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Integrated Multi-storeyed Cropping of Tree Spices in Coconut Plantations for Sustainability under Aberrant Coastal Climate

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Abstract

Coconut is an important irrigated plantation crop of coastal ecosystem and is component of most of the farming households. The multi-storeyed cropping with tree spices in coconut is a solution for sustainability with greater income to counter the climatic fluctuations. Various production models of multi-storeyed mixed cropping are developed for small farmers through rigorous research for suitable varieties, propagation protocols, densities of various spices in the coastal region of Maharashtra. The integrated multi-storeyed cropping system with tree spices continuously for ten years contributed higher returns per hectare elevated the nut productivity from 6300 to 9800 nuts acre^{-1} which helped for the sustainability of coconut plantations under aberrant climate of coastal region.

Key words: Mixed cropping, tree spices, coastal climate, production technology.

Introduction

Coconut is an important irrigated crop constituting major source of livelihood in coastal ecosystem of the country. Presently it is established on 20,92,000 ha area with 15,339 Mt production. Importantly it is a crop of small and marginal farmers since 98% of about five million coconut holdings in the country are less than two ha (Anonymous 2018). The change in climatic conditions has been experienced by the coastal region during last decade in form of cyclones, drought as well as flood which has affected the productivity of these orchards. Moreover, the rate of increase in cost towards labour and inputs is quite high as compared to the increase in the price of these commodities. Hence, it is essential to develop a sustainable mixed cropping system for sustainability of these coconut plantations and for livelihood security of coastal population.

India is the single largest producer, consumer and exporter of spices in the world. The total spice production in the country is 8124 thousand t from an area of 3878 thousand ha. with a productivity of 2.09 tha^{-1}. Among the various spices tree spices are highly remunerable crops. These crops can sustain the climatic changes experienced in the region. Tree spices viz., nutmeg (*Myristica fragrans* Houtt.), cinnamon (*Cinnamomum verum* Bercht. and Presl.), clove (*Syzygium aromaticum* (L.) merr. and Perry), kokum (*Garcinia indica* Thouars), and all spice (*Pimenta dioica* (L.) Merr.) are suitable intercrops in coconut plantation. The air space, partial shade, solar radiation and available irrigation water in the plantation provide scope of growing intercrops.

Efforts were made to develop an integrated multistoried mixed cropping system with different shade loving tree spices in coconut plantations which not only afford the additional yield of spices but also elevate productivity of coconut.

The research was focussed to develop improved varieties, rapid plant propagation techniques and management technology of tree spices coconut plantation.

Varietal improvement of tree spices

Coastal region of Maharashtra is one of the major centres

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of biodiversity where in ample variability in seedling population of nutmeg, cinnamon and kokum exist. The elite types were identified, collected and evaluated for their suitability for commercial cultivation. Number of varieties in nutmeg (*Konkan Sugandha, Konkan Swad* and *Konkan Shrimanti*), cinnamon (*Konkan Tej, Konkan Tejpatta*), Kokum (*Konkan Amruta, Konkan Hatis*) are available for cultivation. These varieties are not only high yielding but are also superior for quality (Table 1) (Anonymous 1998, Anonymous 2003, Anonymous 2005a, Anonymous 1993, Anonymous 2008, Anonymous 1997).

Table 1. Tree spices varieties released for cultivation in Maharashtra.

Crop/ Varieties	Important characteristics
A) Nutmeg	
Konkan Sugandha	Monoecious: produces male and female flowers on same plant, Average, yield 500 fruits tree^{-1} year^{-1}. Average dry nut weight 5 g and dry mace weight 1.2 g fruit^{-1}
Konkan Swad	Female tree. Average yield 600-700 fruit tree^{-1} year^{-1} Average dry nut- 4 g and dry mace weight 0.5 g fruit^{-1}
Konkan Shrimanti	Average yields 800-900 fruit tree^{-1} year^{-1} Bold nut, Average dry nut weight 10 g Dry mace weight 2 g fruit^{-1}
B) Cinnamon	
Konkan Tej	Average yield 200-300 g fresh bark per plant High fresh leaf yield 3.56 kg plant^{-1}, High bark oil 3.20% Cinnamaldehyde (70.23%) and eugenol (6.93%) in bark oil.
Konkan Tejpatta	Yield 1.6 kg dry leaves plant^{-1} year^{-1} Leaf oil 2.8%, Eugenol 80.30% in leaf oil.

