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Integrated nutrient management in vegetable crops

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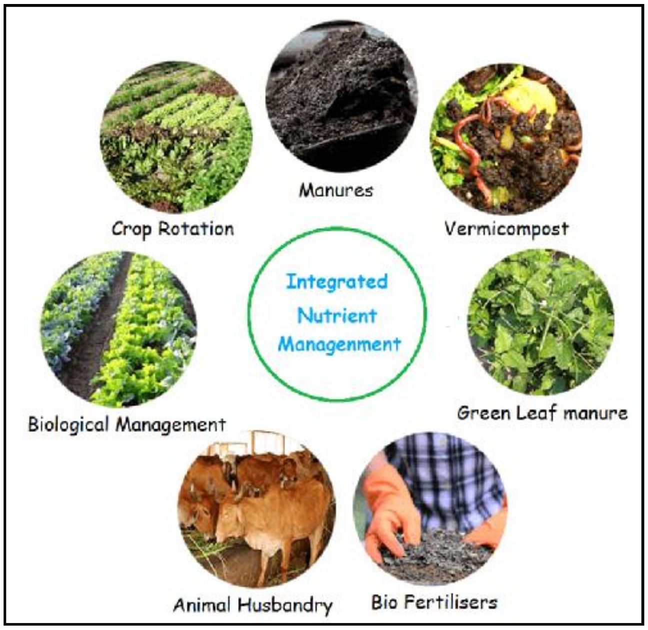
Introduction: India has emerged as second largest vegetable producing country in the world, but the present level of production is not able to keep pace with the increasing population. It is expected that by 2025, our vegetable demand will be 225 million tons against the limitations of expansion of the cultivable land area. The only alternative to achieve this goal is to raise the vegetable production level, through use of high yielding varieties/hybrid, modern production technology. Integrated nutrient management is one of the most important components of modern production technology to sustain the vegetable production and soil fertility in the future. Plant nutrients can be supplied from different sources *i.e.*, organic manures, composts/ vermicompost, crop residues, green manures, biofertilizers and chemical fertilizers. For better utilization of resources integrated nutrient management is the best approach to utilize all possible sources of plant nutrients on the basis of economic considerations and the balance required by the crop is supplemented with chemical fertilizers.



Principles of integrated nutrient management: INM is a holistic approach of plant nutrient management by considering the totality of the farm resources that can be used as plant nutrient and is based on three principles:

– Maximize the use of organic material

– Ensure access to inorganic fertilizers

– Improve the efficiency of their use and minimize the loss of plant nutrients.

Objectives of INM:

– It should increase the availability of nutrients from all sources in the soil during cropping season.

– It should match the demand of nutrients by the crop.

– It should optimize the functioning of the soil biosphere with respect to specified functions such as decomposition of organic matter (mineralization), the control of pathogenic organisms by their natural enemies, the biological formation of soil structure (aggregates, biopores) the decomposition of phytotoxic compounds etc.

– It should minimize the losses of nutrients to the environment, through ammonia volatilization, denitrification in case of nitrogen, surface runoff and leaching NO_3 and PO_4 beyond the rooting zone and prevent eutrophication of the water bodies and ensure no build up of the toxic metals in the soil.

Components of INM:

Organic manures: Organic manure is one of the major and commonly used organic nutrient component in INM. Organic manures include farm yard manure, compost, vermicompost, poultry manure, sheep manure, night soil, oil cakes and excrete of other animals. The annual production of organic manures in India is estimated to provide 17.82 million tons of NPK which is 8.0 million tons less than the required for producing 2.30 million tons of food. The nutrient value of organic manures is not comparable to inorganic fertilizers. However, poultry manure/ vermicompost/oil cakes are comparatively richer sources of nutrients and all of them play a vital role in maintaining soil fertility though their effects on physio-chemical properties of soil (Tandon, 1992). Importance of organic manures in vegetable production is an established fact. Organic manures release nutrients decomposition. Organic manures contain small percentage of nutrients and are applied in large quantities (Table 1).

