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GROWTH AND PERFORMANCE OF CACAO (*THEOBROMA CACAO* L.) AND ARECANUT (*ARECA CATECHU* L.) UNDER MIXED CROPPING SYSTEM

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SUMMARY

Cacao (*Theobroma cacao* L.), though gained entry into India as early as 1798, it was only from the early nineteen sixties that efforts were made to cultivate it as a commercial crop in the country. The environmental conditions required for large scale cultivation of cacao as a monocrop are very limited. Since arecanut (*Areca catechu* L.) is being raised as irrigated crop in south India and since the conditions existing in these gardens seems to compare well with the requirements of cacao, studies were initiated in 1970 to find out the feasibility of growing cacao in arecanut gardens, at the Central Plantation Crops Research Institute, Regional Station, Vittal, India, using a mixed garden of cacao and arecanut having six densities of planting.

Growth parameters and economic yield of the component crops were recorded periodically. Density of planting had influence on the growth (height and spread) of cacao trees. The ratio of height of cacao and arecanut trees which was 1 : 1 at the time of planting got changed to 0.6 : 1.0 after seven years. The rate of horizontal coverage of cacao trees was almost uniform up to eighth year. In so far as the coverage of space available per tree was concerned, it was observed that the percentage of space covered increased with the density of planting, obviously due to the more number of trees in the closer spacings.

Regarding economic yield, spacing had significant influence on the number and weight of cacao pods per tree as well as unit area. The results indicated the optimum combination of the two species to be planted for maximum returns. The season of harvest and density of trees influenced the quantitative characters of pods and beans. Pods harvested during monsoon period had higher pod value and lower beam weight than pods harvested during rest of the period.

CROISSANCE ET UTILISATION DE L'ESPACE AU-DESSUS DU SOL PAR LE CACAOYER (*THEOBROMA CACAO* L.) ET L'AREQUIER (*ARECA CATECHU* L.) SOUS DES CONDITIONS DE CULTURES MIXTES

RESUME

Bien que le cacaoyer (*Theobroma cacao* L.) ait pénétré en Inde dès 1793, ce n'est qu'à partir du début de la période 1960 que des efforts ont été faits pour l'exploiter sous forme de culture commerciale. Les conditions environnementales nécessaires pour une culture pure sur grande échelle du cacaoyer sont très restreintes. Etant donné que l'aréquier (*Areca catechu* L.) est cultivé en irrigation dans le sud de l'Inde et que les conditions environnementales de ces terrains semblent soutenir la comparaison avec les conditions des cacaoyères, des études ont été entreprises pour découvrir la factibilité de cultiver le cacaoyer en cultures mixtes dans les plantations d'aréquiers à l'Institut Central de Recherches sur les Cultures en Plantations à la station régionale de Vittal, en se servant d'un dispositif mixte de cacaoyer et d'aréquier avec six densités de plantation.

Des measures périodiques ont été faites sur les paramètres et sur le rendement économique des deux cultures. La densité des semis influençait la croissance (hauteur et diffusion) des cacaoyers. Le rapport entre la hauteur des cacaoyers et des aréquiers était de 1 : 1 au moment des semis mais il changea pour atteindre 0,6 : 1,0 après sept ans. Le taux de couvert horizontal du cacaoyer était presque uniforme jusqu'à la huitième année. En ce qui concerne l'espace disponible pour le couvert de chaque arbre, l'on remarqua que le pourcentage d'espace couvert augmentait avec la densité des semis manifestement en raison du nombre plus élevé d'arbres dans les populations plus denses.

En ce qui concerne le rendement économique, l'espacement avait une forte influence sur le nombre et le poids des cabosses de cacao par arbre aussi bien que l'unité de surface. Les résultats indiquaient la combinaison optimale des deux espèces à planter pour obtenir le rendement le plus fort. La période de récolte et la densité des arbres influaient sur les caractéristiques quantitatives des cabosses et des fèves. Les cabosses recoltées pendant la période de mousson avaient une valeur de cabosses plus élevée et un poids de fèves inférieur en comparaison avec les cabosses récoltées pendant le reste de la campagne.