Source: Anonymous 1998, Anonymous 2003, Anonymous 2005a, Anonymous 1993, Anonymous 2008 and Anonymous, 1997.

Protocol for rapid clonal propagation

Nutmeg, cinnamon and kokum are cross pollinated and seedling progenies are not true to type and have long juvenile phase. Nutmeg and kokum are dioecious in nature and may produce up to 50 per cent male plants. Tree spices are slow growing and their establishment in the field is difficult due to slow initial growth and lack of vigour. The protocols for the development of healthy and vigorous clonal planting material are available due to extensive research.

Cinnamon

Cinnamon is difficult to root by cutting as it takes greater time for etiolation and further rooting. Air layering technique is advantageous for rapid rooting and strong vigour. September is best month (90%) for successful air layering in cinnamon under coastal conditions followed by April, May and August with 85 per cent success (Anonymous 1993, Ranaware 1993).

Nutmeg

For seed propagation in nutmeg freshly harvested medium sized seeds treated with fresh cow dung slurry in 1:1 for 24 hrs recorded highest germination at 96.38 per cent (Khandekar *et al.* 2006a), followed by rice bran (82.3 %) and sand (82 %) (Khandekar *et al.* 2006). Among vegetative methods, epicotyl grafting was most successful in July-December with 40 to 90 per cent success (Thomas *et al.* 2014, Haldankar *et al.* 1999). Softwood grafting resulted survival of 50 to 80 per cent success during May to July. After preparation of grafts, it is necessary to cover the graft from top below graft joint with plastic bag (6 X 8 inch and 150 gauge) (Khandekar *et al.* 2006, Khandekar *et al.* 2006b, Khandekar *et al.* 2006c). The success of sprouting and survival of softwood graft in nutmeg was positively correlated with minimum temperature, relative humidity, rain fall and negatively correlated with maximum temperature (Khandekar *et al.* 2006c). Six month old scion stick recorded maximum success in softwood grafting (Bagade 1989).

Clove

Seed treatment with GA_3 or NAA had no effect on germination of clove seed but foliar application of GA_3 with 200 ppm improved the growth of seedlings (Sable 1999). Saw dust proved to be the best medium for storage with 85 per cent seed germination (Sable 1999). The seeds of clove sown immediately after harvest resulted in cent per cent germination (Haldankar and Jadhav 2001). The seed stored even up to 14 days in saw dust had 86 per cent germination. But germination decreased rapidly

thereafter (Haldankar and Jadhav 2001). However, the graftability of clove is poor. Attempts were made to graft clove by using the clove and jamun seedling as rootstock (Shinde 2001). The vegetative methods of propagation did not record promising results for commercial multiplication.

Black pepper

Black pepper can be propagated by using stem cutting. Two and three nodes stem cuttings without leaf registered high spouting success (96.66 per cent and 100 per cent respectively). Retention of leaf contributed to lower success in black pepper (Shivraman 1987). To achieve highest success from stem cutting in black pepper, the rooting of stem at nodes when it is still attached to mother vine is necessary (Shivraman 1987). A rapid method of propagation is developed to obtain roots at nodes by using bamboo halves has limitations because of severe attack of termites on bamboo and difficulty in maintenance, replacement and availability of suitable bamboos (Khandekar *et al.* 2004). For rapid multiplication of black pepper, a soil mound technique is developed. A soil mound is prepared to the size of 2.5 m width, 0.60 m height at the centre, 45^0 angle slope and length as per convenience. The vines on both sides of mound are planted at 15 cm. distance. The highest number of root cuttings (i.e. 74 per vine) was obtained by this technique (Anonymous 2011, Khandekar *et al.* 2014). Use of cuttings from orthotropic shoots as propagating with two nodes without leaves treated with *Pseudomonas fluorescence* (10^8 CPU) powder formulation or dipped in common sugar (2 per cent) solution for one minute produced healthy plants and recorded (Haldankar *et al.* 1991, Haldankar *et al.* 1992).