Advantages:

Table 1: Nutrient status of some organic manure

Category	Source	Nutrient content (%)		
		N	P_2O_5	K_2O
Animal wastes	Cattle dung	0.3-0.4	0.10-0.15	0.15-0.20
	Cattle urine	0.80	0.01-0.12	0.50-0.70
Sheep and goat dung (mixed)		0.65	0.05	0.03
Night soil		1.2-1.5	0.8	0.5
Leather waste		7.0	0.1	0.3
Hair and wool waste		12.3	0.1	0.3
FYM/composts	Farm yard manure	0.5-1.0	0.15-0.20	0.4-0.6
	Poulry manure	2.87	2.90	2.35
	Town compost	1.5-2.0	1.0	1.5
	Rural compost	0.1-1.0	0.2	0.5
	Water hyacinth compost	2.0	1.0	2.3
Oil cakes	Castor	5.5-5.8	1.8	1.0
	Cotton seed	3.9	1.8	1.6
	Pongamia pinnata	3.9-4.0	0.9-1.0	1.3
	Neem	5.2	1.0	1.4
	Niger	4.8	1.8	1.3
	Bassia latifolia	2.5-2.6	0.8	1.8
	Rape seed	5.1	1.8	1.0
	Linseed	5.5	1.4	1.2
	Sunflower	4.8	1.4	1.2
Animal meals	Blood	10-12	1.2	1.0
	Raw bone	3-4	20-25	---
	Steamed bone	1-2	25-30	---
	Fish meal	4-10	3-9	1.8

(Source: Gaur *et al.*, 1992)

– They improve soil physical properties.

– Supply macro, secondary and micronutrient.

– Increase nutrient availability.

– When applied with mineral fertilizers, it improves the efficiency of latter due to their favourable effects on soil properties.

– Add nutrients to the soil and reduce dependence on fertilizer (Sharma, 2003).

– Organic manures increase P availability as they have very high cation exchange capacity (Gaur, 1990).

– Organic manures exhibit residual effect, as they are not fully utilized by the crop in the 1st year of application. Nitrogen released by them is very slow (less than 30%) and the balance becomes available for the subsequent crop.

– Improves soil tilth and water holding capacity.

Compost: Compost is an amorphous brown to dark humified material produced as a result of microbial decomposition of organic wastes collected from urban and rural wastes. In addition to microbial decomposition, machines are also used to produce compost, commonly known as mechanical compost. Soil invertebrates (earth worms) are also used effectively for recycling of non-toxic/degradable organic wastes to the soil. Culturing of earth worms is referred as vermiculture and the recycled produce, which is granular, is referred as vermicompost. Compost is rich sources of essential plant nutrients. Besides, nutritional richness, composts are known to improve the physical, chemical and biological properties of the soil. Composts are also helpful in reducing the outlay on fertilizers. The beneficial effects of compost on yield and quality of vegetables have been reported by a number of research workers (Table 3). Composts are also known to provide additional benefits like suppression of soil borne plant pathogens and biological weed control.

Biofertilizers: Are cost effective, eco-friendly and renewable source of plant nutrient to supplements fertilizers for sustainable vegetable production. Hence,

Table 2 : Effect of chemical fertilizers, organics and their integration on the yield/quality of vegetable crops

Crop	Yield (qha^{-1})			Source
	Chemical fertilizers	Organics	Integration of chemical fertilizers with organics	
Brinjal	378.00	351.50	454.66	Jose *et al.* (1988)
Brinjal	96.40	95.70	96.20	Rao *et al.* (2001)
Cabbage	332.96	319.29	329.95	Chattoo *et al. (*2003)
Chilli	61.12	63.93	70.75	Malewar *et al.* (1998)
Capsicum	248.66	193.95	296.63	Magray *et al.* (2002)
Pea	58.00	39.00	103.00	Ndatt *et al.* (2003)
Okra	108.37	101.93	164.53	Abusaleha and Shamugavelu (1988)
Okra	63.74	56.35	67.21	Ray *et al.* (2005)
Okra (seed yield)	23.26	22.72	26.62	Chattoo *et al.* (2009)
Onion	171.60	78.50	187.70	Sharma *et a.* (2003)
Onion	331.94	273.33	336.71	Chattoo *et al.* (2010)
Tomato	276.20	196.30	277.10	Bhardwaj *et al.* (2000)
Tomato	385.77	291.69	510.84	Rafi *et al.* (2002)
Tomato				
Fruit yield	302.58	259.25	318.79	Anonymous (2009)
Seed yield	1.15	1.02	1.14	Anonymous (2009)
Cabbage	372.40	357.00	370.00	Chattoo *et al.* (2006)
Carrot	74.61	73.28	76.36	Singh *et al.* (2003)
Beans	133.77	119.63	136.87	Anonymous (2009)

