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# Onion Seed Response to Drip Irrigation and Fertigation Levels : A Review

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**Abstract**

Onion (*Allium cepa* L.) is one of the most important vegetable crop globally, with significant economic and nutritional value. The efficient use of water and nutrients is crucial for optimizing onion seed production. Drip irrigation and fertigation have emerged as sustainable techniques to enhance water and nutrient management in onion cultivation. This review article comprehensively examines the response of onion seeds to different drip irrigation and fertigation levels, focusing on growth, yield, quality attributes, and water and nutrient use efficiency. It delves into the historical background of onion cultivation in India, the current state of drip irrigation and fertigation practices, potential future scopes for improvement, existing threats to onion seed production, challenges faced by Indian farmers, and proposed solutions to enhance productivity and sustainability.

**Key words : Onion seed production, drip irrigation, fertigation, water management, nutrient uptake.**

The Onion (*Allium cepa* L.) has become one of the most essential vegetable crops cultivated worldwide, valued for its culinary and medicinal properties. India is one of the largest producer and consumer of onions globally, making onion cultivation a critical aspect of Indian agriculture and economy[17][22]. Onion seed production is a significant aspect of the global agricultural sector, with various regions specializing in producing high-quality seeds for both local use and export[17]. Onion belongs to the Alliaceae family and is grown for its bulbs, leaves, and seeds. Onion seeds are essential for commercial onion production, as they serve as the primary means of propagation. Therefore, ensuring optimal seed quality and quantity is crucial for sustainable onion cultivation[11]. Efficient water and nutrient management are essential for maximizing onion seed production, conserving resources, minimizing environmental impacts and achieving high seed yield and quality in onions[3].

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Drip irrigation in India has seen significant growth and development over the past few decades[17]. Drip irrigation, a micro-irrigation technique of irrigation delivers water directly to the root zone of plants through a network of valves, pipes, tubing, and emitters, reducing water wastage and optimizing water use efficiency[9]. Onions, like many other crops, requires consistent moisture during their growth stages, and drip systems can provide this efficiently[44]. This promotes uniform growth and development, which is crucial for seed production where uniformity in seed size and quality is desired[6][44]. The area covered by drip irrigation in India has seen significant growth due to various government initiatives. As of early 2024, about 8.31 Mha have been covered under micro-irrigation schemes such as drip and sprinkler irrigation since the implementation of the "Per Drop More Crop" component of the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY-PDMC) from 2015-16[21].

Fertigation, the application of fertilizers through irrigation water, allows precise nutrient delivery, promoting balanced plant nutrition and improving crop productivity[6]. When implementing drip irrigation and fertigation for onion seed production, it's essential to consider factors such as soil type, plant spacing, water quality, and climate conditions to design an efficient and effective irrigation system. Regular monitoring of soil moisture, nutrient levels, and plant health is also crucial for successful seed production[39][23]. The combination of drip irrigation and fertigation offers several advantages over conventional irrigation and fertilization methods[25][13].

The current review synthesizes available information from scientific literature to give insights into the physiological and agronomic responses of the seeds of onions to different irrigation and fertigation regimes. This review aims to explore the effects of drip irrigation and fertigation levels on onion seed production, focusing on growth parameters, yield attributes, and physiological responses. The review also discusses the challenges associated with drip irrigation and fertigation in onion seed production and identifies potential areas for future research and development.

**2. Status of onion production and storage in India :** Onion cultivation has been practiced in India for centuries, with historical records indicating its presence in ancient texts and agricultural practices. Traditionally, onions were grown using flood irrigation and organic fertilizers. However, with increasing water scarcity and the need for efficient resource utilization, drip irrigation and fertigation gained prominence in the latter half of the 20$^{th}$ century. The historical evolution of onion cultivation in India provides insights into traditional farming methods and the transition to modern agricultural practices [22][19][52].

Onion production in 2023-24 is expected to be around 25.47 MT, compared to the previous year's production of about 30.1 MT. Thus the production of onion this year is expected to be less than last year. In 2023-24 year production is expected to be 3.43 MT in Maharashtra, 0.99 MT in Karnataka, 0.35 MT in Andhra Pradesh and 0.31 MT in Rajasthan. The onion production trend in India is presented in below figure. Onion production is expected to decline by about 15 percent during 2023-24 in India [17][22][47].

