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REVIEW ARTICLE

`*AZOTOBACTER*: AN OPTION FOR NITROGEN FERTILIZER SUBSTITUTION: A DETAILED REVIEW

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ABSTRACT

Nitrogen being a limiting factor for crop production, the supply of nitrogen to the crops has been more chemical-based, affecting soil health and sustainability in the long run. Because of the significance that biofertilizers play in crop productivity, there is a growing area of research in the agricultural sector on the use of beneficial bacteria as biofertilizers. It keeps the soil healthy, enhances plant nutrition, boosts organic matter content, and keeps the soil pH stable. Farmers' bio-fertilizer usage is beneficial for raising crop yield and boosting farmer revenue. *Azotobacter* could be one of the biofertilizer options for sustainable and environmentally friendly maize production in areas where chemical fertilizer is scarce. *Azotobacter* is being researched for its ability to fix nitrogen in soil and has a good impact on soil quality, growth, yield, and biochemical characteristics. Different findings have demonstrated the impact of *Azotobacter* in increasing the grain yield and yield attributing characters. *Azotobacter* provides nutrients to the plants by different mechanisms of nitrogen fixation, creation of phytohormones, and enhancement of nitrogen uptake. *Azotobacter* can be a biological regulator to improve environmental adaptability and crops' ability to use soil nitrogen. Therefore, *Azotobacter* is viewed as a potential substitute for chemical fertilizers where soil health and sustainability are of major concern.

KEYWORDS

Azotobacter, Growth, Productivity, Yield

1. INTRODUCTION

Vegetables are an essential part of our diet. They are widely grown worldwide and are reflected as a protective food as they play a significant role in human nutrition. Cole crops, which include cauliflower (*Brassica oleracea var. botrytis*), cabbage (*B. oleracea var. capitate*), sprouting

There is a rising need for food production and supply due to the yearly increase in human population. To meet the growing need for food, farmers have been reverting to conventional farming, which heavily relies on manufactured chemical fertilizers to produce large yields of crops. The type of fertilizers used as an additional source of vital nutrients for plants is a significant factor in increased crop production. To increase productivity and financial gains, fertilizer application is necessary to replenish nutrients depleted from cropland by earlier plant growth. As a result of the ongoing usage of chemical fertilizers, there is more emphasis on the effects on the soil ecosystem today.

Chemical pesticides and fertilizers have already been shown to have highly adverse long-term side effects that not only affect agricultural yield and soil health but also poison water supplies, leading to disturbance in the food chain and health hazards. Moreover, agroecosystem functioning has been significantly altered by agricultural intensification, which has led to the regional or national extinction of numerous wild plant and animal species (Khushali et al., 2015). Since many soils lack particular microorganisms that have been demonstrated to or are thought to enhance yield, crop plants must typically be inoculated with bacterial preparations. To encourage successful nodulation and adequate nitrogen fixation, *Rhizobium* preparations are widely used as an inoculant on legume crops (Hussain et al., 1987).

Beneficial plant-microbe interactions in the rhizosphere are the determinants of plant health and soil fertility in the era of sustainable agricultural production; the interactions in the rhizosphere play a crucial role in transformation, mobilization, and solubilization from a limited nutrient pool in the soil and reducing the need for chemical fertilizers (Jeffries et al., 2003; Mrkovački and Milić, 2001). Therefore, biofertilizers can be an option to replace those of chemical fertilizers partially. Biofertilizers help promote organic agriculture, where ecological processes, biodiversity, and cycles are essential for its functioning (Bastakoti and Khanal, 2022).

2. MATERIALS AND METHODS

Secondary sources were solely used to collect the data. Different articles, journals, internet sites were visited to gather the related information. The information to the vary topic is then recorded systematically.

3. DISCUSSION

3.1 Bio fertilizers

Biofertilizers, also known as microbial inoculants, are natural substances infused with certain microorganisms that come from the roots and root zones of plants. Research indicates they can enhance the plant's growth and yield by 10% to 40%. When these bioinoculants are applied to seeds,

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plant surfaces, or soil, they invade the rhizosphere and the plant's core, stimulating plant development. In addition to providing nutrients to the soil to increase crop productivity and soil fertility, they shield plants from pests and illnesses (Nosheen et al., 2021). Bio-fertilizer is becoming increasingly popular as a replacement for synthetic fertilizer, cutting crop production costs and improving crop quality, growth, development, and crop output by delivering and increasing nitrogen availability, as well as creating auxin, cytokinin, and gibberellins, which aid in plant growth (Yasin et al., 2012). The development of biofertilizers as a new technology has great promise for the nation's farmers in raising farm productivity and income (Khushali et al., 2015). Bio-fertilizers enhance the quantitative and qualitative characteristics of many plants. Similarly, the efficiency of nutrient usage and crop output is increased when biofertilizers are combined with chemical fertilizers (Yosefi et al., 2011).

