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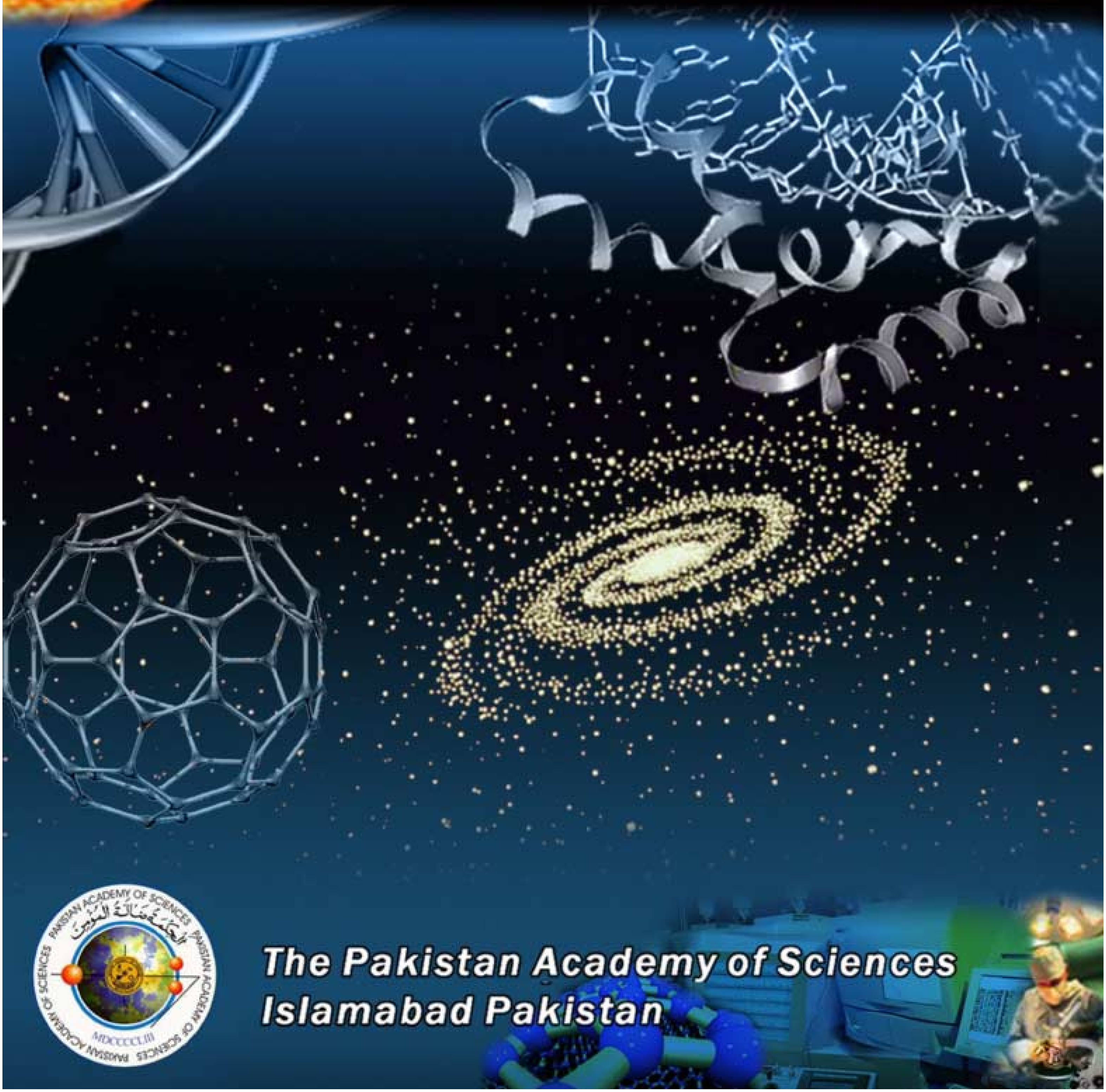

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HERITABILITY AND VARIANCE COMPONENTS OF SOME MORPHOLOGICAL AND AGRONOMIC TRAITS IN ALFALFA (*Medicago sativa* L.)

