PHYSICO-CHEMICAL CHANGES OF BAEL [Aegle marmelos (L.) Correa] FRUITS OF DIFFERENT CULTIVARS DURING GROWTH AND DEVELOPMENT

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ABSTRACT

The studies were carried out on 20 year old uniform and healthy trees growing at N.D. University of Agriculture & Technology, Kumarganj, Faizabad (U.P.) The branches were tagged on four sides of the tree and experiment was laid out in C.R.D. with three replications. First sampling was done on July and subsequent samples were taken at 30 days interval in NB-4, NB-5, NB-7 and NB-9 after fruit set up to maturity of fruits. The variation in respect of flowering and fruiting was recorded in all the cultivars. It was found that bael fruits followed increasing trend in fruit weight, size, fibre content and mucilage content during growth whereas pulp/skull ratio was initially decreased and then increased and became constant later stage of development. The variation in respect of seed content was recorded in all bael cultivars. The NB-5 cultivar was found superior in respect of less fibre (2.95%), mucilage (3.26%), seed content (106) and with highest (4.69%) pulp/skull ratio. The changes in some bio-chemical constituents like T.S.S., acidity, sugars, ascorbic acid, total phenols and total carotenoids of bael fruits in different cultivars during growth and development. The maximum ascorbic acid (21.75 mg/100g) content and, total carotenoids (37.30 µg/100g) and T.S.S. (30.10%) was recorded in NB-9 with minimum acidity content. The ascorbic acid and total carotenoids was increased with advancement of maturity of fruits in all the cultivars while acidity and total phenols content was decreased in all the cultivars.

Bael fruit [*Aegle marmelos* (L.) Correa] is one of the most important underutilized fruit in India having tremendous commercial potentialities. It is known in India from pre-historic time, Hiuen Tsiang, the Chinese Buddhist pilgrim who came to India in 1629 A.D. noted the presence of this tree along with other trees in this region (Sambamurthy and Subrahmanyam, 1989). Bael is a very hardy tree and can be also grown well in swampy, alkaline or stony soils having p^H range from 5 to 8 and up to an altitude of 1200 meters (Orwa *et al.,*2009). Although it is grown in almost all the states of India yet its cultivation has received great impetus in recent years in Northern part of India due to wide adoptability and ability to withstand drought, low cost of cultivation and high economic returns.

Due to its curative properties it is the most useful medicinal plants of India. It is utilized in day-to-day life in various forms. The fruit have excellent aroma which is not destroyed even during processing. Thus there is untapped potential for its processing into various highly nutritive and therapeutically important products which can be very easily popularized in domestic as well as International markets. Green bael fruits are used for preparing preserve (murabba) and candy which are an important Ayurvedic medicinal products and generally prescribed in all types of digestive troubles. The dried bael fruit is used for the preparation of 'No Caffeine Tea' and in Thailand, *nammatoom* (bael juice) is occasionally taken by Bhuddhist monks as an evening beverage to stave off hunger pains. Keeping in view the medicinal importance and processing potential the present study carried out to know the physical changes and the seasonal changes in biochemical constituents during growth and development.

MATERIALS AND METHODS

The studies were carried out on 20 year old uniform and healthy trees. The branches were tagged on four sides of the tree and experiment was laid out in C.R.D. with three replications. Flowering and fruiting characteristics were observed from May month for physical and July months for bio-chemical and subsequent samples were estimated at 30 days interval in NB-4, NB-5, NB-7 and NB-9 after fruit set up to maturity of fruits. Initiation of flowering, end of flowering, flower colour and size, fruit setting and final fruit retention were observed. Fruit weight was recorded on electronic balance and expressed in gram. Fruit size in term of length and width was measured by vernier callipers. The pulp/skull ratio was calculated by dividing the weight of pulp with the weight of skull. Mucilage content was recorded by dividing mucilage with weight of fruit. The fibre content was also recorded by weight of fibre with fruit weight. The number of seed were separated and counted and the seed content were expressed as number of seeds/fruit. The T.S.S. was estimated at ambient temperature by ERMA made Refractometer (0-32) and these values expressed as per cent T.S.S. The acidity, ascorbic acid and sugars were estimated by methods as described by Ranganna (2010). Total carotenoids content was determined by method as suggested by Sagar and Samuel (2008). The total phenols was estimated by the method described by Singhleton and Rossi, 1965 and Singhleton *et al.*, 1999.

