management system, biofertilizer plays an important role as it helps to mineralize the complex form of the primary essential nutrients to increase their availability to the plants. Biofertilizers also help in releasing growth hormones, modifying soil pH and increasing enzymatic activity [13].

1.1 Importance of Fodder Crops for Livestock

In recent years the price and demand for milk have increased gradually. Farmers are getting an assured price from milk which they can’t get in other agricultural products. But the dairy industry is facing several problems as the price of cattle feeds increases so much that the profit after selling the milk can’t exceed the expenditure.

Farmers spent the income that comes from the dairy completely on cattle feed and other farm operations. As they entirely depend on ready cattle feed, their dairy expenditure has increased day by day. Total milk production also decreases with the ignorance of green grass and fodder uses. Paddy straws are generally used as cattle feed which affects animal health and the production of milk. So, farmers should plan their dairy operations with the cultivation of green fodder.

Table 1. Year-wise increment of deficit percentage of green and dry fodder

Year	Dry fodder deficit (%)	Green fodder deficit (%)
2010	10.9	35.7
2020	11.8	30.6
2030	12.5	24.9
2040	12.7	20
2050	14	17.8

(Source: Giridhar and Samireddypalle, [14])

Every dairy animal should supply food according to their body weight. They need 40% dry and 60% wet fodder where 25% should be leguminous fodder and the remaining 75% should be from monocot grasses [15]. Green fodder can also be used as dry fodder rather than paddy straw. Paddy straw contains oxalic acid which is harmful to cattle. It reduces the calcium content in the animal body. The growth of the animal is reduced and the productivity and quality of milk are also affected. So, farmers should avoid paddy straws for feeding the cattle. Finger millet, wheat straw and sorghum stubbles are the main dry fodders which contain useful nutrients for the animals [16]. Berseem, sun hemp, lucerne, cowpea and horse gram can be used as green as well as dry fodder.

Green fodder can be defined as an economic and rich source of protein and nutrients for cattle. It is easily digestible and extremely palatable in nature. Green fodder contains several micro-organisms which are responsible for increasing the digestibility ability of crop residues if they are used in mixed feeding methods [18]. The breeding efficiency of the dairy animals is improved and their health condition has been maintained with the use of green fodder as feeding material. It also helps to minimize the expenditure for the ration of dairy animals. For increasing the availability of green fodder throughout the year, the yield and quality of green fodder should increase by using proper nutrient management and improved fodder variety.

