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A Review of Fluid Flow Applications and Hydraulic Performance of Sustainable Drip Irrigation to Improve Water Resource Management

Zainab T. Al-Sharify [a,b*], *Huda T. Hamad* [c], *Zinah A. Alshrefy* [d], *Salwa Ahmad Sarow* [a], *Thiab Hussein Nail* [e]

a Environmental Engineering Department, College of Engineering, Mustansiriyah University, Baghdad, Iraq.
b School of Chemical Engineering, University of Birmingham, Birmingham, United Kingdom.
c Water Recourses Engineering Department, College of Engineering, Mustansiriyah University, Baghdad, Iraq.
d Quality Assurance and University Performance Department, University Presidency, Northern Technical University, Mosul, Iraq.
e College of Engineering Sciences, Al Rafidain University College, Baghdad, Iraq.

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Corresponding author:

Zainab T. Al-Sharify

Environmental Engineering Department, College of Engineering, Mustansiriyah University, Baghdad, Iraq.

Abstract: Fluid flow applications to improve water resource management towards sustainable irrigation are one of the main targets of engineers nowadays, especially with global climate change. The performance assessment of the irrigation system is an important area of research to improve water resource management. Through drip irrigation systems, this review evaluated the application uniformity of water and nutrients to sustain agricultural production and protect the environment's natural resources. To achieve these goals, the adequate use of nutrients and water must be emphasized by utilizing sufficient water and nutrient management approaches, including a drip irrigation system that supplies the inputs immediately to the crop's root zone. The process operating pressure and the drip line length are the two most crucial aspects that affect the uniformity of the water and nutrient distribution in fields. Inconsistent or inadequate applications of fertilizers and water in the fields contribute to the incorrect supply of useful water and nutrients in the soil profile along the drip line length resulting in a significant decrease in crop yields and poor product quality. The main cause behind the operating pressures in a "micro-irrigation system" is the inadequate distribution of fertilizers and water in the fields. Therefore, the effects of such non-uniform distribution must be carefully quantified and studied to understand the reasons behind soil degradation and groundwater contamination, which occurs due to excess nutrient leaching from the crop's root zone. Data on the distribution and movement of water and nutrients in the soil is essential for designing efficient fertilization systems. Drip irrigation can reduce water exposure and input costs, making agribusiness more resilient, profitable, and successful. This paper discusses the uniformity of the nutrients and water application for crops grown in various agro-climatic regions. In addition, an effort was made to compare the findings' quality of various commonly used methods of water and nutrient application under different climatic conditions.

مراجعة تطبيقات جريان الموائع والأداء الهيدروليكي للري بالتنقيط المستدام لتحسين إدارة موارد المياه

زينب طالب عبد زيد الشريفي [1,2]، هدى طارق حمد [3]، زينة ادريس الشريفي [4]، سلوى احمد سارو [1]، ذياب حسين نايل [5]
[1] قسم هندسة البيئة / كلية الهندسة / الجامعة المستنصرية / بغداد - العراق.
[2] كلية الهندسة الكيميائية / جامعة برمنغهام / برمنغهام - المملكة المتحدة.
[3] قسم هندسة الموارد المائية/ كلية الهندسة / الجامعة المستنصرية / بغداد - العراق.
[4] قسم ضمان الجودة والأداء الجامعي / رئاسة الجامعة / الجامعة التقنية الشمالية/ الموصل - العراق.
[5] قسم علوم الحاسوب/ كلية الرافدين الجامعة/ بغداد - العراق.