becomes an integral part of INM. Biofertilizers are the products containing living cell organisms capable of fixing atmospheric nitrogen, solublizing and mobalizing phosphorus in soil; produce growth, promoting and antifungal substances. Biofertilizers include Rhizobium (Symbiotic nitrogen fixer), *Azotobactor* and *Azospirrilium* (Non-symbiotic nitrogen fixer) Pseudomonas, Phosphobacteria, Flavobacterium (Phosphorus Solublizers) Vesicular arbuscular mycorhizae (Phosphorus mobalizers) etc. These biofertilizers are used as seed, seedling and soil inoculant. Biofertilizer application in vegetable production has attained significant importance, as they were found to improve soil fertility, sustain yield and quality of vegetables and reduce pollution (Chattoo *et al.*, 2003; Rather *et al.*, 2003). Biofertilizer such *Azotobactor*, *Azospirrilium, Phosphobacteria* and VAM have been found to economize the N and P fertilizer upto the tone of 25-50 per cent and increase yield by 1-25 per cent (Table 4). Biofertilizer application has brought social, economic and environmental benefits. Application of half RFD + biofertilizers could produce more or less the same economic yields but helps in saving of 25-50 per cent dose of applied N and P.

Green manuring: Crops grown for restoring or increasing the organic matter content in the soil are refered as green manure crops and this cropping system is called as green manuring. Crops here are grown either *in situ* or brought from outside and upon decomposition, besides releasing nutrients, they add organic matter, produce enzymes, vitamins and antibiotics.

Crop rotation: Crop rotation is beneficial in sustaining both yield and quality of vegetables, as it has a potential to overcome all those factors which are responsible for decline in yield like loss of soil fertility, unbalanced nutrient uptake and presence of pest and weeds, legumes in rotation have been found to increase the yield by 25-30 per cent, besides fixing atmospheric nitrogen to the extent of 30-40 kg ha^{-1} in tropical and sub tropical regions. Singh *et al.* (1991) reported that legumes in rotation can fix nitrogen from 100-200 kg ha^{-1} within 55 days. Rhizobial inoculation can improve the potential of legumes. Thus crop rotation can be an effective tool in integrated nutrient management for realizing sustainable yields.

Crop residues: Crop residues are non-economical plant parts that are usually left in the field after harvest, left in packing sheds or processing units and serve as a potential

Table 3 : Influences of compost, vermicompost either alone or in combination with inorganic fertilizers on vegetable crop improvement

