International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(9): 491-495
Received: 02-06-2024
Accepted: 05-07-2024

Aakash Sharma
Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Ashok Dambale
Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Santosh Korav
Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author:
Aakash Sharma
Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Performance of wheat as influenced by biofertilizer and phosphorus levels under alternate furrow irrigation

Aakash Sharma, Ashok Dambale and Santosh Korav

DOI: https://doi.org/10.33545/2618060X.2024.v7.i9g.1583

Abstract
Wheat scientifically known as *Triticum aestivum* is a cereal crop produced in India and around World. The present work serves as a review of the effect on the performance of wheat as influenced by biofertilizer and phosphorus levels under alternate furrow irrigation on growth, yield, economic and soil health of wheat. The phosphorus levels and biofertilizers alter soil conditions and improve the plant growth and yield. Phosphorus levels and biofertilizers have the ability to improve soil structure, increase water retention, and boost microbial activity. Biofertilizers are valuable tool in agriculture for enhancing crop growth, yield, and quality metrics by boosting nutrient efficiency, reducing fertilizer waste, and cutting cultivation expenses. The present study of phosphorus levels and biofertilizers treatments managing nutrients has switched its emphasis to sustainability and environmental friendliness. The utilization of phosphorus levels and biofertilizers treatments provides soil with beneficial nutrients that help the crops to increase growth, yield, economics and soil health. It is important to boost productivity by using effective phosphorus levels and biofertilizers. The utilization of furrow irrigation is significant for producing adequate crop yield and water productivity. The impact of phosphorus levels and biofertilizers treatments has a positive impact on the growth, yield, economics and soil health of the wheat crop.

Keywords: Biofertilizers, crop, economics, growth, phosphorus, soil health, wheat, yield

1. Introduction

Wheat (*Triticum aestivum*) is a major cereal crop that is produced all over the world. Wheat accounts for 50% of global grain trade and 30% of total output. Wheat is also regarded as a staple food in over 40 countries throughout the world. Wheat is the primary food source for more than one-third of the world's population due to its adaptability and high nutritional value (Kaur *et al*., 2024) [13]. Wheat contributes 20% of the food's calories and around 55% of its carbohydrate content. It comprises carbohydrates (78.10%), protein (14.70%), fat (2.10%), minerals (2.10%), and significant amounts of vitamins (thiamine and vitamin B), as well as minerals (zinc and iron) (Kumar *et al*., 2022) [17]. Wheat is an excellent source of trace minerals such as selenium and magnesium. Wheat is farmed over an area of around 218.5 million hectares throughout the globe. The Green Revolution began in the late 1960s and had a significant impact on improving wheat output in India. In the Rabi season 2020-21, the total wheat area was 31.36 million hectares, the wheat yield was 3.43 t ha^{-1}, and India's wheat production after China was 107.6 MT (Singh *et al*., 2021) [26]. The three biggest wheat-producing states are Uttar Pradesh, Punjab, and Haryana, accounting for over 70% of total wheat production in India. These states are well-irrigated and have the potential for higher output. In Haryana, 98% of the land area under wheat is irrigated, while in Punjab, 96%. Wheat production must be increased to 900 Mt by 2050 (Dwivedi *et al*., 2017) [6]. Usually, the wheat crop is seeded in November through December and harvested in March or April throughout the winter months. Plant roots provide water and minerals to the plants after absorbing nutrients from the soil. It is assessed by measuring the length and density of the roots. Different genotypes and soil compositions have different effects on root development. Compact soil allows for slower root development than loose dirt (Chandra *et al*., 2023; Singh *et al*., 2021) [5, 26]. The environment and precipitation may be important factors in plant growth and development, which is directly influenced by root growth.

Higher concentrations of these two vital elements are nitrogen and phosphorus are required in Indian agriculture to adequately nourish wheat crops and satisfy the nation's growing food demands, as these are the two main minerals for plant development (Tiwari *et al*., 2023) [29].

