SATSA Mukhapatra - Annual Technical Issue ***30*** *: 2026* ISSN 0971-975X

Soil Fertility Management in Horticulture Based Production System of Eastern Plateau and Hill Region of India

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(Received : November 7, 2025; Revised : December 10, 2025; Accepted : December 12, 2025)

ABSTRACT

Climate-resilient crop production practices and sustainable land management are vital for enhancing soil fertility and productivity in the eastern plateau and hill region and similar eco-regions worldwide. The integration of fertigation with optimal plant population under polythene-mulched drip irrigation significantly improves yield performance and enhances nutrient and water use efficiencies in upland vegetable crops such as tomato, cabbage, cauliflower, broccoli, and sweet corn. In fruit-based systems, growing biomass-yielding plants in orchard alleys and recycling their biomass within the tree basins have proven effective in improving soil fertility and promoting vigorous tree growth. Furthermore, the adoption of fruit-based multitier cropping systems maximizes the efficient use of natural resources such as sunlight, water, air, and land by cultivating crops of varying canopy heights on the same plot. Multitier systems involving mango, litchi, and guava have demonstrated high suitability for highland conditions, contributing to sustainable food production. Replacing conventional rice–fallow systems with these multitier systems enhances carbon sequestration, improves soil health, and mitigates greenhouse gas emissions, thereby promoting long-term ecological and agricultural sustainability in the region.

Keywords : Basin enrichment, Fertigation, Precision nutrient management, Multitier cropping system.

Introduction

The biggest challenge for India is its ever increasing population and to match it with food production. In India, the arable land is limited and we have exceeded the carrying capacity of the land. Under these circumstances, there is a compelling need to increase agricultural productivity. Apart from the increasing population, the nutrient requirements of the people are also on the rise. It is estimated that in the next two generations, the world will consume twice as much food as has been consumed in the entire history of humankind. This situation unquestionably calls for a prudent approach for sustainable agricultural development as no other option would provide the answer. In recent times, the yield potential of crop varieties has already reached a plateau owing to several

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constraints. The most important among them is the deficiency of mineral nutrients noticed through the length and breadth of the country; where intensive cultivation has been practiced. The depletion of nutrients particularly micronutrients in the soil is increasing due to adoption of modern technologies in crop production such as raising high yielding crop varieties, multiple cropping, inter cropping etc. where the demand for nutrients is very high and varying. The amount of nutrients depleted is not returned to the soil in the right proportion at right times leading to wide spread deficiency of nutrients especially micronutrients.

Soils are vulnerable to C loss through degradation, but regenerative land management practices can build soil and restore soil health. Soil erosion, loss of soil organic matter (SOM) and nutrient depletion are among the leading contributors to impaired soil health, reduced crop yields, and rural poverty. Soil health-an attribute of physical, chemical and biological processes, is impaired by indiscriminate and intensive cultivation, and over mining of nutrients by crops with lesser replenishments through organic and inorganic sources of plant nutrients. Poorly managed soils are deficient in several major and micronutrients. These deficiencies not only influence crop yields but also the mineral content of seed and feed, and thus affect health of crops, animal and human.

India's eastern plateau and hill region accounting 13% of the total geographical area of the country and covering the states of Jharkhand, Chhattisgarh and Odisha has the major production constraints of soil erosion and acidity, low soil organic carbon (SOC), deficiency of soil moisture for the second crop after rice, and low availability of nutrients especially nitrogen, phosphorus, calcium, magnesium, sulphur, born and zinc are the most important in the uplands (Naik *et al.*, 2015). Fertilizers generally applied by the farmers through broadcasting, which resulted in loss of nutrients through leaching, fixation, volatilization causing low fertilizer use efficiency. The present soil health deterioration in the eastern plateau and hill region of India calls for a comprehensive viable option for eco-restoration and maintenance of soil resources which could sustain long-term soil productivity and improve food security in eastern plateau and hill region of India under the hot and dry sub-humid climate. The different management options for the improvement of soil fertility are discussed here.