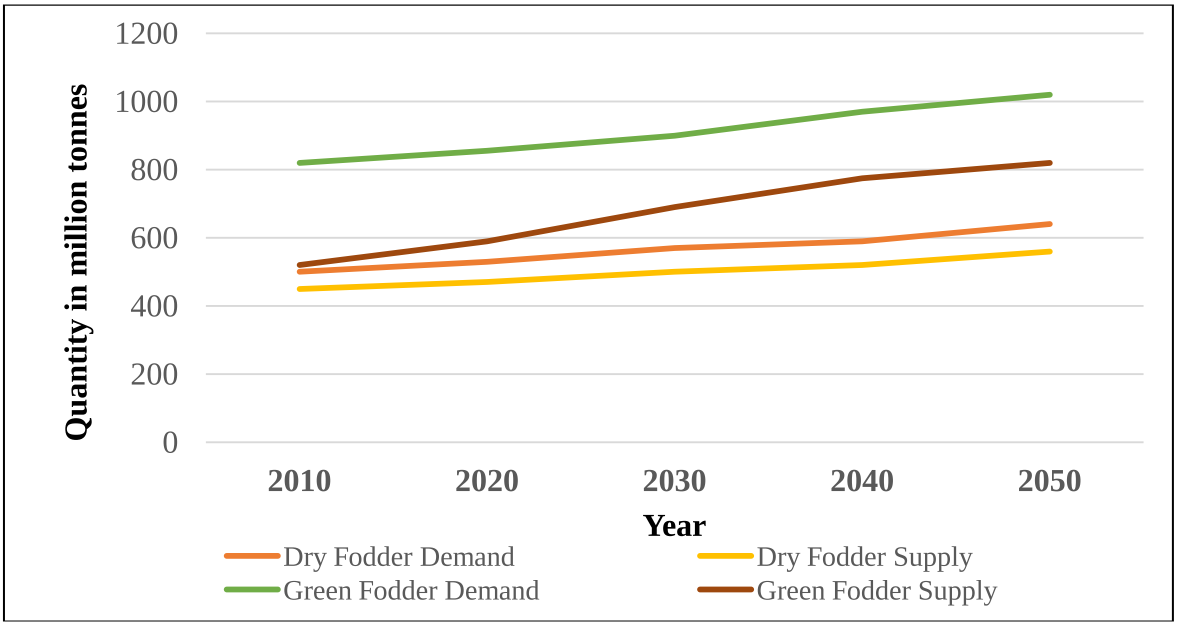

Fig. 1. Year-wise demand and supply of green and dry fodder
(Source: Nouman et al., [17])

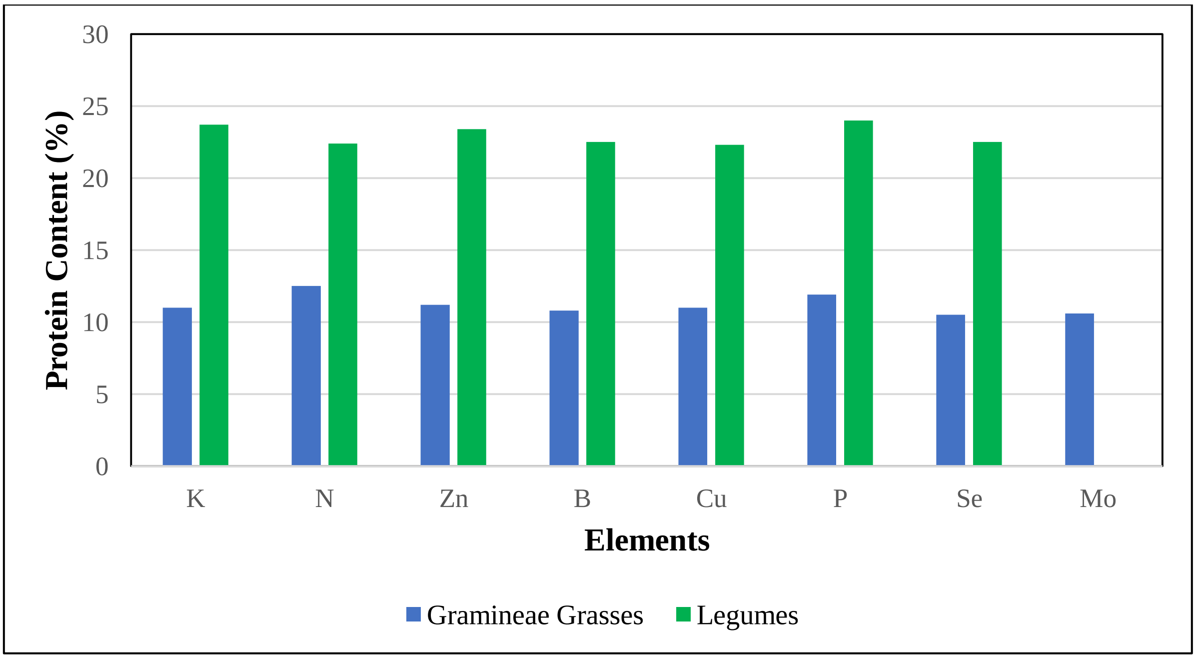

Fig. 2. Percentage of the protein content of different elements in gramineae grasses and legumes
(Source: Erenstein and Thorpe, [23])

1.2 Importance of Berseem as Fodder Crop

Berseem (*Trifolium alexandrinum* L.) Belongs to the Leguminosae family which has 242 species under the genus *Trifolium* and among them only 16 are cultivated as fodder crops [19]. It is a popular fodder crop having the highest cultivated area in the country among the fodder legumes. After sorghum (*Sorghum bicolour* L.) it occupies the second maximum cultivated area around 2 M ha among the fodder crops. Berseem is an important fodder crop for its long-duration availability (November to May) and multi-cut nature (4-8 times can be cut) [20]. It gives a high amount of fodder production (85t/ha) and contains a good amount of crude protein around 20%, Neutral Detergent Fibre 43-49%, Cellulose 22-25%, hemicellulose 9-10% and Acid Detergent Fibre 36-38% on dry matter basis [21]. It is highly digestible and palatable in nature. Berseem stimulates lactating quantity in dairy animals due to its nutritiousness, high crude protein content, total digestible nutrients and succulent nature.

