

Review Article

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4R Nutrient Management in Sugarcane- An Overview

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ABSTRACT

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Precise management of nutrients is most essential for improving crop productivity and nutrient use efficiency (NUE). This could be achieved by following 4R principles *viz.*, applying right source of nutrients with right quantity at the right time in right location. As per the 4R nutrient stewardship approach, the drip fertigation system especially subsurface drip fertigation (SSDF) system has the capability to deliver correct dose of fertilizer nutrients at the correct location in right time as and when required by the plants. SSDF is considered as an environmental friendly technology, because it controls fertiliser related pollution particularly leaching (also of applied K), volatilization and denitrification losses of nitrogen besides reducing the fixation of P and K in soil. Sugarcane is a row crop with higher nutrient and water requirement where drip irrigation in general and drip fertigation in particular is gaining momentum now-a-days. SSDF with 4R nutrient stewardship approach not only enhances the NUE but also improves the productivity of sugarcane.

Introduction

Productivity of crops depends on the available nutrient status of the soil (Yadav and Prasad, 1992). Agricultural development has provided much evidence that adequate supply of nutrients through chemical fertilizer is the most efficient measure for increasing the yield and quality of crops. It is reported that crop yields have increased by at least 30 to 50% as a result of fertilization at global scale (Stewart *et al.*, 2005). Among the various crops, sugarcane is a heavy feeder crop and requires very large quantity of nutrients (N,

P₂O₅ and K₂O) which must be applied through fertilizers to obtain optimum yield on sustainable basis. In India, most of the farmers apply more fertilizer at limited splits through broadcasting on surface soil which leads to heavy loss of nitrogen through volatilization and denitrification and fixation of P and K in the soil ultimately resulting in reduced nutrient use efficiency (NUE). Such practice is very common among sugarcane farmers in India, leading to lower yield and poor quality of produce which in turn impacts farmer income and environmental pollution. With a growing demand for sugarcane, there

is a need for efficient fertilizer management practice to achieve sustainable profit without any detrimental impact on the environment.

4R nutrient stewardship approach enables proper utilization of applied fertilizers by applying right fertilizers to match with crop demand during different crop growth period at the right spot. This approach is at the core of precision nutrient management. Before making a fertilizer application decision in any crop, farmers should have knowledge and awareness about fertilization programme *viz.*, what type of fertilizer to apply, how much to apply, when to apply, how to apply and where to apply. Experimental evidences have shown that precision management of nutrients through right source, rate, time and place can significantly increase crop productivity and reduce environmental footprint of agricultural nutrients (Sapkota *et al.*, 2014). Subsurface drip fertigation has been proved as an efficient nutrient management approach for improving yield, profit and nutrient use efficiency of sugarcane. This article overviews the impact of 4R nutrient stewardship based NPK application on sugarcane crop in India.

4R nutrient management in sugarcane

Right source: matching the fertilizer types to crop needs

Plants absorb the essential nutrients through their root systems from the soil in various forms *viz.*, nitrate (NO_3^-) and ammonium (NH_4^+) for N, primary (H_2PO_4^-) or secondary (HPO_4^{2-}) orthophosphate for P and elemental form (K^+) for K. Fertilizer application is the common practice to supply NPK to meet out the nutrient demand of the crop. Accordingly, selecting the right source of fertilizer is imperative to supply the plant essential nutrients as per the crop. Fertigation is for the most efficient way of nutrient application

(Bar-Yosef, 1991) and provides an excellent opportunity to maximize the crop productivity and minimize environmental pollution (Hagin *et al.*, 2002) by reducing fertilizer needs and improving NUE. It is awfully important to select fertilizers depending upon crop needs and suitability to fertigation. Before selecting fertilizer for fertigation, the following factors should be considered *viz.*, plant nutritional requirements, solubility, nutrient available form, nutrient content and compatibility with other fertilizers. Water soluble fertilizers are very much suitable for fertigation because they are made up of combinations of available forms of nutrients and are fully soluble in nature. So, when the fertilizer dissolves in water, the nutrients can be immediately available for plant uptake (Biswas, 2010). Nutrient content, available form, solubility, pH and insoluble percentages of selected water soluble fertilizers are given in Table 1. For efficient nutrient management through fertigation with 4R nutrient stewardship, it is mandatory to select fertilizer source in which the essential plant nutrients are in readily available forms and fully soluble in water.

