Annual variation in non-timber forest product yield in the Western Ghats, Karnataka, India

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In the Western Ghats part of Uttara Kannada district in Karnataka, sixteen non-timber forest product species were monitored for yield and yield attributes during the years 1997, 1999 and 2000. Average fruit number per tree was computed and yearly variation in fruit number was compared. Correlation coefficients were computed for yield with its attributes such as girth, crown size and height. Further, the correlation coefficients among yield attributes were also computed.

In most species, there was significant difference in fruit number between years, indicating that most tropical tree species exhibit supra-annual cycle of reproduction. An important observation made was that in most species, the yield between two consecutive years was significantly different. Correlations among various yield attributes indicated that though the coefficients among the yield attributes were consistent, correlation with yield was highly variable, indicating that annual variations may be because of the environmental attributes that influence yield. Therefore, the predictive ability of yield for fruits is difficult.

NON-timber forest products (NTFPs) provide livelihood for millions of rural people who live in and around the forest[1,2]. NTFPs offer considerable potential in the conservation of tropical forests through judicious harvest, and by enhancing rural income and motivating people to conserve their resource base[3–7]. Thus, they have become an important aspect in forest conservation programmes that are aimed at extracting NTFPs in a sustainable way and consequently conserve the forest as well.

Apart from providing rural employment, NTFPs also enhance the chances of forest conservation through value addition. Enhancing rural income through over harvesting of NTFPs may have a negative impact on the regeneration and survival of NTFP species[8–11]. In order to use forests in a sustainable manner, particularly NTFPs, it is important to note that we need data on levels of production, extraction and regeneration[7]. Efforts to make sustainable use of forest products may prove futile, if information on these three parameters is not available beforehand[12]. Thus, it is essential to generate such information. The information may particularly be useful, if the local community undertakes forest management. Estimating the production potential will help in setting a schedule of harvest and level of extraction of products. Further, it is not always easy to estimate the yield through visual means. However, the scheduling of mast fruiting cycles could be made through long-term studies on yield. This may enhance the efficiency of indicating whether the given year would be a high or low-yielding one.

Yield is a highly variable parameter that responds to physiological, genetic and environmental traits. Estimating yield would be of immense practical utility to forest managers and local people, particularly in view of the recent trend in participatory forestry programmes operating in various developing countries. Though it is difficult to estimate the yield through proxy variables that may influence it greatly, this communication attempts to document the variation in yield over the years from species in the Western Ghats. Further, it attempts to develop relations that may exist among the yield and yield attributes, which may have some practical utility.

Uttara Kannada district is the northernmost coastal district of Karnataka. It has a total geographical area of 10,291 km^2 and accounts for 5.4% of the total area of the state. The Western Ghats covers a substantial portion of the district. The hills rise to 600–700 m a msl. The average annual rainfall is 2742 mm; rainfall decreases from the coast towards the hills and thereafter rapidly, further eastward. Total forest cover is 781,600 ha, which accounts for nearly 76% of the total geographical area of the district. The major forest types found here are tropical wet evergreen forest, semi-evergreen forest, moist-deciduous and dry deciduous. The species that were monitored for yield, common name, parts used and their usages are listed in Table 1.

The species described above were visited during the fruit harvest time and the trees were tagged. Girth of tagged trees was measured and recorded. Further, the crown size was estimated by measuring the distance from the tree trunk to the extreme point of branch in four different directions, i.e. north, south, east and west. The average of these four values was used to estimate the crown size using the formula for area of a circle, i.e. πr^2. Height of a tree was classified as *A, B, C*, etc., where *A* is height between 1 and 2 m, *B* is between 2 and 3 m and so on. Measurement of yield on the focal tree was done differently for different species depending on the size of the fruit, colour and position of fruits on the tree. Direct counting was followed when the fruits are conspicuous such as large or bright coloured fruits, e.g. *Artocarpus integrifolia*. Generally, fruit number on the focal tree was estimated by counting the number of fruits on the sample branches. A total of six branches were identified, two each from the top, middle and the bottom of the crown in order to take care of the variation, if any, in the position of branches. Fruits were counted on the tree itself, without

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cutting the branches from the tree. Total number of branches in the tree was counted and the product of average fruit number per branch and total branch number was considered as the total fruit from the tree.