RESULTS AND DISCUSSION

1. **Physical parameters :** The data show that flowering was initiated in the month of May and ended on July. Flower colour was light whitish green with small size in NB-4, dark whitish green with medium size and whitish green in NB-7 and NB-9 while NB-7 was produced large size flower and NB-9 with medium size (Table 1). The maximum fruit setting (21.00%) and final fruit retention (6.50%) was recorded in NB-4 while minimum in NB-7. The variation in all above parameters may be due to morphological and genetical characteristics of cultivars as well as external environment factors. The finding of agreement with Srivastawa and Singh (2000), Orwa *et al.* (2009) and Maity *et al.* (2009) in bael.

The fruit weight was continuous increase during growth and development of bael fruit in all four cultivars. Fruit weight took place in two phases i.e rapid phase from July to October and slow phase from November to February. The fruit weight remained constant after 180 DAFS in all the cultivars (Table 2). The maximum fruit weight was recorded in NB-7. Roy *et al.* (1972) and Kaushik *et al.*(2002) also observed that growth of bael fruit was very rapid initially and thereafter it was very slow.

The fruit size in respect of length and width was increased during growth and development of fruit (Table 3). Fruit length and width increased at faster rate in early stage thereafter it was slow down in all the cultivars. The large size fruit was produce by NB-7 cultivars while small in NB-4. The increase in fruit weight and size due to increase in cell size, intercellular space and accumulation of food substances in the fruit pulp. Baker *et al.* (1951) and Garg *et al.* (1977) also close to the findings.

The pulp/skull ratio was observed that on 30th DAFS, skull was not separable in all the cultivars. It was observed decreasing up to 120 DAFS in all the cultivars and thereafter increased slightly up to 240 DAFS (Table 4). The maximum pulp/skull ratio was recorded in NB-5 (4.69) followed by NB-4 (4.61) on 240th DAFS. The great variability was showed due to morphological and genetical characteristics of bael fruits. The results are similar to findings of Singh *et al.* (1973), Tarsem *et al*. (2007) and Kenghe *et al.* (2009) in bael fruits. The higher pulp/skull ratio is considered to be the desirable characters of the bael fruits.

The fibre content could not be separated on 30th DAFS in all cultivars. The NB-5 contains lowest (2.95%) fibre and the maximum (3.17%) fibre content was found in NB-7 during whole period (Table 5). Fibre content showed increasing trend in all the cultivars with growth and development of fruits. This might be due to the fact that genetical and morphological variability of bael cultivars. The findings is supported by other workers, reports also have observed great variability in fibre content in bael fruits (Roy and Singh, 1978) and (lslam *et al*., 2012). The lesser fibre content is a good character of bael fruits therefore NB-5 fruits were better followed by NB-9.

The fruits containing less mucilage were considered to be better than those containing more mucilage. The mucilage content in all the cultivars showed increasing trend with growth and development (Table 6). On 30th DAFS, mucilage content could not be detected in all the cultivars. The NB-5 was containing lesser mucilage during entire period of growth developments. The mucilage content was increased about 2 fold from 60 DAFS to 240 DAFS in all the four cultivars. This might be due to variation in morphological and genetical traits of cultivars and synthesis of more mucilage when fruits proceed towards maturity. Molla *et al.* (2007) and Hogade *et al*. (2011) also reported increase in mucilage content in bael fruits which are in support of present results on mucilage content.

The seed could not be possible to separate and count on 30th DAFS in all cultivars. The minimum seed content was found in NB-5 (106) on 240th DAFS. The variation in respect of seed content was recorded in bael cultivars (Table 7). The possible reason may be due to morphological and botanical variation in all the cultivars. The finding is supported by Jauhari *et al*. (1969) and Islam *et al*. (2012) who also reported variation in seeds content of bael fruits. The less seeds content is desirable in the bael fruits.

