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Fertigation: A way to Achieve Sustainability

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Abstract

Plants need 17 elements for completion of growth and development successfully. The role and behaviourof these mineral nutrients in soil is different in context to their mobility in soil and reaction with other nutrients in soils. The immobility of nutrients in soil makes the nutrients deficient. Indiscriminate use of nitrogenous fertilizers is damaging soil and ground water resources besides lower efficiency to crop plants. The nitrogen from fertilizers after converting in nitrate through microbial action particularly bacteria residing in the soil enters into streams and rivers after leaching into groundwater and washes out of the soil surface.Balanced fertilizer i.e., use of fertilizer nutrients in right proportion and in adequate amount are considers as promising agro-techniques to sustain yield, increase fertilizer use efficiency and to restore soil health.The need of the hour is therefore, maximizing the production per unit drop of water. The foliar application makes the available plant nutrients at appropriate time and amount. Fertilizer application along with irrigation water through micro irrigation systemi.e sprinkler and drip irrigationare most advanced and efficient practice of fertilization particularly for degraded soils like problematic soils, light soils, sloppy soils reduce the fertilizer efficiency by fixation, leaching losses, denitrification, reaction with other nutrients.

Keywords: Fertigation; Micro irrigation; Crop Production.

Introduction

The essential minerals nutrients are taken up by plants in different formslike single or complex as described in Table 1. Highly soluble potassium and nitrogen-based fertilizers can be easily washed out the soil, and phosphate fertilizers can attach themselves to ions of aluminum and iron into chemically insoluble form for plants. Certain physiochemical properties of soil i.e. pH, moisture status, temperature extremes may render a nutrient or nutrients unavailable to the plant root.

In our country and in Rajasthan the consumption of fertilizers is not in recommended ratio i.e.4:2:1as accepted for macro-level monitoring of consumption of plant nutrients for the country. According to the Fertiliser Association of India (FAI), the NPK ratio in the country has reached 6.10:2.46:1in 2017-18. The NPK ratio was closest to the ideal ratio in the year 2009-10, when it was 4.3:2:1. There is wide variation in ratio and also the monsoon behaviourrestrictsthe availability of these mineral nutrientswith the face of plant needs. The continuous use of N fertilizers alone or with inadequate P and K application has led to mining of native soil P and K. The readily-available nutrients are more easily utilized, as they are directly available to a plant while less soluble ions liable to combined with other free ions such as carbonate, bicarbonate, hydroxide, etc, into the soil solution and became unavailable to crop plants. These phenomenon or behavior of nutrients in soils

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Table 1: The forms of absorption of nutrients.

Absorbed as single nutrient ion		**Absorbed in a combined form**	
Nutrient elements	Forms absorbed by plants	Nutrient elements	Forms absorbed by plants
Potassium	K^+	Nitrogen	Ammonium (NH_4^+) and Nitrate (NO_3^+)
Calcium	Ca^{++}	Phosphorus	$H_2PO_4^-$, HPO_4^{--}
Magnesium	Mg^{++}	Molybdenum	MoO_4^{--} (Molybdate)
Iron	Fe^{++} (Ferrous), Fe^{+++} (Ferric)	Sulphur	SO_4^{--}
Manganese	Mn^{++} (Manganous), Mn^{++++} (Manganic)	Boron	H_3BO_3 (Boric acid), $H_2BO_3^-$ (Borate), HBO_3^{--}, BO_3^{---}
Copper	Cu^{++}	Hydrogen	H_2O, H^+
Zinc	Zn^{++}	Carbon	CO_2
Chlorine	Cl^{++}	Oxygen	CO_2, O^{--}, OH^-
Silicon	Si^{++++}, $Si(OH)_4$		
Cobalt	CO^{++}		
Sodium	Na^+		

influences their availability or efficiency of applied fertilizers in soils. The fertilizer use efficiency of major nutrients is given in Table 2.

Causes of low nutrient use efficiency

The nutrients are only taken by plants with water thus optimum moisture is required for achieving efficiency of fertilizers. The FUE of N is ranges from 30-50% and of phosphorus is 15-20%. The efficiency of utilization of chemical fertilizers is very low. It has been reported that nitrogen use efficiency seldom exceeds 40% under lowland and 60% under upland conditions. In case of phosphorous and potassium, the efficiency hardly exceeds 20%. Different NPK combinations can be made, depending on the application required. The following are the possible causes of nutrient deficiency.