To understand yearly variation in the fruit yield, average fruit yield per tree was computed for each year and compared between years using Student's *t* test, as given in Zar[13]. Further, correlation coefficient between consecutive years for all individuals within a species was computed to see whether any inter-individual variation exists among species for yield. In order to understand the relation between yield and its attributes, i.e. height, crown size and girth, correlation coefficients were computed. Further, the average correlation values for the yield attributes and the correlation of these attributes with yield were also computed to compare the variability, using coefficient of variation.

The features of 16 species selected for the study are given in Table 1. All the trees species selected here are used for their fruit, though in some species, seeds are also used, e.g. *Garcinia cambogea*. All species have commercial value, except *Callophyllum inophyllum* and *Randia spinosa*; these are used extensively by the local people for various purposes.

Table 2 indicates the difference in yield during different years for the 16 species. When yield during two consecutive years is considered, all species showed significant yield differences, except in *A. integrifolia*, *A. lakoocha*, *C. inophyllum*, *Semecarpus anacardium*, *Sapindus emarginata* and *T. chebula*. This pattern suggests that most species may be following supra-annual yield cycles, wherein mast fruiting is observed in some years and lower yield in two inter-mast fruit years. This may also suggest that most tropical trees have an alternating fruit-bearing strategy

Table 1. Species under study, part used and their characteristics

Species	Part used	Characteristics	Number of fruits/kg	
			Fresh	Dry
Artocarpus integrifolia	Fruits, seeds and unripe fruits as vegetable	Tall tree in evergreen forests and cultivated lands	–	–
Artocarpus lakoocha	Fruits, seeds as souring agent	Tall tree in evergreen forests	9	73
Azadirachta indica	Fruits and seeds for medicine, fertilizer and pesticide	Tall tree in deciduous forests and cultivated lands	640	2361
Bassia latifolia	Seeds used for extracting oil	Moderate tree in deciduous forests	72	174
Callophyllum inophyllum	Seed oil is extracted	Moderate tree in evergreen forests	91	167
Emblica officinalis	Fruits, edible pickle and medicine	Medium tree in deciduous and scrub forests	150	636
Garcinia cambogea	Fruits, seeds, edible, fat and medicine	Tall tree in evergreen forests	27	180
Garcinia indica	Fruits, edible, medicinal fat extracted	Moderate tree in evergreen forests	44	275
Garcinia morella	Fruits, seeds as edible oil and medicine	Moderate tree in evergreen forests	167	519
Hydnocarpus wightiana	Seeds–oil	Tall tree in evergreen forests	8	22
Myristica malabarica	Aril as spice and medicine	Tall trees in evergreen forests	9	46
Randia spinosa	Fruits as fish poison	Short tree in deciduous forests	41	108
Sapindus emarginata	Fruits as cleansing agent	Tall tree in moist deciduous and evergreen forests	270	818
Semecarpus anacardium	Fruits as marking nut	Medium tree in deciduous forests	188	606
Syzigium cuminii	Fruits–edible	Tall tree in evergreen and moist deciduous forests	644	2210
Terminalia chebula	Fruits–medicine	Medium tree in deciduous forests	–	–

Table 2. Mean fruit number along with standard error of various species studied during different years (numbers in parentheses indicate sample size)

Species	1997	1999	2000	*t* and *p* values
A. lakoocha (60)		45.74 ± 2.26	79.03 ± 16.85	1.95, $P < 0.054$
A. integrifolia (51)		23.37 ± 4.07	26.55 ± 4.55	0.53, $P < 0.06$
A. indica (60)		4587.70 ± 321.53	1601.45 ± 362.39	2.61, $P < 0.03$
B. latifolia (61)		756.51 ± 184.11	205.87 ± 38.95	2.92, 0.004
C. inophyllum (53)		556.30 ± 131.30	411.39 ± 118.16	0.82, $P < 0.41$
E. officinalis (100)		88.35 ± 26.94	16.96 ± 0.57	2.64, $P < 0.009$
G. cambogea (110)	561.86 ± 79.24	703.95 ± 102.27	1259.34 ± 150.21	1.09, 4.1, 3.05
G. indica (70)	2030.00 ± 485.26	611.19 ± 111.87	666.45 ± 88.42	2.84, 2.86, 7.36
G. morella (51)	1526.45 ± 176.42	488.02 ± 56.18	134.10 ± 22.47	5.6, 7.84, 5.6
H. wightiana (35)	142.97 ± 18.86	64.80 ± 12.93	111.45 ± 22.96	1.06, 1.77, 3.41 (0.001)
R. spinosa (47)		13.83 ± 2.51	99.08 ± 19.08	4.43, 0.0005
S. emarginata (48)		468.75 ± 128.92	383.02 ± 71.04	0.58, $P < 0.56$
S. anacardium (100)	314.68 ± 49.57	317.98 ± 102.38	443.61 ± 73.27	0.029, 1.45, 0.99
S. cuminii (60)		14582.02 ± 2918.08	528.82 ± 148.29	4.8, $P < 0.00002$
T. chebula (81)	489.20 ± 70.85	275.96 ± 38.82	271.85 ± 43.29	2.72, 2.75, 0.07

