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Optimizing Irrigation and Fertigation Management for Vegetables

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Abstract:- The review highlights the importance of vegetable fertigation and the benefits of integrating irrigation and fertilization practices. Drip irrigation is introduced as a highly efficient method for precise water and fertilizer application, optimizing resource use. Fertigation further improves water and nutrient utilization, resulting in increased crop productivity and enhanced crop quality. The optimization of irrigation and fertigation is essential for sustainable and productive vegetable cultivation, minimizing resource wastage and ensuring precise water and nutrient delivery. By combining irrigation and fertilization, drip irrigation and fertigation offer effective solutions to enhance water and fertilizer use efficiency, reduce wastage, and improve overall crop performance in vegetable production.

Keywords:- *Fertigation,Crop productivity, Water and nutrient efficiency,*

I. INTRODUCTION

Vegetables play a crucial role in Indian agriculture and nutritional security due to their high yield, short duration, nutritional richness, economic viability, and ability to create employment. Water and fertilizer are essential inputs for successful vegetable production, and they have a significant impact on plant growth and yield.The importance and potential of drip fertigation technology for higher crop productivity and resource use efficiency in vegetable farming was explained in this article. Water and fertilizer are costly inputs, so efforts must be made to enhance their efficiency by reducing wastage. Drip fertigation, which is the application of water and water-soluble fertilizers through a drip irrigation system (Debbarma, *et al.,* 2018). It is highly efficient method and allows for even distribution and timing of nutrients. This technology can help reduce water loss through drainage and minimize the risk of groundwater contamination. By applying small amounts of nutrients as needed by the plant, drip fertigation can save on fertilizer usage and lead to higher crop yields. Proper fertilization by drip irrigation lines can reduce overall fertilizer application rates and minimize the negative environmental impact of vegetable production. (Hartz and Hochmuth,1996).

The article discusses the importance and potential of drip fertigation technology for higher crop productivity and resource use efficiency in vegetable farming. Drip fertigation involves the simultaneous application of water and fertilizer through a drip irrigation system. This technique helps reduce water loss through drainage and minimize the risk of groundwater contamination. The article highlights the significance of implementing drip fertigation to improve crop yields and optimize resource utilization in vegetable farming.

A. BROCCOLI

Metwaly, (2016) conductedfield trials at the experimental station, in agricultural science, Mansoura University. and investigated the effects of nitrogen and boron fertilization on broccoli yield and quality. The results showed that the interaction of N and B was important for vegetative growth parameters, physical quality parameters. Theinteraction of 70 kg nitrogen and 0.8 kg boron per mealwas the most effective treatment, as it recorded the highest values. In contrast, nitrogen content of 80 or 90 kg and high boron content of 1.2 kg for nutritiongave the lowest values of curd yield and quality parameters.

Basel and Mahadeen (2008) were conducted experiments on broccoland concluded that highest yield of broccoli per hectare with organic manure (40.05 tons ha^{-1}). However, increasing the amount of compost can increase the electrical conductivity and organic matter content of the soil. The optimum yield (40.05 tonnes ha^{-1}) of broccoli can be obtained by fattening use of 60 kg of inorganic fertilizer ha^{-1} in 60 tons of compost. The combined use of organic and inorganic fertilizers provided the best result.On same way Patyal and Chamroy (2021) at Lovely Professional University, Vegetable Research Farm, Phagwara, Punjabexperiment showed that inorganic fertilizers i.e.,N:P: K at 125:62.5:62.5kg/ha treatment was significantly better and recorded maximum plant height (35, 96 cm), the number of leaves/Plant, leaf chlorophyll content, head weight, yield/hectare (149.36 q/ha)and benefit cost ratio (4.57).

Jha et al.'s (2017) evaluation of drip and participatory irrigation methods in Saritoli village, Ranchi, serves as a vital contribution to the field. Their study illuminates the advantages of drip irrigation over furrow irrigation, with substantial increases in water productivity observed for potatoes and broccoli. These results underscore the importance of considering drip irrigation as a sustainable and efficient solution for maximizing crop yield while conserving water resources.

In contrast, in a separate set of field trials, the application of increased nitrogen levels at 400 and 600 kg N. ha-1, along with irrigation, demonstrated positive effects on the weight and yield of broccoli. Furthermore, these treatments expedited the process of head formation and resulted in an earlier harvest time. (Babik*et al.,*2002).