2. **Bio-chemical parameters :** The data on changes in T.S.S. content of bael fruits are presented in Table 8. Data show that T.S.S. content of fruits was increase up to 60 DAFS and then started decreasing up to 120 DAFS thereafter T.S.S. content was started increasing again in all the cultivars up to maturity of fruits. The T.S.S. content was maximum (29.10%) in NB-4 followed by NB-9 (27.20%). The increasing, followed by decreasing and again increasing trend in T.S.S. content during growth and development of bael fruits probably due to difference in rate of accumulation of food materials and hydrolysis of polysaccharides into sugars. Kaushik *el al*. (2002) and Roy and Singh (1978) reported that T.S.S. of bael fruits increased continuously with growth and development which are contradictory to the present finding in which increasing followed decreasing followed by increasing in T.S.S. content was observed in bael fruits.

The per cent acidity content was showed decreasing trend in all the cultivars during growth and development of fruits Table 9. The minimum acidity content was recorded in NB-9 cultivars followed NB-4 during entire period of growth and development. NB-7 was significantly higher in acidity content among all cultivars. The acidity content was minimum on 240 DAFS as compare to 30 DAFS in all the cultivars of bael. The decreasing trend in acidity content might be due to rapid utilization of organic acids and conversion of organic acids into their salts and sugars (Ruffner *et al*., 1975). Significantly variation in acidity content among cultivars could be due to cultivar effects. The findings is supported by other workers who have reported that titrable acidity of fruits was decreased with growth in bael (Kaushik *el al*., 2002) and (Nidhi and Gehlot, 2007).

Data show that reducing sugars, non-reducing and total sugars content was increased in all the cultivars during with the growth and development of fruits (Table 10). The maximum reducing sugars, non-reducing and total sugars content was recorded in NB-9 followed by NB-4 during entire period of observation in comparison to other cultivars. After 240 DAFS, NB-9 was significantly observed to be higher in reducing sugars content in comparison to other cultivars. There was no significant difference in total sugars content among the cultivars on 210 and 240 DAFS. The increase in reducing sugars content of fruits might be due to conversion of starch into sugars during growth and development of fruits. The tendency of increment in non-reducing sugars during growth and development might be due to availability of starch amount to hydrolyze into sugars and the increase in total sugars might be because of increase in reducing and non-reducing sugars resulting from the conversion of starch into sugars and variation may account for the cultivars The results are in line with the findings of Roy and Singh (1978), Mukhopadhyay *et al*. (2002) and Molla *et al.* (2007) in bael fruits.

The data recorded on changes in ascorbic acid content during growth and development of fruits in bael cultivars are presented in Table 11. Data show the significant difference in ascorbic acid content between NB-9 and NB-7. The maximum ascorbic acid was recorded in NB-9 (21.75mg/100g) followed by NB-4 (19.90mg/100g) on 240 DAFS. Overall ascorbic acid content increased in all four cultivars of bael with the growth and development of their fruits up to 240 DAFS. The gradual increase in ascorbic acid content could be associated with the greater synthesis of glucose-6- phosphate, which served as a precursor for its synthesis in fruits (Mapson, 1970). The results are confirmed by Selvaraj *et al*. (1999) who reported that ascorbic acid content increased during fruit maturation and ripening of Guava, similar results are also accordance with the findings of Singh *et al*. (1998) in Kinnow mandarin.

The data on changes in total carotenoids content during growth and development of bael fruits are presented in Table 12. Data show continuous increase in total carotenoids content in all the cultivars during the growth and development of fruits. On 240th DAFS, the total carotenoids content was higher in all the cultivars than initial day of observation; however, NB-9 was significantly higher in comparison to others on 240 DAFS. Increase in total carotenoids might have taken place because of the unmasking of these pigments and conversion of chlorophyll into carotenoids as the fruits approached to maturity. The results are similar to Kaushik and Yamdagni (1999) who reported more than 4 fold increase in carotenoids during fruit maturation in bael fruits. The findings is also supported by similar reports of Singh *et al*. (1998) in Kinnow Mandarin.

Data furnished in Table 13 show that total phenol content was continuously decreased during growth and development of fruits in all cultivars. The maximum total phenol content was observed in NB-9 followed by NB-5 during entire period of growth and development. Total phenol content was higher on 30th DAFS in all the cultivars of bael which was decreased when fruits proceeded towards maturity. The possible reason of decrease in total phenols in fruits might be due to reduction in tannins begun with increase in sugar synthesis and the original acrid taste of fruit diminished. The finding is supported by other workers who have also reported that during growth and development total phenol content decreased in bael fruits Roy and Singh, (1980), Kaushik *et al.* (2000) and in papaya (Abu-Gaukh *et al.*, 2010).

