Original Article

Indian Journal of Plant and Soil
Volume 6 Number 1, January - June 2019
DOI: http://dx.doi.org/10.21088/ijps.2348.9677.6119.7

Challenges in Sustaining Pepper (*Piper nigrum L.*) Productivity

V. Ranganathan

Author's Affiliation: Consultant IMT Technologies Ltd., Pune, Maharashtra 411004, India.

How to cite this article:

V. Ranganathan. Challenges in Sustaining Pepper (*Piper nigrum L.*) Productivity. Indian J Plant Soil. 2019;6(1):40-47.

Abstract

Black pepper (*Piper nigrum L.*: Family: *Piperaceae*) the king of spices, associated with the history of Tamil kingdoms in the past and valued for pungency and medicinal properties is a perennial vine originated from monsoon tracks of Western Ghats. There is stagnation in the area of its cultivation and the productivity level so far realized is far below the theoretical potential achievable for the agro climatic conditions of the regions where it is cultivated. This could be due to challenges faced in its cultivation as a commercial crop, particularly in sustaining high productivity to stay economically viable. An effort is made to grasp the role of growth determinants, soil, water, nutrients and climate, in chasing productivity and the ways to manage them to achieve sustainable productivity.

Keywords

Pepper agronomy; Productivity constraints; Pruning and training vines.

Introduction

Black pepper (*Piper nigrum L.*: Family: *Piperaceae*) the king of spices, associated with the history of Tamil kingdoms in the past and valued for pungency and medicinal properties is a perennial vine originated from monsoon tracks of Western Ghats. Its main constituents are the alkaloids (*Piperine* and *Piperidine*), the volatile oils (*Phellandrene* and *Caryophyllene*) and a pungent resin.

It is cultivated in hot and humid rainfall areas (10 to 40^0C with optimum range between 20 and 30^0C, humidity 75 to 80% and rainfall (125 to 200 cm) at latitudes between 20^0N and 20^0S and at altitudes below 1500m MSL. It seems to have no special preference to soil types or soil pH (4.5 to 6.5) except for a high organic matter content. Long drought followed by a 70 mm rainfall within a period of twenty days trigger flowering and fruit set. Continuous wet period is required thereafter for fruit development and to ensure high productivity. In near plain areas at foot hills and in plain areas, drainage facilities are necessary for successful cultivation of pepper.

It is propagated by sowing seeds, marcotting and stem- cuttings from runner shoots and trained on live or inert standards. The adventitious roots at nodes of primary climbing shoots help to cling to supports or standards and their height of climbing regulated by pruning which also triggers the formation of fruit bearing laterals at desired height for ease of picking berries. Cuttings from rooted lateral branches are used for raising bush pepper. In mono crop systems, the standards are spaced normally at 2x2 m spacing (2500 no/ha). In mixed cropping, the number of vines depends on the spacing of host standard. Two vines are normally assigned to each support at 180^0 across its base. The vines per ha in commercial

Corresponding Author: V. Ranganathan,
Consultant, IMT Technologies Ltd.,
Pune, Maharashtra 411004, India.
E-mail: vedantarangan@yahoo.com
Received on 05.03.2019; **Accepted on** 27.03.2019

gardens normally varies between 1000 and 5000. It starts flowering from 3rd year. Flowering starts by May /June and the harvesting done from November to February in the plains and January to march in the hills. Wild pepper is cross pollinated while most of the cultivars are mostly bisexual and self pollinated. Harvesting is done based on the type of end product required-green, black or white pepper. For white pepper, the berries are harvested at a slightly advanced stage of ripeness that is when berries turn red. Then they are soaked in water and fermented for a day or two. Then after removing the outer skin, they are dried until berries turn yellow. To get black pepper the berries are picked at younger stages, heaped for a day or two and then dried under sun. Green pepper is made after treating the green berries with hot water and treating with sulphur-dioxide or other bleachers before drying. Moisture content of fresh green berries is around 65 to 70%. Recovery of white pepper and black pepper from picked berries is 25 and 33% respectively at 8 to 10% moisture in end products. Seven percent of dry matter or biomass produced is fixed in berries. Productivity per vine achieved so far is around 2 to 3 kg per vine. Productivity increases from third year and reaches a maximum at 5 to 7 years and remains productive for 20 to 25 years, if kept free from soil prone pathogens. While the National average productivity linger around 450 kg ha^{-1}, the productivity has touched 5 to 8 tons /ha in well managed gardens with 5000 vines per ha.

