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The performance of papaya (*Carica papaya* L.) on application of different growth promoting substances under net house and open condition

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Abstract
An experiment was conducted under insect proof net and open condition the performance of papaya (*Carica papaya* L.) on application of different growth promoting substances under net house and open condition. The experiment was laid out in factorial randomized block design with three replications and twelve treatments. Results indicated that yield attributes such as number of flowers, fruits, average fruit weight and yield were significantly higher in treatment containing, 100% RDF through Fertigation + Trichokavach (50 g/plant) + Chitosan (20 g/plant) + Seaweed extract (20 g/plant) + *Penicillium pinophilum* (20 g/plant) + *Pseudomonas putidda* (4 ml/litre) + Phosphoric acid (20 ml/plant) + Salicylic acid (300 ppm) + Power plus (5 ml/lit) and grown under insect proof net.

Keywords: Papaya, biofertilizers, fertigation, biostimulants

1. Introduction
Papaya (*Carica papaya* L.) belongs to the genus Carica, of the family Caricaceae with 48 species. It is the most cultivated species and commonly called as papaw or paw paw (Australia), mamao (Brazil) and tree melon (China). It is one of the most important fruit crop cultivated in the tropical and subtropical regions of India (Krishna *et al*., 2008) [15]. Papaya is valued for its economic, nutritional, industrial, pharmaceutical and medicinal values, also for local and export markets. The extensive adaptation of this plant and wide acceptance of fruit offer considerable promise as a commercial crop for local and export purposes. Due to its varied uses and development of new high yielding cultivars having medium sized fruits made its cultivation profitable for the farmers. Papaya being a short duration perennial, every growth phase is critical and any biotic and abiotic stress would immediately reflect on the flowering and fruiting of papaya. Papaya is reported to be susceptible to various maladies caused by fungi, bacteria, nematode and viruses. Among them Papaya Ring Spot Virus (PRSV) is a serious threat to papaya cultivation in India and various parts of the world. This disease is observed in almost all the states of India *viz*., Bihar (100%), Maharashtra (3-100%), Karnataka (60%), Kerala (35-66%) and West Bengal (40%) (Yeh *et al*., 2010). The production of papaya is limited by this destructive disease which ultimately limits the large-scale exportation due to this fact, papaya lags behind banana and pineapple in the world market. These problems can be managed to some extent by selection of improved cultivars and growing under protected conditions along with use of biostimulants and biofertilizers. The protected cultivation technology involves certain of nearly optimum environmental conditions for the sustainable growth of plants. This technology, incorporating several intensive and high-tech practices, which serve as an alternative to open field cultivation. It is most contemporary approach of producing high value crops of good quality by alternating biotic and abiotic constraints like insects, diseases, extremes of temperature, rainfall and light intensity. It facilitates the grower to obtain premium prices from their produce. Hence the present study is aimed at growing the papaya under different growing condition and use of integrated nutrient management along with fertigation for controlling PRSV incidence.

2. Materials and Methods
2.1 Experimental site
The experiment entitled “Impact of integrated nutrient management and fertigation on growth

parameters of papaya (*Carica papaya* L.) Cv. Arka Prabhath under different growing condition" was undertaken during 2020-22. The research was conducted at Yelwala, Mysore, Karnataka and the experimental site was located at a latitude of N $12^0$35'90" and longitude of E $76^0$54'31" with an altitude of 770 meters above mean sea level in the Southern Dry Zone (Zone-6). The details of the materials used and methodologies adopted for the study during the investigation are described below.