الخلاصة
تعد تطبيقات جريان الموائع لتحسين إدارة الموارد المائية نحو الري المستدام أحد الأهداف الرئيسية للمهندسين في الوقت الحاضر، خاصة مع تغير المناخ العالمي. تقييم أداء نظام الري هو مجال مهم للبحث لتحسين إدارة الموارد المائية. من خلال أنظمة الري بالتنقيط، قيمة مراجعة المقال هذه تجانس استخدام المياه والمغذيات من أجل الحفاظ على الإنتاج الزراعي وحماية الموارد الطبيعية البيئية. للقيام بذلك، يجب التأكيد على الاستخدام الملائم للمغذيات، وكذلك الماء، من خلال استخدام نُهج كافية لإدارة المياه والمغذيات. يتضمن ذلك استخدام نظام للري بالتنقيط يوفر المدخلات على الفور لمنطقة جذر المحصول. من المعروف أن ضغط التشغيل للعملية وطول خط التنقيط هما أهم جانبين يؤثران على توحيد توزيع المياه والمغذيات في الحقول. ستساهم التطبيقات غير المتسقة أو غير الملائمة للأسمدة والمياه في الحقول في الإمداد غير الصحيح بالمياه المفيدة وكذلك العناصر الغذائية في ملف تعريف التربة على طول خط التنقيط، مما قد يؤدي إلى انخفاض كبير في غلات المحاصيل فضلاً عن ضعف جودة المنتج. السبب الرئيسي وراء ضغوط التشغيل في "نظام الري الدقيق" هو التوزيع غير المناسب للأسمدة والمياه في الحقول. لذلك يجب قياس الآثار الناتجة عن هذا التوزيع غير المنتظم بدقة ودراستها. يمكن أن يساعد ذلك في فهم الأسباب الكامنة وراء تدهور التربة وتلوث المياه الجوفية، والذي يحدث بسبب تسرب المغذيات الزائدة من منطقة جذر المحصول. تعد البيانات المتعلقة بتوزيع وحركة المياه والمغذيات في التربة ضرورية لتصميم أنظمة التسميد الفعالة. يمكن أن يقلل الري بالتنقيط من التعرض للمياه وتكاليف المدخلات، مما يجعل الأعمال التجارية الزراعية أكثر مرونة وربحية ونجاحه. تناقش هذه المقالة استخدام المغذيات والمياه للمحاصيل الزراعية المزروعة في مختلف المناطق الزراعية المناخية. فضلا عن تم بذل جهد لمقارنة جودة نتائج الطرق المختلفة الشائعة الاستخدام لاستخدام المياه والمغذيات في ظل ظروف مناخية مختلفة.

الكلمات الدالة: جريان الموائع، موارد المياه، تطبيق العناصر الغذائية، كفاءة الري، الهيدروليك، الاستدامة، البيئة.

1.INTRODUCTION

Water is important for maintaining life on earth and is consumed heavily [1]. Agriculture has been declining on a day-to-day basis and is expected to decline further in the future due to increased population growth and industrial development. Population growth as well as industrialization, are the main causes of agricultural land compression. One advantage of drip irrigation is that it does not cause moisture in the leaves of the trees. In addition, this method can assist in the management of the concentration of salts in the root zone [2]. The drip irrigation method requires prudent water to maintain agricultural production, where using fertilizers is important as it is the second most important factor in increasing agricultural production. However, while it is costly, mixing it with water irrigation increases production efficiency and can significantly reduce the cost of using fertilizers. In addition, it can also provide nutrients precisely and in uniform amounts to the wet irrigation area around the tree, where the roots of active nutrition are concentrated. Appling timely fertilizer batches of limited amounts of food to trees during their growing season can also assist in proper management [3]. One of the most advanced technologies is the drip irrigation system, where irrigation techniques have been developed to provide water and food at regular and frequent dosages directly to the crop's root zone with high water uniformity and fertilizer application. The groundwater contamination and degradation, crop quantity reduction, and lower production quality are caused by the erratic use of food and water. Wheat (Triticum aestivum L.) and corn (Zea mays L.) need high levels of nitrogen fertilizers to achieve ideal harvests. The water quality can be adversely affected by leaching such nutrients as NO_3-N and PO_4-P [4]. The standardization process with water and nutrients is important for the developer to have a reliable and cost-effective drip fertilizer system that results in better feedback for end users, which is very important for designers to obtain abundant information on the standardization of nutrients and water contained by agricultural lands involving nutrient dynamics and soil water in the crops root zones. Therefore, useful data on consistency with nutrients and water is critical for designers to obtain effective and inexpensive drops. The fertilization systems result in better input to achieve maximal crops at the end of usage. All such factors are extremely important for designers [5,6]. The present paper aims to review data on water and fertilizer uniformity under drip irrigation, water and nutrient distribution in soil, and nutrient uniformity effects on yield and product quality. It must be noted that an increase in the downward soil water flux is probably due to irrigation. This behavior may result in an enhanced loss of nutrients under the root zone.