Fertilizers are an expensive but necessary input to ensure increased harvests. The key to achieving a larger and more profitable crop is the careful application of fertilizers using the right technique and timing. After nitrogen, phosphorus is the second most important nutrient (Farid *et al*., 2023) [8]. Phosphorus (P) is an essential macronutrient for plants, playing an important role in many physiological and developmental processes, including root growth. Wheat, a key grain crop farmed all over the world, requires enough P for optimal development and output (Lamlom *et al*., 2023) [19]. Phosphorus is essential for root growth and development. It encourages the formation of new roots and lateral root branches by increasing cell division and elongation. It has been established that adding P to wheat enhances root length, surface area, and volume, hence increasing nutrient and water absorption efficiency (Jastrzębska *et al*., 2024; Kumar *et al*., 2022) [11, 17]. Wheat seedlings require phosphorus to develop and establish in the early stages. Adequate P availability during the early stages of development boosts the root-to-shoot ratio, which improves the plant's capacity to endure stressors including drought and nutritional deficits. It is necessary for the development of seeds, grains, and other reproductive organs of plants like flowers (Nadia *et al*., 2023) [22]. By raising the number of spikes per plant, grain weight, and yield, wheat's economic worth may be increased. Phosphorus is essential for wheat root development because it improves nutrition and water intake, encourages early growth, increases stress tolerance, and boosts output. Consequently, for the best possible wheat yield, maintaining sufficient soil P levels and using P fertilizers at the appropriate time and rate are crucial (Kumawat *et al*., 2023) [18].

Utilizing less expensive fertilizer sources, such as rhizobium and phosphatic solubilizing bacteria, is necessary since the cost of phosphatic and nitrogenous fertilizers is rising daily. Through increased biological fixation of atmospheric nitrogen and greater phosphorus availability to the crop, respectively, bio-fertilizers such as rhizobium and phosphate solubilizing bacteria play a significant role in enhancing the availability of nitrogen and phosphorus (Khiniab, 2023) [16]. By increasing nitrogen fixation, the introduction of an effective strain of *Rhizobium* to low-nitrogen soil may assist increase yield. Inoculants of phosphorus-solubilizers in agricultural plants' root zones partially solubilize insoluble phosphate and increase production and phosphorus utilization efficiency (Tiwari *et al*., 2023) [29].

Alternate furrow irrigation (AFI) is a significant strategy for reducing water application and irrigation expenditures while yet producing adequate crop yield and water productivity (Breedt *et al*., 2024) [4]. Therefore, the present paper aims to review the performance of wheat as influenced by biofertilizer and phosphorus levels under alternate furrow irrigation and demonstrated in pictorial form in Figure 1.

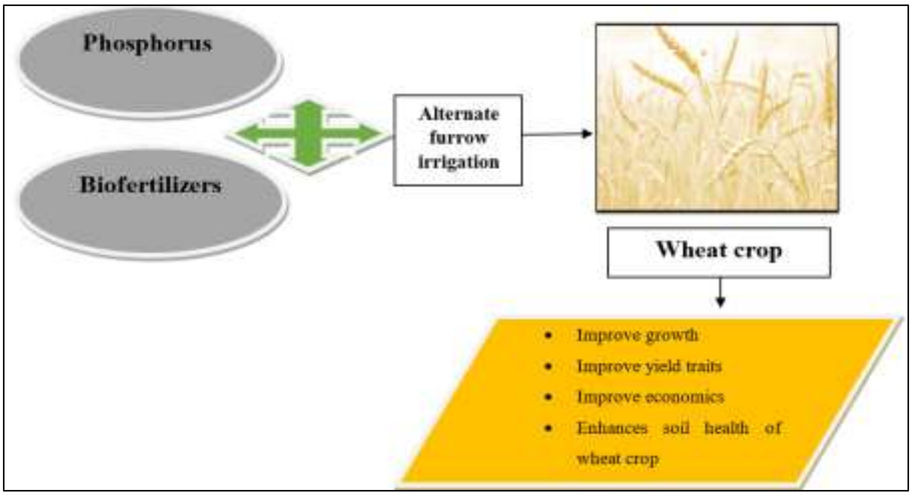

Fig 1: Demonstration of effect of biofertilizer and phosphorus levels under alternate furrow irrigation in wheat crop

2. Effect of biofertilizer and phosphorus levels on growth attributes under alternate furrow irrigation in wheat crop

Biofertilizer and phosphorus levels increases nutrient efficiency, decreases fertilizer waste, and lowers cultivation costs, making it an effective tool for improving crop growth, yield, and quality metrics in agriculture. Because of their large surface area, high sorption capacity, and regulated release kinetics to specific areas, biofertilizer are an efficient delivery system.