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Abstract: Four alfalfa cultivars were investigated using randomized complete-block design with three replications. Variance components, variance coefficients and heritability values of some morphological characters, herbage yield, dry matter yield and seed yield were determined. Maximum main stem height (78.69 cm), main stem diameter (4.85 mm), leaflet width (0.93 cm), seeds/pod (6.57), herbage yield (75.64 t ha^{-1}), dry matter yield (20.06 t ha^{-1}) and seed yield (0.49 t ha^{-1}) were obtained from cv. Marina. Leaflet length varied from 1.65 to 2.08 cm. The raceme length measured 3.15 to 4.38 cm in alfalfa cultivars. The highest 1000-seeds weight values (2.42-2.49 g) were found from Marina and Sitel cultivars. Heritability values of various traits were: 91.0% for main stem height, 97.6% for main stem diameter, 81.8% for leaflet length, 88.8% for leaflet width, 90.4% for leaf/stem ratio, 28.3% for racemes/main stem, 99.0% for raceme length, 99.2% for seeds/pod, 88.0% for 1000-seeds weight, 97.2% for herbage yield, 99.6% for dry matter yield and 95.4% for seed yield.

***Keywords*:** Heritability, variance components, alfalfa, *Medicago sativa* L., agronomic traits

Introduction

Methods employed by breeders to improve the productivity and worth of alfalfa, *Medicago sativa* L., are based upon knowledge of the crop's mode of reproduction and genetic structure. Alfalfa is a naturally out-crossing perennial that depends upon bees for pollination. The flower is complete, therefore selfing can occur. In nature, however, the frequency of selfing is usually much less than that of crossing. Limited cross- and self-pollinations can be made easily by the plant breeder. Some plants are self-sterile or self-incompatible, a few are pollen-sterile, and a very few are ovule-sterile. Alfalfa can be propagated by rooted stem cuttings [1].

Alfalfa is a polymorphic species, adapted to many soils and climates. Inherent variation is immense; the introgression of *M. falcata* into *M. sativa* has increased the genetic variation and range of adaptation. Alfalfa is grown extensively in the temperate climates of all continents [1,2]. The alfalfa breeders are concerned with herb and seed yield, hardiness, nitrogen fixation, quality, growth after cutting, longevity, feeding value and other agronomic traits. These attributes exhibit a continuous range of expression and are quantitatively inherited. The expression of quantitative inheritance is also influenced by the environment. The breeders aim to quantify the impact of genetics and environment. To help breeders distinguish between genotype and environmental effects, a heritability value (h^2) can be determined using the ratio of genotypic and phenotypic variation [3,4,5].

The aim of this study was to determine heritability and variance components of agronomic properties in four alfalfa cultivars.

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Materials and Methods

The investigation was carried out in 1999-2002 on clay soil with pH= 7.1 at Tekirda Agricultural Faculty experimental area (41.0°N, 27.5°E) in Trakya University located at about 5 m above sea level and with a typical subtropical climate. The soil where the research was conducted was clay, low in organic matter (1.17%), moderate in phosphorus content (67.4 kg ha^{-1}) but, rich in potassium content (644.4 kg ha^{-1}). The total annual rainfall was 482 mm, 511 mm and 495 mm during the research years. Rainfall was approximately same as the long term (1989-98) mean (444 mm). The monthly average temperature (first year 16.4°C; second year 15.7°C, third year 16.9°C) and relative humidity (first year 85%; second year 88%, third year 87%) means were similar to the long term average (15.5°C; 84%).

