

NUTRIENT REQUIREMENTS OF SOLANACEOUS VEGETABLE CROPS

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ABSTRACT

The solanaceous group of vegetables (tomato, eggplant, chili and bell peppers) generally take up large amounts of nutrients. The amount of nutrients they take up depends on the quantity of fruit and dry matter they produce, which in turn is influenced by a number of genetic and environmental variables. For tomato to produce 1 mt of fresh fruit, plants need to absorb, on average, 2.5 to 3 kg N, 0.2 to 0.3 kg P and 3 to 3.5 kg K. Eggplant need 3 to 3.5 kg N, 0.2 to 0.3 kg P, and 2.5 to 3 kg K, while chili and bell peppers need 3 to 3.5 kg N, 0.8 to 1 kg P, and 5 to 6 kg K. In the absence of any other production constraints, nutrient uptake and yield are very closely related.

Fruit and fruiting parts in this group of vegetables contain 45 to 60% of total N, 50 to 60% of total P, and 55 to 70% of total K absorbed by the plants. The major proportion of the nutrients in fruit are absorbed from the time of flowering. The proportion of nutrients found in fruit declines with an increase in nutrient applications. A small proportion of the N, and still smaller proportions of the P and K, found in fruit are translocated from the vegetative parts.

The period of greatest nutrient requirements for N, P and K is from about ten days after flowering to just before the fruit begins to ripen. There is diurnal variation in nutrient absorption. A higher proportion of P tends to be absorbed during the night than N or K.

These crops use only a small proportion of N from organic sources. Eggplant is very effective in making use of plant nutrients already available in the soil, whereas tomato, and chili and bell peppers, are not. All these crops prefer $\text{NO}_3\text{-N}$ as a source of N. High concentrations of $\text{NH}_4\text{-N}$ in the growing medium greatly reduces their growth and productivity, especially of tomato and pepper.

For tomato, the ideal anion and cation ratios were found to be 58:36:6 for N:S:P, and 39:32:29 for K:Ca:Mg. To monitor the level of NPK in tomato plants, the fifth leaf from the top, sampled between flowering and the beginning of fruit ripening, was found to be ideal.

The quantity of nutrients to be applied depends on the yield potential of the cultivar, the level of available nutrients in the soil, and growing conditions. Because in these crops vegetative and reproductive stages overlap, and because the plants need nutrients even up to fruit ripening, application methods such as fertigation, split application of fertilizers, use of slow release N fertilizers, and integrated use of fertilizers and organic sources of nutrients have proved very effective in increasing nutrient use efficiency and crop productivity, and reducing nutrient losses.

INTRODUCTION

There are three important solanaceous vegetable crops grown for their fruits viz., tomato, eggplant and pepper. The last crop includes two cultivated types- hot or chili pepper, which is consumed either fresh or dried, and bell pepper, which is

eaten fresh. All crops in this group are grown as annuals, and have much in common with regard to nutrient requirements.

Tomato is a deep-rooted crop. Its roots grow to a depth of 120 - 150 cm or more, unless they are restricted by an impervious layer of hardpan, a rock layer or by a high water table. Eggplant and

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pepper are medium-rooted crops, with roots which extend to a depth of 120 cm.

NUTRIENT UPTAKE

The amount of nutrients taken up by these crops depends on the number of fruit and the amount of dry matter produced. This in turn is influenced by a number of genetic and environmental variables (Shukla and Naik 1993). According to Yawalkar *et al.* (1961), a tomato crop yielding about 38 mt/ha of fruit removes 104 kg N, 9.5 kg P and 116 kg K from the soil. Varieties which take a long time to mature require more nutrients than short-duration ones, mainly because of their higher production of dry matter and fruit.

Hegde and Srinivas (1990) studied NPK uptake in tomato in soils with different levels of soil matric potential and applied N. They observed that nutrient uptake declined with increasing soil moisture stress, and increased with higher levels of N application (Table 1). They reported that a crop yielding 60.8 mt/ha of fruit removed 147.8 kg N, 19.8 kg P and 156.2 kg K. Large variations between tomato varieties in N uptake were reported by Chakraborty *et al.* (1990). They reported that varieties "*Pusa Early Dwarf*" absorbed 20.8, 87.6, 421.9, and 672.2 mg N/plant at 6, 33, 47 and 58 days after transplanting (DAT). In contrast, *Pusa Ruby* absorbed 14.2, 69.5, 308, and 893.2 mg N/plant. Table 2 They further observed significant

differences in N use efficiency between varieties, in terms of dry matter produced per unit of N absorbed (Table 2). The highest concentrations of NPK in tomato were found in the fruit, and the lowest in the roots (Maestrey *et al.* 1987).