than fruiting every year. Apart from yield differences during different years, correlation of yield of individuals (Table 3) between two subsequent years showed no consistency in yield in most species. Correlation values for yield are low between years. Among the 14 observations on yield in two consecutive years, only one showed significant correlation, i.e. *Azadarichta indica*. Among the nine observations made between yield of alternate years, only one showed significance (*Hydnocarpus wightiana*). Among the six observations made for a gap of four years, only one showed significant correlation, i.e. *H. wightiana*. These patterns indicate that there exists a high variation among species with respect to the cycles of fruiting. One species has annual fruiting, while the other has supra-annual mast-fruiting patterns. There exists individual variation in fruiting patterns, wherein some have regular fruiting, while others have irregular fruiting patterns.

Under these conditions, it is suggested that while determining the yield using the measurable parameters, it may be better to classify the years as ‘more fruiting’ and ‘less fruiting’ years. This necessitates a long-term study, at least five years consecutively, on the yield and yield attributes in these tropical species in order to develop an equation that suffices estimating yield. *G. indica* that showed high yield during 1997 and lower yield in subsequent years, reinforces our suggestion that the yield pattern should be studied for at least five years before resorting to developing equations for yield. Such a pattern of mast fruiting of different year cycles has been observed in Strobilanthus and Dipterocarp[14] species varying in mast-fruiting year cycles. A chi-square analysis ($\chi^2 = 0.14$, $df = 2$) of this data is non-significant, indicating that the patterns of community-level mast-fruiting may not be prevalent in this part of the world.

The results on multiple regression involving height, crown size and girth with yield indicate that the yield-determining factor is clear only for a few species. For example, in *A. indica*, during both the years, the height and crown size influence the yield positively, with high coefficient of determination or r^2 (Table 4; 0.67 during 1999 and 0.71 during 2000). For all other species, r^2 values were lower than 0.5, except for *Syzigium cuminii*

Table 3. Correlation between yield species of previous years under study

Species (sample size)	Year	R^2	Regression coefficients Intercept (SE) + yield (SE)	*F* value (*P*-value)
A. integrifolia (51)	1999–2000	0.178	15.7 (5.25) + 0.46 (0.14)	10.65 (0.002)
A. lakoocha (60)	1999–2000	0.05	56.94 (20.9) + 0.12 (0.07)	3.02 (0.087)
A. indica (60)	1999–2000	0.71	484.6 (200.6) + 0.2 (0.02)	142.15 (0.000)
B. latifolia (61)	1999–2000	0.06	992.7 (218.00)–1.15 (0.6)	3.69 (0.06)
C. inophyllum (53)	1999–2000	0.099	– 494.5 (377.7) + 18.1 (7.6)	5.58 (0.022)
G. cambogea (110)	1997–99	0.003	588.9 (103.2) – 0.06 (0.1)	0.33 (0.56)
	1997–2000	0.003	1118.9 (174.03) + 0.11 (0.17)	0.37 (0.54)
	1999–2000	0.124	848.0 (159.4) + 0.59 (0.15)	15.22 (0.00017)
G. indica (70)	1997–99	0.35	344.6 (100.9) + 0.13 (0.02)	36.12 (0.000)
	1997–2000	0.24	491.8 (86.5) 0.08 (0.02)	20.8 (0.000)
	1999–2000	0.18	460.4 (97.2) + 0.33 (0.09)	14.4 (0.0003)
G. morella (51)	1997–99	0.23	253.1 (78.5) + 0.15 (0.04)	14.87 (0.0003)
	1997–2000	0.16	55.9 (32.8) + 0.05 (0.02)	9.45 (0.003)
	1999–2000	0.089	75.6 (34.3) + 0.12 (0.05)	4.8 (0.03)
H. wightiana (35)	1997–99	0.41	2.25 (16.42) + 0.44 (0.09)	23.32 (0.000)
	1997–2000	0.30	14.1 (30.98) + 0.66 (0.17)	14.88 (0.0004)
	1999–2000	0.212	56.4 (26.6) 0.8 (0.26)	9.14 (0.004)
M. malabarica (99)	1997–99	0.175	140.2 (3.56) + 0.26 (0.06)	18.96 (0.000)
Phyllanthus emblica (100)	1999–2000	0.132	738.6 (160.7) + 1.33 (0.44)	8.99 (0.004)
R. spinosa (47)	1997–99	0.14	53.99 (20.85) + 0.4 (0.17)	7.84 (0.007)
S. emarginata (48)	1999–2000	0.017	585.3 (263.7) – 0.08 (0.15)	0.25 (0.62)
S. anacardium (100)	1997–99	0.102	144.2 (123.8) + 0.4 (0.17)	5.25 (0.02)
	1997–2000	0.08	320.3 (91.3) + 0.32 (0.14)	4.79 (0.03)
	1999–2000	0.465	301.5 (77.6) + 0.56 (0.1)	33.4 (0.000)
S. cuminii (60)	1999–2000	0.149	681.7 (391.6) + 0.02 (0.01)	4.72 (0.04)
T. chebula (81)	1997–99	0.04	218.5 (57.4) + 0.12 (0.07)	2.47 (0.12)
	1997–2000	0.013	229.98 (62.97) + 0.07 (0.008)	0.7 (0.4)
	1999–2000	0.206	137.4 (48.1) = 0.4 (0.1)	16.37 (0.00014)