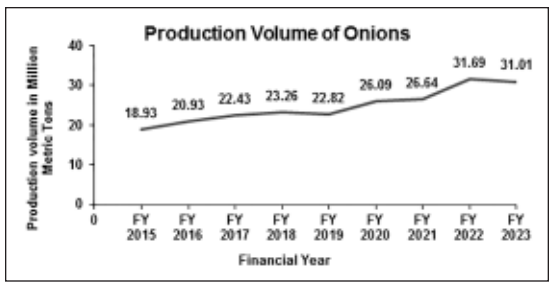


**Fig.** Onion production trend in India

The graph represents that, there are continuous increase in production of onion in India andmaking it the world's leading onion growers, with numerous states well-known for their output. Maharashtra is one of the largest onion-producing states in India and is accounted for 29.8% of the total onion production in the country[17]. The annual requirement for onion seeds in India is approximately 9,400 tons to cover an area of 1.173 million hectares. The organized sector contributes about 40% of the total seed requirement, while the rest is met by farmers who often produce seeds without adhering to isolation requirements[22][11]. The major onion-producing districts in Maharashtra include Nashik, Ahmednagar, Pune, Solapur, and Aurangabad. The Maharashtra government has taken various measures to support onion farmers, such as providing subsidies for seeds, fertilizers, and irrigation, and setting up onion storage facilities to prevent wastage and ensure a steady supply[32].

In contemporary India, onion cultivation extensively employs drip irrigation and fertigation systems, particularly in regions facing water stress and limited arable land. These modern techniques offer precise water and nutrient delivery, resulting in improved onion seed germination, growth, and yield. Farmers across states like Maharashtra, Karnataka, and Gujarat have adopted drip irrigation and fertigation to mitigate water wastage and enhance crop productivity[23]. Drip irrigation has gained popularity among onion seed producers in India. The onion seed production sector in India is evolving with the adoption of modern irrigation and fertigation technologies, improved seed varieties, quality control measures, and government support. These developments are expected to contribute to the sustainable growth of the onion seed industry and benefit farmers across the country[14][5].

The development of new onion varieties in Maharashtra has led to several improvements, comparing newly developed onion varieties in Maharashtra with older ones, highlights significant advancements in yield, disease resistance, storage capabilities, and overall adaptability[4][31]. The new varieties, such as, Phule Samarth, Phule Safed, Bhima Super, Bhima Red generally offer higher yields, better resistance to common diseases, enhanced storage capabilities lead to longer shelf life, reducing post-harvest losses, more adaptable to different climatic conditions, making them suitable for a wider range of growing environments and also improved colour and size in new varieties enhancing market acceptance and export potential, as compared to older ones.

Storage facilities for onions in India are crucial to maintain the quality and prolonging the shelf life of onions post-harvest. Effective storage helps in stabilizing market prices and ensuring supply throughout the year[24]. Various storage methods are used in India, ranging from traditional practices to modern technologically advanced facilities. The evolution from traditional to modern storage facilities in India has significantly improved the preservation of onions, reducing post-harvest losses and stabilizing market supply[37][16]. While traditional methods, such as Kanda Chawls, are still in use due to their low cost, the shift towards improved and modern storage facilities, such as Improved Kanda Chawls, Naturally Ventilated Warehouses, Cold Storage Units and Controlled Atmosphere (CA) Storage, is essential for meeting the demands of large-scale production and export markets.Continued support from government schemes and technological advancements will further enhance the efficiency and effectiveness of onion storage in India.

The future of onion seed production in India hinges on advancing drip irrigation and fertigation technologies. While existing research provides valuable insights, there is a need for further investigation into optimizing drip irrigation and fertigation strategies for different onion cultivars and environmental conditions. Future studies could focus on exploring advanced irrigation technologies, such as sensor-based irrigation scheduling, and assessing their impact on onion seed production and resource efficiency. Research and development efforts should focus on developing cost-effective solutions tailored to smallholder farmers' needs. Additionally, exploring climate-resilient onion varieties, promoting water-saving practices, and integrating digital tools for farm management hold promise for sustainable onion farming in India.