CULTIVO E DESEMPENHO DO CACAU (*THEOBROMA CACAO* L.) E DA ARECA (*ARECA CATECHU* L.) EM CONDIÇÕES DE CULTIVO COMBINADO

RESUMO

Embora o cacau (*Theobroma cacao* L.) tenha sido introduzido na índia já em 1798, foi só no final dos anos 60 deste século que se fizeram esforços no sentido de cultivá-lo em escala comercial no país. As condições ambientais necessárias para o seu cultivo em larga escala como monocultura são muito limitadas. Como a areca (*Areca catechu* L.) está sendo plantada em regime de irrigação no sul da Índia e como as condições existentes nessas plantações parecem bem semelhantes às exigidas pelo cacau, em 1970 iniciaram-se estudos sobre a viabilidade de se cultivar cacau em plantações de areca no Instituto Central de Pesquisas Agrícolas, Estação Regional, Vittal, Índia, usando-se um cultivo combinado de cacau e areca com seis clases de densidade.

Periodicamente registraram-se os parâmetros econômicos e a produção econômica dos cultivos componentes. A densidade da plantação exerceu influência sobre o crescimento (altura e espalhamento da copa) dos cacaueiros. O coeficiente de altura dos cacaueiros e arecas, que era de 1:1 no momento do plantio, alterou-se para 0,6:1,0 depois de sete anos. O coeficiente de cobertura horizontal dos cacaueiros foi quase uniforme até o oitavo ano. No que se refere à cobertura de espaço disponível por árvore, observou-se que a porcentagem de espaço coberto aumentou com a densidade da plantação, obviamente devido ao maior número de árvores num espaçamento menor.

Com relação à produção econômica, o espaçamento exerceu influência significativa sobre o número e o peso de frutos por árvore, bem como sobre a unidade de área. Os resultados indicaram a combinação ótima das duas espécies a ser plantada para a obtenção de um rendimento máximo. A época da colheita e a densidade de árvores influenciaram as características quantitativas dos frutos e amêndoas. Os frutos colhidos durante o período das monções apresentaram valor mais alto de fruto e menos peso de amêndoa do que os frutos colhidos durante o restante do período.

COMPORTAMIENTO DEL CACAO (*THEOBROMA CACAO* L.) Y DE LA NUEZ DE ARECA (*ARECA CATECHU* L.) EN CONDICIONES DE CULTIVO MIXTO

RESUMEN

El cacao (*Theobroma cacao* L.) entró en la India ya en 1798, pero fue sólo a partir de los primeros años de la década de 1960 que se hicieron esfuerzos para cultivarlo como un cultivo agrícola de plantación en el país. Las condiciones ambientales requeridas para el cultivo en gran escala de esa planta como monocultivo son muy limitadas. Como la nuez de areca (*Areca catechu* L.) está cultivándose como cultivo irrigado en el sur de la India, y debido a que las condiciones que existen en esas fincas satisfacen bien a las necesidades del cacao, se comenzaron estudios en 1970 para establecer la viabilidad de cultivar cacao en fincas de nuez de Areca, en el Central Plantation Crops Research Institute, Regional Station, Vittal, India, utilizándose una finca mixta de cacao y areca, en seis densidades de plantación.

Los datos sobre el crecimiento y rendimiento económico de los cultivos fueron registrados periódicamente. La densidad de plantación tuvo efecto sobre el crecimiento, la altura y el perímetro de los árboles de cacao. La relación entre la altura de los árboles de cacao y de nuez de Areca, que era de 1:1 en el momento de plantar pasó a ser de 0,6:1,0 después de siete años. La tasa de cobertura horizontal de los árboles de cacao fue casi uniforme hasta el octavo año. En cuanto de la cobertura del espacio disponible para cada árbol, se observó que el porcentaje de espacio cubierto aumentó con la densidad de plantación, debido sin duda al mayor numero de árboles donde estos fueron plantados más densamente.

En cuanto al rendimiento económico, el espaciamiento influyó marcadamente sobre el número y el peso de las mazorcas por árbol de cacao así como sobre la superficie unitaria. Los resultados indicaron la combinación óptima de especies para obtener un rendimiento máximo. La temporada de cosecha y densidad de árboles influenciaron a las características cuantitativas de las mazorcas y almendras de cacao. Las mazorcas recogidas durante el período del monsón tenían un valor por mazorca más elevado y un peso en almendras inferior comparadas con las mazorcas recogidas durante el resto del período.