- The loss of N through leaching and volatilization.
- The losses of N through denitrification.
- The fixation of phosphorus in Fe and Al oxides.
- The phosphorus converted into insoluble form.
- Imbalanced use of P & K fertilisers and also limited supply.
- Affect/de-stabilize prices in International market.
- In India N:K use ratio is probably closer to 10:1 while the ideal ratio expected is 3:1

Fertigation

Experimental evidences show that nearly all the elements are absorbed more or less readily by the leaves of various plants (Fig.1). Fertiliser elements which are absorbed through roots can be absorbed with equal efficiency through foliage (Rao, et al., 2006). In this contest, right combination of water and nutrients is the key for high yield and quality of produce. Fertigation is derived from the word "fertilizer" and “irrigation" It is the application of fertilizer dissolved in irrigation water in either open or closed system i.e., lined or unlined open ditches and sprinkler or trickle systems, respectively. Fertigation is also defined as field technique which preciselydelivers the plant nutrients via irrigation system inthe crop root zone as per crop demandduring crop growing season.In this method liquid fertilizer as well as water soluble

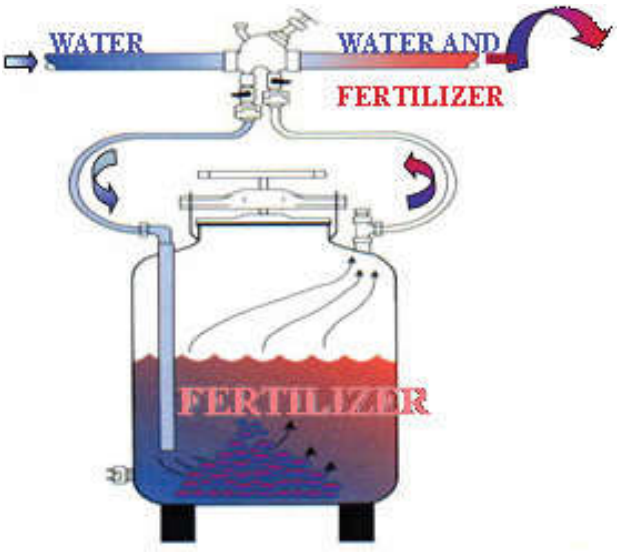

Fig. 1: Method of fertilizer incorporation in Irrigating water

Table 2: Consumption of fertilizers in India (2018-19).

Agri-inputs	Consumptions	Use–efficiency (%)
Food grain production	285 Million tonnes	–
Fertilizer (In terms of NPK)	273.75 Lakh tonnes	–
N	176.28 Lakh tonnes	30–50
P	69.68 Lakh tonnes	15–20
K	27.79 Lakh tonnes	60–80
Micro nutrients	–	1–5
Per ha consumption (Kg) India	133.0	–
Per ha consumption (Kg) Rajasthan	60.75 (15.24 lakh tonnes)	–

(Source: Agriculture statistics at a glance, 2019).

fertilizers are used and fertilizer use efficiency is increased from 80 to 90 per cent.It is an efficient and agronomically comprehensive method of providing soluble plant nutrients directly to the active plant root zone. The increasing area of micro- irrigated crops provides an excellent opportunity to explore new methods of providing complete and balanced plant nutrient programs that have the potential to improve plant health and increase yields (Zafari and Mohammadi, 2019).

Why Fertigation?

Nutrients balancing and fertilizer use efficiency can be achieved by adopting modern method of water and fertilizer applicationi.efertigation. The fertigation combines the two main inputs i.e. water and nutrients in plant growth and development (Fig. 1). The application of fertilizers through fertigation ensures application of the fertilizers directly to the plant roots. Drip irrigation enables, the application of water-soluble fertilizers and other chemicals along with irrigation water uniformly and more efficiently in the root zone of crop. The expensive supply of nutrients in the form of fertilizers was a key factor, along with improved irrigation system and adequate supplies of water with nutrients, in the substantial increase in yields and fertilizer use efficiency. Kumar and Singh (2002) reported that nutrient use efficiency in fertigation increases as a result of controlled and regular application of fertilizers. The agricultural chemicals can be applied more efficiently with drip irrigation and only the crop root zone is irrigated, nitrogen already in the soil is less subject to leaching losses, and applied fertilizer N can be used more efficiently. Monitoring and control of real-time soil, plant and weather conditions are necessary for intelligent irrigation and fertilization to achieve success (Karaşahinet al., 2018). The urgent need of fertigation is as follows:

- If deficiency of any nutrient is observed/ nutrient not applied earlier/peak demand for an immediate or quick growth response.
- In problematic soils, delayed fixation or conversion in unavailable forms of nutrients.
- When soil is deficient in a nutrient.
- Under limited fertilizer availability means wide demand and supply gap
- Chances for ground water contamination
- Plants under stress conditions
- In some states like Punjab, Haryana, parts of Rajasthan ground water samples had Nitrate-N of >22mg/L causes human health issue .

History of fertigation:

This technique was first started in the late 1960's in Israel. In the year 1970 Arscott first reported that urea applied through irrigation system was more efficient than hand broadcasting on soil surface. Now, it became a hi-tech, efficient and a potential method in modern agriculture resulting in higher yields with improved quality of the crop produce.

Crop suited for fertigation: In India,fertigation is not common for food crops. To a limited extent, fertigation is used for cash crop like Sugarcane, cotton and castor. Orchard crops like banana, citrus, guava, pomegranate, vegetables like tomato, chilli, brinjal, lady finger cabbage, clusterbean, cauliflower etc. and flowers are the major crops under fertigation.

Advantages of Fertigation

- Increased in yield by 25-30%.
- Nutrients and water is supplied near the active root zone through fertigation which results in greater absorption by the crops and improve fertilizer use efficiency ranges between 80-90 per cent, which helps to save a minimum of 25 per cent of nutrients
- Fertilizer application is more accurate and uniform distribution.

- Nutrient can be applied as per plant requirement.
- Minimizes nutrient losses through leaching & Evaporation.
- Nutrients are immediately available to plant.
- Saving in time, labour, energy substantially.
- Helps in effective weed management.
- Optimizing nitrogen fertilizer use will help reduce the amount of nitrous oxide released from the soil.
- Control of nutrient losses
- Decrease in environmental pollution, especially by preventing nitrogen leaching
- Avoids soil problems
- Lower dose of fertilizer required and low cost
- Nutrients are available at key growth stage.
- Able to use special fertilizers to prevent minerals deficiencies
- Relatively low cost.
- No foliar burn (with KNO_3 or K_2SO_4)
- Improved yield and fiber quality parameters

Limitations

- Initial investment arehigh in the installation of fertigation system.
- Chemical reaction in drip system leading to corrosion and precipitation of fertilizer.
- Clogging of emitter due to precipitation.
- Sometimenotuniformapplication(concentration of the solution decreases as solution dissolve) leading to poor nutrient placement.
- Possible pressure loss in the main irrigation line.
- Potential nutrient imbalance with single nutrient application.
- Only a limited amount of the nutrient can be applied at one time.
- Possibility of foliar burn (with high concentrations) and leaf damage (Necrosis & burning)
- Incompatibility with certain other agrochemicals.
- The risk of washing of the nutrients is high during the kharif season
- Roots remain airless due to frequent irrigation in heavy soils
- Installation and operation needs experienced staff.
- Risks of clogging of drippers with precipitation of insoluble salts

Characteristics of fertilizer suitable for fertigation:

- Fertilizer should have high nutrient content and readily available to plants.
- Almost 100 percent water soluble at field temperature.
- No precipitation and no clogging of emitters and filters.
- Low content of insoluble's (0.02%)
- Fertilizers must compatible with each other.
- Negligible interaction with irrigation water.
- No drastic changes of water pH.
- Balanced nutrient content as per crops need and should be complete.

Factors influencing absorption of mineral nutrients

The suitability of a fertilizer through micro irrigation is depends on solubility in water, temperature and its reaction with soil particles (clay components) and other minerals. Further it is affected by crop type, growth stage and duration.