Eggplant is a long duration crop, with high yields which remove large quantities of plant nutrients. An eggplant crop yielding about 60 mt/ha of fruit removes 190 kg N, 10.9 kg P and 128 kg K (Gnanakumari and Sathyanarayana 1971). Nutrient uptake in eggplant partly depends on the source of nutrients (Jose *et al.* 1988). Integrated use of both organic and inorganic sources results in higher uptake and increased fruit production (Table 3).

Pepper needs to absorb more nutrients than tomato or brinjal to produce a unit of dry matter or fruit yield. Concentrations of NPK are highest in the leaf, followed by that in the fruit and the stem (Hegde 1989). However Ca and Mg contents are highest in the leaf, followed by those in the stem and fruit. Nutrient uptake and dry matter production (fruit yield) are closely related (Hegde 1988). A crop yielding 18.02 mt/ha of fruit removed 55.5 kg N, 13.2 kg P, 73.1 kg K, 22.3 kg Ca and 20.9 kg Mg (Table 4).

According to the data on nutrient uptake from different studies, to produce one ton of fresh fruit, plants need to absorb 2.5 - 3 kg N, 0.2 - 0.3 kg P and 3 - 3.5 kg K in the case of tomato; 3 - 3.5 kg N, 0.2 - 0.3 kg P and 2.5 - 3 kg K in the case of eggplant; and 3 - 3.5 kg N, 0.7 - 1 kg P and 5 - 6 kg

Table 1. N,P, and K uptake (kg/ha) by tomato as affected by soil matric potential and N fertilization

Treatment	N	P	K
<u>Soil matric potential (kPa)</u>			
-25	130.1	19.6	164.0
-45	118.3	18.3	159.1
-65	130.2	17.7	148.9
-85	116.4	14.2	132.5
CD (5%)	12.7	1.8	12.3
<u>N levels (kg/ha)</u>			
0	75.8	12.9	117.4
80	121.1	18.1	157.0
160	150.7	19.8	173.8
240	147.8	19.8	156.2
CD (5%)	12.7	1.8	12.3

Source: Hegde and Srinivas (1990)

Table 2. Varietal differences in N use efficiency and yield in tomato

Tomato cultivar	Kg dry matter produced/mg N uptake	Fruit yield (mt/ha)
Pusa Early Dwarf	41.8	15.6
Pusa Ruby	41.7	14.9
Marglobe Supreme	38.5	19.0
Suttons Roma	32.8	10.3
Oxheart	37.5	2.6
Punjab Chahare	37.7	9.8
Moneymaker	37.4	7.7

Source: Chakrabarty *et al.* (1990)

Table 3. Effect of combined use of inorganic and organic sources of nutrients on nutrient uptake and yield in eggplant

Treatment	Nutrient uptake (kg/ha)					Yield (mt/ha)
	N	P	K	Ca	Mg	
100 kg N/ha (Urea)	67.2	7.0	66.2	51.4	21.2	37.8
100 kg N/ha (FYM)	60.9	6.0	59.4	45.5	21.3	34.8
100 kg N/ha (Poultry manure)	66.1	6.8	64.5	48.5	23.1	35.5
100 kg N/ha (Pig manure)	63.1	6.1	61.6	46.6	21.9	35.2
100 kg N/ha (Sheep manure)	61.7	6.1	60.4	46.2	21.5	35.1
100 kg N (Urea) + 50 kg N (FYM)	111.9	10.3	94.3	70.5	33.7	39.6
100 kg N (Urea) + 50 kg N (Poultry manure)	135.5	14.6	104.8	80.7	38.7	45.8
100 kg N (Urea) + 50 kg N (Pig manure)	124.9	11.2	98.9	75.3	36.3	41.7
100 kg n (Urea) + 50 kg N (Sheep manure)	121.9	10.6	96.1	72.8	33.3	38.8
CD (5%)	2.5	0.8	3.1	3.2	1.4	0.3

Source: Jose *et al.* (1988)

FYM: Farmyard manure

Table 4. Fruit yield and nutrient uptake in bell pepper as affected by soil-moisture regime and N fertilization