INTRODUCTION

INTO India cacao (*Theobroma cacao* L.) is believed to have been introduced more than 200 years ago. According to Watt (1893), cacao was being grown to a limited extent in the 19th century by the Roman Catholic missionaries in Malabar. Ratnam (1961) reported that eight cacao (criollo) seedlings were first introduced in 1798 from the Amboyna Islands of East Indies by the East India Company into the valleys of Courtallam in Madras Presidency (now mostly comprised of Tamil Nadu). Later in 1842, the Board of Revenue, introduced cacao seedlings to Kolli hills of Salem and later into Nilgiris. According to various other accouts also, small introductions of cacao appear to have been made from Sri Lanka and Malaysia and grown mainly in botanic gardens and government farms. However, no serious attempt had been made to establish it as a commercial plantation crop until India attained independence in 1947 when the need for exploring its potentiality was felt. But since areas with the environmental conditions of rainfall, shade, etc., required for large scale cultivation of cacao as monocrop were limited the progress of planting it was not encouraging. Arecanut (*Areca catechu* L.) to a considerable extent and coconut (*Cocos nucifera* L.) on a limited scale are raised as irrigated crops in southern parts of India. The shade, soil moisture and microclimate conditions in these plantations seem to satisfy the requirements of cacao. Trials were therefore begun at Central Plantation Crops Research Institute (CPCRI) to explore the feasibility of raising the crop in mixed cropping with arecanut. Initial success of these attempts are reported by Bhat and Leela (1968) and Bhat and Bavappa (1972). Further results are discussed in this paper.

MATERIALS AND METHODS

An experimental garden with a mixed crop of arecanut (*A. catechu*) and cacao (*T. cacao*) planted in 1970 in a $6 \times 2 \times 4$ confounded asymmetrical factorial design having six different spacings viz., (S_1) both arecanut and cacao at 2.7 m × 2.7 m; (S_2) arecanut at 2.7 m × 2.7 m and cacao at 2.7 m × 5.4 m; (S_3) arecanut at 2.7 m × 2.7 m and cacao at 5.4 m × 5.4 m; (S_4) both arecanut and cacao at 3.9 m × 3.9 m; (S_5) both arecanut and cacao at 3.3 m × 3.3 m and (S_6) arecanut at 1.8 m × 5.4 m and cacao at 3.6 m × 5.4 m and two fertilizer levels viz., (1) both arecanut and cacao at 100 g N, 40 g P_2O_5 and 140 g K_2O and (2) arecanut at 100 g N, 40 g P_2O_5 and 140 g K_2O and cacao at 200 g N, 80 g P_2O_5 and 280 g K_2O per tree per year was utilized for the studies. Cacao seedlings were 12 months old and arecanut seedlings 18 months old at the time of planting. Both the crops were provided with partial shade with palm leaves during first two years. They were irrigated uniformly during the dry weather period (November to April) each year. Growth characters of the trees were recorded annually. Harvesting ripe fruits was made periodically and yield recorded for both the crops from the first bearing. Data on the wet weight of pods, number of beans per pod, wet and dry weights of beans were collected by taking representative samples of pods from each plot during different months of

TABLE 1
Growth of cacao trees (cm)

Treatment spacing	First year		Fifth year				Tenth year			
	Girth	Height	Girth	Height	Spread (SN)	Spread (EW)	Girth	Height	Spread (SN)	Spread (EW)
S_1	5.0	87	32.4	443	413	426	43.4	514	535	531
S_2	4.6	83	33.0	391	434	457	45.7	485	547	647
S_3	5.2	84	33.0	359	407	412	47.9	462	597	602
S_4	4.7	83	33.4	384	419	418	46.7	477	565	589
S_5	4.9	85	33.9	376	415	418	45.9	473	579	576
S_6	4.8	87	34.6	365	426	438	47.2	478	569	625
Mean	4.8	85	33.3	386	419	428	46.1	482	565	595
CD (P = 0.05)				42.5						44.6