- Solubiulity of fertilizers
- Compatability of fertilaers
- Soil reaction
- Soil cation exchange capacity
- Solution concentration
- Stages of cropgrowth
- Species and variety
- Quality of irrigation water
- Soil texture and structure
- Light intensity and air temperature
- Air humidity
- Wind speed perticullary in sprinklet irrigation.
- Nutritional status and plant development stage

Solubility

To be able to apply a granular fertilizer it should be first dissolved in water. The quantity of fertilizer that can be dissolved in unit quantity of water is called the solubility. The solubility is greatly affected by the temperature variations. Normally these values are taken for 20 degrees C (Tables 3).

Table 3: Fertilizers commonly used in fertigation.

Name	N – P_2O_5 – K_2O content	Solubility (g/l)
Ammonium nitrate	34-0-0	1920
Ammonium sulphate	21-0-0	760
Urea	46-0-0	1100
Monoammonium phosphate	12-61-0	282
Diammonium phosphate	18-46-0	575
Potassium chloride	0-0-60	347
Potassium nitrate	13-0-44	316
Potassium sulphate	0-0-50	110
Monopotassium phosphate	0-52-34	230
Phosphoric acid	0-52-0	457

- Highly Water soluble fertilizers like urea, ammonium nitrate, ammonium sulphate, calcium ammonium sulphate, calcium ammonium nitrate are used as nitrogenous fertilizers in micro fertigation. Urea is highly soluble and dissolves in non-ionic form so it is well suited for injection in micro irrigation system. As it dissolve in non-ionic from, it does not react with other substances and not precipitate in the water.
- Application of K fertilizer does not cause any precipitation of salts. Potassium nitrate, Potassium chloride, Potassium sulphate and mono potassium phosphate are used in drip fertigation.
- Most of the P fertilizer marketed for farm application is too low in their solubility. The phosphorus fertilizers particularly super phosphorus through fertigation must be avoided because it makes precipitation of phosphate salts if the water is hard or contain high Ca. Thus phosphoric acid is more suitable for fertigation as it is available in liquid form. In some opinions, the P in the solution form immediately gets fixed soil contact site itself. This is a researchable issue.
- P + Ca = Calcium phosphate (insoluble)
- P + Ammonium + Magnesium = Magnesium ammonium phosphate (Insoluble)
- P + Iron = Iron phosphate (insoluble)
- The some fertilisers like mono ammonium phosphate, poly feed foliar fertilizer, potassium nitrate brand like Multi K, Potassium sulphate etc. are highly suitable for fertigation as they are highly soluble in water.
- Further, micro nutrients like Mn, Zn, Fe, Cu, B, Mo are also supplied along with special fertilisers in drip irrigation.
- The detail of fertilizer suitable for fertigation is mentioned in Table 3 along with solubility.

Compatibility

Mixing the solutions of two or more than two water soluble fertilizers can sometimes result in the formation of a precipitate. Under such situations special attention has to be paid to avoid mixing them in one tank because these fertilizers are not mutually compatible. For example phosphoric and sulphatic fertilizers may precipitate as calcium phosphate or calcium sulphate, respectively with calcium fertilizers in the same tank. To avoid such circumstances,their solutions should be prepared in two separate tanks. Some fertilizers can also cause clogging problems if they are incompatible with fertigation.

Effect on soil reaction

The fertilizers can be classified into three groups depending upon their effect on the pH of the soil i.e. acidic, basic and neutral. The application of these fertilizers into soil solution may change the pH of the soil resulted in increase or decrease the availability of some other nutrients. The use of acid forming fertilizers e.g. anhydrous ammonia and ammonia compounds tends to increase the solubility of some minor elements such as iron, manganese, copper, zinc and molybdenum. This acidiftying effect persists only for short duration. Phosphatic fertilizers keep the soil pH near neutral but potassic fertilizers increase the soil pH and make the soil basic. The buffering capacity of a growing medium depends on its resistance to chemical changes (pH and EC). Clay type and organic matter content are the major factors affecting these two parameters for any type of soil.

Crop type and Stage of Growth

The availability of nutrients depends upon the quality of growing medium to supply nutrients to the plant. The injection time of fertilizer is depending on the type of crops and these growth stages. The consumption rate of nutrients by the plant depends upon type and variety of crop, plant population, growth stage, climatic condition and expected yield. Nutrient consumption rates are not affected by the characteristics of the growing medium and the irrigation method.