Options for Soil Fertility Management in Horticulture based Production System

i) Basin enrichment for improving soil fertility in the orchards of eastern plateau and hill region

Increasing demand for organic produce as well as increasing cost of manure and fertilizers stresses for alternative cheaper options for sustainable nutrient management. Growing of biomass yielding plants in the alley area of orchards and recycling of harvested biomass in the plant basin of fruit trees have been found to improve soil fertility and plant growth of number of fruit trees. The technology on biological nutrient recycling in fruit orchard through *Tephrosia candida* can help immensely in improving the soil fertility at lower cost and ensuring higher productivity of fruit crops growing in low fertility regions.

A research trial was conducted for a period of 6 years in bael (*Aegle marmelos* Correa) based production system (Figure 1) of the eastern plateau and hill region of India with the approach of enriching the plant basin through mulching or soil incorporation of biomass obtained from different biomass yielding plants (Das *et al.*, 2021). Significantly higher content of soil N, P and K in various treatments were documented in the soil over that of control. Mulching of *Tephrosia* also resulted in markedly higher soil moisture content during drier months of the year. In the present study, integration of biomass yielding leguminous plant, *Tephrosia candida* in the alley area of bael orchard was found to be an effective option in improving the soil fertility and plant growth of bael.

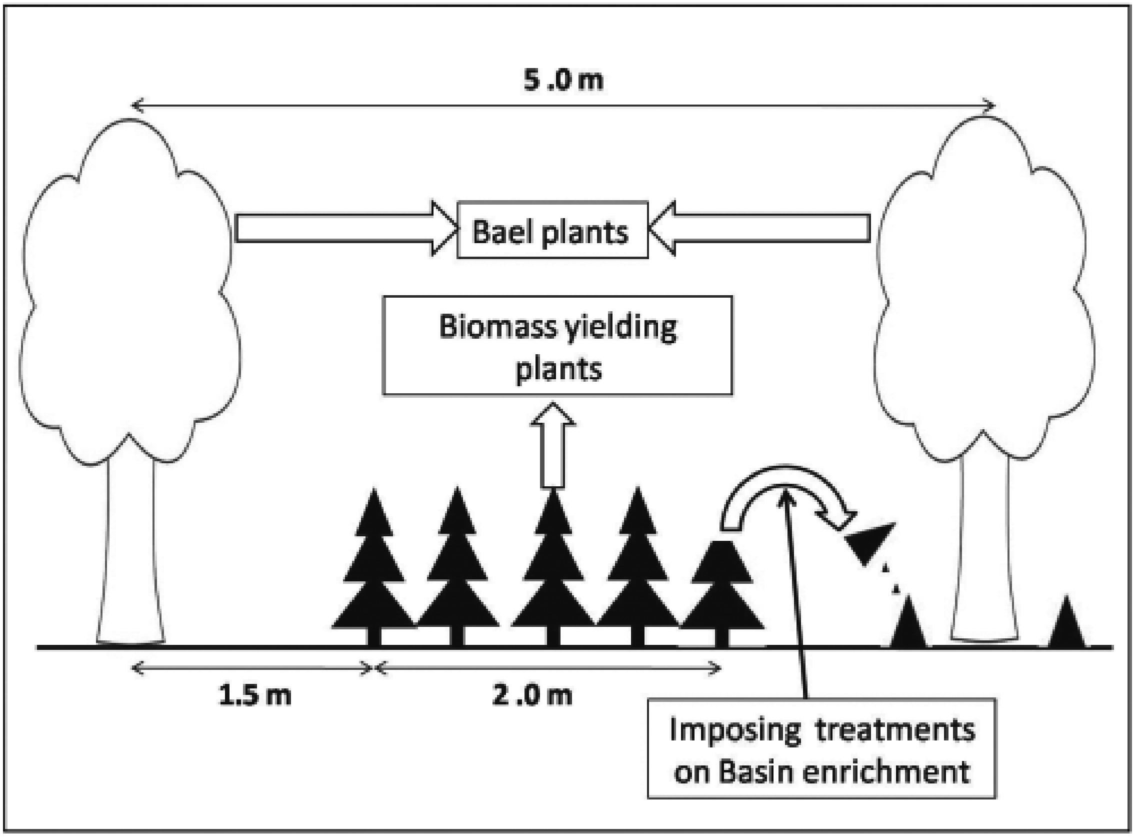

Figure 1. Schematic representation of the basin enrichment of orchards.
Source : Das *et al.* (2021)

ii) Precision nutrient management for enhancing vegetable yield in the uplands of eastern plateau and hill region

