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Studies on fruit growth pattern in nutmeg

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The developing fruit is a potential sink that derives assimilates from the neighbouring functional leaves. According to Hay and Walkar (1989) the availability of assimilates in the formative stages of economic sink development is an important determinant of yield. The term assimilate partitioning encompasses the biochemical and spatial compartmentation of the fixed carbon within the photosynthesizing cells as well as the subsequent movement of sucrose to the phloem of the minor veins where it is loaded into sieve elements. In this view, fruit growth studies are seldom attempted in tree spices in general and in nutmeg in particular. In the current investigation 30 bearing nutmeg genotypes were investigated for assessing the variability in fruit ontogeny.

The study was conducted on 20 years old seedling nutmeg trees planted as intercrop in coconut plantation on 7.5 x 7.5 m spacing at the Regional Coconut Research Station, Ratnagiri (Maharashtra) (17.00^0 N, 73.40^0 E and 3 m from MSL) during 1999 and 2000. The climate is warm and humid and soil is sandy. Thirty bearing nutmeg genotypes constituted the experimental material. To study fruit development, 50 fruits were tagged immediately after fruit set on all the 30 genotypes. Dry pericarp weight, dry mace weight, dry nut weight and total dry fruit weight were recorded. The observations were recorded at an interval of 25 days upto harvesting. Four fruits were randomly selected each time per test plant to record various observations. The statistical analysis was done by the method suggested by Panse and Sukhatme (1995). Among the genotypes studied, two early (N37, N42), two mid late (N37, N72) and two late (N4, N36) harvested types were selected to estimate polynomial equation. Similarly the polynomial equation of the population mean was also estimated. The polynomial equations were estimated as per the guidelines of Hunt (1982).

The period required from fruit set to harvesting differed among the nutmeg genotypes. It was early (225 days) in N7, N11, N29, N42, N43, N70 and N74. The genotypes N4, N22, N23, N26, N34, N36, N56, N57, and N61 were late where this period was prolonged upto 300 days. Among the other genotypes, N1, N10, N24, N37, N46, N51, N63, N66 and N72 were midlate (250 days), while genotypes such as N30, N33, N41 and N55 were harvested after 275 days of fruit setting.

The dry pericarp weight at various stages of fruit development in nutmeg genotypes are given in Table1.

The polynomial equations of changes in dry weight of pericarp in selected nutmeg types are presented in Table 2.

A second-degree polynomial explained more than 91 per cent variation in dry weight of fleshy pericarp. The following equation described the phenomenon of the growth of fleshy pericarp during the ontogeny of nutmeg fruit.

$$Y \text{ (Pericarp)} = - 1.788 + 0.0592 (X) – 0.000157 (X^2)$$

A small value of intercept was followed by a remarkably high magnitude of 'b_1' indicating a rapid increase in dry weight of pericarp during early phase of fruit growth. A diminutive and negative value of 'b_2' suggested that towards maturity the rate of pericarp growth declined steadily. The genotype N4 was characterized by longest duration of fruit growth (300 days). In comparison with population mean for dry pericarp weight the magnitude of pericarp weight in N4 was lower upto 125 days. But thereafter, it remained higher than the population mean and reached the maximum of 5.83 g after 300 days from setting. The growth of dry fleshy pericarp in this genotypes was explained very satisfactorily even by the first degree

Table 1. Dry pericarp weight (g) at various stages of fruit development in nutmeg