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B. CABBAGE

Kumar and Sahu (2013) conducted a study on cabbage, examining the effects of drip irrigation and fertigation. The research revealed that drip irrigation at 100% PE with fertigation at 150% recommended nitrogen dosage resulted in increased plant height and leaf count. Additionally, drip irrigation at 40% PE exhibited higher water use efficiency compared to furrow irrigation. These findings emphasize the benefits of drip irrigation and provide insights for optimizing cabbage cultivation practices.Ayas (2021) conducted a study focused on cabbage yield, irrigation, and fertilization treatments. The highest yield of 73.2 and 68.4 tons per hectare was achieved with the T2F1.0 treatment, which consisted of 100 percent potential evapotranspiration (PE) and 100 percent recommended dose of fertilizer (RDF) at a ratio of 100:100:100 kg NPK. Conversely, the lowest yield of 3.0 tons per hectare was observed in the no irrigation and 100 percent RDF treatment. Notably, 75 percent and 50 percent PE with 100 percent RDF were identified as effective irrigation and fertilization levels for cabbage.

On a similar note, Jadhav et al. (2020) conducted experiments on water management in cabbage cultivation. They found that an irrigation level of 0.4 times the crop evapotranspiration (ETc) resulted in the highest water use efficiency (WUE), while the lowest WUE was observed under the 1.2 ETc irrigation level. Additionally, fertigation with 125 percent RDF exhibited the highest WUE of 116.39 kg-ha mm1 and led to higher curd yields. Conversely, the lowest WUE was observed under 75 percent RDF due to lower curd yields. The treatment combination of 0.4 ETc and 100 percent RDF (RDF: 120:60:60 kg ha-1; N: P2O5:K2O) recorded the highest WUE.

In a study by Mishra et al. (2017), different nutrient levels were evaluated in cabbage cultivation. The highest cabbage yield was achieved with nutrient level N6 (NPK-125:75:60 kg/ha), while the lowest yield was observed with N1 (NPK-75:50:60 kg/ha). Additionally, the combination of Pusa Drumhead variety with NPK-125:75:60 kg/ha demonstrated the highest gross income and benefit-cost ratio.Another study by Madan Kumar Jha et al. (2017) examined the impact of agricultural input management techniques on cabbage growth. The treatment with 95.01% recommended dose of fertilizer (RDF) and 25% nitrogen to farmyard manure (FYM) resulted in the highest head formation percentage at harvest. Moreover, the treatment with 75% RDF and 25% nitrogen to FYM exhibited the maximum head height and head diameter at 60 days after transplanting.These findings emphasize the importance of nutrient balance and proper input management in optimizing cabbage yield and quality. By implementing the recommended nutrient levels and management techniques, farmers can enhance their crop productivity and profitability. These studies contribute valuable insights to cabbage cultivation practices, aiding in the efficient utilization of agricultural resources.

C. CAULIFLOWER

In a study conducted by Randhawa and Bhail (1976) on loamy sandy soils, higher nitrogen doses (120 and 180 kg N/ha) significantly increased the yield of cauliflower compared to lower nitrogen doses and control groups. Similarly, phosphorus doses of 40 kg/ha and 60 kg/ha showed similar effects, resulting in increased yield compared to no phosphorus application. However, applying 20 kg/ha of borax was found to be toxic and reduced yield, while applying 15 kg/ha of borax increased yield compared to 10 kg/ha. The combination of 120 kg N, 40 kg P2O5, and 15 kg borax per hectare resulted in the highest yield.

In another study by Singh et al. (2017), the maximum average curd weight and yield of cauliflower were achieved with fertigation using a combination of 90:60:45 kg NPK/ha and two foliar sprays. The economic analysis demonstrated that drip-irrigated cauliflower was the most profitable crop, exhibiting higher net yield and cost-benefit ratio compared to furrow irrigation.Furthermore,Jha et al. (2017) found that drip irrigation consistently resulted in higher water productivity, with an increase of more than five times in broccoli yield compared to other irrigation methods. They also observed that scheduling drip irrigation at 1.0 Epan (evaporation pan) led to significantly higher curd yield in cauliflower compared to scheduling at 0.8 Epan. Additionally, drip fertigation at 100% recommended dose of nitrogen and potassium recorded higher curd yield compared to 50% recommended dose.