Crop stage-wise need

The amount of fertilizer is needed on the basis of stage of crop. Pre stage crop have require less amount of fertilizer than mature crop.

Water quality

Irrigation water quality should be tested prior to fertigation. The following parameterts of water quality are required to be tested-

- The electric conductivity means total amount of ions present in the irrigation water, especially-the sodium and chloride.
- pH of irrigation water.
- Carbonate & bicarbonate content in the water

Fertigation and its impact on crop production

Studies conducted by various scientists on different crops through application of mineral nutrient in irrigation water and found positive impacts. The foliar application of nutrients particularly for exhaustive crops or high nitrogen requiring crops not only fulfills their N requirements for long period but also reduces the losses of nitrogen though leaching and volatilization and also reduces the growth of weeds during top dressing. The experimental evidences shows that inorganic source of fertilizer with different foliar sprays viz., foliar spray of KCl @ 1% or DAP @ 1% or Boron @ 0.3% gave good results in terms of increasing number of panicles, panicle length, filled grains per panicle and yield of grain and straw of paddy (Sahuet al, 2014). Anjumet al. (2017) reported that the foliar application of sulphur at rate of 1% through Ammonium Sulphate was more efficient for the growth and yield attributes in Canola as compared to control. It is concluded from the present findings that foliar application of ammonium sulphate @ 1% significantly increased the yield and quality attributes of canola (Ali et al., 2016). An experiment was conducted at PAU Ludhiana found that when the same quantity of irrigation water and N was applied through drip irrigation system increases the seed cotton yield to 2144 from 1624 kg ha^{-1} (an increase of 32%) under check basin method of irrigation (Aujlaet al. 2005).Yadav et al., (2015) reported that fertigation at 75% recommended dose of N and K was sufficient to meet the requirement of the sugarcane. He stated that 25% fertilizers in comparison to conventional practice of flood irrigation may be saved in above treatment. Raskar (2004) and Veeraputhiran and Chinnusamy (2009) found that an increase in growth and yield attributes as a result of optimum moisture and nutrition to the crop through drip fertigation due to increased photosynthates and translocation of more assimilates from source to sink. Further, the incidence of whitefly and per cent infestation of spotted bollworm were lower in fertigation treatments in comparison to recommended flood irrigation.

Fertigation Equipment

There are three groups of devices offertilizer injection commonly used for fertigation (Fig.2);

a) Venturi
b) Fertilizer tank and
c) Pumps.

These devices must have high precision, accuracy, and reliability. Further selection of aninjection method best suits the irrigation systemand crop to be grown otherwise an inappropriate selection of theequipment can damage parts of the irrigationequipment, affect the efficient operation of theirrigation system and reduce the efficiency of the nutrients.

Venturi Injector

This is very simple, easy to handle and low cost device. The fertilizer solution is sucked into ventury through a suction pipe from the tank and then enters into irrigation stream due to the pressure drops created by diverting a percentage of water flow fromthe main and passes it through a constriction whichincreases the velocity of flow. The suction rate of ventury is 30 to 120 litre per hour. The venturyis most suitable for small holdings and affordable even by small farmers.

Fertilizer Tank

Fertilizer tanks are available in 90, 120, 160 litres capacity. A part of irrigation water from the main line is diverted to flow through this tank containing fertilizer solution and further connected to the irrigation pipe at the supply point. A slight drop inpressure is created between the off take and returnpipes by means of a pressure reducingvalve.

Fertilizer Injector Pump

These are piston or diaphragm pumps whichare driven by the water pressure of the irrigationsystem