Chicken manure compost	Equally efficient as that of nitrogen fertilizer produced higher yield in sweet corn and cabbage	Nishiwaki and None, 1996
Straw and cattle manure compost	Increased total carbon content of soil	---do---
Cattle manure compost	Reduced nutrient leaching	---do---
Compost from municipal solid waste	Increased water and fertilizer conservation in sandy soil	Qzores Hampton *et al*., 1998
MSWC + N fertilizer@134 t ha^{-1}	Increased yields of tomato by 22% peppers by 17% over non-compost plots	Clark *et al*., 2000
Compost application in acid soil	Increased yields of spinach and lettuce over mineral fertilizer or control	Guodufa, 2000
Compost pure or N enriched compost	Enhanced soil organic matter, total N and K.	Dugoni and Berolasi,
MSWC (Municipal solid waste compost)	Reduced heavy metal content in leaves	2000
Compost + organic manures 22 t ha^{-1} + 45 t ha^{-1}	Increased available and dissolved organic carbon to un-amended soils	Ercih *et al*., 2002
Sea wood compost	Increased growth rate, protein lipids and moisture content of vegetable	Zahid, 1999
Compost from cucumber plant wastes	Increased the cucumber yield by 15% over control	Abon Hadid *et al*., 2001
Compost from chicken manure	Increased the cucumber yield by 34% over control	---do---
Compost from kitchen wastes, yard wastes and FYM	Improved yield, quality and storage performance of cabbage, carrot, tomato and potato resulted in superior sensory quality of tomato	Vogtmann *et al*., 1993
Vermicompost processed from pig manure and food	Suitable potting medium for Soil less culture	Atiyeh *et al*., 2000
Vermicompost	Enhanced growth of tomato, pepper and lettuce in soil less culture	Atiyeh *et al*., 2000
Vermicompost 12 t ha^{-1} + 100% RFD	Recorded highest yield of 5663 kg ha^{-1} in okra Reduced significantly the cost of production	Ushakumari *et al.,* 1999 ---do---
Vermicompost + inorganic fertilizer (50% PK) (50% N + K)	Recorded a tuber yield of 308.21 q ha^{-1} as compared to RFD 353.31 q ha^{-1} in potato	Upadhayay *et al*., 2003
Vermicompost + fertilizer	Recorded larger number of fruits higher level of vit C and sugar in tomato cv. Sunny	Premuzic *et al.,* 2001
Vermicompost + fertilizer	Depicted significant effect on root shoot growth, fruit weight and number of tomatoes	Samawat *et al.,* 2001
Vermicompost (sole)	Was 3, 4, 5 and nine times more than control	---do---
Vermosole (Vermicompost extract)	Increase tomato yield by 7.3%, decreased nitrate content of fruits by 15%	Lozek and Gracova, 1999
Vermicompost + DOS + 75% NPK dose (digested organic supplement)	Recorded highest TSS and ascorbic acid content in cabbage	Mahendranand Kumar, 1997
Vermicompost	Was found effective to inhibit infections by *Oxysporum f.* sp. *Lycopersici* (causing Fusarium wilt) in tomato plants	Szczech, 1999
Vermicompost	Increased the growth and yield of onion in mine soil	Thanunathan *et al.,* 1998
Vermicompost	Reduced the number of galls and egg masses of *Meliodogyne javanica* in lettuce	Ribeiro *et al.,* 1998
Coffee pulp compost	Reduced the reproduction of *M. javarica* in tomato	Zambolim, 1996
Vermicompost	Suppressed the development of diseases in tomatoes and cabbage, thus, can be used as a bio-pesticide	Szczech and Brezeski, 1994
Vermicompost	Reduced nitrate, cadmium and lead levels in cucumber and carrot	Kolodziej and Kostecka, 1994

Table 4 : Response of vegetable crops to *Rhizobium, Azospirillum, Azotobacter*, PSM and VAM inoculation

Biofertilizer	Crop	Increase in yield (%)	Nitrogen economy (%)	Source
Rhizobium	Cowpea	4.09	-	Mishra and Solanki (1996)
	Pea	13.38	-	
	Pea	5.10	-	
Azotobacter	Brinjal	3.5	25	Kamali *et al.* (2002)
	Cabbage	8.60	25	Bhat (2003) M.Sc. Thesis, SKUAST (K)
	Garlic	14.23	25	Anonymous (2003)
	Garlic	14.80	25	Wange (1995)
	Knol khol	9.60	25	Chattoo *et al.* (1997)
	Tomato	13.60	50	Kumahaswamy (1990)
Azospirillum	Brinjal	3.2	25	Kamali *et al.* (2002)
	Cabbage	7.00	25	Jeeva Jothi *et al.* (1993)
	Cabbage	11.87	25	Verma *et al.* (1997)
	Capsicum	9.98	25	Anonymous (2002)
	Chilli	26.70	25	Paramaguru and Natrajan (1993)
	Chilli	15.10	25	Deva *et al.* (1996)
	Knol khol	14.90	25	Chattoo *et al.* (1997)
	Onion	9.60	25	Thiiackavathy and Ramaswamy (1999)
	Onion	6.20	25	Gurubatham *et al.* (1989)
	Onion	21.68	25	Anonymous (2002)
	Onion	7.74	25	Rather (1997) M. Sc. Thesis, SKUAST-K
	Garlic	6.42	25	Anonymous (2003)
	Okra	9.00	25	Subbiah (1991)
	Onion	10.94	25	Chattoo *et al.* (2005)
	Cabbage	9.53	20	Bhat *et al.* (2007)
	Garlic	19.29	25	Chattoo *et al.* (2007)
	Capsicum	2.67	25	Chattoo *et al.* (2003)