Genotype	Days after fruit set								
	25	100	150	200	250	300	Mean	S.D.	C.V.
N1	0.18	2.98	4.01	4.71	4.17	0	3.20	1.55	48.52
N4	0.13	1.85	4.27	6.13	5.09	5.83	3.63	2.17	59.90
N7	0.28	2.22	3.13	3.92	0.0	0	2.51	1.21	48.00
N10	0.11	2.01	2.33	2.81	2.41	0	1.96	0.88	45.30
N11	0.16	2.15	3.33	3.52	0.0	0	2.41	1.22	50.56
N22	0.08	1.41	3.62	4.19	4.29	4.0	2.89	1.58	54.67
N23	0.17	2.23	3.87	7.19	7.14	7.58	4.58	2.74	59.86
N24	0.13	1.39	4.63	5.37	6.10	0	3.26	2.18	66.91
N26	0.12	1.72	2.70	4.58	5.93	6.23	3.43	2.23	65.17
N29	0.15	2.77	3.50	4.03	0.0	0	2.77	1.38	49.88
N30	0.18	2.75	3.17	3.78	4.06	0	2.98	1.35	45.31
N33	0.11	2.20	2.72	2.99	3.16	0	2.23	1.04	46.81
N34	0.15	2.13	2.98	3.42	4.14	3.94	2.72	1.28	47.24
N36	0.15	2.32	4.21	4.70	5.05	4.10	3.28	1.72	52.51
N37	0.14	1.34	2.81	3.36	4.12	0	2.28	1.46	64.16
N41	0.16	2.49	3.90	5.03	3.95	0	3.04	1.46	48.18
N42	0.18	1.73	2.24	3.54	0.0	0	1.91	1.13	59.43
N43	0.13	1.72	1.85	2.27	0.0	0	1.56	0.71	45.40
N46	0.12	1.88	3.09	3.27	3.80	0	2.34	1.19	51.85
N49	0.15	2.29	2.99	2.82	3.15	0	2.41	1.02	42.27
N51	0.14	1.79	2.49	2.67	2.51	0	2.01	0.91	45.46
N55	0.19	2.00	3.78	4.82	5.57	0	3.30	1.87	56.77
N56	0.21	2.22	3.61	5.24	5.19	4.70	3.43	1.82	53.11
N57	0.32	3.25	4.75	6.15	6.15	6.71	4.32	2.04	47.28
N61	0.12	1.05	2.37	3.58	3.51	3.96	2.41	1.50	62.36
N63	0.19	3.09	4.40	5.67	5.62	0	3.64	1.90	52.25
N66	0.22	3.69	5.27	5.84	6.07	0	3.84	2.22	57.90
N70	0.22	2.43	3.01	3.67	0.0	0	2.36	1.22	51.43
N72	0.09	2.02	2.45	3.13	3.02	0	2.09	1.17	55.93
N74	0.18	2.39	2.43	2.65	0.0	0	2.06	0.94	45.54
Mean	0.16	2.18	3.33	4.17	3.47	1.56			
S.D.	0.05	0.58	0.83	1.22	2.21	2.50			
C.V.	31.88	26.58	25.03	29.19	63.68	159.44			

Table 2. The polynomial equations explaining changes in dry weight of fleshy pericarp during fruit growth of some nutmeg genotypes

Genotype	Polynomial equation	R2
N4 (Late)	Y = - 0.176 + 0.023 (X)	0.86
N36 (Late)	Y = - 1.623 + 0.052 (X) - 0.000106 (X^2)	0.95
N7 (Early)	Y = 0.277 + 0.018 (X)	0.91
N42 (Early)	Y = - 0.248 + 0.017 (X)	0.96
N72 (Mid late)	Y = 0.027 + 0.015 (X)	0.85
N37 (Mid late)	Y = - 0.470 + 0.0149 (X)	0.96
Population mean	Y = - 1.788 + 0.0592 (X) - 0.000157 (X^2)	0.92

polynomial. The magnitude of R^2 for this first-degree polynomial was 0.86. The genotype N7 required the shortest period for fruit development. The magnitudes of dry pericarp weight at all the stages of fruit growth in this genotype were higher than those of the population mean.

The genotype N72 represented a common pattern of growth and development of nutmeg fruit. It required 250 days period of overall growth. On the date of first record (25 days) the pericarp was 0.09 g in weight. There was rapid increase in pericarp weight up to 100 days (2.02 g). In further course of time there was steady increase in pericarp dry weight to reach a value of 3.28 g on 225th day from fruit set.

The population mean for dry weight of pericarp at 25 days after fruit set was 0.16 g as against 0.006 g for nut and 0.001 g for mace (Table 3). Thus, more than 96 per cent portion in the initial stage of growth was comprised of fleshy pericarp. The pericarp grew rapidly upto 100 days from fruit setting to reach a magnitude of 2.18 g and thereafter it grew steadily to reach a value of 4.33 g by 225 days. At this time, the contribution of dry pericarp in total weight of fruit was 49 per cent (Table 3).

The dry nut weight at various stages of development of fruit in nutmeg genotypes is given in Table 4.

The nut development in nutmeg fruit showed different trend than that of pericarp. The average weight of nut produced at 25 days after fruit set was 0.006 g. The nut development was steady upto 150 days from fruit setting when it reached a magnitude of 1.16 g. It grew rapidly thereafter upto 200 days (3.06 g) when its growth became steady subsequently to reach 4.02 g at 225 days. Its share in total weight of fruit was 46 per cent (Table 3).

The polynomial equations of changes in dry nut weight in selected nutmeg type are given in Table 5.