There are several commercial nitrogen, phosphorus and potassium fertilisers that can be used for fertigation in sugarcane. Various research works have confirmed that the following fertilizers grades *viz.*, Urea (46% N), as the primary source of N (based on cost), MAP-Mono ammonium phosphate (12% N and 61% P_2O_5) and All 19 (19% N; 19% P_2O_5 and 19% K_2O) for P source and KNO_3 (13% N and 45% K_2O) for K source are most suitable commercial water soluble fertilizers (WSF) for fertigation in sugarcane in order to get higher cane yield and improved NUE. Mahesh (2015) studied the effect of fertigation with WSF (Urea, All 19, MAP and KNO_3) and normal fertilizers (NF) (urea, diammonium phosphate and muriate of potash) on cane yield and NUE of sugarcane under subsurface drip irrigation system (Table

2). This experimental conducted at Tamil Nadu Agricultural University, Coimbatore, India. The revised soil test based crop response nutrient recommendation of 300:100:200 kg N, P₂O₅ and K₂O ha⁻¹ was used for this experimentation. Fertigation was scheduled at 7 days intervals starting from 2nd week to 34th week after planting. Results revealed that WSF outperformed and significantly improved the number of millable canes by 24.34%, individual cane weight by 34.5% and cane yield by 34% compared to NF source under subsurface drip irrigation. Further, the results of the experiment indicated that fertigation through WSF increased NUE (kg of cane per kg of NPK applied) by 29.69% compared to NF. Similarly, use of WSF {Urea (46% N), Poly feed (20% N;10% P₂O₅ and 10% K₂O), MAP (12% N and 61% P₂O₅) and SOP (50% K₂O and 18% S)} through drip irrigation could increase plant height, no. of internodes, girth of internodes, individual cane weight, leaf area and cane yield of suru sugarcane by 2.72, 3.99, 2.14, 9.46, 5.66 & 8.18% respectively compared to normal fertilizer source (Urea, SSP and MOP) (Chaudhari *et al.*, 2010). Similarly, fertigation of water soluble fertilizers (WSF) significantly increased cane yield to the extent of 8.2% than that of straight fertilizers (SF) (Bangar and Chaudhari, 2004).

Right rate- Matching amount of nutrient as per crop requirement

The law of diminishing returns by Mitscherlich (1909) indicates that as the dose of nutrient increases, the growth rate and yield increase but with diminishing rates. Therefore, application of recommended nutrients in different split doses to coincide with nutrients need of crop at different developmental periods is essential to obtain higher cane yield and nutrient uptake. To achieve targeted yield, it is essential to have

knowledge on quantity of nutrients (right rate) to be applied through fertigation. The concept of applying the right rate is providing adequate nutrients to meet crop production and quality goals (Hochmuth *et al.*, 2014). Sometimes, over fertilization may cause toxicity to the crop as well as pollute the ground water and environment. Based on the information of the available nutrients in soil by soil testing and nutrient uptake by the crop through plant analysis, the actual nutrient requirement of the crop could be identified (Harold and Reetz, 2016).

Sugarcane needs higher quantity of NPK nutrients for better performance with respect to yield and quality. According to Shukla *et al.*, (2017) sugarcane require an average 208 kg of N, 53 kg of P, 280 kg of K to produce 100 tonnes of cane yield. But the nutrient uptake varies considerably depending on the climate, varieties and available nutrient status in soil and agronomic management practices followed. It is estimated that for achieving the targeted yield of 200 tonnes per hectare, a nutrients dose (ND) of N, P₂O₅, K₂O = 300:100:200 kg ha⁻¹ would be required under Indian condition (Crop Production Guide, 2020).

The response of sugarcane to different fertilizer rates (100% ND- 300 kg N, 100 kg P₂O₅ and 200 kg K₂O per ha and 75% ND- 225 kg N, 75 kg P₂O₅ and 150 kg K₂O per ha) were studied under SSDF (Table 3) and the result revealed that significantly higher plant growth and yield parameters were registered under 100% ND over 75% ND. Further, significantly higher cane yield (185.65 t/ha) was registered with 100% ND than 75% ND (164.77 t/ha). Similarly, increasing nutrient dose from 75 to 125% increased yield attributes (number of millable canes, number of internodes, internodes girth and cane weight) and cane and sugar yields (Mahadkar *et al.*, 2005).

Table.1 Nutrient content, available form, solubility, pH and insoluble percentages of water soluble fertilizers

Nutrient	Water soluble fertilizer	Nutrient content	Nutrient available form	Solubility at 20°C (kg/100 lit)	pH	Time to dissolve (min)	Insolubles (%)
N	Urea	46:00:00	Urea-N	110	9.5	20	Negligible
P	MAP	12:61:00	NH ₄ ⁺ H ₂ PO ₄ ⁻	40	4.5	20	11
	All 19	19:19:19	Urea-N NO ₃ ⁻ NH ₄ ⁺	-	-	-	-
K	KNO ₃	13:00:45	NO ₃ ⁻ K ⁺	31	10.8	3	0.1
	SOP	00:00:50 18% S	K ⁺ SO ₄ ²⁻	11	8.5-9.5	5	0.5-4