**3. Drip Irrigation in Onion Seed Production :** Irrigation practices are crucial for optimizing onion seed production, impacting yield, quality, and water use efficiency. Different irrigation methods, such as drip, sprinkler, and furrow irrigation, each have unique effects on onion seed production[33]. Drip irrigation method for watering crops, including onions, provides several benefits that directly impact

onion seed production. Drip irrigation is reported to be a water-efficient method that delivers water precisely and reduces water losses [9][44][14]. In onion seed production, drop by drop application of water offers several advantages, including improved water use efficiency, reduced weed growth, and enhanced nutrient uptake. Different authors have highlighted the benefits of drip irrigation in onion seed production and evaluated the effect of different drip irrigation regimes on seed yield, quality, and resource savings[2][44][5].

For onions, the precise water application is crucial because the crop is sensitive to both water stress and over-irrigation[4][7]. Consistent moisture availability promotes better root development, which is crucial for nutrient uptake and plant health, leading to a higher marketable yield. Additionally, reduced water stress helps in preventing quality issues such as splitting and rotting of onion bulbs. Onions grown with drip irrigation showed significantly better root growth and contributing to higher yields.Many authors concluded that, on comparison of drip irrigation with conventional furrow irrigation in onion cultivation, drip irrigation increased water use efficiency by up to 50% as compared to furrow irrigation[9][14][40][43]. Further, drip irrigation can lead to25-30% higher yields and improved quality of onions and as compared to traditional irrigation methods[7].

Since drip irrigation targets the root zone of the crop specifically, the surrounding soil remains relatively dry. This condition suppresses weed growth, which is a significant advantage as weeds compete with crops for water and nutrients[28]. By minimizing leaf wetting, drip irrigation reduces the incidence of foliar diseases such as downy mildew and neck rot. Drip irrigation significantly decreased foliar disease incidence in onion crops[42]. Maintaining optimal soil moisture levels with drip irrigation can also reduce soilborne diseases. Drip-irrigated onions had lower incidences of diseases such as Fusarium basal rot[26][46]. Reduced weed pressure can also lower the need for herbicides and manual weeding, saving time and resources[29].

Thus, drip irrigation has a profound impact on the water use efficiency of onion crops. It conserves water, enhances yield and quality, improves nutrient uptake, reduces weed growth, and offers significant economic and environmental benefits. As water resources become increasingly scarce, adopting efficient irrigation methods like drip irrigation will be crucial for sustainable onion production and overall agricultural sustainability.

**4. Fertigation Practices for Onion Seed Production :** Fertigation is the application of fertilizers through irrigation systems, allowing for precise nutrient management and increased nutrient availability to plants[23][39]. Proper fertigation practices are crucial for optimizing onion seed yield, bulb quality, and nutrient use efficiency. Different authors has discusses the role of fertigation in onion seed production, including the types of fertilizers used, application methods, timing, and dosage[6][1]. They also examined the effects of different fertigation levels on onion seedling growth, bulb development, and nutrient uptake. They reported that drip irrigation allows for precise control over nutrients through fertigation, where fertilizers are dissolved in the irrigation water and delivered directly to the plant roots. This targeted nutrient delivery optimizes nutrient uptake and reduces nutrient leaching[1].

Studies have shown that fertigation improves nutrient uptake efficiency in crops, including onions, leading to increased yields. Fertigation with appropriate nutrient management increased onion bulb yield by 30% compared to traditional methods[15]. Fertigation ensures a

uniform supply of nutrients, resulting in higher quality seeds with better germination rates and vigor. A study [13] also reported that fertigation improved the physical and physiological quality of onion seeds, leading to higher germination rates and seedling vigor. Precise nutrient application, reduces wastage and improving nutrient use efficiency. It [28] reducesnitrogen leaching by 40% and improved nitrogen use efficiency in onion crops [6]. Precision in nutrient application minimizes environmental impacts such as nutrient runoff and leaching. Fertigation systems provide flexibility in nutrient management, which can be adjusted to meet the crop's changing needs. This results in better crop management and labour efficiency. A study [20] demonstrated that automated fertigation systems reduced labour costs by 20% while maintaining optimal nutrient levels for onion growth . In India, adopting fertigation practices has led to a 20% increase in onion seed yield and improved seed quality, demonstrating the effectiveness of this practice[39].