3.2 Azotobacter

There are six species in the genus *Azotobacter*; *A. chroococcum* is the most often found, appearing in various soil types worldwide. Azotobacter produces the previously mentioned compounds, which, when added to seeds, promote seed germination and decrease plant ailments. The exact method via which Azotobacter stimulates plant growth remains unclear. N2 fixation, coupled nitrogen delivery to the plant, the synthesis of phytohormone-like compounds that influence plant development and morphology, and bacterial nitrate reduction, which encourages nitrogen accumulation in inoculated plants, are the three alternative approaches that have been suggested (Baral and Adhikari, 2013).

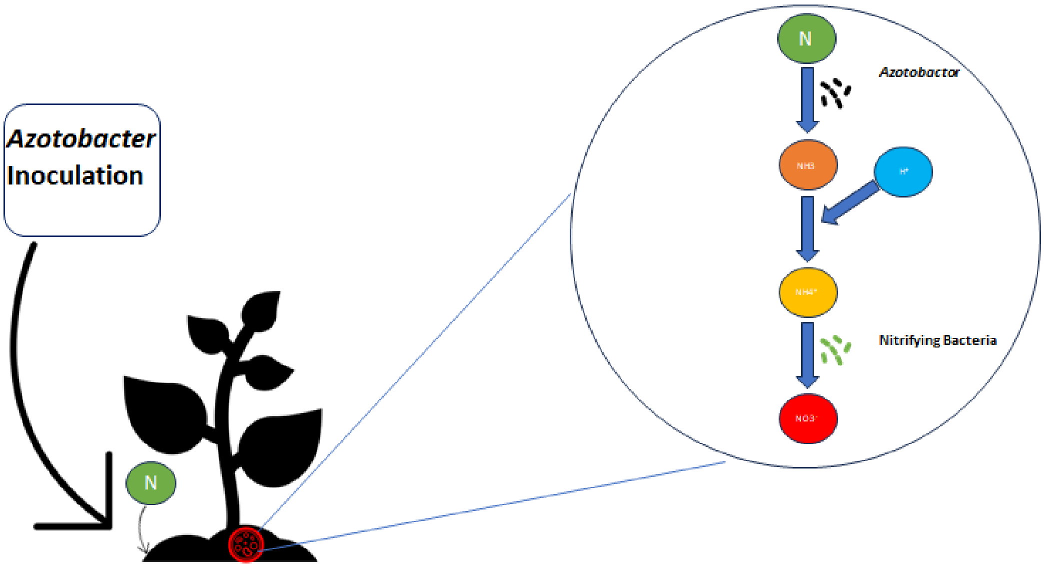

Figure 1: Illustrating the mechanism of Biological Nitrogen Fixation

3.4 Effect of Azotobacter inoculation on the vegetative characters of cereals

In terms of plant height, stem girth, dry shoot weight, root length and width, and root weight, *Azotobacter* demonstrates a favorable rise in all of these measures (Mahato and Neupane, 2018). The usage of *Azotobacter chroococcum* increased the number of bacteria. Azotobacter chroococcum enhanced early plant development (Stančić, 2011). Inoculating maize with *Azotobacter* tends to boost the growth of treated plants, as indicated by an increase in the lengths of the roots and shoots (Mahato and Neupane, 2018). The combination of *Azotobacter chroococcum* strains greatly aided the early growth of maize. The Tisa hybrid plants had a higher height than the control plants by up to 5 cm (Stančić, 2011). An increase in chlorophyll content following bacterial inoculation may have resulted from providing high nitrogen levels for the developing tissues and organs supplied by Azotobacter that fixes N2 (Ld and Okra, 1990).

3.4 Effect of Azotobacter inoculation on the yield components of cereals

Azotobacter inoculation can enhance maize grain production by 35% above the non-inoculated treatment. When no chemical fertilizer was applied, the advantage of *Azotobacter* inoculation was more significant. A positive additive impact of 10 t FYM ha-1 with *Azotobacter* inoculation was observed (15% yield increase) (Baral and Adhikari, 2013). *Azotobacter* paired with modest nitrogen fertilizer treatments had a substantial impact, resulting in increased nitrogen concentrations in grain and stover with higher grain yield (Meshram and Shende, 1982). The grain yield increased by 19.63% and 15.89% over the corresponding control, respectively, when maize (*Zea mays*) seeds with *Azotobacter* strains were sown in fields receiving no fertilizer and fertilizers (N and P at rates of 125 and 40 kg ha-1) instead (Hussain et al., 1987). *Azotobacter* strain inoculation improved wheat and maize yields by 19–30% and the bulk of the above-ground plant portions by 26–50% (Jagnow, 1987).

