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# INFLUENCE OF LIQUID BIO-FERTILIZER APPLICATIONS ON ONION GROWTH, BULB YIELD AND QUALITY UNDER DIFFERENT SEEDLING AGES

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## ABSTRACT

Onion (Allium cepa L.) is an economically important bulb crop whose productivity and quality depend strongly on nutrient availability, microbial activity, transplanting conditions and seedling age. The present research paper examines the influence of liquid bio-fertilizer applications on onion growth, bulb yield and quality under different seedling ages. Liquid bio-fertilizers containing beneficial microorganisms such as Azotobacter, Azospirillum, phosphate-solubilizing bacteria and potassium-mobilizing microorganisms can improve nutrient availability, root development and physiological activity. Seedling age is equally important because excessively young or over-aged seedlings may exhibit poor establishment, reduced vegetative growth and inferior bulb development. Previous field research has demonstrated significant responses of onion to biofertilizer inoculation, while studies on seedling age have reported considerable differences in growth and marketable yield. A combined approach involving appropriate seedling age and liquid bio-fertilizer application therefore provides an important strategy for sustainable onion production. The study emphasizes growth attributes, yield components, bulb quality and the potential for reducing dependence on chemical fertilizers through integrated microbial nutrient management.

***Keywords:*** Onion, Allium cepa L., liquid bio-fertilizer, seedling age, bulb yield, bulb quality, Azotobacter, Azospirillum, PSB

## I. INTRODUCTION

Onion (Allium cepa L.) is one of the most widely cultivated bulb vegetables and has considerable nutritional, economic and culinary importance. Successful onion production requires an adequate supply of macro- and micronutrients throughout the crop growth cycle because bulb formation depends upon the accumulation and translocation of assimilates from leaves to developing bulbs. Conventional onion production frequently relies on chemical fertilizers to obtain high productivity. Although mineral fertilizers can supply nutrients rapidly, excessive or inefficient use may contribute to nutrient imbalance, soil degradation and increased production costs. Consequently, increasing attention is being directed towards biological nutrient management using beneficial microorganisms that can improve nutrient availability and plant growth while supporting soil biological activity.

Bio-fertilizers are preparations containing living microorganisms capable of increasing nutrient availability and promoting plant growth through biological mechanisms. Microorganisms such as Azotobacter and Azospirillum can contribute to nitrogen acquisition and stimulate root development, whereas phosphate-solubilizing bacteria improve the availability of otherwise poorly soluble phosphorus. Potassium-mobilizing microorganisms may similarly increase the accessibility of potassium required for physiological processes and assimilate translocation. Recent research on onion has demonstrated improvements in plant height, leaf number, leaf area, chlorophyll content and photosynthetic activity following microbial inoculation with organisms such as Azotobacter and Azospirillum.

Seedling age is another important determinant of onion establishment and productivity. Seedlings that are too young may have insufficient root and shoot development at transplanting, whereas over-aged seedlings may experience root restriction, transplanting shock and altered subsequent bulb development. Research conducted under different agroecological conditions has shown that seedling age can significantly influence plant height, leaf number, bulb diameter, fresh bulb weight and marketable yield. In Northwest Ethiopia, seedling ages of 30, 40, 50 and 60 days produced significant differences in several growth and yield parameters. Similarly, research in India has shown that 50–60-day-old seedlings can perform better than 70-day-old seedlings under particular winter production conditions.

The interaction between bio-fertilizer application and seedling age is particularly important because microbial treatments may perform differently depending on the physiological condition of seedlings at transplanting. A well-developed seedling with an active root system may establish beneficial microbial associations more effectively than a weak or excessively old seedling. Recent field research involving microbial inoculants and different fertilizer levels demonstrated that PGPR treatments improved onion growth, yield and bulb quality and, in some treatments, permitted a reduction in mineral fertilizer application without yield loss. Therefore, integrating liquid bio-fertilizer management with appropriate seedling age may provide a sustainable strategy for improving onion productivity.

## II. EFFECT OF LIQUID BIO-FERTILIZERS ON ONION GROWTH AND PHYSIOLOGICAL DEVELOPMENT

Liquid bio-fertilizers influence onion growth primarily through microbial activities in the rhizosphere. Beneficial microorganisms colonize the root environment and improve nutrient availability through nitrogen fixation, phosphorus solubilization, potassium mobilization and production of plant-growth-promoting substances. These biological processes can increase root activity and facilitate nutrient uptake during the vegetative phase. Onion plants with improved nutrient acquisition generally develop greater plant height, more leaves and larger leaf area, which are important characteristics because the leaves act as the primary photosynthetic organs responsible for supplying assimilates to developing bulbs. Recent microbial studies in onion have reported significant improvements in plant height, leaf number, leaf area, chlorophyll content and photosynthetic rate following microbial inoculation.