In the past, researchers [3, 8-13] have reported clear findings stating that in drainage waters in permeable soils, the largest phosphorus (P) fraction is due to the dissolved reactive phosphorus (P). A work [14] in phosphate filtration has shown that phosphate filtration is a possible problem only at greater rates than soluble sources and high irrigation. Nevertheless, effective irrigation may reduce nutrient washing due to improved water and the absorption of nitrogen and filter from crops [15]. Hence, it is important to review the different ways of adopting innovative technologies and techniques to ensure nutrients are uniformly distributed in the crops' root zones resulting in increased agricultural production and improved product discharge qualities.

2. WATER AND NUTRIENTS UNIFORMITY

Drip irrigation methods are known to be the best possible approaches around the globe due to their excellent and high uniformity among the other irrigation methods. This method is achieving momentum due to its ability to supply water (around 62%) and fertilizer (around 40%). A drip irrigation system is utilized for supplying nutrients as well as water in the vicinity of the plant root region to ensure that much of the plant root zone system has water and nutrients available [16]. Emitters are a major component in the drip irrigation process concerned with water distribution and water use efficiencies. Emitters' reliability and reliable performance play a major role in standardized water distribution to achieve optimal productivity and yield in water use. To assess water application uniformity, uniformity of emitter discharge and process quality must be evaluated. This study has therefore highlighted the technical and hydraulic evaluation of various online and inline emitters under field conditions.

3. WATER UNIFORMITY APPLICATION

Drip irrigation systems were primarily conceived based on the uniformity of most water applications. The average uniformity, uniformity of distribution, and coefficient of variation were calculated as 74.1%, 50.7%, and 0.376, respectively, for the subsurface system [17]. Due to soil particles, the uniformity in the lower system may be ascribed to the drippers partial plugging [18-21]. A field study on water application uniformity of underground drip irrigation systems was conducted. Pressure, as well as dripper discharge were calculated every 2 m using traditional and ASAEEP-458 methods along both the used and unused tapes and uniformity criteria. The maximum unused and used tapes uniformity coefficient of 34 m were 96.9% and 91.8%, respectively [21]. Nevertheless, in both unused and used recordings, the ASAE test demonstrated slightly lower uniformity, i.e., 1.6% and 3.65%, respectively. In irrigation, system uniformity depends on numerous aspects, including the irrigation process, topographies, soil characteristics (infiltration), irrigation system pressures, and flow rates. Non-uniformity can be caused by several reasons for a sprinkler irrigation system: (1) inadequate choice of pipe diameters (sub-main, multiple, and lateral), (2) unnecessary or too low operating tension, (3) inadequate range of sprinkler nozzles and heads, (4) insufficient sprinkler overlaps, (5) wind impact on the distribution of water, (6) wear and tear over time on the system components, such as pump impellers and pressure regulators [22]. An experiment area was investigated to understand and explore the improvements in trickle (drip) emission uniformities when lateral ends were interconnected, and four types of emitters were used. The research established that the hydraulic efficiency of the "trickle (drip) irrigation systems" was enhanced by linking the lateral ends in a subunit (looped network), as this looping can enhance the tension.

