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**Asheesh Sharma**  
Assistant Professor,  
Horticulture, J.N.K.V.V.  
Jabalpur, College of Agriculture,  
Powarkheda, Hoshangabad  
Madhya Pradesh, India

**Narendra Chaudhary**  
Scientist, ICAR-NRCSS, Ajmer,  
Rajasthan, India

**Rajnee Sharma**  
Assistant Professor,  
Horticulture, J.N.K.V.V.  
Jabalpur, College of Agriculture,  
Powarkheda, Hoshangabad  
Madhya Pradesh, India

**Shobharam Anjanawe**  
Assistant Professor,  
Horticulture, J.N.K.V.V.  
Jabalpur, College of Agriculture,  
Powarkheda, Hoshangabad  
Madhya Pradesh, India

**Correspondence**  
**Asheesh Sharma**  
Assistant Professor,  
Horticulture, J.N.K.V.V.  
Jabalpur, College of Agriculture,  
Powarkheda, Hoshangabad  
Madhya Pradesh, India

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## Multi storied cropping system in horticulture - An approach for more crop per unit area of land

**Asheesh Sharma, Narendra Chaudhary, Rajnee Sharma and Shobharam Anjanawe**

#### Abstract

Monoculture is exceptional, while mixture of species is the rule of nature. Intensive horticultural systems are often based on optimizing the productivity of monoculture. In these system, crop diversity is reduced to one or few species that are generally genetically homogeneous, the planting layout is uniform and symmetrical, external inputs are often supplied in large quantities and monoculture system are widely criticized today for their negative environment impacts. In multi storied cropping system two or more crops of different heights are grown simultaneously on a piece of land in a certain period. A multi storey cropping system accommodates crops of different heights, canopy patterns and root system to maximize use of sunlight, nutrient, sustainable land use and maintain an ecological balance. In this system of cropping, the possibility of more efficient use of resources like sunlight, water, soil and nutrient is leading to increased biological diversity, more crops per unit area and sustainability of production.

**Keywords:** storey cropping, canopy pattern, ecological balance and biodiversity

#### Introduction

India is the second largest producer of fruits and vegetables in the world (Indian Horticulture Database, 2017) [1]. The annual consumption of vegetable and fruit has been increased to meet the nutritional requirement of an estimated 1.5 billion population of India expected by 2030. Although the productivity of vegetable and fruit have increase but it will not be sufficient to feed ever increasing population as a result of increase demand. In India mostly farmers (about 85%) comes under small and marginal farmers. In near future, availability of land for cultivation will be reduce with increasing population and rapid urbanization, hydroelectric project, dams, river, roads, degradation of land due to soil erosion and soil salinity. As per estimate, in India more than 95% holding will be under the category of small and marginal holders by 2050 (Agrawal R.L., 1995) [2]. For solution of this problem, multi storied cropping system will be a potential and efficient option to provide food, nutritional and income security to the growing population of India (Awasthi O.P. *et.al.*, 2008) [3]. This has possible because of the diverse agro climatic condition, enormous biodiversity, wide variation in soil fertility, large cultivable land area in the geographical boundary if India.

The improvement of crop productivity is the common aim of farmers and agriculturists. The key to sustainable agriculture probably lies in increased output per unit area together with arable land expansion. However, the recent demographic pressure has forced agricultural planners and development agencies to review the role of multiple cropping as a means to enhance agricultural production, since the extent of suitable agricultural land is static or decreasing (Midmore D.J. *et.al.*, 1993) [4]. The available arable land could be utilized for horticultural produce to achieve nutritional security with sustainable production.

Diversified cropping system could be one of the solutions for sustainable productivity and maximum income per unit area of land with maintaining soil fertility. This system is popular in Western Ghats because of space constraint in most of the farms. Multi storied cropping system is most suitable for small and marginal farmers with provide more crop per unit area by efficient using resources (Rahim M.A., 1995) [5]. Agriculture/Horticulture/Silviculture based

cropping system especially Hort-Hort and Hort-Agri based cropping system plays a important role in realizing more sustainable productivity and profitable. In multi storied cropping use perennial fruits (Sapota, Mango, Citrus, Aonla, Ber, Banana and Guava etc.), plantation crops (Coconut, Arecanut, Coffee, Cocoa etc.) and vegetable crops (Cluster bean, Cowpea, French bean, Fenugreek, Coriander, Turmeric, Ginger, Sweet Potato, Elephant foot yam, Cucurbits etc.) produce more food products and ensuring sustainable farm income. This system is usually practiced in agro-climatic regions of Western Ghats, North-East India, where tropical and humid climate is predominant.

This review article focus on concept and species suitable for in this system based on horticultural crops and attempt to identify shortcomings in terms of tools, thereby proposing new a idea to popularize this approach.