Four alfalfa cultivars were used in the study. Cultivar Elçi was obtained from Agricultural Faculty of Ankara University (Turkey). Three cultivars, cv. Bella, cv. Marina and cv. Sitel, were obtained from Barenbrug Research Wolfheze, Netherlands. Plots were 5.0x2.0 m, arranged in a randomized complete-block design with three replicates [6]. Plots consisted of 10 rows, each 5 m in length, with 20-cm spacing between rows. Sowing rate of 1 g m^{-2} was used [7]. Seeds were sown on October 28 in 1999 with a hand-seeder. Measurements were done in 2000, 2001 and 2002. Plots were not irrigated and fertilized after sowing and cutting. Three cuts were taken in each year at full-bloom stage of plants. The cutting height was approximately 8-10 cm above the ground level. Main stem height (cm), diameter of main stem (mm), leaflet width and length (cm), leaf/stem ratio, raceme length (cm), number of racemes per main stem were determined on 10 randomly chosen plants. Seeds/pod and 1000-seeds weight (g) were measured on 10 randomly selected plants, when the pods were mature [8]. Main stem diameter was determined between the fourth and fifth node. Leaflet width and length were measured on the leaf at fifth node. Leaflet width and length were found the terminal leaflet [9]. Herbage yield (t ha^{-1}) was determined 2 m^{-2}, and the yield per hectare calculated. Approximately 500 g samples were dried at 78 °C for 24h to determine dry matter. Yield was calculated as t ha^{-1} [7,10]. When the seeds had matured, (2 m^{-2}) were harvested for seed yield (t ha^{-1}). The results were analyzed using the TAR0ST statistical program [9,11]. Variance components, genotypic variance coefficient (GVC), phenotypic variance coefficient (PVC) and heritability values (h^2) calculated according to the equation given by Comstock and Moll [12] and Orak [13].

Results and Discussion

Results of analyses for the traits investigated are given Table 1. The heritability values (h^2), phenotypic variance (Vp), genotype x year variance (Vgy), genotypic variance (Vg), phenotypic variance coefficient (PVC) and genotypic variance coefficient (GVC) for cultivars are given in Table 2.

Plant height, main stem diameter, stems/plant, leaves/plant, leaf length, leaflet width and length, leaflets/leaf are important traits that are used to estimate herbage yield [9,10]. Marina gave higher values ($P<0.01$) than other cultivars for main stem height (78.69 cm), main stem diameter (4.85 mm), leaflet width (0.93 cm), number of seeds per pod (6.57), herbage yield (75.64 t ha^{-1}), dry matter yield (20.06 t ha^{-1}) and seed yield (0.49 t ha^{-1}) ($P<0.01$). Sengül and Sagöz [14] reported that alfalfa grows to 122 cm; whereas Petkova *et al*. [15] found that the alfalfa grows to 49.6-64.7 cm. The stem height values were lower than those reported by Sengül and Sagöz [14] but similar to those found by Petkova *et al*. [15]. Adaptation and some agricultural characters in alfalfa cultivars were investigated by Dikmen [16]. He determined maximum stem diameter (3.15 mm).Herbage yield and. hay yield ranged between 12.27-18.46 t ha^{-1} and 3.08-5.10 t ha^{-1}, respectively. Avc1olu *et al.* [17] reported 12.68 t ha^{-1} herbage yield and 3.82 t ha^{-1} dry matter yields. The results of herbage and dry matter yield were higher than those reported by Dikmen [16].

Table 1. Some morphological characteristics and herbage, dry matter and seed yield of alfalfa cultivars.