Challenges to sustain productivity

Agronomic Factors: Pepper is a day neutral, C3 plant and poor utilizer of incident light. It uses below 7% of incident light while most of other crops uses around 11%. As such higher Leaf area is important for compensating the low utilization of incident light in pepper to sustain viable productivity. The number of lateral branches and no of leaves they carry determine the leaf area index. Regular pruning thus becomes an important operation to stimulate formation of lateral branches and number of leaves, and to create and sustain optimum leaf area. This ensures emerging of optimum number of spikes and manifestation of other spike characteristics vital for expression of productivity. The productivity (Y) per vine could be expressed in terms of yield attributes as below;

$$Y = A * B * C * N * W \qquad (1)$$

where 'A' is the no of vertical leading branches which normally varies between 2 and 4, 'B' is the no of lateral branches per leading vertical branch (5 to 10), 'C' is the number of spikes per lateral branch (2 to 5), 'N' is the number of berries per spike (80 to 120) and 'W' is the weight of berries (0.05 to 0.06 g). The number of wines per ha depends on spacing of host standard or the spacing adopted in mono crop culture. It varies any way between 1300 and 2500 per ha. The impact of agronomic variables on productivity is shown in Table 1.

Soil Om Status: Pepper is a surface feeder and more than 95% roots are seen within 80 cm. Though, the live standards compete for the nutrients applied to Pepper, they compensate it by retuning organic matter in the form of leaf fall and lopping done every year to regulate shade thereby helping to maintain the maintain the OM status necessary for soil structure necessary for retention and release of nutrients and for the movement of air water and nutrients in the rhizhosphere. The equilibrium OM status that could be maintained depends on the rate of its decomposition and annual additions. The OM

Table 1: Impact of agronomic variables on yield @ 2000 vines /ha

A no	B No	C no	N no	W g	Dry berry g/vine	Dry berry kg/ ha
2	6	3	100	0.055	198	396
3	8	5	120	0.055	792	1584
4	10	5	120	0.060	1440	2880

Expansion of 'A, B, C, N and W' see under equation -1 given above

Table 2: Requirements for maintaining soil Organic matter status

Altitude	k	A_{ss}	A_n	C	D
0-100	0.95	1.2	31	12 to 15	16 to 20
100-250	0.8 ± 0.15	1.2	26	12 to 15	11 to 14
250-500	0.6 ± 0.10	1.2	20	10 to 12	8 to 10
500-1500	0.2 ± 0.06	1.2	7	8 to 10	Not required

Altitude- m MSL

k - OM mineralization quotient: $A_{ss} = A_n / k$; A_{ss} -Minimum required steady state om%

A_n - Annual additions required to maintain OM status - t/ha/yr

C - Annual additions of OM available through Natural recycling - t/ha/yr

D - Minimum Om to be applied from extraneous sources - t/ha/yr content dynamics is shown in Table 2.

ONE percent soil OM contains about 30 tons of OM in one ha of soil with a bulk density of 1.2 to a depth of 25 cm. A minimum of 1.2% OM is required to maintain optimum soil tilth to sustain growth of plants. While the additions thru natural recycling processes could maintain soil OM without addition of it from extraneous sources at elevations above 500 m MSL, the addition from extraneous sources at 8 to 20 tons /ha of OM depending on altitude is a must at or below 500 m MSL.