Kokum

For clonal multiplication, softwood grafting technique has been standardized. Research on effect of season and shade provision on softwood grafting of Kokum (*Garcinia indica* Choisy) revealed that October was the best season for softwood grafting and the grafts can be successfully maintained either in glass house or under open sun after grafting (Haldankar *et al.* 1993). The mature scion stick of 5 to 6 month old can be preferred for soft wood grafting. Prior defoliation is not prerequisite for this technique in this crop. The age of root stock should be more than 22 weeks. The retention of leaves on root stock do not influence the success of soft wood grafting (Haldankar *et al.* 2009). The length of scion stick from 2.5 cm to 15 cm did not exhibit any significant influence on the sprouting as well as survival of grafts. The sprouting, survival and growth parameters of the grafts prepared by using erect and semi erect terminal shoots as scion were significantly superior than the grafts prepared by using drooping shoots. The scion sticks could be successfully stored in polythene bags, sphagnum moss and lower chamber of refrigerator for seven days (Thampan 1980). It was further observed that grafts prepared by using orthotropic scion showed orthotropic behavior and graft prepared by using plagiotropic scion showed bushy behavior. The trunk sprouts as well as roots suckers also showed orthotropic behavior when used as scion for preparing grafts (Dhanpal 2010).

Development of various models of intercropping with tree spices

Coconut is monocot palm without branch provide ample space for intercropping. In a well- spaced coconut plantation at 7.5 to 8 m about 80 per cent of sunlight reach the ground level (Kushwah *et al*. 1973). However, quantum of light transmitted through the foliage of the crown of coconut to ground level varies according to the age of plantation as well as diurnal changes in the angle of inclination of the sun (Anonymous 2002). Under good management, 74 per cent of root produced by coconut palm did not go beyond 2 m lateral distance and 82 per cent roots were confined to the 31 to 120 cm depth of soil (Anonymous 2015). This situation of partial shade favours the cultivation of shade tolerant and loving crops.

The planting of cinnamon, nutmeg, black pepper, kokum and clove under coconut as mixed crops were recorded excellent growth and bearing under coastal conditions (Patil *et al*. 1991, Nagwekar *et al*. 2014). Further the mixed cropping of tree spices resulted in increase of the average yield of coconut palm from 23 to 96 per cent at the end of 26^{th} year as compared to the average yield of previous years (Table 2) (Nagwekar *et al*. 2014). Nutmeg proved to be the best intercrop in coconut plantation. With coconut together, it provided a net return of ₹ 93,578 ha^{-1}. Coconut as a mono-crop recorded net profit of ₹ 25,987 ha^{-1}. Inter cropping with nutmeg, kokum, black pepper, cinnamon and clove in the coconut plantations proved beneficial in Konkan region (Table 3) (Nagwekar *et al*. 2014).Variation in coconut yield after planting of tree spices during first two year was not significant (Table 4). However, third year onwards the significant variation was noticed in coconut yields owing to planting of tree spices. The palm from nutmeg block produced the highest yield (121 nuts $palm^{-1}$) followed by those in cinnamon block (114.22

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Table 2. Average yield of coconut per palm before and after planting spice crops and per cent increase in different blocks of spices crops.

Block Particulars	Cinnamon Block	Nutmeg Block	Black Pepper	All spice Block	Clove Block	Garcinia Block	Control Block
Average yield before planting spices	69	71	83	49	47	64	77 Average yield of 26 years
Average yield after planting spices 1982 to 2003	118	119	102	93	92	96	
Percent increase	71	69	23	90	96	50	-

Source: Anonymous 2015.

Table 3. Economics of Coconut-based high density multi species cropping system (per hectare average of 5 years: 1999-2004).

Block	Total Cost ₹	Total Returns ₹	Net Profit ₹	B:C Ratio
Cinnamon	83449	137877	54428	1.65
Nutmeg	86417	179995	93578	2.08
Black Pepper	79313	130213	50900	1.64
All spice	68087	105952	37865	1.55
Clove	77017	109496	32479	1.42
Garcinia	81483	136976	55493	1.68
Control	55207	81194	25987	1.47

Source: Anonymous 2015.