Treatment	Fruit yield (mt/ha)	N	P	K (kg/ha)	Ca	Mg
Soil moisture regime (%)						
80 ASM ^a	13.3	39.3	11.6	63.5	16.3	14.1
60 ASM	15.2	44.1	11.8	68.1	17.2	15.6
40 ASM	15.4	45.6	11.5	64.8	18.4	18.3
20 ASM	12.6	40.6	9.8	55.7	15.8	16.2
CD (5%)	2.04	4.6	1.4	7.8	1.7	1.8
N level (kg/ha)						
0	7.8	22.5	7.6	41.4	9.4	9.6
60	13.8	40.9	11.1	63.9	16.2	14.8
120	17.0	51.3	12.5	72.7	20.4	19.1
180	18.0	55.5	13.2	73.1	22.3	20.9
CD (5%)	2.04	4.6	1.4	7.8	1.7	1.8

^aASM: Available soil-moisture

Source: Hegde (1988)

K in the case of chili or bell pepper.

GROWTH AND NUTRIENT UPTAKE

In tomato, dry matter accumulation during the initial 30 days after transplanting (DAT) is low, less than 5% of the total dry matter produced by the end of the growth cycle (Hegde and Srinivas 1989a, 1989b). Later, there is an almost linear increase in dry matter production up to 90 DAT. It then slows, and during the final stages of the life cycle there may even be a light decline in dry matter, due to leaf fall. The rate of dry matter accumulation in the stem and fruit continues to increase until the crop reaches full maturity. The proportion of dry matter distributed in fruits ranged from 51% in crops without N fertilization, to 39% in crops which had received 240 kg N/ha (Hegde and Srinivas 1989a). Dry matter production and nutrient uptake are very closely related. During the four months after transplanting, about 5% of total nutrient uptake will be achieved by 30 DAT, 12-15% by 45 DAT, 35-40% by 60 DAT, 60-65% by 75 DAT, 85-90% by 90 DAT, and 95% by 105 DAT (Hegde and Srinivas, unpublished data). Thus, about 50% of the total nutrient uptake takes place between 60 and 90 DAT, a period coinciding with peak fruit development.

In the case of pepper, dry matter production continues to the end of the life cycle (Hegde 1987a). Growth in terms of dry matter production is very slow until 30 DAT. It then picks up between 45 and 105 DAT, later slowing down, mainly due to a reduction in leaf dry matter from leaf fall. In this crop also, nutrient uptake and dry matter production are closely related. Around 5, 35 - 40, 75 - 80 and 90% of total nutrient uptake was achieved by 30, 60, 90 and 105 DAT. Thus, about 40% of nutrient uptake takes place during a period of 30 days, between 60 and 90 DAT (Hegde, unpublished data).

In tomato, the period when plants have the greatest requirement for K, N, Ca and P is just before the fruit begin to ripen (Penalosa *et al.* 1988). In pepper, the greatest requirement for N, P and K is during the period from about 10 days after flowering to about 30 to 33 days from flowering (Hegde 1986).

There is diurnal variation in nutrient uptake. In tomato, 28 - 45% of the total nutrient uptake was during the night (Sasuda *et al.* 1990). The proportion of uptake during the night was highest for P compared to other nutrients at all growth stages in tomato (Terabayashi *et al.* 1991). Diurnal variation in tomato was highest during flowering and lowest during fruit development.

Partitioning of Nutrient Uptake

Generally, the proportion of total nutrients found in the fruit declines with an increase in the level of nutrients applied. Hegde and Srinivas (1990) partitioned total nutrient uptake by tomato into different plant parts (Table 5), and found that 45.8 - 59.2% N, 56.5 - 63.6% of P and 62 - 69.6% of K was partitioned into the fruit. The stem contained the lowest proportion of N and P, while the leaf contained the lowest proportion of K. A similar trend was observed in pepper (Hegde 1987a; Hegde 1988), except that the stems contained a higher proportion of P and K than the leaves.

Concentrations of P, K, and to a lesser degree N, tend to decrease with age in the vegetative tissues of tomato. Maestrey *et al.* (1987) observed the highest and lowest concentrations of N, P and K in the fruit and roots, respectively. Shakhazizyan (1989) reported that N concentration declined with age, while P increased initially and then declined as the fruit ripened. A small proportion of the N, and an even smaller proportion of the P and K, which has accumulated in the leaves and stem tends to be translocated into the fruit.