4.WATER DISTRIBUTION IN SOIL

Saturation regions in the vicinity of the drippers are linked to both, the soil properties as well as the discharge of the dripper. Under drip irrigation, the spatial distribution of soil water and the form of the soil-wetted volume along with the potential matrix depend on several factors. These include root distribution patterns (above or below the soil surface), plant water absorption rates, spacing and positioning irrigation concentrations and frequencies, dripper discharge levels, and soil hydraulic properties. The horizontal motion and matrix potential from the source of the drip at different locations are dependent on the discharge of the dripper and the type of soil [23]. Dripper discharge is one of the main parameters defining the soil moisture regime in the dripper vicinity. Therefore, for effective water management practices for drip irrigation, it is best to have an improved understanding of the various parameters that influence irrigation systems. These parameters include the application of nutrients, water rates, absorption patterns, plant root distribution, and soil type [24]. The discharge rates increase results in a rise in the horizontal spread of the moisture front. Earlier works [25] also addressed the effects of the moisture front movement and its shapes. Water flows using a linearized moisture flow formula from a point source under drip irrigation. In Ref. [26], researchers considered specific dripper discharge levels (2, 4, and 8 Lph) to study the horizontal and vertical water movement in sandy soils with active plants. Increasing the discharge rate ensures more water movement horizontally, although lower rates allow more water movement vertically [27]. Researchers have also studied the impact of dripper discharge level on the wetting front radial length and wetting depth under the point source of the sandy soil irrigation system [28]. A rise was observed only for the maximum discharge level at 20-25 cm from the water source, a saturated area below the drip line [28]. The vertical soil-wetting front infiltration distance had a good relationship with the intersection side infiltration time and the side below the drip dripper. Moreover, [29,30] studied the effect on the distribution of water and nitrate of lateral depth and its location between soil layers in layered soils. The water distribution under underground drip irrigation was greatly affected by the depth of the drip line and the textured soil. For both uniform and layered soils, a greater depth of the drip line produced a greater wetted depth resulting in more water moving to a greater depth. Investigators in [31] investigated the dripper discharge effect on the movement of spatiotemporal soil moisture at various system operating pressures. They reported that the moisture content value significantly varied ($p<0.05$) under different operating pressures (0.5, 1.0, and 1.5kg/cm^2) and under and away from the dripper at different locations. The highest soil moisture content values were observed below the drippers as the distance from the dripper increased horizontally and vertically. The soil moisture content values decreased as the distance from the dripper rose in both directions (horizontal and vertical). About 9.4% and 14.3% higher soil moisture values just below the dripper were found with dripper discharges at the operating pressure of 1.0 and 1.5 kg/cm^2 compared to the dripper discharge at the operating pressure of 0.5 kg/cm^2 system.

5.DISTRIBUTION OF NUTRIENTS IN SOIL

Improved knowledge of nutrient dynamics within the plant root zone in the soil under drip fertilization is very useful in developing effective fertilization systems. A properly designed fertilization system leads to the reduction of salt leaching and the optimum amount of available nutrients to plants throughout the growth stages of the crops. Under drip irrigation, the distribution and movement of nutrients in soils depend primarily on the soil properties and the drippers' discharge rates [32-50]. A field experiment at ion on sandy loam soil was performed at Solan, and it was found that most nutrients used in fertilization stayed limited to the surface layers, while K and N transferred to the lowest depths below soil fertilization and irrigation. In the upper soil layers, the NO_3-N content was higher than the traditional soil fertilization leading to losses due to leaching [32]. The NO_3-N content below the drippers was low and rose to 15 cm from the dripper with rising lateral distance and then decreased. The concentration of NH_4-N was greater below the dripper and reduced laterally and vertically with increasing distance. To determine a present theoretical formula for predicting design emission uniformity, several experiments were managed in a research work [51-71]. The design emission uniformity was estimated in the view of field uniformity. The assumptions were checked thoroughly at the time of the formula development and compared with the outcomes of the two formulas with field results. In this connection, two types of experiments were conducted. In the first experiment, different emitters were tested, and the results were compared, showing a relationship between flow rate, coefficient of variation, and pressure head. In the second experiment, the actual emission uniformity was measured in the irrigation system. The results showed that the discharge distribution at the same pressure head was abnormal to its mean in tested emitters. Hence, it seemed better to experiment with the emitters at recommended heads. Manufacturing emission uniformity can be determined by using the results. When the developed formula and existing formulas were used for calculating the emission uniformity values, it was highly appreciable that results were similar when compared with the obtained values in the fields. The formula created required no further action to determine the hydraulic emission uniformity for the trickle subunit [33].