2.2 Experimental design and treatments

The study was conducted under insect proof net and open field condition, the design opted was FRBD, having twelve treatments with three replications were examined in this study, T_1: 100% RDF of NPK plant^{-1} through soil application+ Micronutrient spray. T_2: NPK is supplied through FYM, Vermicompost, Neem cake. T_3: 75% RDF of NPK plant^{-1} through Fertigation+ Trichokavach (50g/ plant) + Seaweed extract (20g/plant)+ *Penicillium pinophilum* (20 g/ plant). T_4: 75% RDF of NPK plant^{-1} through Fertigation+ Trichokavach (50g/ plant) + Seaweed extract (20g/plant) and spray (0.2%) + *Pseudomonas putidda* (4 ml/litre) + *Penicillium pinophilum* (20g/plant). T_5: 75% RDF of NPK plant^{-1} through Fertigation+ Trichokavach (50g/ plant) + Chitosan (20g/ plant) + *Penicillium pinophilum* (20 g/ plant). T_6: 75% RDF of NPK plant^{-1} through Fertigation+ Trichokavach (50g/ plant) + Chitosan (20g/ plant) and spray (0.1%)+ *Pseudomonas putidda* (4 ml/litre)+ *Penicillium pinophilum* (20g/plant). T_7: 75% RDF of NPK plant^{-1} through Fertigation + Trichokavach (50g/ plant) + Salicylic acid (300ppm) + *Penicillium pinophilum* (20g/plant). T_8: 75% RDF of NPK plant^{-1} through Fertigation + Trichokavach (50g/ plant)+ Phosphoric acid (20 ml/ plant)+ *Penicillium pinophilum* (20 g/ plant). T_9: 75% RDF of NPK plant^{-1} through Fertigation + Trichokavach (50g/ plant) + Power plus (5 ml/ lit) + *Penicillium pinophilum* (20 g/ plant). T_{10}: 100% RDF of NPK plant^{-1} through Fertigation $_+$ Trichokavach (50g/plant) + Chitosan (20g/ plant)+ Seaweed extract (20g/plant)+ *Penicillium pinophilum* (20g/plant)+ *Pseudomonas putidda* (4 ml/litre)+ Phosphoric acid (20 ml/ plant) + Salicylic acid (300ppm) + Power plus (5 ml/ lit). T_{11}: 75% RDF of NPK plant^{-1} through Fertigation $_+$ Trichokavach (50g/plant) + Chitosan (20g/ plant)+ Seaweed extract (20g/plant)+ *Penicillium pinophilum* (20g/plant) + *Pseudomonas putidda* (4 ml/litre)+ Phosphoric acid (20 ml/ plant) + Salicylic acid (300ppm) + Power plus (5 ml/ lit). T_{12}: 50% RDF of NPK plant^{-1} through Fertigation $_+$ Trichokavach (50g/plant) + Chitosan (20g/ plant)+ Seaweed extract (20g/plant)+ *Penicillium pinophilum* (20g/plant) + *Pseudomonas putidda* (4 ml/litre)+ Phosphoric acid (20 ml/ plant) + Salicylic acid (300ppm) + Power plus (5 ml/ lit).

Except treatment T_1 and T_2 rest were applied with Neem cake (250g/ plant) along with VAM (5g/plant), Vermicompost (3kg/ plant) and Micronutrient spray (4 g/plant) in common.

2.3 Raising of seedlings

Arka Prabhath seeds were collected from IIHR, Bengaluru. The seeds were treated with 100 ppm of GA_3 for better germination and it was grown under insect net proof cages for 45 days with proper care to obtain virus free seedlings.

2.4 Growing condition

An insect proof net house of 50 m length, 13 m width and 3.2 m height was constructed using wooden and iron poles. All the sides were covered with insect proof net (40 mesh) for natural ventilation and protection from the pests. Whereas, the plants were grown in the ambient condition without any structure in open field condition.

2.5 Fertilizer application

The fertilizers were applied in shallow rings made around the plant according to root zone of plant and immediately covered with soil. The basal dose of 90 g urea, 250 g SSP and 140 g MOP along vermicompost (3 kg/plant), neem cake (250 g/plant), Trichokawach (50 g/plant), VAM (5 g/plant), and *Pencilium phinophilum* (20 g/plant) were applied to the pits as per the treatment details during land preparation. Rest were supplied through 19:19:19 and the balanced potash was given in the form of MOP (Muriate of Potash). Fertilizers were applied in 30 equal split dose after one month of planting at 15 days interval through drip irrigation.

2.6 Yield parameters

Four plants were selected from each replication for recording observations in each treatment. The yield parameters were recorded at 30 days intervals. Yield attributes such as days taken for first flowering, 50 per cent flowering, days for flowering to fruit maturity, crop duration, number of flowers and fruits, fruit setting percentage, average fruit weight, yield per plant and yield per hectare in papaya were recorded.

