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Fertigation for Crops and Nitrogen Fertigation for Sugarcane: A Review

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ABSTRACT

As water becoming the scarce resource, micro irrigation is gaining momentum. Drip fertigation ensures required quantity, proper place, proper time, and regular supply of water fertilizer. Fertigation enhances the utilization of fertilizers and crop yield. So, Drip fertigation not only ensures proper utilization of irrigation water, but also is an effective way to improve the yield quality of crops. Nitrogen is the very important nutrient and the N fertilisers are being the costly input, necessary measures are to be taken to minimise the usage of the fertilisers. Hence the drip fertigation is one of the technologies which is to be addressed off. Also Sugarcane, being the high value crop in India, N management in sugarcane also discussed hereunder.

INTRODUCTION

Since N fertilizer incurs high input cost, and has environmental implications due to nitrogen loss, there is pressing need to optimize the supply of N as per the crop's requirement. It is observed that the efficiency of fertilizer is improved when it is applied by fertigation to most crops [27] including sugarcane [44].

Drip irrigation

Trickle irrigation has gained importance during the last three decades due to increased productivity and greater water and nutrient savings [40]. Drip irrigation is often preferred over the conventional irrigation methods because of its high water application efficiency on account of reduced losses, surface evaporation and deep percolation. Ravi *et al* [53] reported that the drip irrigation equivalent to 100% ET increases the yield by 45 per cent with 44 per cent saving in water over basin or furrow method of irrigation.

Effect of drip irrigation levels on yield

The highest yield of 70.12 q ha^{-1} was recorded in trickle irrigation representing a 35.77 per cent increase in yield over furrow irrigation in bhendi [24]. There can be considerable saving of irrigation water by adopting drip method since water can be almost precisely and directly applied in the root zone without wetting the entire surface area [2,6]. Batchler *et al.* [13] reported that the micro irrigation can be used to improve the irrigation efficiency of vegetable gardens by reducing evaporation and drainage losses by creating and maintaining soil moisture conditions that are favourable to crop growth.

Imtiyaz *et al.* [32] recorded that the higher marketable cabbage yield of 74.26 t ha^{-1} was observed in drip irrigation at 11 mm CPE compared to 22 mm CPE (72.39 t ha^{-1}) and 33 mm CPE (45.23 t ha^{-1}). Cassel Sharmasarkar *et al.* [19] reported that sugar beet yields and sugar contents under drip irrigation were higher (3-28 per cent) than those with flood irrigation. Tognetti *et al.* [67] opined that the drip irrigation influenced positively many of the physiological and technological parameters, as compared to low-pressure sprinkler irrigation. Drip irrigation appears to be consistently advantageous with respect to low-pressure sprinkler irrigation for sugar beet performances in semi-arid environments and there were indications to early harvest. Hebbar *et al.* [28] revealed that the total dry matter production and leaf area index of tomato were significantly higher in drip irrigation (165.8 g and 3.12 respectively) over furrow irrigation with the higher fruit yield of 19.9 per cent in drip irrigation (71.9 Mg ha^{-1}) over furrow irrigation (59.50 Mg ha^{-1}). Manjunatha *et al.* [39] reported that the drip irrigation seemed as a feasible solution in water scarcity areas and the highest fruit yield of brinjal (26.2 t ha^{-1}) was recorded in drip irrigation compared to surface irrigation.

Antony and Singandhupe [3] concluded that the drip irrigation at 100 per cent CPE recorded the maximum capsicum yield of 99.97 g plant^{-1} compared to drip irrigation at 80 and 60 per cent CPE. Imtiyaz *et al.* [31] found that drip irrigation with 100 per cent of pan evaporation replenishment at 2-3 days interval as optimum for sandy loam soil in order to achieve optimum marketable yield, higher irrigation production efficiency, net return and B-C ratio in green pepper, hot pepper, okra and egg plant. The highest marketable yield and higher net return of okra was 20.83 t ha^{-1} and Rs.1,15,182 ha^{-1} at 100 per cent of pan evaporation replenishment. The mean irrigation production efficiency of okra was maximum (2.95 kg m^{-3}) at 60 per cent pan evaporation replenishment.

Swarajyalakshmi *etal.* [63] reported that the highest green chilli yield of 21.56 t ha^{-1} in drip irrigation scheduled at 0.80 ET. This increase was accounted to 34 per cent over conventional method of irrigation. Schock [56] observed increased yield of onion (42.4 t ha^{-1}) in drip irrigation compared to zero N fertigation in surface irrigation system. Ngouajio *et al.* [47] reported that there was an increased tomato yieldby 8 - 15 per cent, fruit number by 12 - 14 per cent with reducing amount of irrigation water by 20 per cent in drip irrigation compared to conventional method of irrigation.