Water Conservation: The difference between field capacity (maximum WHC) and the moisture content at wilting point is the available water capacity and in terms of matric potential it lies between -1/10 to -1/3 bar. Roughly, it is about 70% of the field capacity. Roots normally utilize about 70 % of available water due to exponential decrease in water exploitation due to factors associated with root distributions patterns with the depth. As such only 49% of available water to the depth of profile, where more than 90% of roots are found, is taken by the plants. The mean maximum WHE is around 48%. In Pepper, the maximum root proliferation (calculated as per Gerwitz and Page exponential model (1974)) is seen to a depth of 60 to 80 cm (95% to a depth of 75 cm). The maximum water that could be stored in soil micro-pores in soil profile to a depth of 75 cm is about 43.2 cm. Water that is exploited by the plants works out to 21.2 cm water, out of 43.2 cm stored in soil micro-pores against gravity to a depth of 75 cm. The mean evapo-transpiration (ET_c) rates per month vary from about 7.5 cm to 10 cm at plains to 6 to 8 cm at altitudes above 1000 m MSL and the plants can survive thru a continuous drought of 2 to 3 months depending on altitude of the area with water stored in the soil provided the equilibrium OM status is maintained with annual additions. Pepper areas are classified 'Humid' with Aridity index (Mean annual precipitation in mm/ mean annual PET in mm) greater than 0.65, but they occur in monsoon belts. Irrigation support is a must for viable pepper cultivation in areas where they experience frequent periods of longer than normal drought due to climatic vagaries.

Pest and Diseases: Pepper cultivation faces 4 serious pests, a) Pollu beetle Longitarsus nigripennis), b) Top shoot borer (Cydia hemidoxa), c) Leaf gall thrips (Liothrips karnyi) and d) Scale insects (Lepido- saphes piperis a spidiotus destructor) and 16 minor ones. Protocols for their management is well organized thru ICAR-Indian Pepper Research Institute Pesticides are to be used to minimum to contain their population.

Two diseases pose major problems- 1) Quick wilt or foot Rot (Phytophthora capsici) and 2) Slow decline or slow wilt caused by Soil borne fungi Fusarium sp., Rhizoctonia sp., Pythium sp., Diplodea sp., nematodes- Radopholus similis, Meloidogyne incognita). Third one is caused by Collecto- trichum gloeo-sporioides (Pollu disease). Quick Wilt requires continuous wet condition as in monsoon months for infection and spread leading to damages to leaves, spikes, collar region and roots with associated symptoms such as foliar yellowing and defoliation. The collar infection leads to sudden collapse of the vine. Slow wilt, on the on the hand, infects in dry season co-habituating with nematodes. It ends up with dieback symptoms and gradual loss of vigour and productivity over subsequent dry seasons. As such control measures have to be done throughout the year. While less than 5% of total cost of production is spent on plant protection measures in Tea and most other commercial crops, it is more than 10 to 15% in Cardamom and pepper. About 10 to 12% vines in a year are severely affected and totally unproductive. It has been found that pulling out the affected vines and infilling the vacancies so created every year is much more economical than spending huge amount on chemicals to control them. With 10 to 12% infilling of infected area, the productivity can be sustained over the years increasing the length of planting cycle to more than 25 years. Pulling out the vines has to start during dry season, followed by lightly forking the soil without much disturbance and drenching the soil with copper sulphate solution to rehabilitate it. Infilling may then be done into the growing season following normal procedures. The ability of copper to easily accept and donate electrons ($Cu \rightleftarrows Cu^{+} \rightleftarrows Cu^{2+}$) explains its important role as a soil ameliorant in oxidation-reduction (redox) reactions in reclaiming it after the pathogen attack.

Productivity Constraints: Pepper utilizes only 7% of incident light and therefore sensitive to excess shade. Two important factors limiting NPP are 1) optimum leaf area index that could be maintained by frequent pruning and training of vines to produce more vertical growing leaders and berry bearing lateral branches and 2) lopping host trees and also removing hanging unproductive branches in vines to regulate shade. Incidentally lopping from host trees and pruning from vines help to maintain OM status of the soil.