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TABLES

Table 1: Flowering and fruiting characteristics of various cultivars of bael

Cultivars	Initiation of flowering	End of flowering	Flower colour	Flower size (mm)		Fruit setting (%)	Final fruit retention (%)
				Length	Width		
NB-4	25 May	5 July	Light green	10.00	18.00	21.00	6.50
NB-5	23 May	28 June	Dark green	13.00	23.00	15.91	5.08
NB-7	22 May	25 June	Whitish green	16.00	32.00	10.33	3.50
NB-9	21 May	26 June	Whitish green	13.00	24.00	17.08	5.00
SEm±				**0.302**	**0.535**	**0.334**	**0.118**
C.D. at 5%				**0.985**	**1.746**	**1.090**	**0.386**

Table 2: Changes in fruit weight (g) during growth and development of fruits

Cultivars	Fruit weight at different intervals (days)							
	30	60	90	120	150	180	210	240
NB-4	77.00	305.00	800.00	985.00	1020.00	1190.00	1210.00	1220.00
NB-5	50.00	310.00	745.00	1350.00	1380.00	1605.00	1650.00	1665.00
NB-7	80.00	540.00	1700.00	3000.00	3900.00	4020.00	4120.00	4125.00
NB-9	32.00	445.00	1100.00	1720.00	1870.00	2155.00	2200.00	2230.00
SEm±	**1.554**	**9.544**	**25.706**	**36.983**	**56.395**	**64.074**	**57.408**	**54.036**
C.D. at 5%	**5.660**	**31.124**	**83.832**	**120.609**	**183.913**	**208.958**	**187.220**	**176.220**

Table 3: Changes in fruit size (cm) during growth and development of fruits

Treatments	Fruit size at different intervals (days)															
	30		60		90		120		150		180		210		240	
	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
T1 (NB-4)	5.80	4.70	12.00	11.50	12.50	11.90	12.80	12.70	13.10	12.90	13.60	14.00	13.60	14.10	13.65	14.30
T2 (NB-5)	4.50	5.20	12.50	12.00	13.70	11.50	14.30	14.30	14.50	14.50	14.50	15.00	14.60	15.10	14.70	15.10
T3 (NB-7)	5.40	5.10	13.50	15.50	15.20	16.00	19.00	19.00	20.50	21.10	20.60	21.60	21.00	21.80	21.15	21.90
T4 (NB-9)	4.40	3.50	12.50	13.00	13.60	14.00	15.90	15.60	16.00	16.10	16.40	16.50	16.80	17.00	16.85	17.10
SEm±	**0.099**	**0.068**	**0.282**	**0.281**	**0.316**	**0.325**	**0.359**	**0.337**	**0.246**	**0.318**	**0.393**	**0.359**	**0.357**	**0.377**	**0.393**	**0.414**
C.D. at 5%	**0.323**	**0.223**	**0.920**	**0.916**	**1.032**	**1.060**	**1.169**	**1.099**	**0.804**	**1.037**	**1.282**	**1.171**	**1.166**	**1.229**	**1.283**	**1.349**

Table 4: Changes in pulp/skull ratio during growth and development of fruits

Cultivars	Pulp/skull ratio at different intervals (days)							
	30	60	90	120	150	180	210	240
NB-4	Not separable	7.20	6.50	3.00	3.08	4.31	4.39	4.61
NB-5	Not separable	6.90	6.40	3.25	3.50	4.44	4.62	4.69
NB-7	Not separable	8.50	6.90	3.55	3.70	3.96	4.01	4.09
NB-9	Not separable	6.80	5.60	3.45	3.63	4.15	4.17	4.37

SEm±		**0.157**	**0.152**	**0.076**	**0.075**	**0.096**	**0.088**	**0.099**
C.D. at 5%		**0.513**	**0.495**	**0.248**	**0.245**	**0.312**	**0.288**	**0.323**