NUTRIENT FORMS AND RATIOS

Both tomato and pepper are sensitive to NH_4^+ at low concentrations (Caselles *et al.* 1987). The slower growth rate in tomato when NH_4^+ was the sole source of N was because it induced glutamate dehydrogenase activity in the roots (Magalhaes and Huber 1991). The extent to which NH_4^+ and NO_3^- affects growth depends on their ratio. The addition of small amounts of NH_4^+ to NO_3^- solution (up to 14 ppm) improved plant growth but did not change the uptake of K, Ca, and Mg compared to NO_3^- alone (Errebhi and Wilcox 1990). However, if 28 ppm NH_4^+ or more was used, dry weights and cation accumulation decreased by 35 - 50%.

The ideal anion and cation ratio for tomato was found to be 58:36:6 for N:S:P and 39:32:29 for K:Ca:Mg (Altunaga 1988). For eggplant, the optimum nutrient concentration in the soil under greenhouse conditions was found to be 25 mg N, 40 mg P, 30 mg S, 70 mg K, and 80 mg Ca and Mg per 100 g of dry soil (Suzuki *et al.* 1985).

Tomato requires a large quantity of available plant nutrients. It can utilize only a small percentage of the inorganic N available in the large volume of soil explored by the roots. In N-rich topsoil, there will be poor root development, which could explain the low fertilizer N use by tomato

Table 5. Partitioning of nutrient uptake (%) in tomato in relation to N fertilization

N level (kg/ha)	Plant part	N	P	K
0	Leaf	25.5	20.9	12.9
	Stem	15.3	15.5	17.5
	Fruit	59.2	63.6	69.6
60	Leaf	32.1	21.0	16.2
	Stem	18.7	17.7	18.6
	Fruit	49.2	61.3	65.2
120	Leaf	35.3	25.3	18.4
	Stem	18.9	18.2	19.6
	Fruit	45.8	56.5	62.0
180	Leaf	33.6	25.8	18.9
	Stem	19.6	17.7	16.6
	Fruit	46.8	56.5	64.5

Source: Hegde and Srinivas (1990)

(Jackson and Bloom 1990). Unlike tomato and pepper, eggplant is very efficient in making use of plant nutrients already available in the soil (Shukla and Naik 1993).

For monitoring nutrition of tomato with respect to N, P, K, Ca and Mg, sampling the fifth leaf from the top was found to be ideal (Vielemeyer and Weissert 1990). The period of least variation, which is therefore most suitable for taking samples to monitor nutritional levels, is between full bloom and the beginning of ripening in the case of NPK; during full bloom for Fe and Mn; after full flowering for Cu; at the beginning of fruiting for B; towards full flowering and during full ripening for Zn; and towards the end of the growing cycle for Ca and Mg (Sarro *et al.* 1987).

NUTRIENT MANAGEMENT

The quantity of nutrients which the farmer needs to apply depends on the yield potential of the cultivar, the level of available plant nutrients already in the soil, and growth conditions. Since vegetative and reproductive stages overlap in this group of crops, they need a continuous and steady supply of nutrients throughout their life span. It is necessary to adopt appropriate nutrient management practices which help to supply nutrients in quantities adequate to just meet crop demand and minimize losses, thereby increasing the nutrient use efficiency. Such practices will be environmentally friendly, and lead to sustainability in vegetable production.

Split Applications

Application of N in four splits at 30-day intervals has been recommended by Singh *et al.* (1988) to achieve maximum yields and profits in chili production. Subhani *et al.* (1990) obtained the highest yield of chili when both N and K were applied in four splits at planting, 30, 60 and 90 DAT.

Fertigation

Jaime *et al.* (1987) compared furrow and trickle irrigation in the N nutrition of eggplant. He observed that 180 kg N/ha applied in trickle irrigation could yield (16.8 kg/plant) more than that obtained with 360 kg N/ha under furrow irrigation (16.2 kg/plant). An application of 50% of total NPK in trickle irrigation resulted in a higher nutrient uptake in tomato than when the same NPK was applied before planting (Dangler and Locascio 1990). Goyal *et al.* (1985) reported that fertigated pepper, tomato and eggplant receiving 9, 18 or 30 g urea/plant all had higher yields than plants receiving a side application of urea (15 + 15 g/plant at planting and first harvest). Fertigation with acidifying N fertilizers such as urea may sometimes have an adverse effect on growth and productivity, if Al toxicity is induced by soil acidity below the water emitters (Haynes 1988). In such areas, methods of counteracting or preventing soil acidification below trickle emitters need to be developed if fertigation with acidifying N fertilizers is to be practiced routinely.

Mulching, especially when an overhead irrigation system was used, considerably increased the total recovery of applied nitrogen in tomato (Table 6) (Sweeny *et al.* 1987).