Azotobacter is particularly relevant to onion production because it can contribute to biological nitrogen availability and stimulate plant growth. Nitrogen is required for chlorophyll formation, protein synthesis and vegetative development. However, excessive nitrogen can produce luxuriant vegetative growth and may negatively affect bulb maturity and storage characteristics. Biological nitrogen fixation provides a more gradual nutrient contribution and may complement mineral fertilizer application. Azospirillum can also promote root development and improve nutrient uptake through associative interactions with plant roots. Such microorganisms may be particularly useful during early establishment, when rapid development of an effective root system is essential.

Phosphate-solubilizing bacteria represent another important component of biofertilizer formulations. Phosphorus is involved in energy transfer, root development and several metabolic processes. A considerable proportion of soil phosphorus may occur in forms that are not immediately available to plants. Phosphate-solubilizing microorganisms can release organic acids and other compounds that increase phosphorus availability in the rhizosphere. Improved phosphorus nutrition during early growth can encourage root proliferation and improve subsequent plant establishment. When combined with nitrogen-fixing microorganisms, phosphate-solubilizing bacteria may produce complementary effects on onion growth.

Liquid formulations have certain practical advantages compared with some conventional carrier-based biofertilizers. They can be applied through root dipping, soil drenching, fertigation or foliar application depending on formulation and crop-management requirements. Root dipping at transplanting can expose the young root system directly to beneficial microorganisms, potentially improving establishment after transplanting. Field research using PGPR root-dipping treatments in onion demonstrated improvements in plant growth, yield attributes and bulb quality, with selected microbial combinations producing higher yields than uninoculated controls.

The effectiveness of liquid bio-fertilizers, however, depends on microbial viability, soil temperature, moisture, organic matter, pH, nutrient status and compatibility with other agricultural inputs. Therefore, application should not be considered a replacement for all fertilizers under every condition. Instead, integrated nutrient management combining organic resources, recommended mineral fertilizers and microbial inoculants may provide greater reliability. ICAR's onion and garlic advisory also recommends biofertilizers such as Azospirillum and phosphorus-solubilizing bacteria as part of integrated nutrient management.

## III. INFLUENCE OF SEEDLING AGE ON ONION GROWTH, BULB DEVELOPMENT AND YIELD

Seedling age has a direct influence on transplant establishment and subsequent crop performance. At transplanting, seedlings should possess sufficient root and shoot development to tolerate field conditions. Very young seedlings may suffer from weak root systems and transplanting stress, whereas excessively old seedlings can become root-bound or physiologically over-mature. Therefore, identifying an appropriate seedling age is essential

for achieving rapid establishment and optimum bulb formation. Research conducted under different environmental conditions confirms that seedling age can significantly affect plant height, leaf production, bulb diameter, bulb weight and marketable yield.

The physiological condition of seedlings at transplanting determines their ability to resume active growth after field establishment. Younger seedlings generally require more time to establish a functional root system, whereas moderately aged seedlings may recover from transplanting more quickly. Older seedlings may initially appear larger, but greater seedling size does not necessarily guarantee higher bulb yield. Previous research using different transplant ages and tray cell sizes found that transplant age influenced survival, root development and bulb-size distribution, while very young seedlings could show reduced establishment under stress conditions.

Indian research provides additional evidence that seedling age should be optimized according to agroecological conditions. A study conducted in Haryana evaluated 50-, 60- and 70-day-old onion seedlings and found that 50- and 60-day-old seedlings produced greater plant growth and bulb yield than 70-day-old seedlings under the experimental conditions. Another Indian study examining 6-, 8- and 10-week-old seedlings reported differences between vegetative growth and yield responses, demonstrating that the optimum age may vary according to the desired production objective and environmental conditions.

Seedling age can also affect bulb quality characteristics. Neck thickness, bolting, split bulbs and bulb maturity are important quality indicators in onion. Research in Haryana showed that 50- and 60-day-old seedlings were associated with favorable bulb-quality characteristics compared with older seedlings under the tested conditions. Excessively old seedlings may experience physiological changes that influence subsequent bulb development, while inappropriate transplanting time can further intensify these effects.

The relationship between seedling age and yield is also influenced by variety and environmental conditions. A study in Northwest Ethiopia involving 30-, 40-, 50- and 60-day-old seedlings found that seedling age significantly influenced several growth and yield parameters and identified 60-day-old seedlings as the best treatment under that specific agroecological environment. This indicates that there is no universal optimum seedling age for every production system. Temperature, photoperiod, cultivar, nursery management, soil condition and transplanting season must all be considered.

Consequently, seedling age should be evaluated together with microbial nutrient management rather than as an isolated factor. A properly developed seedling may establish more effectively following bio-fertilizer application because its root system provides a larger surface for microbial interaction. Conversely, weak or over-aged seedlings may not respond optimally even when beneficial microorganisms are supplied. An experimental factorial or split-plot design involving several seedling ages and liquid bio-fertilizer treatments can therefore identify the most effective combination for particular agroecological conditions.