As the stems of the berseem plant are succulent because of its higher water content, berseem can't use for hay. When the berseem plants become dry, their leaves are dropped which is another reason for not using berseem as hay. But, as green fodder, it is one of the most nutritious and fibrous among the fodder and forage crops. Berseem has also an exceptional potential to fix nitrogen for increasing soil fertility as it possesses root nodules. The advantages of the berseem crop are its shorter life cycle and potential to produce significant biomass. Berseem can remove heavy materials from the soil as it can utilize heavy metals such as Pb, Cu, Zn and Cd through its phytoremediation capability [22].

2. EFFECTS OF PHOSPHORUS AND ZINC MANAGEMENT ON FORAGE CROPS AND FODDER CROPS

2.1 Effects of Phosphorus on Forage Crops and Fodder Crops

Phosphorus is an important essential element as nitrogen and potassium in plants. According to Rahman and Kawamura [24], after nitrogen, phosphorus is the most important essential nutrient for the growth and development of crops. There are several disorders which can be seen in dairy animals because of phosphorus deficiency in green fodder crops. Mohammad and Mazahreh [25] stated that Phosphorus is a vital element of phytin, nucleic acids, several coenzymes, proteins and phosphatides. Sufficient application of phosphorus will help in the development of roots. it also plays an important role in cellular respiration [26]. Different metabolic activities such as enzymatic reaction, sugar metabolism and fixation of CO2 can't be completed without phosphorus.

According to McDowell and Houlbrooke [27], the effect of phosphorus application on the increment of plant height can be defined as a favourable environment for the division and enlargement of cells which can be seen as the increment in plant height. The quality and productivity of forage crops directly depend on the supply of phosphorus and potassium. The free form of phosphorus is required in sufficient amounts for a greater number of nodules [28]. Compared to grains, legumes uptake more P and K, as they have to meet the requirement of the microorganism that helps in nitrogen fixation. Through this nitrogen fixation, plants fulfil the nitrogen demand for superior plant growth.

Ali et al. [29] reported that in plant dry matter, phosphorus remains at nearly 0.5%. It is a vital substance in plant structure and energy generation. The availability of phosphorus to the plant is only 15-30% of the applied phosphorus fertilizer and the rest amount remains as residual phosphorus. The feed efficiency of plants enhances with the application of chemical fertilizers. As chemical fertilizers contain a high amount of nutrients, they can be applied in small quantities [30]. Farmers should have proper knowledge about nutrient deficiency in their fields before the application of any type of nutrient fertilizers. Soil should be analysed for deciding the type and quantity of fertilizer in the Berseem field. According to Roy et al. [31], phosphorus helps in the storage processes of plants which are required for cell division. It also plays an important role in storage processes for the growth and development of economic products as well as the vegetative parts of plants. It is an essential constituent of nucleic acid, phytic and phosphor-lipid.

Phosphorus is an important component of cell structure and an active compound in the metabolic activity of plants [32]. It plays an important role in protein synthesis. Berseem needs an adequate amount of phosphorus supply for getting a higher yield. Patel and Rajagopal [33] noticed that applied phosphate fertilizer has a direct effect both on qualitative and quantitative fodder production. The height of the plant, the diameter of the stem, the leaf number per plant, the area of leaves per plant and finally the yield all can be gradually increased through phosphorus application.

According to Roy and Jana [34] ethyl extract, dry matter percentage, crude protein percentage and nitrogen-free extract will be increased with the increment of phosphorus level in the Berseem field from 40 kg to 80 kg/ha. If the phosphorus level has been increased beyond 80 kg/ha, the quality of the berseem will be affected. But in the case of crude fibre, above 80 kg/ha phosphorus dose reacts oppositely in the berseem plant. With the application of phosphorus up to 80 kg/ha, the dry matter percentage and crude protein percentage came to 12.32 and 19.33%. Ethyl extract and nitrogen-free extract were obtained as 3.41% and 41.72%. After increasing the phosphorus level beyond 80 kg/ha, the crude fibre content of the Berseem plant has been recorded as lowest at 21.03% and with the application of phosphorus at 40 kg/ha, the highest crude fibre has been collected at 22.83%.