### Principles of multi-cropping system

Commonly cropping system refers to temporal and spatial arrangement of crops and management of soil, water and vegetation in order to optimize the biomass production per unit area, per unit time and per unit input. Key of successful of multistoried cropping system is the crop with diverse feature (growth habit, root depth and crop duration) such as coriander, radish, beetroot, cluster bean, cowpea etc. are useful in making multi-tier cropping system. Growing more than one crop at a time in the same field, farmers minimize soil erosion, which are the serious drawback of monoculture cropping system. The practice of multi storey cropping system is highly successful in plantation crops such as coconut, arecanut, cashew and coffee for enhancing sustainable productivity and realizing higher income per unit area. The basic principles of multi storied cropping system are (i) opportunities for crop diversification on scientific, ecological and economic principles. (ii) Maximize system productivity. (iii) Utilization of resources with higher efficiency. (iv) Intensive input use and (v) Sustainability of farm resources & environment on long term perspective.

### Advantages of multi storied cropping system

- Increase income per unit area substantially- An advantage of a mixture of species has often been assimilated to a higher yield of the mixture when compared with monocultures as same proportion.
- Minimum risk of crop yield- Multi storied system can sequester carbon over pure crop stands. Trees and cover crops may also enhance the soil carbon content, thus participating in climate change mitigation.
- Reduce the impacts of hazards like high intensity of light, rainfall, soil erosion, flood and landslides.
- Efficiently utilize natural resources like soil, water, sunlight and nutrients.
- Improve soil health and erosion soil fertility.
- Reduce weed, pest and disease incidence- Reduction of insect population due to the diversity of crops growth and reduction of plant disease because the distance between plants of the same species is increased. Reduction of weed through allelopathy and covering crop.
- Enrich biodiversity and maintain ecological balance.

### Feasibility of multi storied cropping system in horticultural crops

- Horticultural crops especially fruits and plantation crops are perennial in nature and long pre-bearing period (Mango, Coconut, Areca nut, Cashew).

- Crops have wider spacing and tall growing eg. Coconut (7.5 × 7.5 m, 15-20 m height), Oil palm (9 × 9 m, 10-15 m height) and Areca nut (2.7 × 2.7 m, 15-20 m height).
- Spreading growth is very slow, take years together and more than 60-70% inter space is not effectively utilized (Mango, Coconut, Sapota, Areca nut).
- Crop geometry and rooting system among perennials, semi-perennials and annual crops could be compatible without any adverse effect on main crops (Areca nut, Banana, Turmeric, Ginger, Cocoa and Pineapple).
- Shade loving, tolerance to rain drops and high humidity crops (Turmeric, Ginger, Pineapple, Pepper, Banana, Cocoa).
- Crops are the good source of bio-mass and by-products which are easily recyclable and decomposable (Coconut, Cocoa, Cashew nut, Areca nut, Tree spices, Mango and Guava).
- Many crops are different harvesting time and period which facilitates for sustainable income (Ginger, Turmeric, Banana, Pineapple, Areca nut, Coconut)
- Some tropical medicinal plants are well adapted to partial shading, moist soil, high relative humidity and mild temperature, allowing them to be intercropped with timber and fuel wood plantations, fruit trees and plantation crops.

### Tools to evaluate the performance of multi storey cropping system

Sustainability of multi storey cropping system, lies in the fact that how much diversified cropping system and the positive interaction among the diverse components of the system.

#### Land Equivalent Ratio (LER)

LER is an important tool for the evaluation of intercropping systems. The LER is calculated by the formula  $LER = \sum (Y_p/Y_m)$ , where  $Y_p$  is the yield of each crop in the polyculture and  $Y_m$  is the yield of each crop in the sole crop or monoculture. LER can be defined as the relative and sole crop that would be required to produce the equivalent yield achieved by intercropping (Willey R., 1979) [6]. LER more than 1 indicates yield advantage, equal to 1 indicates no gain or no loss and less than 1 indicates yield loss.

#### Relative Yield Total (RYT)

The most important index of biological advantage is the relative yield total that can be used to quantify the yield advantages in a replacement series. The equation for RYT, when two species are intercropped  $RYT = X_{mix}/X_{sole} + Y_{mix}/Y_{sole}$ , where  $X_{mix}$  and  $Y_{mix}$  are yields of species X and Y in mixture and  $X_{sole}$  and  $Y_{sole}$  are yields of species X and Y as sole crops. Values of RYT more than 1 indicate that the species make different demands on resources or avoid competition in some way, while values of RYT less than 1 indicate mutual antagonism. RYT values of 1 indicate that the components fully share the same limiting resource i.e. compete fully and show no antagonism (Mead R., 1986) [7].