3. Results and Discussion

3.1 Days taken for first flowering

The plants grown under insect proof net recorded significantly minimum days taken for first flowering (88.05) and maximum (105.57) was noticed under open condition. Among the treatments the days taken for first flowering was observed significantly minimum in plants treated with T_{10} (88.63) and maximum (103.24) was noticed in T_2. The interaction observed between growing conditions and different growth promoting substances on days taken for first flowering differed non significantly (Table 1).

Table 1: Effect of different growing condition and growth promoting substances on days taken for first flowering and for 50 per cent flowering in papaya

Treatments (T)	Days taken for first flowering		Mean	Days for 50% flowering		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Open condition (G_2)	
T_1	89.90	108.69	99.30	118.67	150.09	134.38
T_2	93.58	112.89	103.24	122.50	150.84	136.67
T_3	86.00	105.45	95.73	108.70	139.47	124.09
T_4	85.92	103.25	94.59	108.33	137.45	122.89
T_5	89.67	106.12	97.90	117.50	148.06	132.78
T_6	89.25	103.20	96.23	115.75	140.01	127.88

T_7	90.58	106.48	98.53	118.67	144.90	131.79
T_8	88.83	105.74	97.29	114.33	143.26	128.80
T_9	88.17	106.67	97.42	110.67	142.35	126.51
T_{10}	80.42	96.83	88.63	102.83	130.25	116.54
T_{11}	83.33	100.75	92.04	107.00	133.68	119.45
T_{12}	91.00	110.78	100.89	121.17	150.12	135.65
Mean	88.05	105.57		113.84	140.71	
	G	T	GXT	G	T	GXT
S.Em ±	0.45	1.12	NS	0.39	0.96	NS
CD@ 5%	1.30	3.20	NS	1.12	2.75	NS

3.2 Days for 50% flowering

The significantly minimum days taken for 50 per cent flowering was recorded in plants grown under insect proof net (113.84) and maximum (140.71) was recorded under open condition. Among the treatment T_{10} (116.54) recorded minimum days taken for 50 per cent flowering which was on par with T_{11} (119.45) and maximum (136.67) was noticed in T_2. Whereas, the interaction was observed non-significant between growing conditions and different growth promoting substances on days taken for 50 per cent flowering (Table 1).

These results are confirmatory with Desai *et al*., 2017 [3], Ganesh, 2017 [5] and Godi *et al*., 2020 [6]. The favourable microclimate that prevailed inside an insect proof net promoted better plant growth *viz*., plant height, girth, number of leaves and leaf area which resulted in early supply of photosynthates to the sink facilitating early opening of bud compared to open condition. The fertigation level at 100 per cent RDF along with biofertilizers, biostimulants and organic manures exhibited early flowering, due to effective utilization and accurate placement of fertilizers in soluble form at the active root zone area resulted in vigorous growth leading to increased C: N ratio which would have promoted early flowering. Similar findings were observed by, Yadav *et al*., 2011 [14], Ibrahim, 2013 [8], Chandra, 2014 [2] and Barros *et al*., 2020 [1].

3.3 Days taken for flowering to fruit maturity

The days taken for flowering to fruit maturity in plants grown under insect proof net and open condition differed none significantly. Among treatments, the minimum days taken for flowering to fruit maturity was observed in T_{10} (140.63) which was statistically at par with T_{11} (142.08), T_4 (143.97), T_9 (143.81) and T_3 (144.29), whereas the maximum (148.61) was noticed in T_2. There was no significant interaction noticed between growing conditions and different growth promoting substances on days taken for flowering to fruit maturity (Table 2).