Fertigation

It is commonly accepted that the efficiency of N use can be improved when it is applied by fertigation to most crops[27]. Fertigation enables adequate supplies of water and nutrients with precise timing and uniform distribution to meet the crop nutrient demand [10,11,27,41]. Further, fertigation ensures substantial saving in fertilizer usage and reduces leaching losses [40]. A drip irrigation system can easily be used for fertigation, through which the applied fertilizer is placed to the active root zone and crop nutrient requirements could be met out accurately [16,48].

Effect of irrigation and fertigation levels on yield

Bar Yosef and Sagiv [10] observed that the dry matter content of tomato was increased when the soil water potential decreased, whereas the optimum average N concentration in the irrigation solution was determined to be 130 ppm N. In drip irrigation system, water and nutrients can be applied directly to crop at the root level, having positive effects on yield and water savings and increasing the irrigation performance [34,51] reported that the highest brinjal yield of 822 g plant^{-1} was observed in drip fertigation at 180 kg N ha^{-1} compared to surface irrigation with 360 kg N ha^{-1} (202 g plant^{-1}). Singh *et al.* [59] revealed that, when N and K fertilizers were applied through drip irrigation, higher tomato yield was obtained with 75 per cent of recommended level compared to 100 percent and 50 per cent of recommended levels of fertigation through drip.

According to Intrigiliolo *et al.* [33] the water consumption by orange trees was 21 per cent lower in drip system than normal irrigation and also there was improved water, nutritional and physiological plant status in fertigation compared with the annual application of fertilizers. Parikh *et al.* [49] studied the response of vegetables, sugarcane and fruit crops to micro irrigation system and fertigation and it was reported that the water saving ranged from 10 to 56 per cent in various crops with improved yield of 13 to 60 per cent. Fertigation studies in selected crops showed that about 40 per cent of nitrogenous fertilizers can be saved without detrimental effect to yield and quality. The water use efficiency and fertilizer use efficiency were almost doubled due to fertigation. Malik and Kumar [38] observed that the drip irrigation level of 75 per cent pan evaporation with 25 kg N ha^{-1} fertigation was the optimum combination for maximizing the water use efficiency and yields of peas grown on a sandy loam soil in Himachal Pradesh. Dalvi *et al.* [20] evaluated the effect of irrigation level, fertigation and frequency of micro irrigation on the yield of tomato. The study revealed that drip irrigation scheduled at every second day with irrigation at 79 per cent of ET and fertigationat 96 per cent of recommended dose resulted in higher yield of tomato.

Muralidhar *et al.* [43] reported that the drip fertigation at 80 per cent of recommended N and K level with water soluble fertilizers registered higher tomato yield (22.3 t ha^{-1}) compared to 100 per cent and 60 per cent of recommended levels in drip irrigation. Jeyabal *et al.* [35] reported that the drip fertigation at 75 per cent of recommended N and K level recorded 12.3 per cent higher yield of tomato than drip fertigation at 100 per cent and 50 per cent of recommended N and K levels. Decreasing the fertilizer level by 20 per cent than the recommended level especially under fertigated conditions may not affect the yield level in chilli because of improved FUE. Between furrow and drip methods of irrigation, drip irrigation method resulted significantly higher dry chilli yield with 42 per cent higher water use efficiency over furrow method even with the same level and method of normal fertilizer application [57,68] observed the highest onion bulb yield of 18 t ha^{-1} in drip fertigation at 100 per cent of recommended NPK level compared to 75 and 50 per cent of recommended NPK levels.

Siviero *et al.* [6] observed that fertigation with various amount of N, P and K fertilizers increased the yield of tomato, induced early flowering, and significantly improved the crop quality and water use efficiency. Baskar [12] recorded the highest yield of banana with maximum water use efficiency of 2.18 kg ha^{-1} cm^{-1} in drip fertigation at 75 per cent of recommended NPK level compared to drip fertigation at 100 and 50 per cent of recommended NPK levels. Patel and Rajput [50] reported that the fertigation at 100 per cent of recommended level recorded an increased yield of 25.21 per cent (28.8 t ha^{-1}) compared to conventional method of fertilizer application in bhendi.

Balasubramanium [7] reported that the application of 125 per cent of recommended NPK ha^{-1} under micro irrigation resulted in highest tomato yield of 39.44 t ha^{-1} followed by 100 per cent recommended NPK ha^{-1} (33.61 t ha^{-1}) and 75 per cent recommended NPK ha^{-1} (31.31 t ha^{-1}). Bao-Zhang *et al.* [8] observed that the highest potato yield of 370.6 g $plant^{-1}$ as recorded in drip irrigation at 125 per cent of PE compared to drip irrigation at 100 per cent of PE (251.4 g $plant^{-1}$) and 75 per cent of PE (122.8 g $plant^{-1}$). Singandhupe *et al.* [58] revealed that the application of N through the drip irrigation in ten equal splits at 8 days interval saved 20-40 per cent nitrogen in tomato compared to the furrow irrigation.