### Different multi-storied cropping system based on horticultural crops

#### Coconut based cropping system

Effective utilization of available space, both horizontally and vertically, is the modern concept of cropping system. Growing coconut as monocrop is not the most efficient way of using natural resources. Adoption of coconut based multiple cropping system emerges as the viable way for

improving the economic status of coconut farmers. Studies revealed that natural resource i.e. soil, water, air space and solar radiation are not fully utilized under the spacing schedule 7.5 m × 7.5 m. Further, in India, coconut is primarily a crop of small and marginal farmers (Rethinam, 1990) [8].

Studies conducted at AICRP on palm, Department of Spice and Plantation Crops, BCKV, West Bengal, six coconut based cropping model i.e. Model I: Coconut + Black pepper + Guava, Model II: Coconut + Black pepper + Lime, Model III: Coconut + Black pepper + Lemon, Model IV: Coconut + Black pepper + Pineapple, Model V: Coconut + Black pepper + Banana and Model VI: Coconut + Black pepper were evaluated. Economic assessment of models revealed that out of 6 model V (consist of Coconut + Black pepper + Pineapple) was more remunerative showing highest net return of Rs. 45600/- per/ha. Fruit based cropping system with coconut, comprising of coconut, black pepper, and pineapple was found best under West Bengal condition (Ghosh, D.K. *et al.*, 2011) [9].

Studies conducted at ICAR-CPCRI, Kasargod, show the coconut planting spacing at 7.5 m × 7.5 m, the space available for each palm is 56.25 m<sup>2</sup>, and the maximum concentration of roots lies in 12.57 m<sup>2</sup>, which in turn is only 22.2% of the total area. Thus, it provides about 77.8% of the land available for growing other crops. The pattern of crop canopy coverage and solar energy utilization of sole coconut plantation indicates that about 45-500% of the sunlight is infiltrated on to ground without interception by the coconut. In order to utilize the natural resources like light, soil and water efficiently for sustainable production, the practice of inter/mixed cropping has to be practiced through scientific management. Growing various suitable crops as intercrops in coconut gardens not only increase the productivity per unit area but also ensures additional income, employment and enhancement of soil properties. Thus, several spice crops, tuber crops, medicinal and aromatic plants, flowers and vegetable crops can be successfully grown as mixed/intercrops in coconut gardens. In the initial 5 years of plantation, suitable inter crops of short and medium duration with crop rotation recommended are banana-turmeric-ginger-pineapple-vegetables-papaya, sorghum-legumes, sunflower, tapioca, elephant foot yam, sweet potato, guava etc., profitably grown with the enhancement of 20-30% coconut productivity (ICAR-AICRP report, 2014-15). After 20-25 years, more than 40% of light falls on the ground and also have efficient shade. Therefore, shade loving crops could be grown in the multistoried cropping pattern eg. Coconut + Black pepper + Pineapple + Cocoa/Turmeric/Ginger (Mathew P.A. *et al.*, 1993) [10].

#### Cashew nut based cropping system

A systematic intercropping system involving compatible crops with varying morphological and rooting habits will enable better resources use and more returns. Intercropping in cashew reduce weed growth and maintain soil fertility. Biennial horticultural crops like pineapple, banana and papaya and annual crops like cowpea, tapioca, turmeric and elephant foot yam are suitable intercrops in cashew (Mandal, 1992) [11]. Cashew grafts are normally planted at a spacing of 7 m × 7 m to 10 m × 10 m. In the first year, when planted at a spacing of 7.5 m × 7.5 m (177 plants/ha) very little land area is utilized

by the crop. During the first year, cashew used hardly 1.2 percent of the land area provided to the crop. During the second and third year, the canopy coverage is only 5 percent and 13.4 percent, respectively. This pattern of canopy development offers tremendous scope for intercropping in cashew during early years.

#### Cocoa based cropping system

Cacao (*Theobroma cacao L.*) is a tree crop that highly suitable or compatible under different production system such as intercropping or multi storey cropping system. Cacao is widely planted under and between stands of coconut trees. To be a compatible and productive intercrop, cacao tree is best planted not closer than 2 m from base of coconut trees, at 3 m between hills and 3 m between rows. Furthermore, where, there is limited land for cacao monocropping, the inter-spaces of coconut lands (with 8-15 m of spacing of coconut plants) are amenable for several rows of cacao crop.