However, the fertilization strategy should be tailored to the specific nutrient requirements of onions, which vary throughout their growth stages[29].The use of NPK (Nitrogen, Phosphorus, and Potassium) fertilizers is critical in onion seed production for optimal growth and yield. Nitrogen is essential for vegetative growth, promoting lush green foliage which is crucial for photosynthesis and overall plant vigor. Over-application can lead to excessive leaf growth at the expense of bulb and seed formation, while under-application can stunt growth and reduce seed yield. Phosphorus is vital for root development and energy transfer, supporting the plant's reproductive processes, including flower and seed formation. Adequate phosphorus ensures strong root systems and healthy seed set. Potassium enhances disease resistance, improves water use efficiency, and is crucial for the development of bulbs and seeds. Adequate potassium supports overall plant health and improves seed quality. By managing NPK levels effectively, you can enhance the growth, health, and seed production of onions, leading to higher yields and better quality seeds. In addition to NPK, sulphur is also an essential plant nutrient important for onion crop for improving yield and the pungency of onion bulbs. Sulphur is recommended as basal dose at the time of transplanting[26].

Thus, adopting fertigation practices in onion seed production results in higher yields, enhanced seed quality, efficient nutrient use, and sustainable agricultural practices. By leveraging the benefits of fertigation, farmers can achieve better economic and environmental outcomes.

**5. Combined Effects of Drip Irrigation and Fertigation on Onion Seed Performance :** The combined effect of drip irrigation and fertigation practices on onion seed production has been a subject of interest in agricultural research due to its potential to improve yield, water use efficiency, and nutrient management[13][25]. Many authors have investigated the interactive effects of drip irrigation and fertigation levels on onion seed yield, quality attributes (such as seed size, germination rate, and Vigor), and physiological responses (such as water use efficiency, nutrient uptake, and stress tolerance)[25]. The findings highlight the potential of integrated water and nutrient management strategies in enhancing onion seed production and sustainability[13][38].

Drip irrigation combined with fertigation significantly increase the yield of onion seeds. This method ensures a consistent supply of water and nutrients directly to the root zone, which enhances plant growth and seed productivity[5][15]. This method can result in higher seed yields compared to traditional irrigation and fertilization methods due to improved water and nutrient use efficiency [39]. The quality of onion seeds, including factors such as germination rate and seed vigor, is

positively affected by the precise application of water and nutrients through drip irrigation and fertigation[40] and also helps in maintaining optimal soil moisture levels and reducing nutrient leaching, thereby ensuring better seed quality .

Thus, the combined practice contributes to sustainable agriculture by improving water conservation and reducing the environmental footprint of fertilizer use[10] and support sustainable farming by optimizing resource use and reducing the negative impacts of traditional agricultural practices on soil and water resources [25]. Optimum levels of both irrigation and fertigation often result in the highest WUE and NUE values, indicating an optimal balance between resource input and seed output[13][5]. Improving WUE and NUE not only conserves resources but also reduces production costs and environmental impact[5][33].

**6. Threats and challenges to Onion Seed Production in India :** Onion seed production in India faces several threats and challenges, impacting both yield and quality. These includes erratic monsoons, declining groundwater levels, soil degradation, and pest infestations. Inadequate infrastructure for water storage and distribution exacerbates water scarcity challenges. Furthermore, market fluctuations and trade policies can impact onion farmers' income and livelihoods[8][12][30].

Onion cultivation requires significant water resources, and water scarcity in certain regions can limit seed production and overall crop yields. Erratic weather patterns, including sudden temperature fluctuations, unseasonal rains, and prolonged droughts, can also disrupt the growth and development of onion crops, leading to lower seed yields and poor seed quality[8]. Efficient water management practices and drought-resistant varieties are needed to mitigate this challenge[25]. Onion crops are susceptible to various pests and diseases such as thrips, nematodes, downy mildew, and bacterial blight. These can cause significant damage to the plants, reduce seed production, and lower the genetic purity of the seeds[30][52].