Fertigation scheduling allows for the greater degree of flexibility in effecting changes in quantity and frequency. Fertigation events can be scheduled at an interval of a week or fortnight or a month [64].

Agarwal *et al.* [1] reported that the economic yield of 52.5 q ha^{-1} and highest benefit cost ratio of 3.21 were recorded in pomegranate under 80 per cent of fertigation with water soluble fertilizers. Dawelbeit and Ritcher [22] observed that the drip fertigation system in onion produced higher yields compared to drip irrigation with fertilizer broadcasting. Hebbar *et al.* [28] opined that fertigation with 100 per cent water soluble fertilizers increased the tomato fruit yield significantly (79.2 Mg ha^{-1}) over furrow irrigation with band placement of fertilizers. Aujla *et al.* [4] revealed that when the same quantity of irrigation water and N were applied through drip irrigation system, it increased the cotton yield to 2144 from 1624 kg ha^{-1} (an increase of 32 per cent) compared to check basin irrigation. When the quantity of water through drip was reduced to 75 per cent, the increase in cotton yield was 12 per cent. Bhanu Rekha *et al.* [14] observed the functional relationship of bhendi under drip fertigation in sandy loam soils. The irrigation water and N indicated a linear response with a mean coefficient R^2 of 0.997. The highest bhendi yield of 4188 kg ha^{-1} with the highest water use efficiency (8.23 kg ha^{-1} mm^{-1}) was noted in drip irrigation at 1.0 pan evaporation with fertigation at 120 kg N ha^{-1} compared to drip irrigation at 75 per cent pan evaporation and 50 per cent pan evaporation with fertigation at 120 kg N ha^{-1}.

Hartz *et al.* [25] reported that the K fertigation increased the fruit yield of tomato with color improvement of fruits but K fertigation did not affect the fruit soluble solids concentration. Solaimalai *et al.* [61] reported that the drip fertigation recorded higher use efficiency of water and fertilizers, minimum losses of N due to leaching, supplying nutrients directly to root zone in available forms, control of nutrient concentration in soil solution and saving in application cost. Soumya *et al.* [62] observed that the higher marketable fruit yield of 94.50 t ha^{-1} was recorded in drip fertigation at 100 per cent recommended level of NPK with the higher water use efficiency of 143.11 kg ha^{-1} mm^{-1} compared to drip fertigation at 75 per cent recommended dose of NPK (70.01 t ha^{-1}). Darwish *et al.* [21] reported that fertigation of N at 125 per cent gave significantly higher N recovery (61 per cent of applied N), despite the clay nature of the soil. Saving of 119 mm of water without reduction in fresh tuber yield was observed. It could be safe to deplete the soil water content down to 56.6 mm in the upper 30 cm soil layer, which is equivalent to 40 per cent of water depletion.

Rajput and Patel [56] registered that the highest yield of onion in daily fertigation (28.74 t ha^{-1}) followed by alternate day fertigation (28.4 t ha^{-1}) whereas the lowest yield was recorded in monthly fertigation frequency (21.4 t ha^{-1}).

Rajput and Patel [56] showed that the highest yield of 29.4 t ha^{-1} in weekly fertigation with 100 per cent irrigation requirement than weekly fertigation with 80 per cent of irrigation requirement (26.5 t ha^{-1}) and weekly fertigation with 60 per cent irrigation requirement (22.5 t ha^{-1}) in Indo-American hybrid onion.

Mahajan and Singh [37] revealed that drip irrigation at 0.5 pan evaporation with fertigation at 100 per cent recommended nitrogen resulted in increased tomato fruit yield by 59.5 per cent compared to conventional method.

Badr and Abou Ei Yazied [5] concluded that the highest tomato fruit yield of 67.75 t ha^{-1} was recorded in weekly drip fertigation compared to daily fertigation (65.13 t ha^{-1}) and fertigation once in three days (63.29 t ha^{-1}).

Hongal and Nooli [30] opined that the fertilizer requirement could be reduced by 15 – 25 per cent with fertigation through drip and application of higher dose of fertilizers not only caused economic loss but also led to adverse chemical changes in soil and reduced the yield.

N- dynamics under fertigation

Usually, optimizing N management with drip irrigation would require that attention be paid to soil N dynamics, crop N requirements as well as soil and plant monitoring techniques [26]. Boswell *et al.* [15] reported that nitrate – N is relatively unreactive and therefore, susceptible to movement through diffusion and mass transport in the soil water because, (1) Nitrate compounds are readily soluble in water and (2) They are not usually adsorbed on the negatively charged clay particles. Since nitrate-N is highly soluble and non adsorbing, it is more likely to be lost through surface runoff and deep percolation of water.