that had high r^2 during the year 1999 with contribution from crown size (0.62), *G. indica* ($r^2 = 0.53$) with contributions from crown size and girth and *G. morella* ($r^2 = 0.51$) with contributions from girth. For most species the standard errors of regression coefficients were high indicating that the yield is determined by various factors.

Pairwise correlations among yield attributes, and yield attributes with yield indicate the following (Table 5):

(i) There was no large-scale variation in the correlation coefficients over the years among height, crown size and girth.

(ii) There was large-scale variation in correlation coefficients among the yield attributes with yield.

Average correlation of the yield attributes (0.53) and the yield (0.32) indicated that the relation among attributes is stronger. The correlations of yield attributes with that of yield are significantly different ($t = 6.24$, $P < 2.2 \times 10^{-9}$). Furthermore, the coefficient of variation for correlation among yield attributes was 47.1%, while for correlations of yield it was 73.5%. In conclusion, it is suggested that the observation on yield and yield parameters be continuously monitored for at least five years, for understanding

Table 4. Regression equations for the NTFP species under study using parameters such as height, canopy and DBH of the tree with fruit number in the tree during different years

		Regression equation coefficients					
Species (sample size)	Year	Intercept (SE)	Height (SE)	Crown size (SE)	Girth (SE)	R^2 (adjusted r^2)	SE of *Y* (*F* probability)
A. lakoocha (60)	1999	191.7 (91.8)	4.2 (7.48)	– 1.68 (0.98)	1.18 (2.62)	0.05 (– 0.001)	233.1 (0.41)
	2000	82.4 (52.4)	1.7 (4.2)	– 0.03 (0.55)	– 0.15 (1.46)	0.006 (– 0.004)	1320 (0.94)
A. integrifolia (51)	1999	20.9 (18.5)	– 1.4 (1.9)	0.39 (0.11)	– 0.15 (0.38)	0.27 (0.22)	25.5 (0.0017)
	2000	– 19.5 (18.5)	0.77 (1.85)	0.35 (0.1)	0.37 (0.32)	0.39 (0.36)	25.53 (0.00020)
A. indica (60)	1999	5423.3 (2698.4)	– 1418.1 (574.8)	152.3 (19.3)	60.33 (126.4)	0.67 (0.65)	6046.9 (1.6×10^{-13})
	2000	2637.9 (1550.2)	– 791.8 (330.2)	91.2 (11.1)	51.16 (72.61)	0.71 (0.67)	3473.9 (5.2×10^{-15})
B. latifolia (61)	1999	– 866.1 (465.4)	44.7 (68.9)	14.75 (8.6)	24.5 (27.6)	0.4 (0.36)	1145.8 (2.1×10^{-6})
	2000	211.8 (120.3)	– 42.3 (17.6)	0.63 (2.11)	15.03 (6.98)	0.11 (0.06)	294.4 (0.08)
C. inophyllum (53)	1999	12.1 (10.3)	1.4 (1.6)	4.7 (1.2)	0.006 (0.001)	0.5 (0.47)	10.8 (1.4×10^{-7})
	2000	– 424.9 (807.1)	52.52 (124.8)	– 102.6 (108.8)	17.7 (8.28)	0.096 (0.04)	842.5 (0.17)