Farmers often face challenges in accessing high-quality onion seeds, which are essential for ensuring good yields and crop health. Poor-quality seeds can result in low germination rates, weak plants, and reduced productivity [18][34][35]. The lack of adequate infrastructure for seed processing, storage, and distribution can hinder the efficient supply of quality onion seeds to farmers[53]. This can lead to delays in planting, reduced crop uniformity, and increased susceptibility to pests and diseases[14][30][42]. Continuous cultivation of a limited number of onion varieties can lead to genetic erosion, reducing the diversity and resilience of the crop against evolving pests, diseases, and environmental stresses.

Volatility in onion prices and market demand can affect farmers' incentive to invest in onion seed production. Price fluctuations can also impact seed availability and affordability for growers[12][35]. Inconsistent or inadequate policies related to seed certification, intellectual property rights, and agricultural practices can create uncertainties for seed producers and farmers, affecting the overall seed supply chain[9][34].

## Conclusion

In conclusion, the review paper on "Onion Seed Response to Drip Irrigation and Fertigation Levels" presents a comprehensive overview of the significant impact of precision irrigation and nutrient management practices on onion seed production. Through an in-depth analysis of existing literature and empirical studies, this review elucidates the crucial role of drip irrigation and fertigation in optimizing seed yield, improving seed quality attributes, and enhancing resource use efficiency in onion cultivation.

The adoption of drip irrigation, characterized by its targeted water delivery directly to the root zone of plants, has revolutionized agricultural water management. By minimizing water wastage and maximizing water use efficiency (WUE), drip irrigation ensures that onion plants receive adequate moisture essential for growth and development. However, the choice of drip irrigation levels significantly influences seed production outcomes. Thus, striking a balance in drip irrigation rates is paramount to harnessing its benefits while mitigating potential drawbacks. In tandem with drip irrigation, fertigation emerges as a pivotal component in optimizing onion seed quality ensuring that plants receive essential nutrients in the right quantities and at the right times. The concentration and timing of fertigation play a crucial role in shaping seed quality attributes such as germination rate, seed vigor, and disease resistance. Thus, maintaining optimal fertigation levels is crucial for enhancing nutrient uptake by onion plants, thereby improving seed quality and overall crop performance.

Resource use efficiency (RUE) is a cornerstone of sustainable agriculture, and the judicious management of water and nutrients is instrumental in achieving optimal production outcomes. Studies consistently demonstrate that optimum levels of both drip irrigation and fertigation often result in superior water use efficiency (WUE) and nutrient use efficiency (NUE) compared to extreme levels. This underscores the importance of fine-tuning irrigation and fertigation practices to strike a balance between resource input and output, thereby optimizing production while conserving resources. The synthesis of findings from diverse studies underscores the nuanced interplay between drip irrigation, fertigation, seed yield, and quality in onion cultivation. Optimum level of drip irrigation coupled with balanced fertigation emerges as a winning combination, offering a harmonious blend of water and nutrient availability conducive to robust seed production.

Looking ahead, future research avenues beckon towards refining and innovating irrigation and fertigation technologies for onion seed production. Embracing sensor-based irrigation scheduling, precision nutrient delivery systems, and exploring the interplay of different onion cultivars with varying environmental conditions can further optimize seed production outcomes. Furthermore, evaluating the economic viability and scalability of these practices is crucial for their widespread adoption and integration into sustainable agricultural frameworks.

In conclusion, this review underscores the critical importance of tailored drip irrigation and fertigation practices in maximizing onion seed production while promoting resource efficiency and sustainability. By unravelling the intricate dynamics of water and nutrient management in onion cultivation, we pave the way for informed decision-making and transformative advancements in agricultural practices.

## References

AbouSeeda, M. A., A. Khater , S. A. Hammad, E.A. A. Abou El-Nour and Yassen A. A. 2020. Maximization of Nutrient Use Efficiency and Crop Production through Fertigation Technologies: An overview. Middle East J. of Agriculture Research. Vol. 9 (3) 558-585.