3.4 Crop duration

The days taken for fruit maturity was recorded significantly minimum in plants grown under insect proof net (233.57) and maximum (250.34) was recorded under open condition. Among the treatments, the minimum days taken for fruit maturity was observed in T_{10} (228.88) which was statistically at par with T_{11} (234.12) and maximum (252.94) was noticed in T_2. The interaction between growing conditions and different growth promoting substances on crop duration was observed no significant (Table 2). The lesser days taken to maturity in fertigation level at 100 per cent RDF along with biofertilizers, biostimulants and organic manures might be due to fact that, the same treatment recorded early flowering and also due to better source to sink relationship of translocation of carbohydrates efficiency to the developing fruits. These results are in accordance with the findings of Shivakumar (2010) [11], Suresh *et al*. (2010) [12] and Yadav *et al*. (2011) [14]. The favourable microclimate that prevailed inside an insect proof net promoted early fruiting compared to open field condition and also early flowering was noticed under protected condition.

Table 2: Effect of different growing condition and growth promoting substances on days taken for flowering to fruit maturity and crop duration of papaya

Treatments (T)	Days for flowering to fruit maturity		Mean	Crop duration		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Insect proof net (G_1)	Open condition (G_2)
T_1	146.25	146.17	146.21	237.99	254.86	246.43
T_2	146.97	150.25	148.61	242.73	263.14	252.94
T_3	144.00	144.58	144.29	231.34	250.03	240.69
T_4	143.52	144.42	143.97	229.52	247.67	238.60
T_5	145.23	144.67	144.95	235.67	250.79	243.23
T_6	145.00	145.00	145.00	234.95	248.78	241.87
T_7	147.00	145.17	146.09	238.75	251.65	245.20
T_8	145.42	145.08	145.25	233.49	250.82	242.16
T_9	144.20	143.42	143.81	232.83	250.09	241.46
T_{10}	140.25	141.00	140.63	220.67	237.08	228.88
T_{11}	142.08	142.08	142.08	225.41	242.83	234.12
T_{12}	146.85	145.50	146.18	239.50	256.28	247.89
Mean	144.73	144.78		233.57	250.34	
	G	T	GXT	G	T	GXT
S.Em ±	NS	1.62	NS	0.97	2.39	NS
CD@ 5%	NS	4.64	NS	2.79	6.84	NS

3.5 Number of flowers (Nos) at 120 and 180 DAP

The plants treated with T_{10} and grown under insect net proof recorded significantly maximum number of flowers (25.36 and 67.25) whereas, the minimum number of flowers (7.01 and 35.69) was recorded in plants treated with T_2 and grown under open field at 120 and 180 DAP respectively (Table 3). The pattern of flowering in papaya plants appears compact as the plant height is restricted under open field condition when compared to protected conditions. This is because internodal length between two leaves is constricted under open condition. Whereas under protected conditions, the plant height is more due to increased internodal length which ultimately leads to more number of flowers (Reddy and Gowda, 2014 and Godi *et al*., 2020) [6]. The results obtained in the present study indicated the maximum number of flowers produced by application of 100 per cent RDF through fertigation along with biofertilizers, biostimulants and organic manures this might be due to, the regular and continues supply of nutrients for longer period aided synthesis and deposition of photo assimilates. This might have increased fruit bud differentiation and induced precocious flowering as well as increased flower production in papaya with significant level. Similar findings were reported by Deshmukh and Hardaha, 2014 [4].

Table 3: Effect of different growing condition and growth promoting substances on number of flowers (Nos) in papaya

Treatments (T)	Number of flowers (Nos) at 120 DAP		Mean	Number of flowers (Nos) at 180 DAP		Mean Open condition(G_2)
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Insect proof net (G_1)	
T_1	19.45	7.50	13.48	54.74	40.12	47.43
T_2	13.25	7.01	10.13	52.30	35.69	43.99
T_3	19.86	9.26	14.56	59.45	43.23	51.34
T_4	23.12	9.85	16.49	61.27	44.00	52.63
T_5	14.36	9.00	11.68	60.31	41.23	50.77
T_6	16.78	9.45	13.12	62.37	42.36	52.36
T_7	18.00	9.00	13.50	56.25	40.45	48.35
T_8	18.25	9.24	13.75	67.48	41.00	54.24
T_9	20.45	8.69	14.57	60.38	40.00	50.19
T_{10}	25.36	11.24	18.30	67.25	55.23	61.24
T_{11}	23.78	10.00	16.89	63.21	50.25	56.73
T_{12}	14.00	7.00	10.50	54.36	38.12	46.24
Mean	18.89	8.94		59.95	42.64	
	G	T	GXT	G	T	GXT
S.Em ±	0.14	0.34	0.48	0.23	0.58	0.82
CD@ 5%	0.40	0.98	1.39	0.67	1.65	2.34

3.6 Number of fruits (Nos)

The plants treated with T_{10} and grown under insect net proof recorded maximum number of fruits (65.36) whereas, the minimum number of fruits (26.45) was recorded in plants treated with T_2 and grown under open field (Table 4).