TABLE 2
Area covered by the canopy of cacao

Spacing	Area available/ plant (m^2)	Area covered (m^2)				
		2nd year	4th year	6th year	8th year	10th year
S_1	7.29	3.78 (51.9)	8.29 (113.7)	13.82 (189.6)	21.03 (288.5)	22.31 (306.0)
S_2	14.58	3.20 (21.9)	8.27 (56.7)	15.58 (106.9)	22.95 (157.4)	27.75 (190.3)
S_3	29.16	3.27 (11.2)	6.66 (22.8)	13.17 (45.2)	22.48 (77.1)	28.18 (96.6)
S_4	15.21	3.12 (20.5)	6.95 (45.7)	13.76 (90.5)	20.38 (134.0)	26.14 (171.9)
S_5	10.89	3.31 (30.4)	7.31 (67.1)	13.62 (125.1)	22.26 (204.4)	26.19 (240.5)
S_6	19.44	3.53 (18.2)	8.12 (41.8)	14.65 (75.4)	21.40 (110.1)	27.93 (143.7)
Mean		3.36	7.60	14.1	21.8	26.4

Figures in parentheses give the percentage of available space covered.

harvest. Representative samples of arecanut from different seasons were taken, dried and husked and dry weight of kernel (*chali*) recorded. The effect of fertilizers on the performance of the trees is not proposed for presentation in this paper.

RESULTS

Growth habits

Cacao trees: From the data (Table 1) on growth parameters, it is seen that at the time of planting the differences in the heights and girths of plants are not significant. At the fifth year there is significant difference in height, the trees in closest spacing are tallest and those with the widest spacing shortest. In the tenth year also the height of trees under the closest spacing (S_1) is maximum and under the widest spacing minimum and the east-west spread is significantly lowest in closest spacing. The cacao plants which recorded mean height of 85 cm at the time of planting attained a mean height of 482 cm i.e., about 5.7 times the original height in ten years. The difference in the girth of plants planted under different densities is not significant.

The rate of horizontal spread and area covered by the canopy of trees are fairly uniform at different ages irrespective of the densities up to eighth year from planting (Table 2). At the end of tenth year the trees under closest spacing S_1 have comparatively lesser spread than trees with wider spacing. In so far as the space available per tree is concerned, the percentage of area covered increases with the density of planting. Under the closest spacing S_1, 51.9% of the available space is covered within two years and by tenth year the canopy occupies 306.0% of the available space, i.e., only about one-third of the canopy is within its zone and two-thirds of the branches spread far beyond into the adjoining rows. The situation in the widest spacing S_3 is that about 45.2 per cent of the available space is covered only after six years and not fully covered even at the end of ten years.

Arecanut palms: The data (Table 3) on growth (height and girth of stem) parameters of palms show no significant differences in the height and girth of palms at the time of planting. The different densities of planting also have no significant influence on the height of palms at later stages of growth.

The relative heights of arecanut palms and cacao trees at different ages when compared show that the height of arecanut palm is slightly less than or almost on par with cacao plants in the first two years. Thereafter the arecanut palms take a lead. The ratios in the heights remain almost constant (1.0 : 0.6) till the end of the seventh year. Later the arecanut palms grow faster. It is also seen that though the total height of arecanut palms

TABLE 3
Growth of arecanut palms (cm)

Spacing	First year		Fifth year		Tenth year	
	Girth	Height (total)	Girth	Height of stem	Girth	Height of stem
S_1	10.5	165	44.0	231	45.3	626
S_2	10.3	155	45.1	235	45.5	636
S_3	10.4	158	46.0	218	46.7	620
S_4	10.4	160	46.7	237	46.7	618
S_5	10.5	168	45.1	214	45.6	603
S_6	10.6	166	44.8	233	45.1	636
Mean	10.4	162	45.3	228	45.8	623

TABLE 4
Relative heights of arecanut and cacao at different ages

Age of tree (year)	Height of tree* (cm)		Ratio
	Arecanut	Cacao	
1	152	200	1.0 : 1.32
2	265	250	1.0 : 0.94
3	388	286	1.0 : 0.74
4	511	323	1.0 : 0.63
5	635	364	1.0 : 0.57
6	686	416	1.0 : 0.61
7	778	446	1.0 : 0.57
8	870	475	1.0 : 0.55
9	954	496	1.0 : 0.52
10	1039	517	1.0 : 0.50

*From ground level to top of canopy.

is more than that of cacao trees, even in the early years, it is only after five or six years that the entire crown of arecanut palm gets lifted up above the level of cacao canopy (Table 4).