In a study conducted by Kumar et al. (2015), different irrigation levels were examined to determine the effect on cauliflower yield and water use efficiency. They found that maintaining soil moisture at 80% of field capacity throughout the crop growth stages resulted in the highest curd yield and water use efficiency. Proper irrigation scheduling based on crop water requirements is crucial to avoid water stress and maximize cauliflower productivity.Verma et al. (2019), different fertigation levels were assessed to optimize nutrient management in cauliflower cultivation. They found that applying nitrogen, phosphorus, and potassium through fertigation at a rate of 100% recommended dose resulted in higher curd yield, head weight, and nutrient uptake compared to conventional soil application. Fertigation allows for precise nutrient delivery, improving nutrient use efficiency and reducing nutrient losses.

Moreover, the importance of micronutrients in cauliflower production has been investigated. In a study by Padhi et al. (2018), the impact of boron application through fertigation on cauliflower yield and quality was examined. They found that applying boron at the rate of 2 kg/ha through fertigation significantly increased curd weight, improved curd compactness, and reduced hollow curd incidence. Proper micronutrient management, including boron, is essential for achieving optimal cauliflower yields and marketable quality.

D. CHILLI

Singh et al. (2017) reported that fertigation with 75% recommended dose of fertilizer (RDF) resulted in the highest average fruit weight per fruit and fruit yield of chilli crops. These findings emphasize the effectiveness of fertigation at optimal RDF levels in achieving desirable yields and economic benefits compared to lower RDF levels.Veeranna et al. (2001) found that using 80% water-soluble fertilizer (WSF) through fertigation led to significantly higher chilli fruit yield compared to traditional soil application of normal fertilizers at 100% recommended dose. The use of WSF in both furrow and drip irrigation methods resulted in increased yields and a 20% reduction in fertilizer usage, indicating the potential for improved efficiency in nutrient application.

Tumbare and Nikam (2004) observed that fertigation of recommended doses of fertilizer at regular intervals significantly increased the yield of green chillies and nutrient uptake of nitrogen, phosphorus, and potassium. This suggests that fertigation with proper nutrient management can enhance both yield and nutrient utilization efficiency in chilli cultivation.Furthermore, Pandey et al. (2013) demonstrated the benefits of drip irrigation and fertigation in chilli cultivation. Drip irrigation led to increased fruit yield, higher net income, reduced crop duration, and minimized weed and disease incidences. Closer plant spacing and fertigation further enhanced yield, water savings, and total irrigation time compared to traditional top-dressing methods.

Ramachandrappa (2010) highlighted the importance of water and fertilizer management in chilli cultivation. Fertigation with appropriate doses of MAP (monoammonium phosphate) and KNO3 (potassium nitrate) at 75% RDF resulted in higher fruit yield and water use efficiency compared to soil application. Fertilizer use efficiency (FUE) was also improved with fertigation practices.Mali (2019) evaluated the effects of fertigation patterns and planting geometries on chilli cultivation. Higher fertilizer doses during the early reproductive stage, combined with denser planting geometries, led to higher nitrogen recovery, nitrogen use efficiency, and chilli yield per unit area. Water productivity was also improved with appropriate fertigation practices.

E. CUCUMBER

Beyaert (2007) found that surface drip irrigation with fertigation provided the highest irrigation water use efficiency compared to overhead sprinkler irrigation. Additionally, subsurface drip irrigation systems were observed to increase water use efficiency, particularly on course-textured soils during periods of high temperature and low rainfall.

Shinde et al. (2010) demonstrated that drip irrigation with eight splits and 100% recommended dose of nitrogen (RDN) led to increased fruit length, girth, density, and overall yield. Drip irrigation also showed improved water use efficiency compared to other irrigation methods. Furthermore, the treatment of 100% RDN through fertigation with eight splits provided the highest net returns and benefit-cost ratio. Fang et al. (2015) investigated the effects of irrigation and fertigation levels on cucumber growth and quality in greenhouse conditions. They observed positive correlations between irrigation and fertilization levels and plant height, leaf area, dry mass, yield, and quality of cucumber. The treatment with 75% of reference evapotranspiration (ET0) and full fertigation (Z100) resulted in the highest yield and water use efficiency. This treatment allowed cucumber plants to achieve both high yield and quality.Whereas, Patil and Gadge (2016) reported that applying 125% of the recommended dose of NPK through drip irrigation resulted in the highest cucumber yield and net income. The treatment with 100% NPK through drip irrigation showed the maximum fertilizer use efficiency.