Table 4: Effect of different growing condition and growth promoting substances on number of fruits (Nos) and fruit setting percentage (%) of papaya

Treatments (T)	Number of fruits (Nos)		Mean	Fruit setting percentage (%)		Mean Open condition (G_2)
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Insect proof net (G_1)	
T_1	45.25	30.39	37.82	72.37	51.79	62.08
T_2	40.25	26.45	33.35	71.05	49.71	60.38
T_3	42.25	30.12	36.19	73.74	63.29	68.52
T_4	45.36	32.85	39.11	76.14	63.63	69.89
T_5	42.95	30.00	36.48	72.53	63.05	67.79
T_6	42.36	32.00	37.18	73.83	61.07	67.45
T_7	40.25	34.25	37.25	77.11	73.86	75.49
T_8	42.58	34.95	38.77	73.16	59.87	66.52
T_9	40.26	33.12	36.69	73.73	60.80	67.27
T_{10}	65.36	40.25	52.81	81.16	69.94	75.55
T_{11}	55.45	36.89	46.17	79.20	64.42	71.81
T_{12}	45.69	28.02	36.86	73.87	52.31	63.09
Mean	45.67	32.44		74.82	61.15	
	G	T	GXT	G	T	GXT
S.Em ±	0.28	0.69	0.97	0.17	0.52	0.72
CD@ 5%	0.80	1.97	2.79	0.49	1.50	2.09

3.7 Fruit setting percentage (%)

The plants grown under insect proof net (74.82%) recorded significantly maximum fruits set percentage and minimum fruits set percentage (61.15%) was recorded under open condition. The fruits set percentage was observed significantly maximum in plants treated with T_{10} (75.55%) and minimum (60.38%) was noticed in T_2. Among interaction, the plants treated with T_{10} and grown under insect net proof recorded maximum fruits set percentage (81.16%) which was on par with T_{11} (79.20%) whereas, the minimum

fruits set percentage (49.71%) was recorded in plants treated with T_2 and grown under open field (Table 4). This might be due to split application of 100 per cent recommended dose of fertilizers along with biofertilizers, biostimulants and organic manures to papaya up to effective fruits pickings favoured to increase growth attributes accompanied with more absorbed photosythentically active radiation reflected in higher photosynthetic rate. These photosynthates were effectively translocated towards fruit formation finally resulted in increase in number of fruit per plant. The combined effect of fertigation, biofertilizers, biostimulants, organic manures and micronutrient spray led to increased development of primary flowers, production of viable flowers with improve pollination which ultimately resulted in higher fruit set percentage. Similar observations were reported by Shivakumar (2010) [11], Suresh *et al*. (2010) [12], Yadav *et al*. (2011) [14] and Tandel *et al*. (2014) [13] in papaya.

3.8 Average fruit weight (g)

The plants grown under insect proof net (1538.96 g) recorded significantly maximum average fruit weight and minimum average fruit weight (1338.60 g) was recorded under open condition. Among treatments, the plants applied with T_{10} (1684.55 g) recorded significantly maximum average fruit weight and minimum (1175.31 g) was noticed in T_2. The interaction between growing conditions and different growth promoting substances on average fruit weight differed significantly. The plants treated with T_{10} and grown under insect net proof recorded significantly maximum average fruit weight (1845.25 g) whereas, the minimum average fruit weight (1025.36 g) was recorded in plants treated with T_2 and grown under open field (Table 5).