Aku, A., P. Mshenga, V. A. Sefa and Ochieng J. 2018. Effect of market access provided by farmer organizations on smallholder vegetable farmer's income in Tanzania. Cogent Food & Agriculture. Vol. 4: 1560596.

Aku, R., P. Kristiansen and Coleman, M. 2023. Water management and irrigation for bulb onion (*Allium cepa* L.) growth and development in the Papua New Guinea Highlands: A review.Asia Pacific Journal of Sustainable Agriculture Food and Energy. Vol. 11 (2) 47-58.

Alemu, D., C. Kitila, W. Garedew, L. T. Jule, B. Badassa, N. Nagaprasa, V. Seenivasan, A. Saka and Ramaswamy K. 2022. Growth, yield and yield variables of onion (*Allium Cepa* L.) varieties as influenced by plant spacing at DambiDollo, Western Ethiopia. Scientific Reports 12, Article number: 20563.

Aruna, S., P. Indira and Menon J. S. 2021. Effect of Varieties and Planting Time on the Performance of Onion under Tropical Planes of Kerala. Indian Journal of Agricultural Research. Vol. 57 (4) 507-512.

Ashrafi, M. R., M. Raj, S. Shamim, K. Lal and Kumar G. 2020. Effect of fertigation on crop productivity and Nutrient use efficiency. Journal of Pharmacognosy and Phytochemistry. Vol. 9(5): 2937-2942.

Bagali, A. N., Patil, H. B., Guled, M. B. and Patil, R. V. 2012. Effect of scheduling of drip irrigation on growth, yield and water use efficiency of onion (*Allium cepa* L.). KarnatakaJournalAgricultural Sciences. Vol. 25 (1) 116-119.

Bhakare, B. D. and Fatkal, Y. D. 2008. Influence of Micro-irrigation and Fertilizer Levels through Fertigation on Growth, Yield and Quality of Onion Seed. Journal of Water Management. Vol. 16(1) 35-39.

Bhasker, P., R. K. Singh, R. C. Gupta, H. P. Sharma and Gupta P. K. 2018. Effect of drip irrigation on growth and yield of onion (*Allium cepa* L.). Journal of Spices and Aromatic Crops, Vol. 27 (1) 32-37.

Chanu, K. I., A. K. Bijaya Devi, U. C. Singh, N. S. Devi and Singh N. G. 2022. Effect of different levels of nitrogen and spacing on growth and yield of common onion (*Allium cepa* L.) cv. Prema 178 under Manipur condition. The Pharma Innovation Journal. Vol. 11 (4) 1268-1274.

Cramer, C. S., S. Mandal, S. Sharma, S. S. Nourbakhsh, I. Goldman and Guzman I. 2021. Recent Advances in Onion Genetic Improvement- Review. Agronomy. Vol. 11 (3) 482. https://doi.org/10.3390/agronomy 11030482

Dinakaran, D., G. Gajendran, S. Mohankumar, G. Karthikeyan, S. Thiruvudainambi, E. I. Jonathan, R. Samiyappan, D. G. Pfeiffer, E. G. Rajotte, G. W. Norton, S. Miller and Muniappan R. 2013. Evaluation of Integrated Pest and Disease Management Module for Shallots in Tamil Nadu, India: a Farmer's Participatory Approach. Journal of Integrated Pest Management. Vol. 4 (2).

Dingre, S. K., D. D. Pawar, K. D. Kale and Kadam M. M. 2016. Onion seed productivity, nutrient use, and quality response to drip fertigation in semi-arid India. Journal of plant nutrition. Vol. 39 (10) 1391-1403.

Dingre, S. K., D. D. Pawar, and K. G. Kadam. 2012a. Productivity, water use and quality of onion (*Allium cepa*) seed production under different irrigation scheduling through drip. Indian Journal of Agronomy 57(2): 186-190.

Dudhat M. S. and Asodaria K. B. 2011. Effect of drip irrigation levels on onion seed production. Advance Research J. of Crop Improvement. Vol. 2(2) 232-234.

Dweh, T. J., J. Nayak, P. Rout and Parween A. 2024. Food storage and preservation. Futuristic Trends in Agriculture Engineering & Food Sciences. Vol. 3 (9).