Table 5 : Nutrient content of green manuring crops and green leaf manure

Crop/ Plant	Scientific Name	Nutrient content (%) on dry basis		
		N	P_2O_5	K_2O
Green manuring crops				
Sunhemp	*Crotalaria juncea*	2.30	0.50	1.80
Dhaincha	*Sesbania aculeate*	3.50	0.60	1.20
Sesbania	*Sesbanis speciosa*	2.71	0.53	2.21
Wild indigo	*Tephrosia purpurea*	2.40	0.30	0.80
Green leaf manure				
Glyricidia	*Glyricidia sepium*	2.76	0.28	4.60
Pongamea	*Pongamea glabra*	3.31	0.44	1.39
Neem	*Azadirachta indica*	2.03	0.28	0.35
Gulmohar	*Delonix regia*	2.76	0.46	0.50
Peltoforum	*Peltoforum ferrugenum*	2.63	0.37	0.50

source of nutrients, besides promoting and improving soil and water conservation, soil fertility and crop productivity. The potential of crop residues available for recycling in the country has been estimated to be 185263 thousand tones with a nutrition potential of 3320 thousands tones.

Sewage and sludge: Sewage has been used in agriculture from start of human civilization. Application of sewage in agriculture offers a promising alternative, as sewage is rich in organic matter and nutrients and can be a substitute for irrigation water. The potential benefits of this practice include reduced cost of treatment and energy inputs, reduction/elimination of problems related to sludge handling storage and disposal as well as an increase in the amount of organic matter in the soil. Nutrient supplying potential of sewage is directly related to its composition. In general the sewage contains more than 90 per cent water. The solid portion contains 40-50 per cent organics, 30-40 per cent inert material, 10-15 per cent bio-resistant organics and 5-8 per cent miscellaneous substance on oven dry basis. It contains good amount of NPK and micronutrients like Fe, Zu, Cu, and Mn. However, sewage also contains heavy metals like Pb, Cd, Cr, Co and Ni. These heavy metals pose serious problems regarding metal pollution, eutrophication and ground water contamination by nitrate and health risks from pathogens, are of great concern. Sewage has a positive effect on vegetable production and it not only increases the yield but has also resulted in the improvement of soil physical properties and level of macro and micronutrients (Mahida, 1981 and Juwakar *et al.*, 1994).

In-organic sources:

Major nutrients: Vegetables need bulk of major nutrients. Requirement of nitrogen in most of the vegetable crops is quite high and brings a linear increase in yield. Increase in yield due to N fertilization could be attributed to luxuriant growth increased photosynthesis and better translocation of photosynthates. Requirement of phosphorus is not too high but is essential for plant health and is reported to have significant effect on the yield of vegetables. Potassium is required in higher quantity to improve the quality and shelf-life of vegetables (root crops). Improper and imbalanced use of chemical fertilizers is hazardous

Table 6 (a): Effect of sewage on the yield of vegetable crops

Crops	Yields (t ha^{-1})			
	Well water	Untreated sewage	Primary treated sewage	Diluted (1:1) sewage
Cabbage	13.3	14.8	16.4	15.7
Cauliflower	16.4	18.2	19.7	16.9
Okra	3.1	3.4	4.8	4.0
Tomato	13.7	15.5	16.4	16.1
Brinjal	9.1	12.1	12.7	10.1
Potato	6.4	7.1	8.1	7.1

(Source: Juwarkar *et al.*, 1994)

Table 6 (b): Effect of sewage on the yield of vegetable crops

Crops	Yields (t ha^{-1}) undiluted sewage	Diluted (1:1) sewage	Canal water
Beet root	16.27	15.60	8.75
Carrot	11.75	8.72	9.71
Radish	8.33	6.14	7.26
Potato	9.33	7.00	6.12
Knol Khol	16.57	11.76	9.70
Cabbage	12.13	11.32	9.27
Cauliflower	9.09	7.08	9.96
French beans x	8.06	8.20	6.63
Tomato	13.38		10.01

(Source: Mahida,1981)

with respect to over all soil health, yield and quality of vegetables. Sustainable yields can be harvested only if they are used in combination with other sources of plant nutrients like organic manures, compost and bio-fertilizers.