Table 5: Effect of different growing condition and growth promoting substances on average fruit weight (g) of papaya

Treatments (T)	Average fruit weight (g)		Mean
	Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)	Insect proof net (G_1)
T_1	1525.20	1170.25	1347.73
T_2	1325.25	1025.36	1175.31
T_3	1589.25	1320.56	1454.91
T_4	1600.89	1489.25	1545.07
T_5	1500.26	1395.25	1447.76
T_6	1559.76	1425.36	1492.56
T_7	1445.10	1365.20	1405.15
T_8	1578.25	1370.25	1474.25
T_9	1500.20	1352.20	1426.20
T_{10}	1845.25	1523.85	1684.55
T_{11}	1645.37	1500.35	1572.86
T_{12}	1352.68	1125.36	1239.02
Mean	1538.96	1338.60	
	G	T	GXT
S.Em ±	4.54	11.13	15.74
CD@ 5%	12.98	31.80	44.97

3.9 Yield per plant (kg)

The plants grown under insect proof net (91.01 kg) recorded significantly maximum yield per plant and minimum yield per plant (48.01 kg) was recorded under open condition. Among the treatments, the significantly maximum yield per plant was observed in T_{10} (100.51 kg) and minimum (46.70 kg) was noticed in T_2. The significant differences were noticed for yield per plant between growing conditions and different growth promoting substances. The plants treated with T_{10} and grown under insect net proof recorded significantly maximum yield per plant (134.01 kg) whereas, the minimum yield per plant (29.15 kg) was recorded in plants treated with T_2 and grown under open field (Table 6).

3.10 Yield per hectare (t): The yield per hectare was recorded significantly maximum in plants grown under insect proof net (227.52 t) and minimum yield per hectare (120.02 t) was recorded under open condition. The significant differences were observed with respect to yield per hectare among the treatments grown under insect proof net and open field. The yield per hectare was observed significantly maximum in plants treated with T_{10} (251.26 t) and minimum (116.75 t) was noticed in T_2. The interaction between growing conditions and different growth promoting substances on yield per hectare differed significantly. The plants treated with T_{10} and grown under insect net proof recorded significantly maximum yield per hectare (335.03 t) whereas, the minimum yield per hectare (72.87 t) was recorded in plants treated with T_2 and grown under open field (Table 6).

Table 6: Effect of different growing condition and growth promoting substances on yield per plant (kg) and yield per hectare (t) of papaya

Treatments (T)	Yield per plant (kg)		Mean	Yield per hectare (t)		Mean
	Growing condition (G)			Growing condition (G)		Open condition (G_2)
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Insect proof net(G_1)	
T_1	76.06	36.22	56.14	190.14	90.54	140.34
T_2	64.26	29.15	46.70	160.64	72.87	116.75
T_3	86.86	47.16	67.01	217.15	117.90	167.53
T_4	100.24	56.82	78.53	250.61	142.06	196.34
T_5	83.84	47.85	65.85	209.58	119.63	164.61
T_6	92.04	52.97	72.51	230.10	132.43	181.27

T_7	82.62	49.52	66.07	206.55	123.81	165.18
T_8	98.80	47.01	72.91	247.01	117.51	182.26
T_9	90.46	46.72	68.59	226.15	116.81	171.48
T_{10}	134.01	67.00	100.51	335.03	167.49	251.26
T_{11}	110.73	59.38	85.06	276.81	148.45	212.63
T_{12}	72.21	36.30	54.26	180.52	90.76	135.64
Mean	91.01	48.01		227.52	120.02	
	G	T	GXT	G	T	GXT
S.Em ±	0.28	0.69	0.98	0.83	2.03	2.87
CD@ 5%	0.81	1.99	2.82	2.37	5.81	8.22

An average fruit weight and yield increased with an application of 100 percent RDF in combination with biofertilizers, biostimulants and organic manures and grown under insect proof net, this might be due to increase in growth parameters, higher nutrient uptake by the plant and also due to the absence papaya ringspot virus (PRSV) incidence in insect proof net resulted in maximum number of harvests with bigger sized fruits. Higher fruit yield in papaya is due to increase in number of fruits and fruit weight per plant. These results elucidate the findings of Suresh *et al*. (2010) [12], Ganesh (2017) [5] and Godi *et al*. (2020) [6] in papaya, Hazarika and Ansari (2010) [7] and Kuttimani *et al*. (2017) [9] in Banana.

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