Table 5: Changes in fibre content (%) during growth and development of fruits

Cultivars	Fibre content at different intervals (days)							
	30	60	90	120	150	180	210	240
NB-4	Not visible	1.89	1.84	2.13	2.35	2.81	2.97	3.05
NB-5	Not visible	1.93	1.90	2.07	2.07	2.70	2.90	2.95
NB-7	Not visible	3.14	2.60	2.91	2.94	2.98	3.03	3.17
NB-9	Not visible	2.25	2.45	2.83	2.79	2.81	2.95	3.02
SEm±		**0.053**	**0.047**	**0.053**	**0.053**	**0.060**	**0.064**	**0.061**
C.D. at 5%		**0.172**	**0.154**	**0.174**	**0.172**	**0.200**	**0.211**	**0.204**

Table 6: Changes in mucilage content (%) during growth and development of fruits

Cultivars	Mucilage content at different intervals (days)							
	30	60	90	120	150	180	210	240
NB-4	Not Measurable	2.28	2.75	2.83	3.35	3.94	4.04	4.30
NB-5	Not Measurable	1.36	2.15	2.23	2.70	3.10	3.16	3.26
NB-7	Not Measurable	1.49	2.35	2.35	2.95	3.68	3.71	3.80
NB-9	Not Measurable	1.87	2.49	2.68	3.17	3.80	3.85	3.90
SEm±		**0.034**	**0.054**	**0.056**	**0.068**	**0.065**	**0.092**	**0.084**
C.D. at 5%		**0.112**	**0.177**	**0.184**	**0.223**	**0.212**	**0.299**	**0.275**

Table 7: Changes in seed content (number) during growth and development of fruits

Cultivars	Seed content at different intervals (days)							
	30	60	90	120	150	180	210	240
NB-4	Not countable	120	119	118	121	121	120	122
NB-5	Not countable	102	108	105	109	108	107	106
NB-7	Not countable	136	140	134	145	139	142	140
NB-9	Not countable	122	123	125	124	124	122	123
SEm±		**2.800**	**2.021**	**2.520**	**3.039**	**2.681**	**2.248**	**2.679**
C.D. at 5%		**9.132**	**6.590**	**8.218**	**9.912**	**8.743**	**7.332**	**8.737**

Table 8: Changes in total soluble solids content (%) during growth and development of fruits

Cultivars	T.S.S. at different intervals (days)							
	30	60	90	120	150	180	210	240
NB-4	28.10	32.10	22.10	19.20	22.10	23.10	27.10	29.10
NB-5	25.10	26.10	20.20	16.20	19.20	20.00	21.20	26.20
NB-7	22.20	28.10	19.20	18.20	20.10	21.00	22.10	24.10
NB-9	30.10	31.20	21.10	14.10	19.00	20.20	22.10	27.20
SEm±	**0.574**	**0.663**	**0.455**	**0.341**	**0.449**	**0.480**	**0.507**	**0.486**
C.D. at 5%	**1.872**	**2.162**	**1.483**	**1.111**	**1.464**	**1.565**	**1.655**	**1.585**

Table 9: Changes in acidity content (%) during growth and development of fruits

Cultivars	Acidity content at different intervals (days)							
	30	**60**	**90**	**120**	**150**	**180**	**210**	**240**
NB-4	0.54	0.51	0.50	0.48	0.46	0.43	0.38	0.35
NB-5	0.58	0.55	0.53	0.51	0.48	0.44	0.39	0.36
NB-7	0.61	0.57	0.54	0.52	0.49	0.45	0.42	0.37
NB-9	0.52	0.50	0.48	0.44	0.42	0.41	0.37	0.33
SEm±	**0.013**	**0.012**	**0.012**	**0.008**	**0.010**	**0.008**	**0.009**	**0.006**
C.D. at 5%	**0.043**	**0.039**	**0.038**	**0.025**	**0.032**	**0.025**	**0.028**	**0.020**