Secondary and micro nutrients: Adoption of improved technology in vegetable in vegetable production had decreased the level of secondary and micronutrients in most of the Indian soils, which is evident by response to addition of these nutrienys. Among secondary nutrients, requirement of sulphur is at par with that of phosphorus. Micronutrients along with secondary nutrients are known to improve the yield and quality of vegetables. So their application becomes indispensable for sustainable vegetable production. For optimizing plant nutrient efficiency the time and method of application plays a key role. Nitrogenous fertilizers should be applied in split doses, while phosphatic and potassic fertilizers as basal treatments. Organic manures/composts should be well decomposed and applied at least 20-25 days prior to planting. Microbial inoculants should be applied 24-48 hours after chemical fertilizer application. Sustainability in vegetables also depends upon source of nutrients. Urea is an efficient source of N. Water soluble phosphatic fertilizers are more suitable for direct application in vegetable crops. K_2SO_4 is considered better option for K fertilization. As for organic sources are concerned their nutrient content depends on sources from which they are prepared. Poultry manure proved superior to sheep and farm yard manure.

Advantages of integrated nutrient management: The integrated nutrient management approach has several advantages:

– Integrated nutrient management is eco-friendly and economically profitable.

– Ensures, reduction in indiscriminate use of chemical fertilizers, which is often a cause of poor soil health and ecological hazards.

– Helps in the conservation of nutrients, benefiting the soil productivity, through favourable impact on chemical and biological properties of soil.

– INM ensures regular supply of macro, micro and secondary nutrients, besides improving soil biological health.

– Improves fertilizer use efficiency of applied fertilizers due to their favourable effect on soil properties, resulting in yield improvement.

– NM not only pushes the production and profitability, but it also helps in maintaining the soil fertility.

– INM had not only enhanced the yield of vegetable crops but had exhibited beneficial residual effect on succeeding crops.

– Ensures better quality as compared to sole applications.

– INM helps to release of N and other plant nutrients in the same pace as required by the crop.

Constraints in adoption of INM: The technology developed for implementing INM does not find popular acceptance among the farmers upto the expected level owing to some constraints.

– Lack of awareness among the farmers regarding its utility and importance.

– INM is skill oriented and knowledge intensive technology needs much understanding of organics.

– Chemical fertilizers are still seen as a progressive approach by vegetable growers.

– Farming community does not find this approach acceptable, as it will take much time to change their attitude from the chemical fertilizers for ideological reason; the benefits have to be immediate for them.

– Lack of manpower, as INM is a knowledge intensive technology.

– Information on the use of organics and chemical fertilizers is lacking.

– Lack of proper co-ordination among teachers, Extension workers and farmers.

– Slow action of organic sources of plant nutrients.

– Inadequate supply of biofertilizers, vermicompost and other sources of plant nutrients coupled with their quality production.

– Lack of adequate literature and good extension activities faced by the farmer in the adoption of INM.

Future strategies: In order to provide a sound and logical support for successful implementation of INM in near future following steps need to be taken:

– Greater awareness needs to be created among the farmers on farm resource generation and its proper recycling.

– Soil test laboratories should be strengthened and upgraded for soil/plant analysis.

– Generation of block/ district wise data base on nutrient resources.

– Greater awareness needs to be created among the farmers about the soil health

– Advantages of introduction of green legumes in the cropping systems should be promoted.

– Enhancement of shelf-life of biofertilizers, development of techniques for assessing viability of bio-fertilizers.

– Promotion/ popularization of compost production.

– INM practice is for the farmers, by the farmers and of the farmers. Therefore, it should be implemented in farmer's participatory mode right from the planning, implementation and monitoring.

– Environmental concerns should be given sufficient prominence while developing INM technologies.

Conclusion: The prolonged and over usage of inorganic fertilizers had adversely effected, human and soil health, besides creating serious concerns of environmental pollution. The farmers are also looking for low cost input alternatives mainly of N fertilizer, which constitute a major component among the chemical fertilizers used in vegetable production. Hence, the use of integrated nutrient management becomes indispensable for maximizing vegetable production, productivity, sustaining soil health and quality. In future we have to produce more vegetables for increasing population under limited plant nutrient resources. Sustainability advocates an integrated use of various production resources in a manner to mention/ enhance productivity on one hand and to safeguard soil health and quality on the other. The crop produce/products received through INM will not only be higher in bulk but also high in quality in terms of nutrition.

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