6.FERTIGATION WITH NITROGENOUS FERTILIZER

The nitrate – N has no tendency to react chemically and its addition to soil water makes it soluble. However, normally, nitrates do not adsorb in negative particles of clay [34]. Nitrate - N is mostly not recommended due to its solubility and non-adsorbate nature during fertigation. Further, it is highly likely to be lost during the process of leaching [34]. Drip nitrogen management is needed for managing the availability of N in the soil, for N requirements in plants, and N dynamics [35]. Compared to other plant nutrients, most crops require relatively large amounts of nitrogen [13]. The leaching processes result in losses of N in the soil and plant system. This usually happens if a sufficient amount of nitrogen is already present in the soil. The prevailing concentration of nitrate shows its important role in connection to losses of nitrogen from the roots of plants. The right quantity at the right time is recommended to reduce the extra amount of nitrogen. Nitrate and potassium movement and distribution during drip fertilisation shows that nitrogen ammonium is formed and is dominant in the upper layers of the soil. Nitrate nitrogen is proved more powerful in the general procedure, but its considerable amount is lost through leaching.[36] studied the effect of nitrate ammonium nitrate (NH_4NO_3) fertilisation approaches on the patterns of wetting and distribution of nitrogen in the soil. It is observed that a high amount of ammonium concentration is found in wetted areas of soil. The only solution to this issue is fast flushing time of residue to remove the remaining fertilizer from roots. The benefit of this strategy is that it helps save nitrate in the root zone. The drip irrigation method is the best approach to developing soil solution patterns in wetted soil where a large amount of solvent is stored near the dripper. A little amount of solution is recommended to apply to minimise deep percolation losses of water and solutes [37,38]. Many authors tried different methods to investigate sustainable ways, some used Computational fluid dynamics and validate it by experimental work through soil porous media [71-76], and others worked on the water treatment before applying it for different uses or returning it to the river [76-80]. In addition, recently authors used GIS to validate the amount of useful water and the water quality in addition to the pollutant concentrations [81-85]. Furthermore, freshwater scarcity is a global concern that is exacerbated by an increasing global population and climate change caused by global warming. As a remedy to this challenge, the largest water-using sector has employed a variety of drip irrigation technology [86-91]. The primary aims of drip irrigation are to reduce water shortages at the root zone, reduce evaporation, and use less water [92-95]. The number of research on drip irrigation is growing dramatically, as is the range of applications for it [96-98]. Field research was performed to check the dripper discharge effect on different system operating pressures on nitrate movement in the soil. The results showed that at 1.5 kg/cm^2 pressure, more NO_3–N concentration was obtained in soil depth; however, at 0.5 kg/cm^2 pressure, the concentration was low after one day of fertilization [38]. Another study was conducted on the baby corn root system to determine fertilization use, its effect, and operating system stress on NO_3-N dynamics. The research was conducted in three seasons, and nine treatments were performed at three different pressures and three different rates of fertigation. At 0-15 cm soil depth, the NO_3-N content was high in all studied processes. The nitrogen per fertilization was not fully consumed by plants in the initial and growth stages, especially in quarterly fertilization at a 1 kg/cm^2 pressure. The NO_3-N content increased at 0-30 cm of soil depth. The NO_3-N content after the soil's maturity reached a stage of leaching at a depth of 45 cm, and the rest of the soil showed no change. NO_3-N in lower soil (30-60 cm depth) was affected in 2 weeks and by weekly fertilization. At all depths, the NO_3-N content depended on the frequency adopted, and fortnightly fertilization was common. It was also observed that fertilization depended on the yield of baby corn at different operating pressures. In Ref. [3], the researchers worked with greenhouse tomatoes between fertilization and watering processes. The effect of NO_3-N in soil and vertical distribution under drip fertilization was examined regularly. The rate of irrigation was W1 (100% ET0), W2 (75% ET0), W3 (50% ET0), and three grades of fertilizers were used. The response of NO_3-N showed that the N level reached to wet floor in 43 days, and the NO_3-N content was 1.23 times higher at 0-60 cm. The content of NO_3-N depends upon the nitrogen present in the fertilizer. The crop yield can be maintained, and N content can be utilized efficiently by avoiding N leaching through controlled irrigation and fertilizer application.

7.FERTIGATION USING POTASSIUM FERTILIZERS

The use of potassium (K)fertilizers in fertigation has no side effects if applied to irrigation water. The danger of blockage in lateral pipes and drippers is also reduced in this way. However, the addition of insoluble salts results from the use of potassium with other fertilizers. The roots of plants obtain nutrients by diffusion and diffused soil provides K to roots [37]. The rate of K diffusion depends on soil water having nutrients near the roots. The successful method for better K is to use the drip irrigation method. In Ref. [37], Thompson worked on seedless grapevines and studied the effect of K fertilization and drip irrigation. The lower value of K was obtained with higher irrigation levels in root plants. The yield was reduced due to higher K values as competition increased between chloride and nitrate ions [39]. The water movement between K and N was studied in Ref. [40] for vegetables grown in sandy soil, and the drip irrigation method was applied. The distribution of K was unexplored in the field of underground drip irrigation. Some researchers were involved in the measurement of K in good drip soil. In Ref. [26], it was reported that fertilization treatment provided maximum potassium availability in radish plant root zone by comparing gout and furrow irrigation. Also, Kumar et al. [40] investigated phosphorous fertilizers using pre-plant soil in drip-irrigated summer squash. It was concluded that the yield of fruit, number of fruits, and the uptake of P were all higher with P-fertilization than pre-sowing the soil. Thus, the yield was positively correlated to the uptake of P. The efficiency of fertilizer having P using (PFUE) was high; however, with higher rates of

P application, the efficiency decreased. The pH of the soil in the top oil reduced with an increase in the rate of P due to the phosphoric acid's acidifying effects. Also, it was found that more P was collected in the top 15 cm, becoming moderately soluble.