NPP is arrived thru different approaches. Traditional approach is based on a) solar energy incident on earth surface (@ 400 calories $cm^{2}d^{-1}$ in tropics and sub-tropics) b) photosynthetic efficiency c) respiration losses), d) energy required for biomass synthesis (@ 19 MJ kg^{1} biomass per year and, e) efficiency of natural recycling process limited to 60 to 70% by thermodynamic laws. Recent satellite studies have shown that solar radiations incident on surface can be fixed to yield 200 t ha^{-1} carbon per year roughly equivalent to 450 t ha^{-1} biomass (delucia *et al.* 2014). Harvest index which is around 7% then decides the productivity in terms of economic end product. Crops are grown in non-ideal conditions defined by agro climatic conditions (Ranganathan 2014, 2017) besides social and economic factors which affect the harvest index. The theoretical maximum productivity as revealed by the above approaches is shown in Table 3.

Under unlimited supply of water and nutrients, the theoretical average maximum productivity seems to be between 14 and 32 t per ha with an average around 23 t/ha.

Water and its efficiency of utilization is the limiting factor in most of the areas. Physiogists have shown that around 250 kg of water has to be transpired for every kg of biomass manufactured to keep the tissue temperature at optimum against the increase during the bio-synthesis using respiration energy. Rain and irrigation water efficiency is less than one as slightly negative soil water potential is required for soil aeration and is calculated from rainfall and soil tilth characteristics (Ranganathan 2014). Maximum productivity that could be achieved under the rainfall regimes seen in Pepper areas with and without irrigation support and the rain fall required to achieve the NPP (23 t/ ha berries) are shown in Table 4.

Sources of nutrients are weathering of soil, and mineralization of organic wastes retained or added to soil to maintain OM status necessary to maintain soil structure, the synonym for soil fertility. All nutrients are taken in a definite ratio and N is taken as the ref nutrient as indicator to follow productivity trends and quality traits assuming all other nutrients are available and taken by the plant in the proportion required for holistic metabolism to achieve both of them. The equilibrium or the steady state soil organic matter increases with the altitude and the rate of mineralization of OM decreases with the altitude. As such the available N from the natural recycling processes is almost the same irrespective of altitude. After giving allowances for leaching and de-nitrification losses of 'N' and, soil volume explored by roots, its ultimate availability hang around at 90 kg ha/yr. The Productivity that could be supported by soil nitrogen assuming all other nutrients are also available is shown in Table 5.

Table 3: Evaluation of NPP -different approaches under unlimited supply of nutrients and water

Approach	Parameters used SR $TJ\ ha^{-1}yr^{-1}$	EiCi	E to B $MJ\ kg^{-1}$	Total Biomass $t\ ha^{-1}\ yr^{-1}$	Biomass Distribution % stem	% Leaf	% root	% Berry	Dry Berry t/ha
Traditional	75.26	0.046	17	204	35	41	17	7	14.3
Delucia et al.	X	x	x	450	35	41	17	7	31.5

SR- Annual integrated incident solar radiation TJ ha^{-1} yr^{-1}
E to B- Energy to biomass, MJ kg^{-1}: in some cases value '19' is also in use
EiCi- Energy captured and used (Theoretical daily energy stored in biomass of C3 plants (4.6%)
delucia et.al.-NPP 200 t C/ha (450 t/ha biomass)

Table 4: Water - Limiting NPP-under unconstrained supply of nutrients

Rain cm	Rain water Use efficiency	Available quantity water M ml ha^{-1}	Biomass t/ha	Berries t//ha
A- without irrigation support				
100	0.6	60	24	1.68
175	0.6	105	42	2.94
250	0.6	150	60	4.20
B- with irrigation support during dry spells				
100	0.8	80	32	2.14
175	0.8	140	56	3.92
250	0.8	200	80	5.60
C- At Full Water Requirement for Theoretical Max				
1029	0.8	823	329	23.00