Table 5. The water and nutrients given for different Coconut-based spice interplanting systems (1983-1990). The plots were 3375.5 m^2 in size.

Components of system	Amount of water		Nutrients kg $plot^{-1}$		
	l $plot^{-1}$	l m^{-2}	N	P_2O_5	K_2O
Coconut palms Nutmeg trees	432	1.28	21.8	14.0	21.0
Coconut palms Clove trees Cinnamon	459	1.36	11.6	11.0	16.4
Coconut palms Clove trees	360	1.07	12.6	9.6	12.6
Coconut palms	162	0.40	6.00	3.0	6.0

Source: Patil *et al.* 1991.

Table 4. Number of nuts harvested from different Coconut-based spice interplanting systems during 1981 to 1989.

System	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average
Cinnamon	87	56	90	145	126	109	115	146	154	114.22
Nutmeg	78	79	135	147	120	122	134	120	154	121.00
Clove	63	64	85	78	76	75	92	88	102	80.33
Control	83	57	81	88	78	78	69	64	94	78.00
Mean	77.75	64.03	79.72	114.43	99.89	95.80	102.71	104.37	120.03	95.41
S.E.	8.95	8.88	8.99	8.64	7.78	7.96	6.28	8.35	9.41	
C.V.	30.44	37.97	70.88	71.89	60.18	54.31	61.10	77.55	60.33	

Source: Patil *et al.* 1991.

nuts $palm^{-1}$). The coconut mono crop block produced the lowest yield (78 nuts $palm^{-1}$) (Anonymous 2005b).

In the mixed cropping block it was further revealed that population in nutmeg block received maximum water per day (459 L) followed by cinnamon (432 L) and clove (360 L) whereas the mono crop block received only 162 L of water. The variation in yield level of coconut was in correspondence with the amount of water given to crop population in different spice blocks. It is important to note that the coconut palm possesses a very active root system which spread over an area of about 7.0 m in the periphery of the palm but mostly restricted only to a depth of 1.5 m (Kushwah 1973). On the contrary, nutmeg, cinnamon, and clove have a tap root system which penetrates deep into the soil even beyond the reach of the fibrous root mat of coconut. The mono

crop block received minimum amount of N, P_2O_5 and K_2O whereas the maximum amount of nutrients were received by crop population in cinnamon block (Table 5) (Anonymous 2005b).

High density multistoried system in coconut plantation with nutmeg, cinnamon, banana, black pepper and pineapple contributed very high returns (Table 6 and Figure 1) (Anonymous 2005c). The yield of coconut before planting with different component crops was 5,320 nuts acre^{-1} which was increased to 6,300 to 9,800 nuts acre^{-1} after planting of component crops. The banana and pineapple recorded average yield of 1.76 to 2.2 t and 4 to 6.4 t, respectively from second year onwards whereas, nutmeg yield commenced from 4th year and it was 15,000 nuts and 7.5 kg mace (aril) per acre respectively from 10th year onwards (Anonymous 2005c). The cinnamon started yielding from 3rd year and it was 50 kg dried bark acre^{-1} and 370 kg dried leaves acre^{-1} at 10th year whereas black pepper recorded 105 kg dried black pepper yield at the age of 10th year (Table 7).

Table 6. Plant population in one acre of coconut plantation.

Name of crops	Variety	No. of plants
Coconut	D X T	70
Nutmeg	Konkan Swad	54
Cinnamon	Konkan Tej	246
Banana	Safed Velachi	246
Black pepper	Panniyur-1	140
Pineapple	Kew	4320

Source: Nagwekar *et al.* 2014.

The estimated economics of the gross return increased from ₹ 50,400 to ₹ 1,84,010. The net profit ranged from ₹ 59,010 to ₹ 1, 25,760 (Table 8) (Khandekar *et al*. 2014b, Anonymous 2007a). Integrated cropping system with coconut plantation intercropped with nutmeg, cinnamon, banana, pineapple and poultry unit was also profitable as compared to mono cropping of coconut (Figure 2 and 3) (Hegazy 2003).