Kaur *et al*. (2024) [13] examined that the improving growth of the wheat crop depends critically on having a sufficient and balanced supply of biofertilizer and phosphorus levels. Indigenously available organic sources of nutrients have been shown to improve efficiency and decrease the need for chemical fertilizers. Because chemical fertilizers are prohibitively expensive, Indian farmers the majority of whom are marginal and small farmers do not provide these energy-rich crops with the recommended doses of nutrients. Fertilizers, biofertilizers, biostimulants, and their combination treatments under integrated nutrient management and alternate furrow irrigation may all provide phosphorus with nutrients. The phenology, growth habits, and requirements for temperature and photoperiod units vary throughout wheat varieties, and these factors together dictate the varietal adaptability to varying planting sites and timings. Determining the growth patterns, physiological characteristics, and yield qualities that would positively affect wheat grain yield and biomass under normal and late seeded conditions thus calls for a comparative examination of varieties appropriate for early, normal, and late sown conditions. Hasan *et al*. (2021) [9] conducted to investigate the effects of phosphorus levels and biofertilizers on wheat growth. The design of the experiment was a randomized block layout. using two variables: Phosphorus levels, or P_1 - (50 kg/ha), P_2 - (60 kg/ha), and P_3 - (70 kg/ha), which was repeated three times, and biofertilizers, or *Azotobacter* and *Azospirillum*. Results showed that the application of *Azospirillum* + 70 kg/ha Phosphorus resulted in significantly higher plant height (83.84 cm), number of tillers per m^2 (248.00), dry matter accumulation (614 g/m^2), and effective tillers per m^2 (229.33). As a result, it was found that *Azospirillum* + 70 kg/ha Phosphorus performed substantially better than other treatments. A study conducted by Mumtaz *et al*. (2014) [21] evaluated the effect of furrow irrigation system and phosphorus levels on wheat crop. To examine their impacts on wheat development, three irrigation levels (I_1 = well-irrigated, I_2 = water stress at reproductive stage, and I_3 = water stress both at vegetative + reproductive phases) and five different phosphorus levels (P = 0, 30, 60, 90, and 120 kg ha^{-1}) were used. Increased phosphorus application combined with optimal irrigation had a major impact on wheat growth. Increased rates of phosphorus application counteract the effects of water stress throughout both the vegetative and reproductive phases of life. Compared to stress during the reproductive stage, the effects of drought stress during the vegetative and reproductive stages were more severe. Maximum reduction in plant height and number of tillers was induced by lower rate of phosphorus application during water stress. It was determined that applying phosphorus at a greater rate might significantly lessen the negative effects of water stress. When it came to overall performance, applying phosphorus at a rate of 120 kg ha^{-1} performed better than other phosphorus levels when water stress was present. Similarly, El-Zeky (2005) [7] evaluated the effects of phosphorus fertilizer levels and biofertilizers on wheat development were studied in two field tests. Plant height, the number of tillers per plant, spike length, 1000-grain weight, and grain protein content were significantly increased when the amount of phosphorus fertilizer was increased from 45 to 60 and 75 kg P/fed. Additionally, grain and straw's absorption of N and P rise noticeably in both seasons. When compared to the uninoculated treatment in both seasons, the inoculation of wheat grain with biofertilizers led to a significant increase in plant height, spike length, 1000 grain weight, protein content of the grain, and P absorption of both grain and straw. The development of the wheat crop was significantly impacted by the relationship between biofertilization and phosphorus levels. With the dual inoculation was most compatible, as it has the highest wheat growth above uninoculation control, even if the maximum wheat growth and its components were recorded with the dual inoculation at the highest P rate (75 kg/fed).

3. Effect of biofertilizer and phosphorus levels on yield attributes under alternate furrow irrigation in wheat crop

Plants require biofertilizer and phosphorus levels to germinate, grow, and reproduce. Growth characteristics include plant height, number of plant spread, number of branches/plant, number of days to 50%, branches per plant, length of spikes, grain yield, straw yield etc. Biofertilizer and phosphorus levels application play an essential role in the yield improvement of plants. Plants generally depend on biofertilizer and phosphorus levels application through the soil and improved the yield of wheat crop.