According to Chouhan et al. [35], the application of P2O5 at 75 kg/ ha and 5g phosphorus solubilizing bacteria for 1 kg of seed at the time of seed treatment will provide the maximum yield in berseem. From every plot, the yield can be obtained at 63.75kg and 31877 kg from 1 ha of land. The minimum yield is 49.21 kg per plot and 24610 kg per ha land if the phosphorus dose will be 45 kg per ha and seeds are not treated with PSB. The requirement of phosphorus at 30 DAS lies between 0 to 40 kg for 1 ha of land for cowpea fodder. With the application of 60 kg of phosphorus, the height of the plant will be increased gradually.

Kumar et al. [36] reported that the application of phosphorus between the dose of 100 kg/ha and 80 kg/ha will higher the green fodder yield as well as the dry matter yield. But the number of tillers and height of the plant will be average. If the phosphorus dose has been minimized from 80 kg/ha or above that to 60 kg/ha, there will be the emergence of more tillers which will give a higher green forage yield. According to Bilal et al. [37], the response of Berseem for the phosphorus fertilizer was recorded as up to 100 kg/ha. With the application of phosphorus fertilizer at the dose of 100 kg/ha, the green fodder yield and the dry matter yield increased up to 21.8% and 28.4% comparing the dose of 60 kg/ha. Compared to the dose of 80 kg/ha, the increment was noticed as 9% and 12.1%.

2.2 Effects of Zinc on Forage Crops and Fodder Crops

According to Mir et al. [38], Micro-nutrients play a vital role in increasing the productivity and nutritional quality of fodder crops. These also help to overcome several abiotic stresses such as high temperatures and drought. Biotic stresses like pests and diseases can also be minimized through micronutrients. It mainly increases the quality of crops. If these micronutrients are not supplied in adequate amounts with fertilization, different deficiency symptoms will take place like RNA destruction, lower photosynthesis rate and decrease of protein synthesis and the soluble carbohydrate process. As an essential micronutrient, Zinc plays an important role in the composition of growth hormones and the reproductive processes of some plants [39]. It helps to improve qualitative production by interacting with several plant metabolism. Zinc plays a vital role in several metabolic processes of plants such as the uptake of nitrogen, chlorophyll synthesis, protein quality, nitrogen metabolism and maintaining the activity of the carbon anhydrase. It also helps to resist the biotic and abiotic stresses of plants. It has a great influence on protecting plants from oxidative damage [40].

Zinc is needed for the biosynthesis process of tryptophan. It also plays an important role as a precursor of $C_{10}H_9NO_2$ [41]. Zinc helps in the metabolic processes of carbohydrates. It can also be found as the structural element of several proteins at various stages such as metalloenzymes. According to Potarzycki and Grzebisz [42], by practising suitable nutrition management processes and applying an adequate amount of zinc, maximum yield can be obtained in rabi fodder crops. It also creates favourable conditions for the plant growth. for the composition of auxin, chlorophyll and carbohydrates, zinc plays an essential part in rabi fodders [43].

According to Singh Dhaliwal et al. [44] through the application of zinc, farmers can do agronomic fortification which will improve the quality as well as productivity of fodder crops. The problem of Zn deficiency is the most severe case among all micro-nutrients in India [45]. By applying adequate zinc requirements in fodder crops, zinc deficiency in animals can be reduced. Alloway [46] reported that the requirement of zinc for plants is a modicum but that required concentration is critical for plants and animals. Due to the deficiency of zinc, both are suffered from several physiological stresses. Dysfunction of different metabolic processes and enzyme systems happens in which zinc is essential to complete the process. Zinc deficiency can decrease the activities of different antioxidant enzymes in plants. As a result, it will damage chlorophyll, lipids, protein and nucleic acids by widening the oxidative change of enzymatic reactions [47].

The impact of different levels of zinc fertilizer on plant growth is different among the crops as the response of fodder crops depends on the application of zinc fertilizer [48]. Fodder crops require less amount of zinc for their growth but with the deficiency of zinc in fodder crops, vegetative growth will be affected and the yield will be minimum. According to Kumar et al. [49] with the application of zinc at the dose of 28 kg/ha the maximum yield of dry matter can be obtained. The zinc uptake in the berseem crop has increased from 35.9 to 48 kg/ha with the application of zinc fertilizer at 4kg/ha [50]. But higher doses of zinc will decrease the uptake of zinc from the soil. Meena et al. [51] reported that There will be significant growth of the plant with the application of Zinc sulphate at the dose of 20 kg/ha. The uptake of zinc has increased with a progressive increment of zinc doses in berseem and lentil crops. The maximum uptake of zinc by the berseem crop was found 7.5 kg/ha can. Yield is also increased with the significant increment of zinc uptake in the berseem crop [52].