## IV. COMBINED INFLUENCE OF LIQUID BIO-FERTILIZER AND SEEDLING AGE ON BULB YIELD AND QUALITY

The combined management of seedling age and microbial nutrition represents an important approach to sustainable onion production. Bulb yield is the final result of several developmental processes, including plant establishment, leaf production, photosynthetic activity, assimilate accumulation and bulb enlargement. Bio-fertilizers can improve nutrient acquisition, while optimum seedling age can ensure successful establishment. When both factors are properly synchronized, the crop may achieve greater vegetative growth and improved resource-use efficiency.

An important advantage of microbial inoculation is its potential to improve yield without relying exclusively on higher mineral fertilizer rates. Research involving PGPR inoculants in onion demonstrated improvements in bulb yield and quality, and selected treatments produced higher yields even when mineral fertilizer application was reduced. The study reported that certain microbial combinations with 75% NPK generated higher yields than uninoculated full-NPK treatments, suggesting the potential of microbial inoculants to contribute to fertilizer-use efficiency.

Bulb quality should be evaluated alongside total yield because a high total yield does not necessarily represent high marketable production. Important quality parameters include bulb weight, bulb diameter, neck thickness, total soluble solids, dry matter, ascorbic acid, pyruvic acid and storage behavior. Microbial inoculation has been reported to improve several of these characteristics, including ascorbic acid, total soluble solids, pyruvic acid and dry matter, while reducing physiological weight loss during storage. These effects may increase both market value and storage potential.

The age of seedlings can further influence bulb quality through its effects on crop maturity and plant architecture. Research involving different planting dates and seedling ages found significant differences in bolting, split bulbs and neck thickness. Under the Haryana conditions examined, 50–60-day-old seedlings produced favorable combinations of growth and bulb quality. These observations suggest that seedling age management should be considered an important component of quality-oriented onion production.

A suitable experimental design for evaluating the combined effects of liquid bio-fertilizers and seedling age would include multiple seedling-age treatments and several microbial treatments. For example, seedlings could be categorized into young, medium and advanced age groups, while bio-fertilizer treatments could include an uninoculated control, individual microbial inoculants and a consortium containing nitrogen-fixing, phosphorus-solubilizing and potassium-mobilizing microorganisms. Growth observations could include plant height, number of leaves, leaf area, chlorophyll content and root characteristics. At harvest, bulb diameter, average bulb weight, marketable yield and total yield could be assessed.

The overall significance of this integrated approach lies in developing a practical nutrient-management strategy that combines biological efficiency with appropriate crop establishment. Recent evidence indicates that microbial inoculants can improve onion physiological performance and rhizosphere characteristics, while seedling-age studies demonstrate substantial effects on yield and quality. Therefore, optimizing the interaction between liquid bio-fertilizer and seedling age may provide farmers with a sustainable means of improving productivity, reducing unnecessary fertilizer use and maintaining bulb quality.

## V. CONCLUSION

Liquid bio-fertilizers have considerable potential for improving onion growth, nutrient acquisition, bulb development and quality. Microorganisms such as Azotobacter, Azospirillum, phosphate-solubilizing bacteria and potassium-mobilizing microorganisms can contribute to improved rhizosphere functioning and nutrient availability. Evidence from onion research indicates that microbial inoculation can enhance vegetative growth, yield attributes and several bulb-quality characteristics. Therefore, liquid bio-fertilizers should be considered an important component of integrated nutrient management rather than merely an alternative to chemical fertilizers.

Seedling age is equally important in determining onion crop performance. The evidence demonstrates that both excessively young and over-aged seedlings may be less suitable than seedlings transplanted at an appropriate physiological stage. However, the optimum age varies according to cultivar, climate, soil, nursery conditions and transplanting season. Studies have reported favorable performance from medium-aged seedlings under some Indian conditions, while other environments have demonstrated advantages from older seedlings. Thus, local experimentation remains necessary for identifying the most appropriate transplanting age.

The combination of optimum seedling age with liquid bio-fertilizer application can potentially improve nutrient-use efficiency and crop establishment. Beneficial microorganisms may enhance root activity and nutrient uptake, while appropriately aged seedlings can recover rapidly after transplanting and develop an effective photosynthetic canopy. This complementary relationship may ultimately improve bulb size, marketable yield, quality and storage performance. Integrated microbial nutrient management may also reduce excessive dependence on mineral fertilizers and contribute to environmentally sustainable onion cultivation.

Future experimental studies should evaluate different microbial formulations, application methods, doses and frequencies together with different seedling ages under contrasting soil and climatic conditions. Measurements should include growth, root characteristics, yield, bulb quality, nutrient uptake, soil microbial activity and economic returns. Such studies would help establish location-specific recommendations for farmers. Overall, integrating liquid bio-fertilizers with scientifically determined seedling age represents a promising strategy for sustainable, productive and quality-oriented onion cultivation.

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