G. cambogea (110)	1997	– 420.4 (278.0)	77.3 (21.64)	5.64 (2.7)	– 0.29 (6.16)	0.18 (0.16)	764.2 (7.8×10^{-5})
	1999	– 251.1 (380.5)	– 2.68 (28.98)	2.68 (4.34)	32.43 (8.24)	0.17 (0.13)	881.3 (0.002)
	2000	– 501.4 (442.0)	– 50.2 (36.2)	83.1 (9.8)	83.1 (9.8)	0.43 (0.41)	1162.4 (5.6×10^{-12})
G. indica (70)	1997	– 2038.4(1305.3)	– 279.3 (203.5)	79.8 (36.1)	328.9 (83.1)	0.53 (0.51)	2841.7 (6.6×10^{-11})
	1999	– 169.2 330.2)	– 10.95 (54.5)	38.2 (11.8)	13.6 (27.0)	0.43 (0.40)	712.4 (6.5×10^{-7})
	2000	72.81 (276.8)	48.2 (43.2)	43.7 (9.6)	– 34.1 (21.6)	0.40 (0.37)	573.5 (4.1×10^{-7})
G. morella (51)	1997	– 1013.4 (489.1)	32.28 (53.8)	– 3.1 (10.2)	151.0 (28.1)	0.51 (0.48)	909.4 (2.9×10^{-7})
	1999	– 353.5 (165.3)	32.6 (23.8)	2.6 (3.4)	28.5 (11.3)	0.43 (0.39)	312.2 (6.6×10^{-6})
	2000	– 113.9 (76.8)	7.86 (11.02)	1.3 (1.6)	8.5 (5.3)	0.23 (0.18)	145.0 (0.006)
H. wightiana (35)	1997	– 8.1 (78.4)	1.1 (5.3)	2.3 (0.75)	0.3 (1.0)	0.23 (0.16)	103.5 (0.03)
	1999	41.9 (59.5)	– 4.3 (4.0)	0.36 (0.56)	0.95 (0.75)	0.08 (– 0.005)	77.82 (0.436)
	2000	– 4.5 (99.0)	– 5.1 (6.7)	2.1 (0.94)	1.05 (1.35)	0.17 (0.009)	128.9 (0.112)
M. malabarica (99)	1997	– 97.8 (81.1)	22.1 (6.4)	– 1.99 (1.2)	– 0.27 (4.5)	0.20 (0.18)	275.9 (7.3×10^{-5})
	1999	38.9 (52.3)	– 3.56 (4.1)	– 0.9 (0.92)	9.1 (2.8)	0.14 (0.11)	186.0 (0.004)
P. emblica (100)	1999	– 278.7 (142.9)	– 4.8 (19.4)	32.8 (11.3)	– 5.86 (5.6)	0.18 (0.14)	309.8 (0.009)
	2000	– 474.4 (309.6)	– 37.1 (47.1)	– 2.9 (8.4)	92.1 (25.9)	0.18 (0.16)	951.7 (0.0002)
R. spinosa (47)	1997	7.93 (7.9)	1.75 (2.1)	– 0.08 (0.23)	– 0.09 (0.11)	0.02 (– 0.04)	17.22 (0.76)
	1999	– 101.9 (47.3)	32.7 (12.6)	1.5 (1.4)	– 0.9 (0.7)	0.37 (0.33)	103.2 (6.3×10^{-5})
S. emarginata (48)	1999	– 1074.4 (1440.2)	– 203.9 (269.5)	10.9 (12.1)	37.5 (26.8)	0.22 (0.04)	1044.0 (0.33)
	2000	– 259.7 (298.4)	44.9 (45.0)	0.34 (1.33)	7.68 (5.5)	0.15 (0.09)	468.9 (0.06)
S. anacardium (100)	1997	– 442.3 (130.6)	79.35 (22.6)	4.1 (4.7)	3.4 (8.0)	0.28 (0.26)	425.3 (4×10^{-7})
	1999	– 159.3 (312.4)	60.9 (55.8)	19.6 (12.6)	– 18.1 (22.12)	0.1 (0.04)	694.1 (0.18)
	2000	– 410.6 (188.0)	5.33 (33.8)	28.9 (7.5)	11.5 (13.8)	0.43 (0.4)	428.7 (2×10^{-6})
S. cuminii (60)	1999	– 6656.3 (5250.8)	– 957.7 (708.5)	402.7 (75.1)	302.3 (166.2)	0.62 (0.59)	14340.3 (9.6×10^{-12})
	2000	286.8 (715.2)	– 117.4 (92.3)	9.3 (11.2)	40.9 (32.3)	0.26 (0.17)	1347 (0.006)
T. chebula (81)	1997	– 411.2 (270.1)	– 1.7 (38.25)	4.5 (2.8)	39.4 (6.2)	0.44 (0.41)	441.76 (7.4×10^{-6})
	1999	– 488.0 (126.7)	56.75 (20.5)	1.1 (2.1)	5.7 (1.8)	0.47 (0.45)	260.9 (1.47×10^{-10})
	2000	48.5 (158.2)	– 32.3 (24.7)	– 0.95 (2.62)	7.4 (2.18)	0.24 (0.21)	287.7 (0.0005)