FAO. 2020. "FAOSTAT Database." Food and Agriculture Organization of the United Nations.

Garg, M., S. Singhal, K. Sood, R. R. Apoga and Grima S. 2023. Price discovery mechanism and volatility spillover between national agriculture market and national commodity and derivatives exchange: the study of the Indian agricultural commodity market. Journal of Risk Financial Management. Vol. 16(2) 62.

Hanci, F. and Cebeci, E. 2018. Improving Stress Tolerance in Onion: Selection Studies Under Salinity Conditions. The International Journal of Engineering and Science. Vol. 7 (9) 54-58.

Hegde, D. M., S. N. Sudhakara Babu, A. Azlz Qureshi and Murthy I. Y. L. N. 2007. Enhancing nutrient-use efficiency in crop production - A review. Indian Journal of Agronomy. Vol. 52 (4) 261-274.

https://www.pib.gov.in/PressReleaseIframePage.aspx ?PRID=1795499

ICAR-DOGR. 2021. "Onion and garlic research." Indian Council of Agricultural Research - Directorate of Onion and Garlic Research.

Incrocci, L., D. Massa and Pardossi A. 2017. New Trends in the Fertigation Management of Irrigated Vegetable Crops - Review. Horticulturae. 3(2) 37.

Kakade, S. R., V. P. Kad, G. N. Shelke, G. B. Yenge and Kamble K. J. 2023. Different onion storage structures: Dimensions, materials and effects on the quality of onions: A review.The Pharma Innovation Journal. Vol. 12 (8) 1969-1983.

Kedar, P. B., P. R. Jaybhaye and Deshmane A. B. 2022. Effect of fertigation on performance of summer onion under different water regimes. The Pharma Innovation Journal; 12(1): 2928-2933.

Khokhar, K. M. 2019. Mineral nutrient management for onion bulb crops – a review. The journal of Horticultural Sci. and Biotechnology. Vol. 94 (6) 1-15.

Kiran, P. R., P. Aradwad, T. V. A. Kumar, N. N. Parvathy, C. S. Ramya, M.Sahoo, S. B. Urhe, R. Yadav, A. Kar and Mani I. 2024. A comprehensive review on recent advances in postharvest treatment, storage, and quality evaluation of onion (*Allium cepa* L.): Current status, and challenges. Future Postharvest Food. Vol.1(1)1-34.

Koye, T. D., A. D. Koye and Amsalu Z. A. 2022. Analysis of technical efficiency of irrigated onion (*Allium cepa* L.) production in North Gondar Zone of amhara regional state, Ethiopia. PLoS One. Vol. 17 (10) e0275177.

Kumari, G. 2022. Effect of different NPK levels and intervals of fertigation on growth and yield of onion (*Allium cepa* L.) in the central dry zone of Karnataka. The Pharma Innovation Journal. Vol. 11 (3) 2266-2269.

Likhi, A. 2020. Strengthening Market Access for Small and Marginal Farmers Through Farmer Producer Companies in India: Issues and Way Forward. National Institute of Agricultural Extension Management (MANAGE). Series, No.1/2020.

Mahatma Phule Krishi Vidyapeeth (MPKV). Research and Development Reports on Onion Varieties. Retrieved from MPKV Publications.

Megersa, H. G. 2017. Onion (*Allium cepa* L.) Yield Improvement Progress in Ethiopia: A Review. International Journal of Agriculture and Biosciences. Vol. 6(5): 265-271.

Mishra, S., S. K. Pyasi, M. K. Awasthi and Shrivastava R. N. 2023. Improving water efficiency and crop yield of drip-irrigated onions through the application of deficit irrigation, mulching, and fertigation. The Pharma Innovation Journal. Vol. 12(10) 2368-2371.

Muthukumar, G., R. Udhayakumar, A. Muthukumar, N. Muthukumaran and Ayyandurai M. 2022. Survey on disease incidence of basal rot of onion incited by Fusariumoxysporum f. sp. cepae in major onion growing tracts of Tamil Nadu. The Pharma Innovation Journal. Vol. 11 (8) 1445-1454.