In order to increase crop yields, large amounts of fertilizers are being applied to soil, which eventually leads to reduced fertilizer use efficiencies and increased environmental degradation due to loss of fertilizers into water resources. Further, increasing cost of irrigation infrastructure and escalating prices of fertilizers necessitates improvements in water and fertilizer use efficiency at field scale. Besides environmental and management factors, the crop yields under drip fertigation were also influenced by the relative arrangement of plants (planting geometry) and plant spacing. The research results showed application of right amount of fertilizers at right stage of crop growth can provide better results than using uniform dose. The different vegetable crops having different planting system in combination with fertigation doses recommended in the eastern plateau and hill region of India are,

a) *Chilli :* Triangulated paired row planting having 60 cm spacing between paired row with crop spacing of 40×30 cm in combination with application of higher fertigation dose during early reproductive stage (6% of recommended fertilizer [RS] in 3rd to 8th week; 8% of RF in 9th to 10th week; 10% of RF in 11th to 13th week; 4% of RF in 14th to 15th week; 2% of RF in 16th to 20th week after transplanting) is recommended for drip fertigation of chilli pepper in the eastern plateau and hill region of India (Mali *et al.*, 2019).

b) *Broccoli* : Field study showed that triangulated paired row planting having 60 cm spacing between paired row with crop spacing of 40 x 30 cm in combination with fertigation pattern of higher dose during developmental stage (7% of recommended fertilizer in 1st to 4th week; 8% of RF in 5th to 7th week; 12% of RF in 8th to 9th week; 9% of RF in 10th to 11th week; 2% of RF in 12th to 14th week after transplanting) recorded highest broccoli yield and was 46.7% more yield than conventional fertigation pattern (Mali *et al.*, 2016).

c) *Tomato :* Triangulated paired row planting having 60 cm spacing between paired row with crop spacing of 40×70 cm in combination with application of higher fertigation dose during mid-stage (2% of recommended fertilizer in 1st to 6th week; 4% of RF in 7th to 9th week; 8% of RF in 10th to 12th week; 10% of RF in 13th to 16th week; 6% of RF in 17th to 18th week after transplanting) of the crop growth period recorded highest tomato yield (Mali *et al.*, 2016).

d) *Sweet corn* : The crop geometry of rectangular planting system with spacing of 50×15 cm having plant population of 1,33,300 plants per hectare in combination with fertigation pattern of higher fertilizer dose during late reproductive stage (4% of recommended fertilizer in 1st to 3rd week; 6% of RF in 4th to 6th week; 8% of RF in 7th to 9th week; 10% of RF in 10th to 12th week; 8% of RF in 13th to 14th week after transplanting) recorded maximum cob yield (Jha *et al.*, 2015).

iii) *Enhancing carbon stock through fruit based multitier cropping system*

The technology on fruit based multitier cropping system comprise of planting of fruit trees with large canopies (Mango, Litchi) as main crop, planting of precocious bearing fruit species with dwarf canopy (guava, peach, aonla etc.) between rows and between plants in the same field as filler crop and growing of inter crops in the inters paces. The Mango plants of cv. *Amrapali* planted at a spacing of 10 (p-p) x 20 (r-r) m as main crop and a fast growing timber species *mahogany* was planted at a spacing of 10 x 20 m along with main crop such the distance between mango and mahogany was 5 m within the rows of the main plants. The filler trees like aonla (Var. NA-7) and peach (Var. Florida prince) were planted at 5 m apart between and within the rows of main plants of mango, while 10 m apart within the same rows. The inter crops like rice and finger millet were grown in different combinations in the multitier production system. It has been observed that Mango+ Mahogany + Aonla + Rice and Mango+ Mahogany + Peach + Rice had higher total organic carbon, active pool, passive pool, soil biological properties, higher carbon management index and thus considered as the best production systems to sequester carbon and maintenance of soil health in the eastern plateau and hill region of India.