There is ability of single inoculation of *A. chroococcum* to fix atmospheric nitrogen with a significant positive response in all growth parameters (including shoot length, root length, shoot fresh and dry weight, root fresh and dry weight, and panicle number) of both vegetative and reproductive stages of rice plants (Prajapati et al., 1970). Inoculated plants outperformed non-inoculated plants in terms of plant height, grains per ear, and biological yield, according to the results. Inoculating *Azotobacter* had a positive effect, but as N levels increased, the effect diminished. The number of nodules and yield increased significantly with inoculation (Soleimanzadeh and Gooshchi, 2013).

3.3 Effect of *Azotobacter* inoculation on vegetables

The effect of *Azotobacter* on onion (*Allium cepa L.*) and demonstrated a considerable increase in germination percentage (85%), bulb weight (120.7g), maximum diameter of bulb (6.2cm), dry weight of bulb (23.9g), dry weight of plant (28.2g), harvest index (69.35%), plant height (57.3cm), and number of leaves (11.4) (Nayak et al., 2022). The maximum plant height, i.e., 98.4, and maximum number of fruits per plant, i.e., 40.31, was found in Brinjal with *Azotobacter* + Phosphate Solubilizing Bacteria (PSB) + 50 % RDF (Recommended Dose of Fertilizers). The combined treatment of *Azotobacter* and PSB appears to compensate for half the amount of chemical fertilizer as reported by (Vd and Pb, 2014). A group researchers concluded that seedling root dipping in *Azotobacter* had a considerable impact on the broccoli's growth and yield characteristics and concluded that growing broccoli may be a profitable business if full nitrogen doses (100 kg/ha) and *Azotobacter* inoculation were used (Bhardwaj et al., 2007). Maximum Plant height, leaf area, and curd weight were obtained when *Azotobacter* was inoculated with a full dose of nitrogen. Moreover, it was determined that applying *Azotobacter* to seedlings may save 50% of the nitrogen, increasing the yield and morphological character. This means that 50% of the nitrogen could be replaced by the use of bio-fertilizer (Subedi et al., 2019). A group researchers concluded that the maximum yield parameters and accessible N, P, and K in the soil after harvest were shown by 100% RDF+ commercial *Azotobacter* + commercial Phosphate Solubilizing Fertilizer, which was followed by 100% RDF + efficient *Azotobacter* + efficient Phospthate Solubilizing Fertilizer (Raut et al., 2021). Additionally, it was discovered that a simultaneous inoculation of *Azotobacter* and phosphate solubilizing fungus has a more harmonic influence on the growth and yield of chili than single inoculation.

3.4 Effect of Azotobacter inoculation on Fruits

The duration of watermelon's edible maturity is influenced by organic manures and biofertilizers, particularly the use of Azotobacter in conjunction with vermicompost and PSB (Sonkamble et al., 2022). The number of runners and crowns per plant and fruit set per plant in strawberries is significantly influenced by *Azotobacter* inoculation with PSB and *Azospirilium* (Tripathi et al., 2016). *Azotobacter* inoculation in mango increases the nutrient uptake and microbial plant biomass in mango, thereby contributing to the greater yield (Sharma and Kumar, 2008). *Azotobacter* improved plant development and recorded maximum fresh weight in pineapple (González et al., 2011).

Table 1: Effect of Azotobacter on yield of crops

S.N.	Crop	%Yield increased by *Azotobacter* inoculation
1.	Rice	5 (Hakeem et al., 2016)
2.	Wheat	8-10 (Hakeem et al., 2016)
3.	Maize	19–30 (Jagnow, 1987)
4.	Vegetables	2-45 (Pandey and Kumar, 1989)
5.	Sugarcane	9-24 (Pandey and Kumar,1989)
6.	Potato	38.3 (Triplett Jr et al.,1996)

4. CONCLUSION

The proper use of biofertilizers can lower the required dose of NPK fertilizers and production costs and hold the potential to reduce soil contamination. However, they cannot compete with conventional fertilizers to replace yields. Consequently, it is crucial to combine fertilizer sources from both organic and inorganic sources carefully. The application of *Azotobacter* reduced the amount of synthetic chemical-N fertilizer (urea) needed for crop development and can lessen the detrimental effects of chemical-N fertilizer on the environment. Yields from use of lower doses of nitrogen in crops and Azotobacter inoculation were almost identical to the use of recommended dosages of fertilizers. As a result, it will be wise to use Azotobacter as a supplement in addition to other chemical fertilizers because it makes sense from an economic and environmental standpoint.

AUTHORS CONTRIBUTIONS

The corresponding author Babita Bastakoti conceptualizes the topic and collected the required materials for the review and finalize the content. The Co-authors Dipak Khanal and Dhurba Banjade supported to review courses and proof reading.

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

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