Chand (2014) concluded that cucumber plants receiving 100% recommended dose of fertigation exhibited higher nutrient use efficiency and recorded significantly higher yield and water use efficiency. The economic analysis showed that 100% recommended dose of fertigation resulted in the maximum benefit-cost ratio.WhereasJilani (2009) highlighted the effectiveness of NPK fertilizer application (100-50-50) in various parameters of cucumber production, including flowering time, fruit setting, maturity, fruit size, and yield.

F. EGGPLANT

Narayanamoorthya et al. (2018) conducted research in Tamil Nadu, India, and highlighted the benefits of drip irrigation for eggplant cultivation. Their results showed that drip irrigation, in addition to reducing water usage and electricity consumption, increased fertilizer efficiency by 31% and overall yield by 52%. Additionally, net profit was found to increase by 54% compared to conventional irrigation methods, making drip irrigation a cost-effective and attractive option for sustainable eggplant production.

De Souza et al. (2017) explored the fertilization requirements of eggplant, specifically focusing on nitrogen (N) and potassium (K). They found that 14-17 g of N per plant (145-177 kg N/ha) resulted in the highest fruit yield, while single doses of potassium did not significantly influence yield or root dry matter. Their research indicated that 200 kg NPK/ha was adequate for optimal growth, dry matter production, and yield in both field and greenhouse conditions.

Esfahani et al. (2018) studied the water requirements of eggplant and concluded that deficit irrigation, providing water at 70-80% of crop evapotranspiration (ETc), resulted in the highest yield and water use efficiency. This research emphasized the potential for water savings without compromising eggplant productivity.El-Awady et al. (2019) investigated the impact of different irrigation schedules on eggplant water requirements in a sandy soil. They observed that maintaining soil moisture levels around 70-80% of field capacity throughout the growing season resulted in optimal plant growth and yield. This research emphasized the importance of monitoring soil moisture to avoid water stress and optimize water use efficiency.Mazumdar et al. (2020) studied the effect of varying irrigation levels on eggplant yield and water use efficiency. They reported that irrigating eggplant at 80% ETc resulted in the highest fruit yield and water use efficiency compared to lower or higher irrigation levels. This research highlighted the need for proper irrigation management to achieve optimal crop performance.

Furthermore, Abdel-Razzak et al. (2016) investigated the response of eggplant to deficit irrigation and found that reducing irrigation levels during the vegetative stage had minimal impact on yield while significantly reducing water consumption. This study suggested that careful management of irrigation during specific growth stages could help conserve water resources without compromising eggplant productivity.Singh et al. (2019) investigated the impact of different irrigation levels on eggplant yield, water use efficiency, and nutrient uptake. They reported that deficit irrigation at 70% of crop evapotranspiration (ETc) resulted in higher water use efficiency and comparable yield to full irrigation. Additionally, they found that moderate water stress during certain growth stages could enhance nutrient uptake and improve overall crop performance.

Wani et al. (2017) conducted research on drip irrigation scheduling for eggplant cultivation and compared different irrigation regimes. They observed that applying water at 80% of ETc through drip irrigation resulted in optimum growth, yield, and water use efficiency. This study emphasized the importance of precise water management through drip irrigation to achieve optimal eggplant performance.

G. OKRA

Sharma and Kaushal (2006) investigated different fertilizer treatments and drip irrigation ratios on okra water productivity. The F3I1 treatment (100% recommended dose of fertilizer (RDF) N and an irrigation water to crop evapotranspiration (IW/CPE) ratio of 0.60) resulted in the highest water productivity, followed by the F2I2 treatment (80% RDF and IW/CPE ratio of 0.80). F2I2 also recorded the maximum yield, demonstrating the potential of drip fertigation in improving water productivity and yield in okra.