iv) Optimizing nutrient management in zones of high root activity to enhance the productivity of fruit crops

Optimizing nutrient management in zones of high root activity (Table 1) is crucial for enhancing the productivity and sustainability of fruit crops. The majority of nutrient uptake in perennial fruit plants occurs in specific soil zones where fine feeder roots are most active. Proper identification and targeted management of these zones ensure efficient use of fertilizers and organic amendments, minimizing nutrient losses through leaching or volatilization. By applying nutrients at the right place, rate, and time—particularly around the active root zones—plants can achieve better growth, yield, and fruit quality. Moreover, integrating site-specific nutrient management with soil moisture conservation and organic matter enhancement further improves soil health and nutrient-use efficiency. Overall, focused nutrient management in root-active zones supports sustainable fruit production systems by balancing crop demand with soil nutrient supply.

V) Identification and management of yield-limiting nutrients of mango orchards in the eastern plateau and hill region of India

Five leaf nutrient guides / ranges have been derived using mean and standard deviation as deficient, low, optimum, high and excess for each nutrient and presented (Bhargava and Chadha, 1988; Bhargava, 2002). Sufficiency ranges of nutrients derived from a nutrient indexing survey of mango orchards of eastern plateau and hill region (Naik and Bhatt, 2017) are given in Table 2. The optimum leaf N for mango ranged from 1.21 to 1.40%, whereas the optimum P ranged from 0.13 to 0.15% indicating a lower requirement of P compared to N. It was observed that P was generally much less limiting factor for mango production. The optimum K ranged from 0.76 to 0.88% and thus the requirement of K is always next only to N as it is involved not only in the production but also in improving the quality of mango. The optimum concentration range for Ca was from 2.10 to 2.93%, whereas the

Table 1. Zones of high root activity of some fruit crops

Crop/Variety	Age (years)	Radial distance		Soil depth	
		cm	%	cm	%
Surface oriented root activity distribution					
Citrus/ Coorg mandarin	6	120	80-95	0-15	78-88
Citrus/ Sweet orange	7	120	65-81	0-30	70-90
Citrus/ Kagzi lime	4	120	75-80	0-25	94-97
Deep rooted root activity distribution					
Mango/ Alphonso	8	100	75-80	0-40	69-75
Guava/ Arka mridula	6	100	55-85	0-30	57-60
Uniform root activity distribution					
Papaya/ Surya	1	100	100	0-45	100
Banana/ Robusta	7 months	0-25	85	0-20	64
		25-50	15	20-40	36
Banana/ Ney Poovan	7 months	0-25	76	0-20	82
		25-50	14	20-40	18

Source : Kotur (2011)

optimum Mg ranged from 0.24 to 0.43% indicating a lower requirement of Mg compared to N, K and Ca. The optimum concentration of S ranged from 0.12 to 0.18% and the requirement of S is next only to P. Among the micronutrients, the optimum B, Zn, Cu, Fe and Mn concentrations in leaf ranged from 13 to 16, 19 to 24, 17 to 31, 86-125 and 71-150 mg kg^{-1}, respectively (Table 2). Wider optimum ranges of micronutrients observed in mango leaf was due to larger variations in soil properties.

DRIS provides a means of ordering nutrient ratios into meaningful expressions in the form of indices. A DRIS index is a mean of the deviations of ratios containing a given nutrient from their respective normal or optimum values. The DRIS norms recognized from N, P, K, Ca, Mg, S, Zn and B concentration of mango leaf samples were further employed to compute DRIS indices from the foliar composition of mango orchards in eastern plateau and hill region of Jharkhand, India.