Table 5. Correlation values for the NTFP species under study using parameters such as height, crown size, girth and yield (df, degrees of freedom)

Species	Year	Height and crown size	Height and girth	Height and yield	Crown size and girth	Crown size and yield	Girth and yield
A. integrifolia	1999 (df = 50)	0.32	0.41	0.04	0.69	0.50	0.28
	2000 (df = 50)	0.32	0.46	0.29	0.59	0.61	0.48
A. lakoocha	1999 (df = 66)	0.60	0.66	0.01	0.56	– 0.17	0.00
	2000 (df = 66)	0.60	0.60	0.02	0.53	– 0.05	– 0.00
A. indica	1999 (df = 58)	0.74	0.88	0.42	0.80	0.78	0.54
	2000 (df = 58)	0.74	0.88	0.60	0.80	0.84	0.71
B. latifolia	1999 (df = 59)	0.81	0.84	0.57	0.82	0.61	0.58
	2000 (df = 59)	0.81	0.83	– 0.07	0.82	0.04	0.11
C. inophyllum	1999 (df = 51	0.64	0.42	– 0.04	0.56	– 0.02	0.40
	2000 (df = 51)	0.64	0.41	0.10	0.60	0.08	0.28
G. cambogea	1997 (df = 107)	0.31	-0.04	0.39	– 0.01	0.29	– 0.02
	1999 (df = 107)	0.31	-0.05	0.00	0.03	0.02	0.47
	2000 (df = 107)	0.31	-0.06	– 0.12	– 0.04	– 0.01	0.65
G. indica	1997 (df = 70)	0.39	0.66	0.34	0.72	0.64	0.69
	1999 (df = 70)	0.39	0.66	0.29	0.82	0.65	0.57
	2000 (df = 70)	0.39	0.63	0.27	0.84	0.67	0.45
G. morella	1997 (df = 50)	0.32	0.54	0.43	0.41	0.27	0.71
	1999 (df = 50)	0.32	0.75	0.58	0.31	0.39	0.63
	2000 (df = 50)	0.32	0.75	0.42	0.30	0.25	0.46
H. wightiana	1997 (df = 34)	0.05	0.24	0.27	0.14	0.48	0.13
	1999 (df = 34)	0.05	0.23	– 0.10	0.12	0.13	0.19
	2000 (df = 34)	0.05	0.28	– 0.07	0.12	0.37	0.14
M. malabarica	1999 (df = 98)	0.40	0.76	0.42	0.46	0.02	0.29
	2000 (df = 98)	0.40	0.73	0.18	0.46	0.07	0.34
P. emblica	1999 (df = 98)	0.41	0.63	0.23	0.58	0.17	0.36
	2000 (df = 98)	0.41	0.69	0.24	0.58	0.26	0.41
R. spinosa	1999 (df = 49)	0.80	0.52	0.05	0.53	– 0.00	– 0.08
	2000 (df = 49)	0.80	0.78	0.58	0.83	0.52	0.54
S. emarginata	1999 (df = 46)	0.33	0.60	0.27	0.28	0.31	0.41
	2000 (df = 46)	0.33	0.58	0.33	0.28	0.16	0.36
S. anacardium	1997 (df = 98)	0.61	0.72	0.48	0.61	0.37	0.28
	1999 (df = 98)	0.61	0.80	0.38	0.73	0.36	0.27
	2000 (df = 98)	0.61	0.76	0.41	0.71	0.60	0.36
S. cuminii	1999 (df = 58)	0.73	0.67	0.51	0.71	0.77	0.64
	2000 (df = 58)	0.73	0.72	0.24	0.81	0.41	0.38
T. chebula	1999 (df = 84)	0.57	0.78	0.63	0.52	0.55	0.54
	2000 (df = 84)	0.57	0.98	0.37	0.57	0.15	0.38