The variation of 93 per cent in dry weight of nut was explained by a third degree polynomial equation. This following equation explained the pattern of nut development during the ontogeny of nutmeg fruit.

$$Y\ (nut) = 1.353 - 0.057\ (X) + 0.000593\ (X^2) - 0.00000134\ (X^3)$$

The nut weight recorded in the late genotype N4 at 25 days after fruit set was 0.004 g which was less than population mean (Table 3). Its magnitude for nut weight remained lower than the population mean upto 225 days after fruit set. Thereafter, it remained higher than the population average and reached 3.98 g at 300 days from fruit set. The first-degree polynomial explained 86 per cent variation in nut development in this genotype. Similar trend of nut development was also noticed in N36 where the fruit development required longer period.

In early genotype N7, the fruit development was quicker than the other genotypes under study (Table 3).

Table 3. Proportion of fruit components at various stages in developing nutmeg fruit

Particulars	Days after fruit set											
	25		100		150		200		250		300	
	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%
Pericarp	0.16	96	2.18	84	3.33	72	4.17	55	3.47	48	1.56	47
Nut	0.006	3	0.35	13	1.16	25	3.06	41	3.19	44	1.48	44
Mace	0.001	1	0.08	3	0.12	3	0.31	4	0.51	8	0.29	9
Total	0.167	-	2.61	-	4.61	-	7.54	-	7.17	-	3.33	-

Table 4. Dry nut weight (g) at various stages of development of nutmeg fruit

Geno-	Days after fruit set								
type	25	100	150	200	250	300	Mean	S.D.	C.V.
N1	0.005	0.64	1.84	3.67	3.81	0.0	1.91	1.59	83.19
N4	0.004	0.10	0.55	1.39	3.53	3.98	1.40	1.54	109.58
N7	0.005	0.71	1.52	4.09	0.0	0.0	1.66	1.57	94.41
N10	0.004	0.72	1.63	2.46	3.67	0.0	1.69	1.44	85.20
N11	0.004	0.66	1.37	2.68	0.0	0.0	1.38	1.35	98.56
N22	0.004	0.10	0.65	2.54	4.62	5.40	2.11	2.11	100.01
N23	0.009	0.13	0.72	3.76	4.71	6.41	2.30	2.38	103.29
N24	0.004	0.13	2.60	5.68	4.90	0.0	2.31	2.29	99.25
N26	0.004	0.09	1.52	2.02	5.35	5.20	2.19	2.24	101.99
N29	0.004	0.71	1.89	4.86	0.0	0.0	1.78	1.86	104.35
N30	0.004	0.51	0.96	4.06	4.59	0.0	2.05	1.92	93.50
N33	0.004	0.40	1.00	2.01	2.95	0.0	1.32	1.17	88.72
N34	0.004	0.32	0.66	1.93	4.90	4.45	1.85	1.88	101.44
N36	0.004	0.22	0.78	2.62	3.54	4.10	1.67	1.56	93.75
N37	0.004	0.13	0.74	3.91	4.44	0.0	1.51	1.76	115.93
N41	0.004	0.46	1.57	2.63	3.61	0.0	1.76	1.39	78.82
N42	0.004	0.22	0.66	4.24	0.0	0.0	1.34	1.68	125.65
N43	0.003	0.45	1.07	2.65	0.0	0.0	1.14	1.11	97.46
N46	0.004	0.18	1.05	3.52	3.78	0.0	1.44	1.55	107.88
N49	0.004	0.57	1.42	2.96	4.28	0.0	1.96	1.68	85.70
N51	0.004	0.28	1.40	1.97	3.73	0.0	1.40	1.33	94.92
N55	0.004	0.13	0.58	1.97	3.96	0.0	1.49	1.66	111.31
N56	0.004	0.15	0.66	1.96	3.96	5.46	1.78	1.93	108.62
N57	0.004	0.50	1.23	3.58	3.63	5.06	2.13	1.80	84.57
N61	0.004	0.06	0.36	1.46	3.97	4.31	1.49	1.73	116.11
N63	0.004	0.08	1.68	3.47	5.10	0.0	1.84	1.89	102.71
N66	0.009	0.49	1.89	4.14	5.66	0.0	2.18	2.27	104.52
N70	0.004	0.49	0.93	3.18	0.0	0.0	1.25	1.32	104.98
N72	0.007	0.55	1.40	3.50	4.75	0.0	1.78	1.64	92.13
N74	0.004	0.76	1.51	2.91	0.0	0.0	1.37	1.28	93.56
Mean	0.006	0.35	1.16	3.06	3.19	1.48			
S.D.	0.007	0.23	0.52	1.02	1.87	2.30			
C.V.	108.63	67.12	44.98	33.19	58.65	155.22			

In this, the nut weight was 0.005 g at 25 days of fruit set as against 0.006 g of population mean. The nut growth was steady upto 150 days (1.52 g) of fruit set there after it grew rapidly upto 200 days (4.09 g) and became steady again to record 4.37 g at the time of harvest. The first-degree polynomial equation explained the nut growth pattern in N7.