Table 10: Changes in sugars content (%) during growth and development of fruits

Treatments	Sugars content at different intervals (days)											
	30			**60**			**90**			**120**		
	Reducing	**Non-Reducing**	**Total**	**Reducing**	**Non-Reducing**	**Total**	**Reducing**	**Non-Reducing**	**Total**	**Reducing**	**Non-Reducing**	**Total**
T1 (NB-4)	3.10	6.65	9.75	3.75	7.60	11.35	4.00	8.55	12.55	4.65	8.40	13.05
T2 (NB-5)	2.05	6.65	8.70	3.15	6.75	9.90	3.70	7.90	11.60	4.00	7.65	11.65
T3 (NB-7)	2.20	5.70	7.90	3.25	6.60	9.85	3.80	6.65	10.45	4.10	7.20	11.30
T4 (NB-9)	3.15	6.65	9.80	4.00	8.50	12.50	4.20	8.65	12.85	4.90	8.70	13.60
SEm±	**0.060**	**0.146**	**0.206**	**0.070**	**0.162**	**0.239**	**0.096**	**0.155**	**0.197**	**0.101**	**0.182**	**0.247**
C.D. at 5%	**0.196**	**0.475**	**0.672**	**0.229**	**0.530**	**0.779**	**0.312**	**0.504**	**0.642**	**0.330**	**0.592**	**0.807**

Treatments	Sugars content (%)											
	150			**180**			**210**			**240**		
	Reducing	**Non-Reducing**	**Total**	**Reducing**	**Non-Reducing**	**Total**	**Reducing**	**Non-Reducing**	**Total**	**Reducing**	**Non-Reducing**	**Total**
T1 (NB-4)	4.75	8.55	13.30	4.95	8.65	13.60	5.05	9.00	14.05	5.05	9.20	14.25
T2 (NB-5)	4.45	8.25	12.70	4.75	8.40	13.15	4.85	8.80	13.65	4.90	8.95	13.85
T3 (NB-7)	4.55	8.00	12.55	4.80	8.15	12.95	4.90	8.30	13.20	4.95	8.55	13.50
T4 (NB-9)	5.00	8.80	13.80	5.10	8.90	14.00	5.15	9.25	14.40	5.20	9.50	14.70
SEm±	**0.103**	**0.168**	**0.264**	**0.076**	**0.158**	**0.193**	**0.062**	**0.156**	**0.241**	**0.061**	**0.182**	**0.219**
C.D. at 5%	**0.335**	**0.547**	**0.861**	**0.249**	**0.514**	**0.629**	**0.202**	**0.508**	**0.787**	**0.199**	**0.593**	**0.713**

Table 11: Changes in ascorbic acid content (mg/100g) during growth and development of fruits

Cultivars	Ascorbic acid at different intervals (days)							
	30	60	90	120	150	180	210	240
NB-4	10.50	11.00	11.50	12.70	14.65	15.89	18.05	19.90
NB-5	9.70	9.85	10.25	12.05	13.80	15.30	16.90	18.50
NB-7	9.30	9.55	10.10	11.70	13.10	14.00	16.15	17.25
NB-9	11.00	11.20	12.70	13.30	15.00	17.65	19.20	21.75
SEm±	0.203	0.255	0.258	0.272	0.319	0.314	0.388	0.447
C.D. at 5%	0.662	0.831	0.840	0.888	1.041	1.023	1.264	1.457

Table 12: Changes in total carotenoids content (µg/100g) during growth and development of fruits

Cultivars	Total carotenoids at different intervals (days)							
	30	60	90	120	150	180	210	240
NB-4	14.20	14.50	14.90	17.00	20.90	23.10	26.20	30.75
NB-5	14.50	14.80	15.20	18.60	21.10	24.50	29.30	32.50
NB-7	13.00	13.10	13.55	15.20	18.08	20.04	23.90	27.10
NB-9	15.40	16.20	17.50	20.10	24.50	29.20	33.80	37.30
SEm±	0.309	0.280	0.352	0.384	0.498	0.426	0.685	0.742
C.D. at 5%	0.009	0.914	1.147	1.253	1.625	1.390	2.234	2.420

Table 13: Changes in total phenols content (mg/100g) during growth and development of fruit

Cultivars	Total phenols at different intervals (days)							
	30	60	90	120	150	180	210	240
NB-4	71.50	70.00	62.50	57.30	46.70	40.00	35.20	30.80
NB-5	72.60	71.20	63.40	58.00	47.10	42.80	36.00	31.50
NB-7	69.80	65.40	61.00	55.80	42.30	38.00	34.10	28.60
NB-9	74.50	72.50	66.60	59.00	48.60	43.20	38.90	32.40
SEm±	0.706	1.131	1.128	0.605	1.057	0.718	0.813	0.626
C.D. at 5%	2.302	3.687	3.678	1.972	3.448	2.340	2.653	0.042