Yield

Cacao: The cacao trees commenced to yield fruits from the second year of planting and assumed to near full capacity from six years. The data (Table 5) on mean yield of pods per year for the period from seventh to eleventh year after planting show that spacing has significant influence on the yield of pods, the widest spacing S_3 giving the maximum and the closest spacing S_1 giving the minimum yield per tree. On hectare basis S_5 recorded maximum yield which is significantly more than all other spacings except S_1. The lowest yield per hectare is under S_3 which is significantly lower than all other spacings.

Regarding seasons of harvests, the crop is available almost throughout the year. On an average 55.1% of the pods is harvested during the south-west monsoon period (from June to September), 16.2% between October and January and the remaining 28.7% between February and May.

The season of harvest and density of plants influenced one or more characters of pods and beans (Table 6). The mean wet weight of a pod harvested in February–March is significantly more than that harvested either in May–June or July. The weight is minimum for May pods. February–March harvests give significantly more number of beans per pod than pods harvested during May, June or July. The wet weight of 100 beans is significantly more for June, July crop, followed by February, March crop and minimum for May harvest. The dry

TABLE 5
Average yield of cacao and arecanut/year (7th to 11th year)

Treatment	Cacao				Arecanut				Combined yield of cacao + areca/ha ('000 kg)
	No. of pods/tree	Wet wt. of pods/tree (kg)	No. of pods/ha ('000)	Wt. of pods/ha ('000 kg)	No. of nuts/palm	Wt. of nuts/palm (kg)	No. of nuts/ha ('000)	Wt. of nuts/ha ('000 kg)	
S_1	38.2	12.9	52.5	17.7	146.4	4.8	200.9	6.6	24.3
S_2	65.0	21.9	44.6	15.0	178.4	5.7	244.8	7.8	22.8
S_3	83.3	26.7	28.6	9.2	222.1	7.0	304.7	9.6	18.8
S_4	61.2	20.7	40.2	13.6	210.2	6.8	138.1	4.5	18.1
S_5	62.5	20.9	57.4	19.2	192.0	6.3	130.6	5.9	25.1
S_6	72.6	25.2	37.3	13.0	188.9	6.0	194.4	6.2	19.2
Mean	63.8	21.4	43.4	14.6	189.7	6.1	210.6	6.8	21.4
CD (P = 0.05)	15.98	5.37	8.34	3.14	45.49		57.52	1.89	3.9

TABLE 6
Influence of Season and density on pod and bean characters

Treatment	February–March		May		June–July		Mean	
	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)
S_1	373	40	298	37	332	36	334	38
S_2	372	38	294	37	338	36	335	37
S_3	346	42	282	35	299	35	309	37
S_4	385	42	305	37	341	36	344	37
S_5	394	41	288	36	335	35	339	38
S_6	390	40	305	38	329	36	341	38
Mean	377	41	295	37	329	36	334	38
CD (P = 0.05) for seasons							14.8	1.4
for spacing							21.0	—

(i) Weight of a pod (g); (ii) Number of beans/pod.

Treatment	February–March			May			June–July			Mean		
	(iii)	(iv)	(v)	(iii)	(iv)	(v)	(iii)	(iv)	(v)	(iii)	(iv)	(v)
S_1	221	96	26	208	95	29	248	87	32	226	93	29
S_2	235	96	28	209	95	29	245	82	35	229	91	31
S_3	228	94	26	218	99	30	227	78	38	224	90	31
S_4	218	91	26	215	99	28	253	86	33	229	92	29
S_5	227	97	25	215	95	30	257	86	33	233	93	30
S_6	245	102	25	229	102	26	252	84	33	242	96	28
Mean	229	96	26	216	97	29	247	84	34	231	92	30
CD (P = 0.05) for seasons										9.7	3.6	1.4
for spacing										—	—	2.0

(iii) Wet weight of 100 beans (g); (iv) Dry weight of 100 beans (g); (v) Pod value.

weight of beans is significantly more for May crop than June, July crop. The mean dry weights of beans of February, March harvests and May do not differ significantly. The pod value (number of pods required to produce one kg of dry beans) is significantly more (34) for June, July crop, followed by May crop (29) and minimum for February, March harvests (26). The influence of density of plants is significant on weight of pod and pod value.