Table 5. The polynomial equations explaining changes in dry weight of nut during fruit growth of some nutmeg genotypes

Genotype	Polynomial equation	R^2
N4 (Late)	$Y = - 1.280 + 0.016 (X)$	0.86
N36 (Late)	$Y = - 1.154 + 0.017 (X)$	0.92
N7 (Early)	$Y = - 1.243 + 0.023 (X)$	0.91
N42 (Early)	$Y = 0.656 + 0.025 (X) + 0.00019 (X^2)$	0.94
N72 (Mid late)	$Y = - 1.254 + 0.022 (X)$	0.94
N37 (Mid late)	$Y = - 1.536 + 0.022 (X)$	0.82
Population mean	$Y = 1.353 - 0.057 (X) + 0.000593 (X^2) - 0.00000134 (X^3)$	0.93

In N72, the nut weight was 0.007 g at 25 days from fruit set and increased steadily upto 150 days (1.40 g). The nut development became fast afterwards upto 200 days (3.50 g) and became steady to reach 4.75 g at the time of harvest (246 days). The first-degree polynomial was observed to be the best for this genotype as it explained 94 per cent variation in nut weight during fruit ontogeny. Similar trend of nut development was observed in the early genotype N37.

The dry mace weight at various stages of development of fruit in nutmeg genotypes is presented in Table 6.

The mace development pattern showed a different trend than that of pericarp and mace. The average mace produced by the 30 genotypes under study was 0.001 g at 25 days after fruit set, which was 1 per cent of the total fruit weight. Its proportion was the lowest among the other components viz. nut and pericarp. It gradually increased upto 175 days and thereafter it grew rapidly upto 225 days (0.46 g) and remained afterwards steady to reach 0.51 g at 250 days after fruit set. Its proportion to total fruit at 225 days was 5 per cent.

The polynomial equations of changes in dry nut weight in selected nutmeg type are given in Table 7. A third degree polynomial explained 91 per cent variation in dry weight of mace. The equation below explained the mace development during ontogeny of fruit.

Table 6. Dry mace weight (g) at various stages of fruit development in nutmeg

Geno-	Days after fruit set								
type	25	100	150	200	250	300	Mean	S.D.	C.V.
N1	0.001	0.09	0.18	0.43	0.73	0.0	0.27	0.25	94.89
N4	0.001	0.04	0.13	0.33	0.33	0.74	0.22	0.22	100.00
N7	0.001	0.07	0.14	0.32	0.0	0.0	0.15	0.16	101.42
N10	0.001	0.06	0.13	0.18	0.38	0.0	0.16	0.14	93.47
N11	0.001	0.04	0.07	0.11	0.0	0.0	0.08	0.10	113.75
N22	0.001	0.03	0.14	0.35	0.60	0.82	0.30	0.29	98.63
N23	0.001	0.05	0.15	0.34	0.53	1.78	0.44	0.60	136.10
N24	0.002	0.05	0.22	0.51	1.01	0.0	0.32	0.35	108.38
N26	0.001	0.05	0.10	0.30	1.16	1.15	0.43	0.48	111.34
N29	0.001	0.06	0.09	0.23	0.0	0.0	0.12	0.12	101.96
N30	0.001	0.06	0.12	0.35	0.48	0.0	0.23	0.21	93.53
N33	0.001	0.06	0.11	0.18	0.45	0.0	0.17	0.16	97.69
N34	0.001	0.04	0.10	0.26	0.55	0.60	0.22	0.22	98.43
N36	0.001	0.04	0.11	0.22	0.42	0.81	0.23	0.26	114.22
N37	0.001	0.01	0.06	0.22	0.48	0.0	0.13	0.16	125.22
N41	0.001	0.07	0.18	0.45	0.51	0.0	0.25	0.22	85.56
N42	0.001	0.04	0.09	0.51	0.0	0.0	0.15	0.19	124.24
N43	0.001	0.06	0.10	0.22	0.0	0.0	0.13	0.13	100.29
N46	0.001	0.04	0.14	0.35	0.73	.0	0.22	0.25	113.67
N49	0.001	0.05	0.11	0.25	0.43	0.0	0.19	0.19	99.98
N51	0.001	0.04	0.13	0.17	0.50	0.0	0.16	0.17	110.95
N55	0.001	0.04	0.12	0.23	0.70	0.0	0.25	0.28	112.69
N56	0.001	0.04	0.11	0.34	0.87	1.11	0.35	0.39	110.92
N57	0.001	0.13	0.22	0.41	0.90	0.99	0.39	0.35	89.87
N61	0.001	0.03	0.04	0.14	0.22	0.61	0.18	0.22	119.57
N63	0.001	0.09	0.16	0.37	0.77	0.0	0.26	0.26	102.14
N66	0.002	0.06	0.14	0.36	0.83	0.0	0.23	0.26	113.68
N70	0.001	0.06	0.10	0.26	0.0	0.0	0.14	0.15	107.28
N72	0.002	0.07	0.12	0.31	0.57	0.0	0.18	0.18	99.05
N74	0.001	0.08	0.12	0.22	0.0	0.0	0.13	0.14	105.14
Mean	0.001	0.08	0.12	0.31	0.51	0.29			
S.D.	0.003	0.09	0.04	0.11	0.41	0.48			
C.V.	30.00	113.66	31.10	36.45	80.55	166.38			