8.INFLUENCE OF NUTRIENTS UNIFORMITY ON THE QUALITY AND THE PRODUCT YIELD

8.1.Fertigation Effects on Crops

Enhanced product quality and layer crop yields are obtained by the best combination of nutrients and water. Fertigation means providing fertilizers to crops and watering by drip or sprinkler systems so that nutrients are properly absorbed by the plant. The fertigation process maintains the correct quantity of water and nutrients in the roots of plants. In Ref. [41], it was suggested that preparing fertilizer solution requires a great amount of time because a liquid fertilizer was mixed with different recipes according to the plant requirements considering the climate and growing stages. Fertigation provides nutrients in small doses to satisfy crop demands for nutrients. In addition, it also ensures savings in fertilizer usage [42]. Moreover, fertigation is environmentally friendly as it prevents fertilizer leaching [43]. The plant's demand to provide sufficient water and nutrient in case of the root's limited volume can be fulfilled by matching the supply of water and nutrient considering the growing stages. Fertigation is a process that allows supplying the correct amount of water and nutrients to vegetables, cotton plants, cereals, or trees. The fertilizer rate is estimated by the plant demand in its growing season. The fertilizer quantity is measured as a milligram of the nutrient and liters of water supplied per plant every day. In [23], tomato fertilization analysis was performed, and it was found that minerals and nutrients were present in dunes. Drip fertilization increased the yield by 30 % with substantial fertilizer and water savings [44]. The fertilization with pure NPK- enhanced the tomato yield by 58.76t ha-1 over furrow irrigated controlled. The drip irrigation was increased by 50 % fertigation (48.18 t ha^{-1}) and 75% fertigation (54.16 t ha^{-1}) [8]. Comparably, the amounts of fruits and fruit weight per crop were significantly higher than drip and furrow irrigation. In Ref. [41], it was noted that the green cob yield (17.70 t ha-1) was significantly higher than other irrigation regimes. Amongst the fertilization rates, a substantially increased green cob yield of 18.06 t ha-1 was achieved by 100 percent RDF through drip and par with 75 percent RDF with drip irrigation.

8.2.Fertilizer Savings by Fertigation

The use of fertilizers increases crop yield while minimizing environmental hazards. It is the most expensive input in the agricultural sector. The nutrient quantity should be adequate to ensure that the crop yield per unit area is enhanced. It all depends upon the fertilizer quality. The best method is to use good fertilization techniques and ensure proper fertilizer distribution in roots at the most appropriate times. In Ref. [24], the researchers studied fertilization performance and concluded that about 4 tons of additional tomato yield were obtained compared to former crops. In Ref. [26], the work investigated the influence of fertilizer placement on crop growth. The results showed that 24% more yield was obtained than the broadcast yield. Investigators in Ref. [38] planned a three-season experiment with baby maize crops. Ten treatments were conducted at three different pressures and three fertilization frequencies with one control. They stated that the highest cob, baby corn, and fodder yields were recorded on a two-week fertilization schedule at a 1.0 kg/cm^2 device operating pressure. Moreover, the smallest yields of cob, baby corn, and fodder (conventional fertilizer application and furrow irrigation) were recorded in command. Between April and July, the maximum benefit-cost ratio (3.63) was observed between bi-weekly fertilization care. Nonetheless, the lowest benefit-cost ratio value (1.42) was observed under control care during August-November. The findings also showed that the savings of 244.56 kg/ha of urea, 56.25 kg/ha of potash, and 75.00 liters/ha of phosphoric fertilizers cost Rs. 4897.37 (Rs. 2613.04 per ha of N fertilizer, Rs. 1182.42 per ha of P fertilizer and Rs. 1101.92 per ha of K fertilizer). The annual government subsidy would be substantially reduced with baby maize produced under drip fertilization. In addition to saving fertilizer and government subsidies, farmers' net annual income would also significantly increase from Rs. 2,20,576 through traditional fertilizer application system, i.e., furrow irritation, to Rs. 5,32,195 under drip fertigation per year.