Need based nutrient management through foliar application

The yield of black pepper was enhanced by foliar application of 25 per cent cattle urine along with drenching of 25 per cent cattle urine (1 l) per vine once in the month of June, September, October, and November

Table 8. Economics of Lakhi Baug (in one acre).

Year	Total Cost ₹	Gross Return ₹	Net Profit ₹
1st	94,670	50,400	-44,250
2nd	38,426	1,14,600	76,170
3rd	41,990	1,13,600	71,640
4th	46,430	1,05,440	59,010
5th	44,520	1,26,240	81,660
6th	44,309	1,57,380	1,16,990
7th	55,070	1,28,330	73,260
8th	48,350	1,28,300	79,950
9th	53,145	1,69,650	1,16,500
10th	58,243	1,84,010	1,25,760
		Average	75,669

Source: Anonymous 2005c

Table 7. Yield of coconut and different components crops in Lakhi Baug (in one acre).

Name of the crop	Year									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Coconuts (no.)	6300	7000	8400	8400	9100	9100	9100	9100	9100	9800
Nutmeg										
i) No. of Nuts	-	-	-	250	500	1000	2500	5000	10000	15000
ii) Mace (kg)	-	-	-	0.100	0.200	0.500	1.250	2.500	5.000	7.500
Cinnamon										
i) Dried bark (kg)	-	-	-	12.3	-	24.6	24.6	37	37	49
ii)Dried leaves (kg)	-	-	-	196	-	370	370	370	370	370
Banana (t)	-	2.2	1.76	2.2	1.76	2.2	1.76	2.2	1.76	2.2
Pineapple (t)	-	6.4	4.0	-	6.4	4.0	-	6.4	4.0	-
Black pepper (kg)	-	-	-	-	14	70	70	70	70	105

Source: Nagwekar *et al.* 2014.

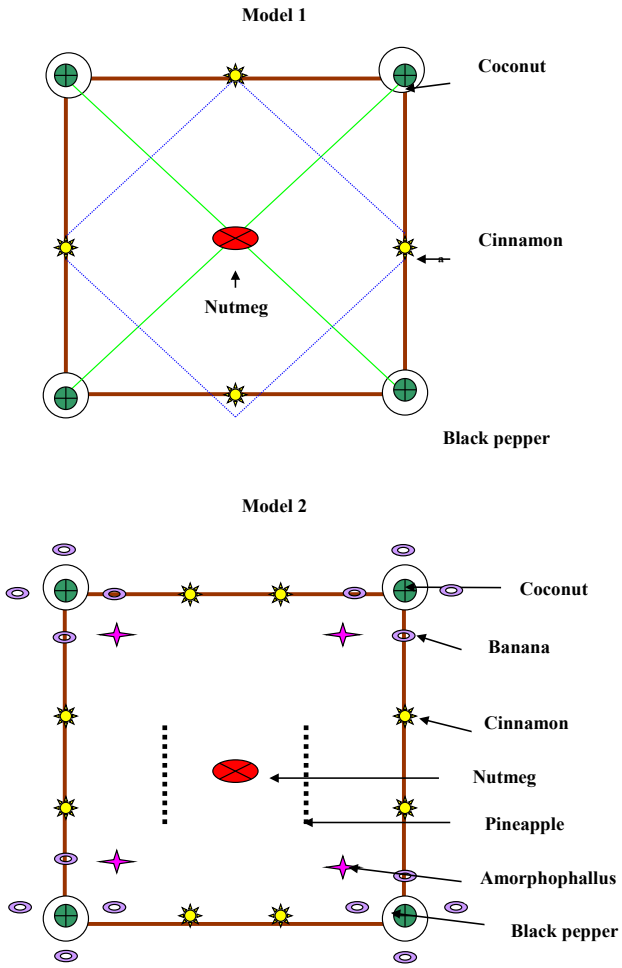

Fig. 1. High density multispecies cropping system model in coconut.

Fig. 2. Intercropping of coconut with black pepper, nutmeg and cinnamon.