Table 7. The polynomial equations explaining changes in dry weight of mace during fruit growth of some nutmeg genotypes

Genotype	Polynomial equation	R^2
N4 (Late)	$Y = - 0.168 + 0.0002 (X)$	0.86
N36 (Late)	$Y = - 0.217 + 0.003 (X)$	0.80
N7 (Early)	$Y = - 0.126 + 0.002 (X)$	0.85
N42 (Early)	$Y = 0.085 - 0.003 (X) + 0.000022 (X^2)$	0.90
N72 (Mid late)	$Y = -0.146 + 0.002 (X)$	0.89
N37 (Mid late)	$Y = 0.075 - 0.002 (X) + 0.00001 (X^2)$	0.99
Population mean	$Y = - 0.157 - 0.006 (X) + 0.0000607 (X^2) - 0.00000012 (X^3)$	0.91

$$Y \text{ (mace)} = 0.157 - 0.006 (X) + 0.0000607 (X^2) – 0.00000012 (X^3)$$

In the late maturing genotype N36, the increase was steady in mace growth upto 250 days (0.42 g) thereafter it was rapid upto 275 days of fruit set (0.73 g) and was steady afterwards to reach a peak at 300 days (0.81g). In N37, the mace growth remarkably increased from 175 days (0.11g) up to harvest (246 days). A second-degree polynomial explained more than 99 per cent variation in dry weight of mace in N37.

Thus, the dry matter accumulation in the three components of fruit showed a peculiar pattern. In the initial 100 days, the fleshy pericarp was a predominant sink (Table 7). The nut became a stronger sink from 125 days onwards and the mace grew steadily throughout the course of fruit ontogeny. About 96 per cent photosynthetic accounted in terms of dry matter was accumulated in fleshy pericarp at 25th day of development. At this stage, the nut derived only 3 per cent dry matter and mace had only 1 per cent biomass in total fruit weight. In further period of time, there was continuous decline in per cent proportion of fleshy pericarp, which was accompanied by a continuous increase in per cent dry matter proportion of nut as well as mace. From 225 days onwards the growth of nut and mace when taken together derived more proportion of dry matter than the pericarp. The trend continued till the maturity of fruit. This suggested that the fleshy pericarp acted as a temporary and primary sink for dry matter which were further contributed for growth of nut as well as mace. Importantly the nut and mace development followed a linear curve in most of genotypes. Of the total weight of fruit 48 per cent was contributed by pericarp, 44 per cent was shared by nut and 8 per cent portion was allocated to mace. The substantially long period for fruit development in nutmeg was also reported by Flach (1966), Nazeem (1979) and Anonymous (1989). Further Nazeem (1979) also reported the slow growth in the later stages of fruit development in nutmeg. Deinum (1949) noticed pericarp to be the major component in nutmeg fruit with its proportion of 77.8 % followed by nut (18.2 %) and mace (4.0 %). Higher proportion of pericarp in nutmeg was also reported by Shanmugavelu and Madhava Rao (1977) and Krishnamoorthy *et al.* (1996). Nutmeg fruit takes long period of 300 days for development. Based on this experimentation, the early and mid late genotypes such as N7, N42, N37and N72 can be recommended for early yield.

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Department of Horticulture,
College of Agriculture,
Dapoli 415 712, Dist. Ratnagiri,
E-mail: parag5663@yahoo.com

P.M. Haldankar[1],
B.M. Jamadagni,
P.C. Haldavnekar,
V.V. Shinde,
D.D. Nagwekar