the patterns of fruiting in these species. Furthermore, it is also important to understand other environmental parameters such as rainfall, temperature, etc. on the fruit-yielding patterns in these species.

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Studies on levels of glutathione S-transferase, its isolation and purification from *Helicoverpa armigera*

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Helicoverpa armigera **is a polyphagus pest of agricultural importance all over the world. In insects, glutathione S-transferase (GST) provides an important defence mechanism against plant allelochemicals as well as insecticides. The present work has been initiated in lepidoptern pest, *H. armigera* related to GST and its purification, characterization and endosulphan resistance. Spectrophotometrically, GST activity was measured and endosulphan bioassay was done with field-collected *H. armigera* at Akola Central India during August 1998 to March 2000. GST was detected in the eggs; it increased throughout the larval stages and was the highest in two-day-old fifth instar larva. On purification, maximum GST was found in the 70% ammonium sulphate fraction, while by affinity chromatography maximum activity was found in the bound fraction. Electrophoresis resolved only one isozyme having a molecular weight of 30 kDa. It was concluded that GST is responsible for endosulphan resistance, as GST levels and endosulphan resistance pattern were the same.**

GLUTATHIONE S-transferase (GST EC 2.5.1.18) is a family of multifunctional isozymes found in all eukaryotes. One of the main functions of GST is to catalyse xenobiotics, including pesticides in the mercapturic acid pathway leading to the elimination of toxic compounds[1]. In insects, this family of enzymes has been implicated as one of the major mechanisms for neutralizing the toxic effects of insecticides[2–8]. In recent years, the management of *Helicoverpa armigera*, the American bollworm, has become increasingly difficult due to development of resistance to various groups of insecticides, particularly pyrethroids and cyclodyienes[9]. *H. armigera* is an important polyphagous pest of cotton and many other crops of agricultural importance all over the world. In insects, GST provides an important defence mechanism against plant allelochemicals[10] as well as insecticides[11]. Therefore, GST plays an important role in insects. In India, there is little information on insecticide detoxifying enzymes in *H. armigera*. In the present investigation purification, characterization and correlation of GST with cyclodiene and pyrethroids has been studied.

Larvae of *H. armigera* were collected weekly from a range of crops in the farmers'[1] fields within 40 km radius of Akola, Maharashtra during July 1998 to March 2000. Larvae were fed on chickpea-based semisynthetic diet[9]. All rearing procedures were carried out at 27 ± 2°C, relative humidity 78 ± 2% and photoperiod of approximately 13 : 11 light : dark.

The technical grade insecticides, viz. Fenvalerate (976 g kg^{-1}; Sumitomo, Japan), Cypermethrin (900 g kg^{-1} Zeneca Agrochemicals, UK), Endosulphan (Dhanuka Pesticides, Japan) were used for bioassay. 1-Chloro-2,4 dinitrobenzene (CDNB), reduced glutathione (GSH), phenylthiourea (PTU), ethylenediaminetetraacetic acid (EDTA), phenylmethylsulphonyl fluoride (PMSF), Sepharose 4B and all other chemicals were of high purity, and obtained either from Sigma Chemicals, USA; Loba Chemicals, India or Himedia Chemicals, India.

Ten larvae each of first to fifth instar of *H. armigera* were dissected out separately and their midguts were removed. Dissections were carried out with the help of a sterilized dissecting needle in ice-cold sodium phosphate buffer (0.1 M, pH 7.0) containing potassium chloride (11.5 g/l). Fat bodies and food particles were removed from the midguts, which were then homogenized individually in fresh sodium phosphate buffer containing

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