Table 5: Threshold productivity of Pepper soils

Elevation	0 to 1500 m MSL
Equilibrium, OM	0.8. to 4 %
N release by OM decomposition	90 kg per ha per year
Soil N utilization efficiency	60%
N utilized by the plants from Soil N available /ha/year	54 kg /ha/yr.(60% of 90 kg)
N content, whole plant analysis	2.00%
Equivalent Biomass	2700 kg/ha
BERRIES at harvest index of 0.07	189 kg/ha

Discussion

The threshold limit of productivity is limited by nutrients available thru natural nutrient recycles and water by vageries in rainfall patterns. The theoretical maximums possible under natural conditions are summarized in Table 6.

Nutrient content of whole plant: Seven elements (C, O, H, N, P, S and Ca) enter the chemical composition of the biomass and they are required in large quantities. The nine mineral nutrients (K, Mg, Fe, Mn, Zn, Cu, B, Mo and Cl) occur in ionic forms. K aided by B regulates water balances in the system. Mg is the central ion in chlorophyll molecule and plays a key role in photosynthesis. Other mineral elements are transition elements with incomplete outer shells and help in electron transfer reactions. They serve as coenzymes in bio-cycles in the synthesis of organic chemicals for biomass production. All chemicals required for growth are manufactured thru bio cycles involving an enzyme and a coenzyme, an ion for electron transfers. Some bio-cycles are ion specific and others have no specific options other their charge they carry. Some of the chemicals are specific to the quality criteria of the crop for which they are grown. As such mineral nutrient deficiency affects the quality requirements of the end product for which the crop is grown. Nutrient requirement of Pepper plant is almost similar to other plants except it requires more of N, K, Ca, and Mg. Nutrient content of Pepper plant as compared to other plants are depicted in Table 7.

Application rates: When dealing with moderate targets, the application rates are based on field trials, response curves and evaluation of economic doses, In High target programs, all nutrients are applied in the ratio found in whole plant analysis for the bio-mass to be synthesised based on harvest index. The harvest index is 7% for Pepper plant - 1440 kg biomass is required for 100 kg dried berries. For every 100 kg berry requirement of N is 48 kg at 2% N of the whole plant and at 60% efficiency of utilization soil N, All other nutrients are to be given in the ratios found in the whole plant analysis so that none of then turn out to be a limiting one to attain targeted productivity with quality intact. Soil available nutrients are not taken into account in arriving rates of application of nutrients and they help to maintain the minimum salt concentration in soil solution required to protect the soil physico-chemical properties against desiccation and wetting. Om additions are required to maintain soil tilth for efficient utilization of nutrients applied.

Finer aspects of fertilizer application: Both organic

Table 6: Threshold limits of Productivity under natural conditions

A: NPP Unlimited supply of nutrients and Water		
1	NPP, kg/ha	23 t/ha
2	Water requirement to reach NPP (in rainfall units, cm)	1029 cm
3	Nutrient requirement to reach NPP, N kg/ha* with proportional application of other nutrients	11040 kg/ha
B: NPP, unconstrained supply nutrients		
1	Uniformly distributed rain, capsules kg/ha per 100 cm rainfall	2140 kg/ha
2	Rainfall only with dry periods; Capsules kg/ha per 100 cm rainfall	1680 kg/ha
3	Rainfall + irrigation; Capsules kg/ha, per 100 a cm rainfall	2140 kg/ha
C: NPP, unconstrained supply of water		
1	Soil nutrients, only natural resources	189 kg/ha

To produce 100 kg capsules cardamom requires water equivalent to 4.5 cm rainfall at 80% water utilization efficiency and 48 kg N with proportional amounts of other nutrients