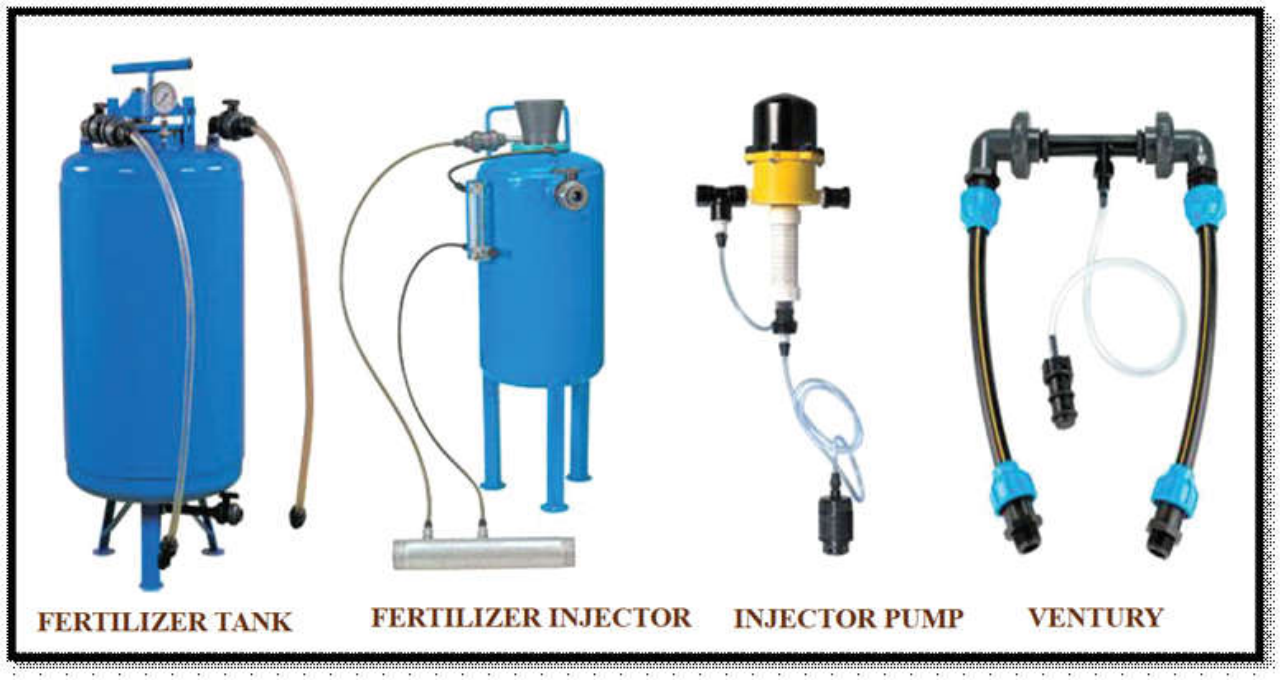

Fig. 2: Devices of fertilizer injection.

and such as the injection rate is proportionalto the flow of water in the system. The fertilizer pump is a standard component of the control head. The fertilizer solution is held in non-pressurised tank and it can be injected into the irrigation water at any desired ratio. Therefore the fertilizer availability to each plants is maintained properly.

Preparation of Stock Solution

- Assume 30 kg of N is to be fertigated throughurea.
- Amountof Urea required = 30/0.46 = 65.21 kg
- Solubility of Urea (summer) is 1100 g/liter
- Amount of water required for dissolution = 65.21/1.1 = 60liters
- About 50 liter capacity container be taken andfilled with 60 liters of water and then dissolve the 30 kg urea by mixing it slowly
- Siphon the clear solution for injecting through thefertigation applicator

Constraints in Fertigation

In India, the holding size and quality of irrigation water restricts the use of fertigation equipment. The rate of adoption of micro irrigationsystem is more popular in horticultural crops because the agronomic crops are sown at narrow spacing create a burden for more expanse on installation of equipment. Of course the technique is water saving technique but poor quality of water alone or in combination with fertilizers in sprinkler and mini sprinkler systems causes scorching of foliage. Although, fertigation offers numerousadvantages but it is not being used widely due to thereasons given below

- There is lack of study in respect of its rate ofapplication, amount applied and frequencyto be adopted under varied agro-climatic conditions and for different crops.
- The water soluble fertilizers require for fertigation are marketed at higher prices as compared to conventional fertilizers. Further, the conventional fertilizers are available at subsidy in India, a higher investment on fertilizer input reduces the profitability in general and in water abundantly available area in particular.
- The chances of clogging of micro irrigation system are more due to algal growth and deposition of salts.

Conclusion

Fertigation system is an alternative towards controlling the fertilizer investments, through tweaking the fertilizer dosages on demand in accordance with the requirements. These controlled fertilizer dosages reduce the groundwater contamination and leaching. Fertigation increases

the crop yield and its quality at low by precise use of resources like fertilizer and water.

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