2.3 Phosphorus-Zinc Interaction in Plants

Micronutrients play a vital role in dry matter production and crop yield. So, the low concentration of micronutrients can decrease the crop yield. Sultana et al. [53] Phosphorus and Zinc are the two most essential macro and micronutrients which are related to the growth, development, quality and productivity of crops. They are also the primary elements of different enzymes, compounds and plant metabolism.

According to Mousavi [54], the deficiency of micronutrients can be seen in soil because of the overuse of phosphate fertilizer in crop production. With the soil, plants are also affected by several micronutrient deficiencies. There will be a decreased concentration of zinc, manganese, copper and iron in the root and shoot portion of plants with the higher application of phosphorus. The dilution effect in the shoot portion and the translocation of elements from the root zone of the plants are not responsible for this decreased concentration. Aboyeji et al. [55] suggested that if zinc becomes the segment of the root fabric, the availability of zinc will decrease and the transportation of zinc to the leaves will be lower even with higher zinc fertilizer application. Through the formation of zinc phytate, Phosphorus can circumvent zinc in roots. At higher pH, the concentration of phosphorus in the solution increased and zinc concentration has been decreased. At lower pH, the opposite result of the concentration of these elements happens [56].

Siddiqui et al. [57] reported that in different biochemical processes, Zinc plays a vital role as an active element. It has also several chemical and biological actions with some other elements. Among them, phosphorus is the most vital element to interact with zinc in an antagonistic way. Phosphorus interferes with the uptake of zinc by the plants. For the plant, phosphorus and zinc availability always fluctuates. If the concentration of phosphorus increases it causes lower availability of zinc in plants which results in Zn deficiency and vice-versa.

According to Anitha et al. [58], the interaction between zinc and phosphorus causes an imbalance which affects several metabolisms of the plant cells. Specific positions of different organelles in the plant cell are hampered due to imbalances in the concentration of these two elements. When the concentration of zinc in plants has been decreased or lowered, the uptake of phosphorus from the soil solution has been increased and the transport of phosphorus to the shoots and leaves also increases [59]. At a point, this high concentration can be the cause of toxicity to the plant. Among all micronutrient availability or deficiencies, it only happens when zinc deficiency takes place in the plant. Actually, the permeability of the plasma membrane has been increased with the zinc deficiency in the plant root.

According to Pandey et al. [60], the higher concentration of zinc causes limited root growth which indirectly decreases the uptake of phosphorus from the soil solution. When zinc phosphates precipitate in the root zone, phosphorus and zinc show an antagonistic effect. The interaction between phosphorus and zinc also happens within plants. If the applications of phosphorus consist of high levels, the Zinc concentration in the root zone of the plant will be increased but the concentration of zinc in the shoot portion will be minimum or decreased. The linear transport process of zinc transport from the top of the root to the upper portions and the fission of the zinc transport process to the vascular tissue is the cause of this phosphorus and zinc interaction in the root zone.

According to Singh and Singh [61], the uptake of zinc increases with the application of zinc fertilizer at 2.5, 5.0, 7.5 and 10.0 kg/ha and in every stage the zinc uptake is greater than the control plot. Yield is also recorded higher with the increment of zinc uptake in the berseem crop. If zinc fertilizer is applied at a higher rate, it will decrease phosphorus availability in the berseem crop. With the application of zinc fertilizer at 10 kg/ha in the berseem field, phosphorus uptake will be minimum at 4.6 kg/ha. Ali et al. [62] reported that phosphorus uptake increases with the decrease in levels of phosphorus application. Due to the antagonistic effect between phosphorus and zinc, overuses of any element translocate the other from the root zone. The application of higher doses of zinc can be the cause of lower sulphur availability and uptake by plants as well. With the application of zinc at 10 kg/ha, the uptake of sulphur also decreases to the minimum at 4.3 kg/ha in the berseem crop. Lowered sulphur uptake for higher concentrations or application of zinc can result in decreased yield in the berseem crop.