#### Areca nut based cropping system

Under coastal Karnataka condition studies on intercropping in areca nut plantation comprising of seven crops namely- *Amorphophallus*, Chinese potato (*Coleus rotundifolius*), Colocasia (*Colocasia esculenta*), Ginger (*Zingiber officinale*), Sweet potato (*Ipomoea batatas*), tapioca (*Manihot esculenta*) and turmeric (*Curcuma longa*) revealed that all the intercropping system recorded higher mean yields of areca nut than the sole cropping of areca nut. The highest LER of 1.76 was recorded in arecanut + ginger with highest benefit: cost ratio (3.3:1) closely followed by areca nut + colocasia (3.15:1) (Hegde *et al.*, 2001) [12].

The studies conducted at farm of UBKV, Coochbehar, West Bengal with seven different cropping models based on areca nut. Mixed cropping in areca nut plantation has promoted more growth and yield of main crop of areca nut as indicated by increased number of leaves and increased yield per palm compared to sole crop. The maximum income and B: C ratio of Rs. 36919.95 and 3.68:1 respectively were recorded in Model-III (Areca nut + Banana + Turmeric), while minimum income Rs. 15637.15 was in Model-I (Areca nut as monocrop). Minimum B:C ratio of 1.13:1 was observed to be in Model-VI (Areca nut + Banana + Okra + Brinjal). It can be concluded that, Model-III (Areca nut + Banana + Turmeric) was the best remunerative one and the farmers can adopt this model in this region as areca nut based multi storey cropping system for more income per unit area (Chandrashekhar G. *et al.*, 2018) [13].

#### Coffee based cropping system

Sustainable cropping system in coffee plantations should involve successful management of natural resources like soil, moisture and sunlight to satisfy changing needs of increasing number of small and marginal farmers who constitute majority. It is also quite imperative to maintain or enhance the very basic quality of environment and conserve natural resources in the high ranges of coffee growing tracts of Western Ghats in South India. Productivity of coffee plantations should be increased by intensive cultivation of coffee and resorting to diversification with suitable mix crops to improve and sustain high income (Sathish B.N., 2005) [14].

**Some successful model of multi storey cropping system on the horticultural crop basis**

Cropping system	Place of report	Remarkable outcome of the system	Reference
Coconut + Cocoa + Banana + Drumstick + Pineapple	AICRP, Aliyarnagar	This cropping system with 75% NPK + organic recycling with Vermicompost recorded highest nut yield of 182 per palm and highest net income (Rs. 3.80 lakhs per ha) and B:C ratio (2.71)	Nimbolkar <i>et al.</i> (2016) [15].
Coconut + Cocoa + Lime +Banana + Drumstick	AICRP, Arasikere	With all physical and chemical quality of coconut, this system recorded net income of Rs. 294810 per ha compared to mono crop (Rs. 68200 per ha.)	Roy <i>et al.</i> (2001) [16].
Mango + Cowpea + Indian mustard	Todapur Research orchard of Horticulture Division, IARI, New Delhi	This system recorded significantly highest values of system productivity, gross returns, net returns and B: C ratio during both the crop seasons	Mirjha and Rana (2016) [17].
Mango + Phaseolus acutifolius + Pigeon pea	Mango orchard in the Soconusco, Chiapas, Mexico	The biomass of Cajanus cajan and Phaseolus acutifolius and their incorporation to the ecosystem produced positive effect on the quality and yield of mango.	Agreda <i>et al.</i> (2006) [18].
Mango + Cowpea(kharif) + Bengal gram(Rabi)/ Mango + Pigeon pea + Tomato	Madhya Pradesh	First system gave maximum productivity per ha whereas second system came up with maximum monetary returns.	Baghel <i>et al.</i> (2010) [19].
(Aonla + Ber + Cluster bean + fennel), (Aonla + Bael + Cluster bean + Coriander), (Aonla + Khejri + Cluster bean + Ajowain)	Arid region of Rajasthan	These system were reported as sustainable and remunerative under the arid ecosystem	Hare Krishan <i>et al.</i> (2013) [20].
(Aonla + Ber + Karonda + Cluster bean + Brinjal), (Aonla + Ber + Karonda + Mothbean + Indian mustard)	Arid region of Rajasthan	Plant height, number of branches per plant, fruits per plant and yield was found to be superior in these multi species cropping system as compared to sole cropping.	Arya <i>et al.</i> (2010) [21].

**Conclusion**

Multistoried cropping system in horticulture is found to be a perspective approach for sustainable productivity in fruit crops (Mango, Ber, Aonla, Pomegranate, Banana and Pineapple) and plantation crops (Areca nut, Coconut, Coffee, Cashew nut) by which natural resources are utilized efficiently to enhance productivity of main crop (15-20%) and high revenue realization per unit area (50-90%). This approach is boon to small and marginal farmers, majority of farmers in our country under this category. Multistoried cropping system opens a new door to earn whole round the year as well as there is less risk of complete crop failure.

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