Fig. 3. Intercropping of coconut with Black pepper

(Haldankar 2012). Kokum fruits in coastal region are mostly harvested in the month of May. These fruits are mostly caught in pre-mansoon rains and become unuseful for consumption and processing. The losses are as high as 35 to 40 percent (Jaisankar *et al*. 2010). The post flowering foliar nutrient sprays of 3 per cent KNO_3 at fruit set and 20 days after fruit set, hastened the harvesting by 34 days, improved the yield and resulted in maximum harvest before rains (Anonymous 2015).

Canopy management for enhancing harvesting and yield

Cinnamon is harvested for its bark and leaf. The yield varies with the time of peeling and extraction of bark and size of shoot according to different agro climatic conditions (Anonymous 2010). After coppicing many sprouts grow from main stem. If all sprouts are allowed to grow, the growth and yield of cinnamon is adversely affected. The retention of five sprouts after coppicing in normal harvesting season of cinnamon is advisable to obtain appropriate bark and leaf yield (Khandekar *et al*. 2012). Further, 5 to 6 cm thick branches are ideal for obtaining higher bark yield in cinnamon (Chandramohan and Merin 2010, Anonymous 2006).

Appropriate Plant Protection

Disease management in the inter-cropping systems under plantations differs from that of sole cropping. A holistic

approach is followed for economic and efficient disease management in the intercropping system with several crops (Anonymous 2007b). *Phytophthora* foot rot is the major disease in black pepper nursery which aggravates during high rainfall. Silver oak + black pepper proved as the best mixed cropping system, which shows minimum incidence of foot rot and *Phytophthora* blight (Khare 2002). Effective management of *Phytophthora* in black pepper nursery was achieved by use of solarized potting mixture fortified with *Trichoderma harzianum* @ 1 g kg^{-1} and VAM @100 cc kg^{-1}. However, for control of foot rot and Phytophthora blight of black pepper under plantation crops, spraying of bordeaux mixture (1 %), drenching of copper oxychloride (0.2 %) twice during June to September or spray of Ridomil MZ-72 @ 1.25 g l^{-1} and drenching twice during June to August is benefecial. For management of leaf blight and foot rot black pepper caused by *Phytophthora capsici*, spraying of 1 per cent bordeaux mixture and drenching of 1 per cent copper oxychloride or spraying of 0.3 percent potassium phosphonate and soil application of *Trichoderma harzianum* @ 50 g $vine^{-1}$ with 1 kg of neem cake twice on rainy season are useful. If monsoon is prolonged, third application may be given if necessary (Anonymous 1999, Parkar 2002).

Pytosanitory measures in the orchard and spraying with 0.2 per cent copper oxychloride at the initiation of disease was effective for management of shot hole disease in nutmeg (Anonymous 2007b). Removal of dead branches and application of Bordeaux paste on the cut ends followed by spraying with 0.1% carbendazim or 0.25% Mancozeb or 1 % Bordeaux mixture at an interval of 15 days initiating from 4^{th} week of September was effective for management of die back in nutmeg.

In clove intercropped with coconut, management of leaf rot can be done by three spraying of Mancozeb 0. 1 per cent at an interval of 15 days along with sticker 0.1 per cent is recommended (Anonymous 2007c). Further, for management of clove leaf rot, four sprays of *Trichoderma harzianum* 8 g l^{-1} water (10^8 cfu ml^{-1}) along with 1 ml l^{-1} sticker teepol at 15 days interval proved effective.

Conclusion

Coconut is important plantation crop of coastal India. The climatic aberrations affect the productivity as well as profitability of these orchards. The adoption of integrated multistoried mixed cropping system (*Lakhi baug*: a garden ie, baug which can help farmers to earn a lakh of rupees) recorded higher net returns per unit area as compared to sole coconut plantation. Various production models of multi-storeyed mixed cropping are developed for small farmers through rigorous research for suitable varieties, propagation protocols, densities of various spices in the coastal region of Maharashtra. Thus, the coconut plantations are more remunerable and sustainable with adoption of integrated multistoried mixed cropping tree spices like black pepper, nutmeg, clove, cinnamon and Kokum under coastal ecosystem even under changing climatic conditions.

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