Raval et al. (2011) focused on the effect of fertigation levels and intervals on okra fruit yield. They found that fertigation with 100% recommended dose of nitrogen (RDN) at a weekly interval resulted in the highest fruit yield, while an increase in nitrogen levels from 60% to 100% showed a linear increase in yield. Weekly fertigation intervals outperformed two- and three-week intervals in terms of fruit yield and economic profitability.

Sharma and Kaushal (2015) emphasized the benefits of drip fertigation in okra cultivation. Their study revealed water savings of 20% to 61%, yield increases of 13% to 76%, and fertilizer savings of 15% to 30% compared to traditional methods. Additionally, drip fertigation resulted in higher water use efficiency and proved to be economically viable, with benefit-to-cost ratios ranging from 1.41 to 2.99.

Sharma and Patel (2013) found that fertigation with 100% recommended dose of fertilizers (RDF) in drip irrigation resulted in higher plant height, fruit weight, and yield in okra. Singh and Patel (2014) reported that combining drip fertigation with plastic mulching increased plant height, fruit yield, and nutrient uptake in okra. Jat et al. (2016) compared drip fertigation with conventional methods and found that drip fertigation improved water use efficiency, yield, and net returns in okra.

H. ONION

Savitha*et al.,* (2010) The results showed the better effects of fertigation with 75% of the recommended dose of fertilizers on onion bulb yield. In the case of the Agrifound Dark Red onion variety, 75 per cent RDF fertigation resulted in higher bulb yield comparedto other treatmentofsoil application of fertilizer. Similarly, in the case of the COOn5 small onion variety, fertigation also led to higher bulb yield.

Bhakare and Fatkal (2008) stated that water soluble fertilizers at125 per cent of recommended dose with fertigation gave the highest yield of onion seed and also the improved the contributing parameters to yield, such as plant height, number of umbels per plot and per plant, diameter of umbel. But the yield was at par with 100 per cent of RDF with fertigation. WhereasSavitha (2010) indicated that the application of 75 per cent RDF fertigation recorded the highest benefit cost ratio.The pattern of nutrient uptake was also increased with of 75 per cent application of RD of fertilizer. Kedar (2023) showed that in case of onion the irrigation scheduled at 0.8 ETc noticed higher plants height, number of leaves and bulb yield. Where the fertigation level 100per cent RDF (100: 50: 50 kg ha^{-1}) recorded the superior plant height, number of leaves also yield of onion bulb. The 0.8 ETc and fertigation at 100per cent RDF treatment combination produce highest yield than other treatment combination. The maximum Water Use Efficiency 268.26 kg $ha^{-1}mm^{-1}$while maximum WUE observed in case of fertigationat 100per cent RDF.

I. TOMATO

Shedeed et al. (2009) found that drip irrigation significantly increased total dry matter production and leaf area index in tomatoes compared to furrow irrigation. Fertilization with 100% NPK also resulted in higher total dry matter and leaf area index. Tomato yield was 28% higher with drip irrigation, and fertilization with 100% NPK further increased yield. Fertilization treatments improved fruit number, main fruit weight, NPK uptake, recovery, and fertilizer use efficiency. The even distribution of nutrients through fertigation improved fertilizer use efficiency and reduced nutrient leaching.

Hayrettin et al. (2009) concluded that the highest marketable yield of tomatoes was achieved at 100% pan evaporation replenishment, and the maximum irrigation water productivity was observed at 80% pan evaporation replenishment. Jha et al. (2017) also reported increased yields of tomatoes by 58.7% through the application of drip irrigation in Saritoli village, Ranchi.

Gupta et al. (2013) observed that drip irrigation at 80% evapotranspiration and fertigation with 60% recommended dose of NPK significantly enhanced fruit yield, water use efficiency, and fertilizer use efficiency in tomatoes. Whereas,Ameta et al. (2021) suggested supplementing tomato crops grown in polyhouse conditions with 125% recommended dose of fertilizer at a three-day interval for improved plant height, number of branches, leaf area, fruit yield, and yield per square meter.

II. CONCLUSION

The combination of drip irrigation and fertigation techniques in vegetable crop cultivation allows for precise water and nutrient management. This approach improves yield, quality, water use efficiency, and nutrient uptake, leading to more sustainable and efficient farming practices. By implementing drip irrigation and fertigation, farmers can achieve sustainable and productive vegetable cultivation practices more effectively.

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