Singh *et al*. (2016) [25] reported the effects of biofertilizers with varying NPK levels on wheat yield. In a Randomized Block Design, four NPK fertilizer levels (150:75:50, 120:60:40, 90:45:30, 60:30:20 kg NPK/ha) and four biofertilizer treatments (control, *Azotobacter*, Phosphate Solubilizing bacteria (PSB), and co-inoculation of *Azotobacter* + PSB) were replicated three times. The control, 100%, 75%, and 50% RDF correspond to these levels. As NPK fertilizer levels increased, the yield qualities increased as well. The greatest yields of grain (54.10 q/ha) and straw (79.69 q/ha) were observed at 125% RDF. Because *Azotobacter* and PSB inoculation were on par, the yield attributes were improved above control. A study conducted by Singh *et al*. (2013) studied how wheat performance is affected by phosphorus levels, farmyard manure (FYM), and biofertilizers. The yield characteristics and yield of wheat were considerably enhanced by seed inoculation with *Azotobacter* and *Azospirillum* compared to no inoculation. But in terms of the previously stated criteria, both were comparable. Using 10 tonnes FYM/ha, a higher mean grain yield of 4.443 tonnes/ha was found; this was 26.3% and 9.1% greater than the control group's 5 tonnes FYM/ha. The application of 120 kg P/ha enhanced the yield characteristics and wheat yield. The application of 120 kg P/ha enhanced the mean grain production by 8.1 and 22.4% as compared to 90 and 60 kg P/ha, respectively. The treatments increased the absorption of P by wheat grain and straw. The addition of these inputs produced beneficial modifications in the soil's accessible P concentration. FYM and application enhanced the available P content. Similarly, Kachroo and Razdan, (2006) [12] carried out to investigate the impact of phosphorus levels and biofertilizers on wheat crop yield parameters. A 1:1 combination inoculation of *Azotobacter* and *Azospirillum* greatly improved the yield properties. The figures for phosphorus-use efficiency were similarly greater. Significant increases in yield-attributing characteristics and wheat yield were seen with each unit increase in P level. With the highest P level, the largest grain yield (53.55 q/ha) was observed. Up to 80 kg P/ha, there was an increase in the phosphorus-use efficiency (PUE), phosphorus-efficiency ratio (NER), and physiological efficiency index of absorbed nitrogen (PEIN); however, these values dropped as the P level increased. Likewise, Afzal *et al*. (2005) [2] investigated the study under rainfed circumstances to determine the effects of Phosphate Solubilizing Microorganism inoculants on phosphorus absorption and their impact on wheat yield. The effect of a combination of *Pseudomonas* and *Bacillus* species on phosphorus absorption and yield in wheat variety 'Rawal - 87' was investigated. The treatments resulted in a considerable increase in seed phosphorus content (%) and tillers per m^2 compared to the control. The treatments considerably boosted grain yield and biological yield, with greatest yield achieved when PSM was combined with phosphorus or organic matter. It was observed that PSM alone or in conjunction with other combinations had a significant impact on grain and biological yield, tillers per m^2, and seed phosphorus content.

4. Effect of biofertilizer and phosphorus levels on economics under alternate furrow irrigation in wheat crop

Biofertilizer and phosphorus levels has positive effects on economic parameters when applied to wheat cultivation.

Abbasi and Yousra, (2021) [1] evaluated a review of various studies and discovered that the use of phosphorus levels and biofertilizers, improved soil health and led to higher wheat economics across different agroclimatic regions and had highest gross returns, net returns and B:C ratio. A study evealuated by Yadav *et al*. (2022) [30] conducted out to investigate how integrated nutrient management and furrow irrigations affect wheat economics. In a randomized block design, the experiment has ten treatment combinations. Each of the three replications has a distinct combination of biofertilizer and phosphorus levels. It can be concluded that during the first year (2020–21) and second year (2021–22) of experimentation, the maximum gross return of Rs. 15,8043/ha and Rs. 15,6367/ha, net return of Rs. 9,4499/ha and Rs. 9,7635/ha, and benefit cost ratio (B:C ratio) of 1.57 and 1.62 were recorded under treatment T_{10} [100% NPK + FYM + Zn5 +*Azotobacter* + PSB]. A similar maximum cultivation cost of Rs. 60192/ha was reported in the first year and Rs. 60408/ha in the second year using treatment T_{10} [100%NPK + FYM + S30+ Zn5 + *Azotobacter* + PSB]. Similarly, Kaushik *et al*. (2012) [14] outlined a field experiment to investigate the impact of nutrient sources, biofertilizer, and their combination on wheat economics and productivity. Higher net yields and a better B:C ratio were obtained when 3.0 t vermicompost plus 100% RDF was applied as opposed to vermicompost alone (1.5 and 3.0 t/ha). In comparison to *Azospirillum* and the inoculated control, the dual inoculation of *Azospirillum* + PSB resulted in noticeably greater net returns and a B:C ratio. Mahanta and Rai, (2008) [20] evaluated an economic and soil health analysis of furrow irrigation and integrated nutrient management practices in wheat crop and discovered that practices such as the use of phosphorus levels and biofertilizers improved soil health and reduced production costs. A research by El-Zeky, (2005) [7] discovered that phosphorus levels and biofertilizers significantly improved soil health indicators such as soil organic matter, soil fertility, and microbial biomass, resulting in increased wheat yield. Phosphorus levels and biofertilizers can improve soil health indices during wheat cultivation. They can enhance soil organic matter, soil pH, soil nutritional status, soil microbial activity, and soil water-holding capacity, resulting in increased plant growth and production.