Naeem, M. Y. and Selamoglu Z. 2021. Abiotic stresses and vegetable production in the era of climate change: A review. International Journal of Aquatic Research and Environmental Studies. Vol. 3(1) 37-72.

National Horticultural Research and Development Foundation (NHRDF). Onion Varieties Development and Performance Reports. Retrieved from NHRDF Publications.

Onion Cold Storage - Potential to Stabilize Price Fluctuation. ICAR-Directorate on Onion and Garlic Research, Pune. https://icar.org.in/node/4701.

Ortolá M. P. and Knox J. W. 2014. Water relations and irrigation requirements of onion (*Allium cepa* L.): A review of yield and quality impacts. Cambridge University Press. Vol. 51(2).

Patel, N. and Rajput T. B. S. 2005. Effect of fertigation frequency on onion (*Allium cep*a L.) yield and soil nitrate-nitrogen. Indian Journal of Agricultural Sciences. 75 (11): 725-30.

Patel, N. and Rajput, T. B. S. 2007. Effect of Drip Tape Placement Depth and Irrigation Level on Yield of Potato. Agric. Water Management. Vol. 88, 209-223.

Pokharkar, D. S., I. K. Kale and Pawar D. B. (2010). Management of Onion Thrips (*Thripstabaci* L.) through Varietal Screening and Newer Insecticides. Journal of Agric. Res. and Tech. Vol. 36 (2) 237-240.

Qin, H. and Liao T. F. 2016. Labor out-migration and agricultural change in rural China: A systematic review and meta-analysis. Journal of Rural Studies. Vol. 47, Part B, 533-541.

Rao, K. V. R., S. Gangwar, P. Aherwar and Yadav D. 2019. Growth, yield, economics and water use efficiency of onion (*Allium cepa* L.) under different micro irrigation systems. J. of Pharmacognosy and Phytochemistry. Vol. 8 (3) 3866-3869.

Sankar, V., A. Thangasamy and Lawande K. E. 2015. Effect of Drip Irrigation on Onion (*Allium cepa* L.) Seed Production under Western Maharashtra Conditions. International J. of Tropical Agriculture. Vol. 33(2).

Sankar, V., Lawande, K.E. and Tripathi, P.C. 2008. Effect of micro irrigation on growth, yield and water use efficiency of onion (*Allium cepa* L.) under western Maharashtra conditions. Indian Journal Agriculture Sciences. 78(7), 584-588.

Satpute, S. T., M. Singh, M. Khanna and Singh D. K. 2015. Modelling nutrient leaching below crop root zone of onion under drip fertigation. Journal of Agricultural Engineering. Vol. 52 (4) 50-58.

Schwartz, H.F., and Mohan, S.K. 2008. "Compendium of onion and garlic diseases and pests." APS Press.

Sethi, R. R., S. K. Jena, B. Renukarani and Jamanal S. K. 2022. Advanced Water Management Technology for Enhancing Agricultural Productivity. ICAR – IIWM & MANAGE.

Singh, G., A. Bhuker, V. S. Mor&Panghal V. P. S. (2018). Seed Quality Enhancement through Priming in Onion (*Allium cep*a L.). Seed Research J. Vol. 45 (2) 1-3.

Tripathi, P., and Lawande K. E. 2016. Designing and evaluation of onion storage structures for Indian conditions. International Journal of Agricultural Sciences. Vol. 6 (2) 918-924.

Vyankatrao, N. P. 2017. Impact of climate change on agricultural production in India: effect on rice productivity. Bioscience Discovery. Vol. 8 (4) 897-914.

Yadav, M., B. B. Vashisht, S. K. Jalota, A. Kumar and Kumar D. 2022. Sustainable Water Management Practices for Intensified Agriculture. Soil-Water, Agriculture, and Climate Change Water Science and Technology Library, 2022, p. 131-161

Zanjad A. B., A. R. Pimpale, S. M. Ghawade and Wadatkar S.B. 2021. Water use efficiency and cost economics of onion under different fertilizer levels in surface and drip irrigation. International Journal of Agriculture Sciences. Vol. 13(9) 10876-10879.