2.4 Phosphorus-zinc Interaction in Soil Properties

According to Jajra et al. [63], plants need both phosphorus and zinc equally for their suitable growth and development. But sometimes they play an antagonistic effect on each other. If the phosphorus application in any soil is higher, zinc availability in that particular soil will decrease.

Phosphorus content in soil can be increased by the improper overuse of phosphate fertilizers and higher phosphorus-containing manures. It also causes eutrophication in the waterbody as phosphorus is lost through the runoff with the rainwater and irrigation water and mixes with nearby waterbody [64]. phosphorus residual should be utilized efficiently by cultivating those crops which have the most phosphorus use efficiency. Different phosphorus pools can also be used by optimizing the doses of phosphorus fertilizer application. Microbial activity is the major one for phosphorus utilization in the plant root zone [65]. The range of phosphorus content in Indian soils mostly varies from low to medium [66]. So, adequate management of phosphorus application is required for superior growth and development of the forage and green fodder crops. Otherwise, the deficiency symptoms will be reflected in green and dry fodder.

Rathore et al. [67] have noticed that the response of fodder crops is different for different zinc statuses in the soil as fodder crops have larger adaptability of zinc stresses and sensitivity depending on the soil types. The status of zinc in different soil properties is very useful to understand the actual capacity of the soil to supply zinc to the plant. Actually, zinc possesses an interrelationship between the availability of zinc in soil and other soil characteristics. Under suitable environmental conditions, the response of berseem crops to different doses of zinc fertilizer is limited especially in light-textured soil. Farmers don’t use zinc fertilizer properly in their fields which is the main reason behind the deficiency of zinc in most of the soils of India. So, before the cultivation of fodder crops zinc application is required as high zinc removal has been done by the cultivated main crop before the fodder crop [68].

3. EFFECTS OF BIOFERTILIZER ON FORAGE CROPS AND FODDER CROPS

According to Heisnam et al. [69], Bio-fertilizers are used to increase the fertility status of the soil and help in optimum plant growth and development when these are applied with the seed treatment, plant body or general soil application. They mainly contain beneficial microorganisms which are essential for maintaining soil fertility. By using plant parts mainly root and fertile soil, biofertilizers are made to minimize the requirement for synthetic fertilizer as well as the cost of cultivation [70].

The over-dependency of Indian farmers on chemical fertilizer results in increments in the price of the chemical fertilizer, soil and water pollution and poor soil fertility. So, with the use of biofertilizers, the efficiency of nitrogen fixation and the availability of macro and micronutrients can be increased [71]. Trace elements will be more assessable and they will produce several substances which play a vital role to promote plant growth. It also helps in the stimulation of different plant growth hormones like Gibberellic Acid, Indole Acetic Acid and Indole Butyric Acid. Biofertilizers increase the nutrient availability, solubilization of phosphorus and tolerance for moisture stresses. The number of Viable cells of any particular strain is nearly 10 million in a unit carrier of that particular biofertilizer [72].

According to Dutta et al. [73], Zinc-solubilizing bacteria are used as the supplementation of zinc fertilizer which helps to convert the form of applied zinc from inorganic to accessible form to the plant. Rhizobacteria species are mainly responsible for mobilizing zinc in soil solutions. These bacteria species produce or excrete several organic acids to make the zinc compounds solubilized. This solubilizing process of zinc is done in several steps to dissolve the unavailable zinc compounds in soil solution. The first step of this process is acidification. Microorganisms help to dissolve the zinc cations by producing organic acids and also minimize the pH of the soil.

4. CONCLUSION

Plants need both macro and micronutrients for their optimum growth and development. Indian farmers have knowledge only about the usefulness of primary macronutrients such as Nitrogen, Phosphorus and Potassium. According to them, higher doses of primary macronutrients will give them more yield. It is one of the main reasons behind the zinc deficiency in most of the Indian soils. So, farmers have to consider the application of micronutrients in their field practices, especially zinc fertilizer. As phosphorus plays an antagonistic relationship with zinc, doses of phosphorus should be optimum for the availability of both nutrients to the plant. In the case of fodder crops, effective yield and nutritious quality both are required. Microorganisms are mainly responsible for the availability of micronutrients in the soil as they convert complex nutrient compounds to simpler ones. So, the use of zinc-solubilizing bacteria with zinc sulphate will give an efficient result in fodder crops with optimum phosphate fertilizer doses.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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