9.FERTIGATION FREQUENCY EFFECTS ON THE CROP YIELD AND GROWTH PARAMETERS FREQUENCY OF FERTIGATION

Agriculture's main motive is to save water, labor, and fertilizer needs while achieving a maximum yield. Drip irrigation is a successful method to save water and fertilizer needs. The increase in the fertilizers cost and the water crisis has motivated researchers to work further to reach optimum solutions. Many studies proved that using water and fertilizers at minimal values produces the maximum yield of crops by increasing the leaching degradation. In this connection, root zones watering and applying fertilizers must be done at the right times during different crop growth stages [45-68]. The most effective results are obtained using high-quality nutrients and water (NUE and WUE) to produce better and more crops. The fertilization rate positively and negatively influences the quantity of nutrients and water percolating under the root zone. In Ref. [45], researchers studied bell pepper in a greenhouse and found the effects of P application and fertilization frequency. The results showed that increasing fertilizer frequency produced more manganese and phosphorus in root zones. In between the above leaf and ground biomass P concentration in the initial vegetative stages, a substantial linear regression was achieved. In daily, alternative day, and weekly fertilization, the yield of onion was insignificantly affected. There was a lower monthly fertilization yield pattern [41]. Daily fertilization (28.74 t ha-1) recorded the highest yield, followed by alternative day fertilization (28.4 t ha^{-1}). Monthly fertilization frequencies (21.4 t ha^{-1}) recorded the lowest yield. Mirjat et al. [46] studied the effect of fertilization schedules on the production capacity of tomatoes in sandy soil and adopted solid sprinkler irrigation systems and surface drip irrigation methods. An increase in the yield of tomatoes was observed by 25.6, 49.3, and 20.3 percent water and fertilizer usage efficiencies, respectively, with surface drip as contrasted to irrigation systems with solid sprinklers. A positive relative pattern was found with the quantities of nutrients added and the residues of NPK in the fruit under the irrigation systems being investigated. In another study [45], investigators researched the effect of hybrid maize of drip fertilization rates and frequencies on crop growth and yields. Once in 6 days, the fertilizer frequency schedule showed higher grain yields independent of fertilizer rates and balanced other frequencies. There was an insignificant difference between different fertilization frequencies in grain yield. Some researchers [38] investigated the impact of fertilization frequency and operating system pressure on NO_3-N dynamics in baby corn's soil root system. The study consisted of nine treatments for three consecutive seasons, which included three different pressures (0.5 kg/cm², 1 kg/cm², 1.5 kg/cm²) and three fertilization timings (weeklyand fortnightly). It was also found that NO_3-N contents are lowest at the soil surface (0-15 cm depth). In addition, the total nitrogen applied per fertilization was incompletely used by plants during the initial and developmental stages, especially in quarterly fertilization at 1.0 kg/cm² operating pressure system causing a rise in NO_3-N content at 0–30 cm depth of soil. The NO_3-N available in 0–30 cm depth of soil leached up to 45 cm soil depth at maturity, and the rest of the soil profile stayed virtually unchanged in terms of its contents. NO_3-N in lower soil profiles (30–60 cm depth) was slightly altered in the frequency schedule of two weeks and daily fertilization. Fertigation was considerably influenced by the yield attributes of baby corn at various operating pressures of the process.

10.CONCLUSION

Applying water and nutrients with drip irrigation is a challenging task toward sustainability. Determining effective fluid flow distribution of water and nutrients motivates researchers to solve the problem of efficient irrigation timing and system development. The review of the fertigation literature indicates that the operating stress and the drop-line length of the process are the two significant factors influencing the uniformity of the distribution of nutrients and water in the fields. Inadequate water and fertilizer application in the fields can result in non-uniform distribution of the nutrients and water in the soil profile along the drip line distance, causing a significant decrease in crop yield and exceptional product quality. Inadequate water and fertilizer application can also contribute to soil degradation and groundwater contamination because of extreme nutrients leaching from the plant root zone. Data on the distribution and movement of nutrients in the soil is essential to the environment and is important for developing effective, sustainable fertilization systems.

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