Table 7: Chemical Composition of Pepper compared to other crops

	%							%		PPM							
Index	**C**	**O**	**H**	**N**	**P**	**Ca**	**S**	**K**	**Mg**	**Fe**	**Mn**	**Zn**	**Cu**	**B**	**Mo**	**Cl**	**Si**
P	45	45	6	2.00	0.21	1.09	0.18	2.62	0.49	608	363	53	224	30	3	100	n/a
O	45	45	6	1.5	0.20	0.50	0.10	1.0	0.20	100	50	20	6	20	<1	100	N/A
	Elements that go into chemical composition of the biomass							Supporting elements essential for biosynthesis and life processes									

P – Pepper mean of available reports : O – Mean for other crops and inorganic sources for nutrients are used; Organic sources are costlier and slow reacting but their retention period in the soil is longer than the inorganic ones which are available as straight, physical mixtures, complexes and chemical compounds. Their uses are determined by local customs, availability and economics.

About P: Phosphates undergo similar transformations in the soil and are precipitated as insoluble iron and aluminium phosphates in acidic soils and calcium phosphates in alkaline soils. 'P' concentration in soil solution is dogged by the solubility product constant of phosphate system specific to a pH and E_h (Redox potential) matrix in the soil. The solubility of precipitated phosphates decreases with ageing and are available over years. Mobility of 'P' in the soil is therefore restricted and roots grow in search of it. As such P is always placed below the root zone to induce deeper rooting and its ramification in the subsoil which remains moist for a longer time than the surface soil. As P is fixed and less mobile than other nutrients, 3 years requirements can be placed in alavangu (crowbar) holes or pressing the fork in the soil, raise it without pulling it out and put the phosphate in the space between the fork and soil surface, below 20 cm once in 3 years, All forms are equally effective and the choice could be made on availability and cost factor. As the placement is a labour intensive operation, one third of the area could be covered in a year done in any part of the year when the labour is freely available. 'P' requirement is 3 kg for every 100 kg berry for the targeted yield.

About N, K, Ca and Mg: The divalent ions are held more strongly than the monovalent ones in clay complexes. Divalent ions also help in soil aggregation, important for maintaining soil tilth, a synonym for soil fertility. Ca and Mg are therefore best applied once in 2 to 3 years as liming materials containing 20% magnesium carbonate or liming material fortified with magnesium sulphate..They can be applied broadcast before the rainy season and they slowly react when the soils are moist and move down acting both as soil amendment and as a nutrient. Soil pH can be brought to around 6.5 by traditional approaches and maintained by annual applications of Ca and Mg at the rates16 and 7 kg per 100 kg dry berries respectively for the targeted productivity.

N and K are highly mobile in the soil their retentive time is short. N losses occur thru leaching and de-nitrification and that of K mainly thru leaching. The efficiency of utilization of N is 30% in low productivity levels and increases to 60% with increase in productivity to 60% in high target programs. In high target programs, the requirements of N and K, respectively, are 48 and 47 kg per 100 kg berries for the targeted yield at 60 and 80% utilization efficiencies. As they move freely in the soil, they have to be applied in split doses at frequent intervals- 4to 6 times in a year. Both vegetative growth phase for future crop and reproductive phase for current season crop overlap each other, there is no need to alter the quantities to be applied in the different splits. The total quantities of N and K required can be applied as 1:1 NK mixture in 4 to 6 splits avoiding very wet and dry periods – if irrigation support is available it can be spread over the year uniformly in six splits. Sulphur requirement is about one fifteenth that of N and it can be met with by applying at least 20% of N as ammonium sulphate.

About micronutrients: There is no need to apply Fe, Mn, and Si as they are freely available in most of the situations.Cl requirement is taken care thru K Cl used as K fertilizer. Of the remaining micro elements, their requirements for every 100 kg berries for the targeted productivity are a) Cu-323g b) Zn -76g c) B- 43 and d) Mo-7.2g. Their requirement can be met by applying to soil by broadcasting them as salts straight or fortified with NK mixtures or thru foliar spraying. In foliar spraying mixtures Mn is added to increase cell permeability for active absorption. Where Cu sprays are used extensively for diseases control, there is no need to apply it separately. Organic acids from decomposing OM increase the retention time of micronutrients by chelation and regulating their concentration by their hydrolysis constants.