Arecanut: The arecanut palms commenced to yield fruits from the fourth year after planting. The yield per palm differs under different densities. The yield per hectare also differs under different densities. The plots under S_3 spacing recorded significantly more yield than plots under all other spacings except those under S_2 spacing (Table 5).

DISCUSSION

The two perennial crops involved in the study have contrasting above ground morphological characters. Arecanut palm, an important economic garden land crop in India, having tall slender single stem with a raised crown made up of a tuft of leaves has been chosen as a shade tree for the cacao tree with a comparatively short stem but with a much wider branching canopy. The studies made have revealed the much differing architectural and growth pattern of the species involved. Because of the different growth habits of the two species, the distance in the vertical gap between the crown of arecanut palm and the canopy of cacao trees widens as the trees grow. There is thus a possibility of more and more slant rays of sun falling on the canopy of cacao as the age of palms advances. The unfurled umbrella like crown of arecanut palm with its tall slender stem casts uniform shade to the canopy of cacao trees growing underneath.

When the economic yield of cacao is considered, S_5 has the highest yield per hectare. The estimated dry bean yield per hectare is 2,107 kg. The yield compares well with the yield reported from other important cacao growing countries. Alvim (1977) reported that in most producing areas where traditional methods are used the mean yield varies from 300 to 500 kg of dry beans per hectare per year, though with high yielding cultivars and improved cultural practices it is possible to harvest 2,000 to 3,000 kg per hectare per year. Under a situation like this it is the combined yield of component crops that is important than the individual crop yields. The spacing S_5 has recorded the highest combined yield closely followed by S_1 though they are not significantly better than S_2 spacing (Table 5). The arecanut palms are yet to reach the full bearing stage and hence the order of ranking is likely to change in another four or five years.

In assessing the efficiency of multiple cropping Hildebrand (1976) emphasized that the only way to realistically compare the system is by the market value of the produce. Similar approach has been adopted here in assessing the impact of introduction of cacao in arecanut gardens. Since the price of the two commodities are changing often a sliding price scale method has been attempted. The total revenue from different spacing combinations of the component crops under different price situations for cacao (dry beans) and arecanut (dry kernel estimated (Table 7) show that maximum gross revenue per hectare can be expected from S_5 combination until the price of cacao is almost equal to that of arecanut. At 1 : 1 price ratio, the gross revenue from S_1 spacing also equals to that of S_5. When the ratio of cacao and arecanut price reaches to 1.0 : 1.25, the gross revenue is maximum under S_2 spacing. With further increase in price of arecanut and with the price ratio reaching 1.0 : 1.5 and above the gross revenue is maximum at S_3. Thus it is indicated that it is necessary to have some flexibility in selecting a combination in view of the fluctuating prices of the component crops. The normal spacing for arecanut is 2.7 m × 2.7 m. Considering this, as well as the combined yield of the two crops and the revenue expected, it is safe to select either S_1 or S_2 combination, but since the yield difference between these two is not appreciable and in view of the operational advantages combination S_2 is preferable over S_1.

TABLE 7

Total revenue (Rs./ha) from treatment combination under different price situation (on dry weight basis) for cacao and arecanut cacao: Arecanut

Price ratio	S_1	S_2	S_3	S_4	S_5	S_6
1 : 0.25	2.34	2.11	1.58	1.75	2.46	1.79
1 : 0.50	2.73	2.57	2.14	2.02	2.80	2.15
1 : 1.00	3.50	3.49	3.27	2.54	3.50	2.88
1 : 1.25	3.89	3.95	3.84	2.81	3.85	3.24
1 : 1.50	4.28	4.40	4.41	3.07	4.20	3.60
1 : 2.00	5.06	5.32	5.54	3.59	4.90	4.32
1 : 2.50	5.84	6.24	6.67	4.12	5.59	5.05
1 : 3.00	6.62	7.16	7.81	4.64	6.29	5.77
1 : 4.00	8.18	8.99	10.07	5.69	7.69	7.22

Values inside the table has to be multiplied by a "K".
Where K = Value in Rupees for 1,000 kg of cacao (dry beans).

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