5. Effect of biofertilizer and phosphorus levels on on soil health in sustaining the climate change scenario under alternate furrow irrigation in wheat crop

Biofertilizer and phosphorus levels are essential in contemporary agriculture for boosting crop yields and feeding a rising population. However, it is critical to consider the possible environmental implications of its use (Shahane and Shivay, 2021) [24]. Fertilizers can have an impact on soil health, groundwater, and air quality. The use of biofertilizer and phosphorus levels has an impact on the environment and the climate change scenario (Panwar *et al*., 2022) [23].

5.1 Soil Health

Biofertilizer and phosphorus levels can all have a beneficial or negative effect on soil health. Positively, they supply vital nutrients that boost soil fertility and encourage plant development. However, using biofertilizer and phosphorus levels incorrectly or excessively might have unfavorable effects. The natural balance of nutrients in the soil can be upset by an over-reliance on biofertilizer and phosphorus levels, which can result in nutrient imbalances and worse soil quality (Sreethu *et al*., 2024) [28]. This may lead to a reduction in soil fertility, a loss of organic matter in the soil, and a greater vulnerability to erosion. Conversely, over time, organic fertilizers help to improve the health of the soil. They have components in them, which improves the soil's nutrition availability, water retention, and structure. Additionally, promoting a better and more resilient soil ecology, biofertilizer and phosphorus levels also benefit beneficial soil microbes (Shahane and Shivay, 2021) [24].

5.2 Groundwater

Biofertilizer and phosphorus levels can all be hazardous to the quality of groundwater, particularly if they spill too much nutrient into nearby water sources. Because they are more soluble than organic fertilizers, inorganic fertilizers are more likely to seep into groundwater (Lamlom *et al*., 2023) [19]. Because it can pollute supplies of drinking water, nitrogen in the form of nitrates and phosphorus in phosphates form is especially concerning. Particularly for young children and expectant mothers, high nitrate and phosphorus levels in water can be detrimental to human health. Because biofertilizer and phosphorus levels release nutrients more slowly, there is less chance of nutrient leakage (Khan *et al*., 2023) [15]. Their ability to release nutrients more gradually and under control reduces the possibility of adverse effects on groundwater quality. Additionally, biofertilizer and phosphorus levels increase soils' ability to store water, which lessens the chance of runoff and leaching (Imran, 2024) [10].

5.3 The Environmental Impact of Fertilizer Production

Fertilizer producing industries contribute significantly to supplying worldwide fertilizer demand. However, their activities might have a negative impact on the climate and environment. Inorganic fertilizer manufacture, such as the Haber-Bosch process, frequently requires the high-temperature burning of fossil fuels (Mahanta and Rai, 2008) [20]. This process emits significant volumes of carbon dioxide (CO_2) into the atmosphere, which contributes to greenhouse gas emissions and climate change. Furthermore, extracting and processing raw materials for fertilizers can lead to habitat degradation, deforestation, and biodiversity loss (Ambedkar *et al*., 2023) [3]. To reduce their environmental effect and contribute to global efforts to combat climate change, these industries must embrace cleaner and more sustainable manufacturing techniques, such as the use of renewable energy sources and the implementation of carbon capture and storage technology. The utilization of biofertilizers has a positive impact on the environment and the climate change scenario (Imran, 2024) [10].

6. Conclusion

It is observed from the investigation that different biofertilizer and phosphorus levels under alternate furrow irrigation improved the growth, yield, economic and soil health of wheat crop. Biofertilizer and phosphorus levels result in better growth characteristics and yield-contributing traits. Utilization of biofertilizer alone or in conjunction with and phosphorus levels increases seed quantity and quality. Biofertilizer and phosphorus levels not only preserve the physical properties of the soil and a good nutritional balance, but they also make a great substrate for microorganism development. Proper utilization of biofertilizer and phosphorus levels improves the overall growth, yield, economics and soil health of wheat crop. As a result, using biofertilizer and phosphorus levels treatments in the wheat crop will benefit the farmer by improving soil nutrient management and providing critical nutrients to the plant.

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