Table.2 Effect of WSF and NF on yield and NUE in sugarcane under fertigation

Source of fertilizers	NMC (lakhs ha ⁻¹)	Millable cane length (cm)	No of internodes	Cane weight (kg cane ⁻¹)	Cane yield (t ha ⁻¹)	Sugar yield (t ha ⁻¹)	NUE (kg/kg of NPK applied)
WSF	1.31	342	29.90	1.90	185.69	25.31	309.45
NF	1.00	263	24.76	1.55	143.16	16.43	238.6

Source: Mahesh and Asokaraja (2015)

WSF: Urea, MAP, All 19 and KNO₃

NF: Urea, DAP and MOP;

Table.3 Effect of fertigation levels on yield and NUE in sugarcane under fertigation

Fertilizer dose (N:P ₂ O ₅ :K ₂ O kg/ha)	NMC (lakhs ha ⁻¹)	Millable cane length (m)	No of internodes	cane weight (kg cane ⁻¹)	Cane yield (t ha ⁻¹)	Sugar yield (t ha ⁻¹)	NUE (kg/kg of NPK applied)
300:100:200	1.31	3.42	29.90	1.90	185.69	25.31	309.45
225:75:150	1.12	3.02	26.52	1.70	164.77	20.53	366.15

Source: Mahesh and Asokaraja (2015)

Table.4 4R nutrient management fertigation schedule for sugarcane

Right source	Right Rate (kg/ha)	Right Time		Right place	Nutrient requirements		
		Stage (days)	No. of times		N kg/ha	P ₂ O ₅ kg/ha	K ₂ O kg/ha
MAP	44.30	7-30	3	Placing the fertilizer at the most dense root zone area of the crop <i>i.e.</i> 25 cm below the soil surface through subsurface drip fertigation system	45.00	31.90	10.60
All 19	25.65						
KNO ₃	12.82						
Urea	72.06	31-60	4		54.60	31.90	17.70
MAP	42.50						
All 19	31.45						
KNO ₃	26.19						
Urea	85.91	61-90	4		54.60	19.10	17.70
MAP	22.50						
All 19	28.50						
KNO ₃	27.44						
Urea	92.00	90-120	4		60.00	17.00	21.30
MAP	20.00						
All 19	25.35						
KNO ₃	36.62						
Urea	104.40	120-180	8		64.50	0.00	71.00
KNO ₃	157.78						
Urea	97.58						
KNO ₃	136.70	180-210	4	21.30	0.0	61.50	
Urea	8.32						
			27	Total	300	100	200

Table.5 Effect of fertigation and soil application of fertilizers on yield and NUE in sugarcane

Fertilizer placement	Tiller production (No./m)	Plant height (cm)	Cane weight (kg cane ⁻¹)	CCS (%)	Cane yield (t ha ⁻¹)	Sugar yield (t ha ⁻¹)	NUE (kg/kg of NPK applied)
Fertigation SSDF	21.4	345.1	2.12	9.77	193.6	18.91	344.17
Soil application	11.7	217	1.28	7.77	86.8	6.74	192.88

Source: Gurusamy *et al.*, (2013)

*SSDF- sub-surface drip fertigation

Right time-providing nutrients when crop demands

The rate of nutrient application by the crops is totally based on the type, stage and need of

the crops, also nutrient supplying capacity of the soil (Khan *et al.*, 2001; Hartz and Hochmuth, 1996). Plants require different rates of nutrients over the growing season as per various physiological stages. In this

context, applying large quantity of fertilizers in limited splits cause N losses by leaching and denitrification and fixation of P and K in the soil ultimately results in poor fertilizer use efficiency and pollution of environment (Dangler and Lacascio, 1990). Further, untimely fertiliser application reduces nutrient uptake as well as its efficiency (Kwong and Deville 1987). Thus, for efficient nutrient management, supply of nutrients should be adjusted to counterpart with need of the crop at different times during growing periods. Nutrient accumulation patterns could be observed by doing tissue analysis at regular intervals, at the same time soil analysis could help to understand the nutrient depletion patterns in the soil and capacity of soil to supply nutrients for plant uptake. With this information, it can be possible to quantify the nutrients needs by the plant at different times during growing periods (help to decide time and frequency of fertilizer application). Hence, it is essential that timing of fertilizer application should meet with nutrient demands of the crop (nutrient uptake pattern) for maximizing fertilizer use efficiency.