Importance of chasing Productivity: Increase in productivity help in reducing the fixed charges component in the cost of dry berries per kg. Variable charges are related to productivity and they come under three major heads- 1) Manuring, 2) Picking, and 3) post harvest processing and taxes and duties, Their cost per kg due to VC comes thu is fixed. Any change in COP per kg comes thru reducing the COP per kg of fixed charges. Cost analysis of two fields having two different productivity levels is shown in Table 8.

Variable cost per kg berry is the same in both the fields. Fixed charges per ha is almost similar. But the COP per kg is ₹ 26,2 in the low yielding field and it is ₹ 17.7 in the high yielding field increasing the profit margin by ₹ 8.5 per kg berry. Sustaining high productivity is, therefore, a prime requisite for the economic viability of Pepper cultivation. Challenges in sustaining high productivity may be

Table 8: Impact of productivity on cost per kg of dry berry at estate level (1989-1994)

Field	A					B				
Productivity level	280 kg/ha					118 kg/ha				
Entry	COP			Man days		COP			Man days	
Detail	₹/ha	₹/kg	%	/ ha	/ kg	₹/ha	₹/kg	%	/ ha	/ kg
Fixed charges (FC)	1600	5.7	32	40	0.14	1700	14.2	55	43	0.36
Variable charges (VC)	3360	12.0	68	58	0.21	1416	12.0	45	24	0.21
Total	4960	17.7	100	98	0.35	3116	26.2	100	67	0.57

Break-up of Variable Charges all data per kg berry

Item	Manuring			Picking			Processing			Total		
Entry	cost ₹	%	MD	cost ₹	%	MD	cost ₹	%	MD	cost ₹	%	MD
Value	4.0	33	0.05	5.0	42	0.13	3.0	25	0.04	12.0	100	0.22

Table 9: Productivity trends in Pepper

Year	2001-05	2006-10	2013-14	2014-15	2015-16	2016-17	2017-18
Area, '000 ha	225.4	209.9	122.4	123.9	131.8	134.3	135.9
Productivity, kg/ha	316	269	303	565	368	425	471

Source: a) 2001-2010- International Pepper Community -2011, Yogesh, and Mokshapathy (2013)
b) 2013-2018 -State Agri/Hort. Departments/DASD Kozhikkode Cardamom: Estimate by Spices Board
c) (2017-18- Provisinal) - WWW.indianspices.com/statistics.

Table 10: ETc values –pepper tracts

System	Etc mm d^{-1}	Kc	PET mm d^{-1}
Monocrop E. indica	3.0	0.66	4.55
Mixed cropping Coconout, Areca nut	3.7	0.85	4.35

one of the reasons for stagnation in cultivated area of PEPPER in the current decade.

Summary

The productivity trends in Pepper are exposed in Table 9.

Pepper responds to nutrients and water but the main limiting factor is in enlarging and maintaining optimum leaf area index. Regular pruning and training the vines to produce more vertical climbing branches and berry bearing lateral branches should receive more attention. Spike and berry chacterestics can be improved by judicial manuring programs. Etc and Kc values of vines trained on Coconut and Areca nut in mixed cropping systems and that of vines in mono crop systems with E, indica supports don't differ significantly (Table 10) and hence pepper can be expected to do well in both situations alike. The expenditure on pest and disease control is high compared to other crops and more attention has to be given to develop resistance cultivars to pests and diseases.

Acknowledgement

The study was done at R&D Division of M/s Ram Bahadur Thaakur Ltd., Cochin (1989-95). I, once again record the support of Dr. SS RANADE, Chairman and Managing Director Of IMT Technologies Ltd., Pune and late Mr. CB Sharma Chairman and Managing Director of M/s Ram Bahadur Thakur Ltd., Cochin after my retirement for keeping me active in pursuing research.

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