As per DRIS indices obtained (Table 3), the kin deficiencies for each nutrient for 6-7 year old orchard were identified as Ca > S > K > B > N > P > Mg > Zn whereas for 9-10 year old orchard were identified as Mg > Zn > B >Ca > N > P > S > K. The results indicated that Ca, S, K and B was most limiting nutrient for young age orchard (6-7 yr) whereas, Mg, Zn and B

Table 2. Sufficiency ranges of nutrient requirement in mango tree orchards of Eastern plateau and hill region

Variable	Deficient	Low	Optimum	High	Excessive
N (%)	< 1.10	1.10-1.20	1.21-1.40	1.41-1.50	> 1.50
P (%)	< 0.09	0.09-0.12	0.13-0.15	0.16-0.18	> 0.18
K (%)	< 0.69	0.69-0.75	0.76-0.88	0.89-0.94	> 0.94
Ca (%)	< 1.63	1.63-2.0	2.10-2.93	2.94-3.36	> 3.36
Mg (%)	< 0.13	0.13-0.23	0.24-0.43	0.44-0.53	> 0.53
S (%)	< 0.07	0.07-0.11	0.12-0.18	0.19-0.22	> 0.22
B (mg/kg)	< 9	9-12	13-16	17-18	> 18
Zn (mg/kg)	< 15	15-18	19 -24	25 -28	> 28
Cu (mg/kg)	< 8	8 -16	17-31	32 -38	> 38
Fe (mg/kg)	< 65	65 -85	86-125	126-145	> 145
Mn (mg/kg)	< 30	30-70	71-150	151-190	> 190

Source : Naik and Bhatt (2017)

Table 3. Nutrient requirement order in different age group of mango orchard and soil reaction in Eastern plateau and hill region

Parameter	Nutrient requirement order
Age of orchard (yr)	
6-7	Ca > S > K > B > N > P > Mg > Zn
9-10	Mg > Zn > B >Ca > N > P > S > K
pH range of orchard soil	
4.5-5.0	Ca > K > S > Mg > P > B > N > Zn
5.1-5.5	Ca > Mg > B > N > S > Zn > P > K
5.6-6.0	B > Zn > N > Mg > S > K > Ca > P
6.1-6.5	Zn > N > B > S > K > P > Ca > Mg

was the most limiting nutrient for older age orchard (9-10 yr). When compared age wise, B was found as the most common nutrient limiting mango yield. Under different pH range of soils, the nutrient requirement for orchards varied. The DRIS indices at pH 4.5 to 5.0 were identified the following limiting nutrient as, Ca > K > S > Mg > P > N > B > Zn indicating that the Ca, K, S and Mg was having negative value of index and considered as most limiting nutrient. Similarly the order of limiting nutrient at pH 5.1 to 5.5 was as, Ca > Mg > B > N > S > Zn > P > K indicating that the Ca and Mg was considered as most limiting nutrient in mango orchards. Furthermore, the most limiting nutrients in mango orchards at pH 5.6 to 6.0 was B, Zn and N whereas the most limiting nutrients at pH 6.1 to 6.5 was Zn, N, B, S and K.

Conclusion

The eastern plateau and hill region of India, characterized by undulating topography and inherently low soil fertility, requires innovative and site-specific nutrient management strategies to sustain and enhance agricultural productivity. Basin enrichment practices in orchards have proven effective in improving soil fertility and moisture retention, thereby creating a favorable rhizosphere for perennial crops. Similarly, precision nutrient management in upland vegetable systems ensures efficient input use and significantly enhances yield and nutrient-use efficiency. The adoption of fruit-based multitier cropping systems contributes not only to diversified income but also to enhanced carbon sequestration and long-term soil health. Moreover, optimizing nutrient management within zones of high root activity in fruit crops maximizes nutrient uptake and productivity, while the identification and correction of yield-limiting nutrients in mango orchards address key constraints to fruit yield and quality. Collectively, these approaches highlight the importance of integrating site-specific soil fertility enhancement, precision nutrient management, and carbon enrichment strategies to achieve sustainable intensification of horticultural systems in the eastern plateau and hill region of India.

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