Rate and pattern of nutrient uptake by the sugarcane crop is mainly decided by stage of the crop, soil moisture conditions, forms of nutrients, available nutrient status of the soil, climatic factors and variety used. The uptake of nutrients (NPK) varies considerably with growth stage of sugarcane. N, P and K for sugarcane cane is usually applied in split doses under drip fertigation. The total N, P and K can be given in 27 splits starting from 7-210 days of planting. Out of 100% RDF (N, P₂O₅, K₂O=300:100:200 kg ha⁻¹), the splits can be given as: 15% N, 31.90% P₂O₅ and 5.32% K₂O at germination stage (7-30 days-3 splits), 18.20% N, 31.90% P₂O₅ and 8.88% K₂O at early tillering stage (31-60 days-4 splits), 18.20% N, 19.14% P₂O₅ and 8.88% K₂O at peak tillering stage (61-90 days-4 splits), 20% N, 17.02% P₂O₅ and 10.65% K₂O

at canopy establishment stage (91-120 days-4 splits), 21.80% N, 0% P₂O₅ and 35.50% K₂O at grand growth stage (121-180 days-8 splits) and 7.30% N, 0% P₂O₅ and 30.76% K₂O at maturity stage (181-210 days-4 splits). The nutrient requirement of sugarcane at different growth stages have been worked and presented in Table 4. Fertigation of 100% recommended NPK through water soluble fertilizers in 20 equal splits at weekly interval improved the cane yield by 32.50% in comparison to soil fertilization of straight fertilizers with surface irrigation (Bangar and Chaudhari, 2001). However, study of Yadav *et al.*, (2015) indicated that fertigation of recommend nutrients either in 9 splits at 20 days interval or 12 splits at 15 days interval was more effective in enhancing cane yield than surface irrigation with soil fertilization with corresponding increments in cane yield by 25.34% and 24.33%, respectively. Similarly, drip fertigation at 100% RDF with WSF (urea, urea phosphate and MOP) increased the cane yield by 33.86% and 40.72% when applied at 12 and 26 splits, respectively over surface irrigation with soil application of 100% RDF with NF (Pawar *et al.*, 2014).

Right place - keeping nutrients where crops can use them

The proper placement of fertiliser is the key for better nutrient utilization and avoidance of nutrient losses from the soil. Under soil fertilization through broadcasting method, applied nitrogen fertilizer in soil is not fully utilized by the plants due to various losses *viz.*, leaching, run-off and volatilization losses as well as nutrient fixation in soil. In order to maximize the NUE, it is essential to place the nutrients where the plants can absorb more. Further, it can be assumed that placing the fertilizers at the right location could help the roots to absorb more nutrients for the entire cropping season. Generally, placement of

fertilizers either in the most concentrated root zone or 20 cm deep in the subsoil layer is considered as best spot to place fertilizers in order to maximize their utilization by the plants. Nutrients are mainly absorbed by the roots, therefore spreading fertilizers around the root zone could help to improve the probability of nutrients absorption by the plants. Fertigation is the innovative tool to apply the fertilizer more efficiently (Kafkafi and Tarchitzky, 2011). Moreover, subsurface drip fertigation could facilitate direct delivery of the nutrients at the intensive root zone below the soil surface thus improving fertilizer use efficiency by reducing different losses.

Subsurface drip fertigation is superior technology for efficient nutrient management in sugarcane. It offers an opportunity for placing fertilizer nutrients along with irrigation water at the right location below the soil surface (20-25 cm), using buried drip tapes (Ruskin, 2000; ASAE, 2001; Lamm, 2009). It ensures that nutrients are supplied as per the need of crop (nutrient applied vs. nutrients removed by crop) at the specific location thereby results in higher crop yields and quality (He and Kang, 2000). This improves nutrient use efficiency; minimize leaching and volatilization losses as well as ground water contamination. The effect of subsurface drip fertigation and soil application of fertilizer in sugarcane (Gurusamy *et al.*, 2013) is presented in Table 5. Dhotre *et al.*, (2008) registered higher cane yield of 134.9 t ha⁻¹ under subsurface drip irrigation (SSDI) compared to surface irrigation (65 t ha⁻¹). Similarly, SSDF at 100% RDF at 1.8 m lateral spacing with double side planting increased cane yield and sugar yield by 77.08% and 98.18%, respectively over surface irrigation with soil application of 100% RDF (Mahesh *et al.*, 2010).

In conclusion the adoption of efficient nutrient management is extremely important

not only to improve crop yield on sustainable basis but also to enhance nutrient use efficiency for environmental protection. Fertigation is the right option for supplying water and nutrients to the high biomass producing crop like sugarcane. Since, it will facilitate maximum nutrient uptake and in turn the yield; ultimately maximizing the nutrient use efficiency. Especially, subsurface drip fertigation has the capability to deliver the right nutrients, each at the right quantity, at the right location and at the right stage. However, to achieve full benefits out of this technology, it is essential to educate the farmers with technical skills in the areas of fertigation system operation, fertilizers selection, time of fertigation, rate of fertigation, method and location of fertilizer placement, irrigation frequency and amount, *etc.* From the above discussion, it could be concluded that to achieve higher crop productivity and nutrient use efficiency in sugarcane cultivation on sustainable basis, there is a need to promote the efficient nutrient management by using 4R nutrient stewardship approach.

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