Slow-Release Fertilizers

Slow-release fertilizers hold great promise for the production of solanaceous vegetables such as eggplant and tomato. Gezerel and Donmez (1988) compared slow-release fertilizer (Plantacote) and conventional fertilizers at 100:80:90:30 kg/ha NPKMg. They found that slow-release fertilizers produced 92 mt/ha of tomato, compared to only 42 mt/ha when ordinary commercial fertilizers were used.

Integrated Nutrient Management

The basic concept underlying the principles of integrated nutrient management is the maintenance, and possible improvement, of soil fertility for sustaining crop productivity on a long-term basis. Sustained productivity may be achieved through the combined use of various sources of nutrients, and by managing these scientifically for optimum growth, yield and quality of different crops, in a way adapted to local agro-ecological conditions. In vegetable production in Asian countries, farmers have been using organic manures for centuries, together in recent decades with chemical fertilizers, to meet the nutrient demands of crops. Integrated nutrient use has assumed great significance in recent years in vegetable production, for two reasons. Firstly, the need for continued increases in per hectare yields of vegetables requires that applications of nutrients increase. Not enough chemical fertilizer is available

in many developing countries in Asia, to meet crop nutrient requirements. Secondly, the results of a large number of experiments on manures and fertilizers conducted in several countries reveal that neither chemical fertilizers alone, nor organic sources used exclusively, can sustain the productivity of soils under highly intensive cropping systems (Singh and Yadav 1992).

Subbiah *et al.* (1985) obtained higher yields of tomato and eggplant with combined use of FYM and fertilizers. For eggplant, applications of 100 kg N/ha, half in urea (50%) and half in poultry manure (50%), resulted in higher yields (45.8 mt/ha) than the same level of nitrogen applied in urea alone (37.8 mt/ha). The integrated use of urea and poultry manure also resulted in a higher nutrient uptake (Jose *et al.* 1988). Jablonska (1990) reported that the combined use of rye straw and nitrogen resulted in higher yields of tomato, eggplant and pepper than either N fertilizer or FYM used alone. Hosmani (1993) also reported higher yields of chili with integrated use of chemical and organic fertilizers than with the use of either of these separately.

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Table 6. Fertilizer N budget for treatments using ^{15}N depleted NH_4NO_3

Plant or soil component	Fertilizer derived N (kg/ha)			
	Trickle irrigation		Overhead irrigation	
	Mulch	No mulch	Mulch	No mulch
Tomato (fruit)	63	43	46	45
Tomato (plant)	27	28	73	30
Inorganic soil N	8	7	27	1
Organic soil N	25	38	67	44
Accounted for N	123	116	213	120
Unaccounted for N	101	108	11	104

Total recovery ranged from 52 to 95% of 224 kg N/ha applied.

Source: Sweeny *et al.* (1987)

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DISCUSSION

In the Discussion, Dr. S. Lian of Taiwan was interested that the integrated application of organic manure with urea had increased vegetable yields. As he pointed out, this suggested that the efficiency of N uptake was very poor. The net yield increase was not necessarily obtained only by combining urea with organic manure. An increase in the amount of applied urea might give an even higher yield increase.

Dr. Hegde felt that if the same cropping system is followed year after year, the use of chemical fertilizers alone might lead to problems. In long-term tests of the integrated use of organic and chemical fertilizers, there had been no difference after 10 years, but a perceptible difference after 15 years.

One participant asked why farmers are applying organic manure, whether they think of it only in terms of fertilizer, or whether they feel it has other qualities. Dr. Hegde replied that part of the benefit is the relatively slow release of nutrients. Farmers feel that if they use a heavy application of organic fertilizer, there is no need for topdressing.

One participant was interested in the possibility of recycling. He pointed out that 50% of the nutrients go to the fruit, and 50% to the stem and leaves. This means that a lot of nutrients are removed with the fruit. He asked whether work had been done on recycling these nutrients. Dr. Hegde replied that in India, vegetable crop residues are used as fertilizer after the crops had been harvested.

It was pointed out that according to Dr. Hegde's data, the take-up by vegetables of potassium was only a small proportion of the amount of nitrogen and phosphorus taken up by the plant. He was asked whether fertilizer recommendations are based on that ratio. Dr. Hegde replied that vegetable production needs only a maintenance dose of 40-60 kg/ha of potassium. This can be compared to the 400 kg/ha naturally present in the soil. Indian soils are very deficient in nitrogen and phosphorus, while they have a high potassium content. Potassium applications are recommended only for soils poor in potassium. Long-term experiments are now in progress to monitor crop response to applied potassium.