Except when large amounts of N fertilizers are surface applied first before heavy rainfall events, soluble N losses through surface runoff are generally low. There is usually more gain in N through rainfall events than is lost through surface runoff [15]. Gaseous N losses mostly involve denitrification and volatilization of ammonia. Denitrification is the process by which nitrates are converted to N gases through micro- organism activities in the soil. Leaching of N is probably the dominant way in which N lost in the soil – plant system especially if the soil already contains substantial amounts of nitrate-N. Although the background concentration of the nitrate-N plays a significant role in the overall loss of N beyond the rooting zone, the rate and time of N fertilizers is also important in avoiding both excessive amounts of N on applying it unnecessarily.

Scheduling of fertigation

As plants grow, their demand for nutrients change and as such, some nutrients that are easily taken up by plants may get depleted sooner than the exclude dones. This preferential uptake of solutes can lead to high concentrations of the excluded salts in the rhizosphere that could prove to be detrimental for optimum plant growth. Thus fertigation is often necessary to augment nutrient fertilizer. A fertigation scheduling plan is often compounded by the changing demands of fertilizer requirements of growing plants. Nevertheless, fertigation should be carried out, not to adversely alter the solute dynamics in the root zone, but should provide tolerant and optimum concentration of nutrients and salts in the rhizosphere. Hence, accurate prediction of when and how much fertilizer to apply is critical for fertigation management. The amount of fertilizer to be applied depends on the plant requirement. The frequency of application for fertilizers depends on the soil type, system design constraints, and the length of the growing season. According to Hochmuth [29], the frequency of fertigation is usually not as critical as achieving the right rate of application at a given crop stage.

Fertigation in sugarcane

Ng Kee kwong and Deville [44] reported that the uptake of fertilizer N by sugarcane was indeed improved by supplying the urea daily through the drip irrigation network. Also they indicated that, although N fertilizer use efficiency was nearly doubled by fertigating the sugarcane daily over a 10 week period, the improvement in N fertilizer use efficiency was however not accompanied by a correspondingly significant increase in cane or sugar yield. On the contrary, extending the daily N fertigation of the sugarcane to 20 weeks led to a reduction in recoverable sucrose and hence sugar yield. As a result of the improvement in fertilizer N use efficiency. 120 kg ha^{-1} as presently recommended in Mauritius, would under drip fertigation provide the cane with more N than it actually requires achieving its highest yield potential.

There are few sources of information on which to base practical guidelines for the fertigation of sugarcane [65]. Issues that remain unexplored include optimal timing of fertilizer application to exploit the degree of control that the sub surface drip irrigation system affords. Untimely N fertilizer application in sugarcane reduces its efficiency and compounds N losses to the environment [45]. Timing the fertigation to coincide with periods of demand from the crop (growth curve nutrition) is a common method of maximizing fertilizer use efficiency in many high value crops with complex phenology and nutrient requirements, but there have been no formal field studies to assess the merits of this concept in sugarcane [17, 54] developed an optimal urea fertigation schedule for sugarcane crop grown under drip irrigation in sandy clay loam soil for a site specific climatic conditions using Hydrus – 2 D model.

Response of sugarcane for fertigation

It is commonly accepted that the efficiency of fertilizer use can be significantly improved when it is applied by fertigation to most crops [27] including Sugarcane [44] which is one of the main crops grown under trickle irrigation [9].

Gains in fertilizer use efficiency would be particularly useful for nitrogen (N) in sugarcane systems, as significant losses of N from volatilization [23] and denitrification [70] can occur with conventional means of application. Also sugarcane yield response curves tend to be flat at N application rates above the optimum [36]. Excess application of N can also decrease the sugar content of cane [42,46,71] and substantially increase leaching of N from the root zone [69]. While there are recommendations for N application rates in conventional management systems [18], there is little information on what the optimum N rate should be for fertigated sugarcane [9,65]. Based on experience in other crops and the studies on sugarcane, the N rate is likely to be in order of 20 – 30 per cent lower than rates in conventional management systems [46,55,65]. Continuing to apply the same N rates used in conventional management systems to fertigated sugarcane crops would probably result in lower N – use efficiency by the crop and increased losses of N to the environment.

Thorburn *et al.* [66] confirms that N application rates can be reduced in fertigated sugarcane, with the optimum rate for sugarcane production being approximately half that recommended for conventionally managed sugarcane. Losses of N to the environment were substantial at higher than optimum rates, with a significant proportion of these losses being due to large amount of N mineralized from soil organic matter. Mineralization was likely to be simulated by the high soil water contents maintained with daily application of irrigation water through the trickle system.

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