	2000	**2001**	**2002**		**2000**	**2001**	**2002**	
Cultivars	**Main Stem Height (cm)**			**Average**	**Main Stem Diameter (mm)**			**Average**
Marina	78.03	83.23	74.83	78.69**a**	4.85	4.88	4.83	4.85**a**
Sitel	67.75	66.93	68.03	67.57**b**	4.49	4.38	4.37	4.41**b**
Bella	57.40	53.30	53.13	54.61**d**	3.62	3.40	3.11	3.38**c**
Elçi	61.90	59.03	61.77	60.90**c**	3.91	4.09	4.17	4.06**b**
LSD	Cultivars:6.26** Years: ns				Cultivars: 0.38** Years: ns			
Cultivars	**Leaflet Width (cm)**				**Leaflet Length (cm)**			
Marina	0.89	0.94	0.96	0.93**a**	2.19	2.01	2.03	2.08**a**
Sitel	0.80	0.80	0.68	0.76**c**	2.13	1.95	2.03	2.04**a**
Bella	0.71	0.68	0.64	0.67**d**	1.66	1.63	1.66	1.65**b**
Elçi	0.88	0.84	0.85	0.86**b**	1.90	1.91	1.90	1.90**a**
LSD	Cultivars: 0.05** Years: ns				Cultivars: 0.24** Years: ns			
Cultivars	**Leaf/Stem Ratio**				**Number of Racemes per Main Stem**			
Marina	1.22	1.20	1.24	1.22**a**	16.63	16.50	14.34	
Sitel	0.95	1.02	1.02	0.99**b**	13.73	13.80	13.37	
Bella	1.20	1.20	1.18	1.19**a**	12.73	12.30	11.99	
Elçi	1.03	0.91	0.87	0.94**b**	15.13	14.30	14.22	
LSD	Cultivars: 0.14** Years: ns				Cultivars: ns Years: ns			
Cultivars	**Raceme Length (cm)**			**Average**	**Number of Seeds per Pod**			**Average**
Marina	4.33	4.41	4.42	4.38**a**	6.57	6.62	6.53	6.57**a**
Sitel	4.22	4.17	4.22	4.20**a**	5.97	6.10	6.12	6.06**b**
Bella	3.12	3.13	3.19	3.15**b**	3.96	3.98	4.26	4.07**d**
Elçi	4.44	4.24	4.12	4.27**a**	4.80	4.74	4.92	4.82**c**
LSD	Cultivars: 0.23** Years: ns				Cultivars: 0.32** Years: ns			
Cultivars	**1000-seeds Weight (g)**				**Herbage Yield (t ha^{-1})**			
Marina	2.48	2.46	2.53	2.49**a**	70.10	76.58	80.23	75.64**a**
Sitel	2.46	2.39	2.42	2.42**a**	57.70	58.93	61.05	59.23**b**
Bella	1.90	1.96	1.96	1.94**b**	43.25	42.20	41.10	42.18**d**
Elçi	2.02	2.11	2.23	2.12**b**	46.75	46.58	48.27	47.20**c**
LSD	Cultivars: 0.25** Years: ns				Cultivars: 2.83** Years: ns			
Cultivars	**Dry Matter Yield (t ha^{-1})**				**Seed Yield (t ha^{-1})**			
Marina	19.51	20.41	20.25	20.06**a**	0.48	0.49	0.49	0.49**a**
Sitel	16.71	16.91	16.80	16.81**b**	0.41	0.40	0.42	0.41**b**
Bella	13.27	13.05	13.16	13.16**d**	0.30	0.30	0.30	0.30**d**
Elçi	14.67	14.58	14.46	14.57**c**	0.34	0.35	0.34	0.34**c**
LSD	Cultivars: 0.65** Years: ns				Cultivars: 0.03** Years: ns			

** $P<0.01$, ns: $P>0.05$; 0.01

Table 2. Heritability values (h^2) and variance components for some agronomic traits of alfalfa cultivars.

Characters	h^2	Vp	Vgy	Vg	PVC	GVC
Main stem height	0.910	113.630	0.407	103.420	1.74	1.58
Main stem diameter	0.976	0.389	0.001	0.380	9.30	9.10
Leaflet length	0.818	0.044	0.0077	0.036	2.30	1.90
Leaflet width	0.888	0.0134	0.0013	0.0119	1.61	1.40
Leaf/stem ratio	0.904	0.021	0.001	0.019	1.90	1.70
Racemes/main stem	0.283	7.301	5.156	2.065	5.42	1.47
Raceme length	0.990	0.330	0.00067	0.327	8.30	8.20
Seeds/pod	0.992	1.316	0.01	1.306	2.45	2.43
1000-seeds weight	0.880	0.075	0.009	0.066	3.39	2.90
Herbage yield	0.972	225.473	5.414	219.153	4.50	3.91
Dry matter yield	0.996	9.050	0.005	9.022	5.60	5.59
Seed yield	0.954	0.0066	0.00033	0.0063	1.73	1.63

h^2: Board sense heritability value, Vp: Phenotypic variance, Vg: Genotypic variance, Vgy: Genotypic variance x Environmental variance, PVC: Phenotypic variance coefficient, GVC: Genotypic variance coefficient.

Soya *et al*. [18] observed 3-7 seeds/pod and 0.4-1.5 t ha^{-1} seed yield in alfalfa. Seeds/pod and seed yield values were similar to those reported by Soya *et al*. [18]. Leaflet length ranged from 1.65 to 2.08 cm, and highest leaflet length measured was 2.08 cm in Marina, 2.04 cm in Sitel and 1.90 cm in Elçi cultivars (P<0.01). The highest values for the leaf/stem ratio of cultivars were found to be 1.22 and 1.19 in Marina and Bella, respectively. The leaf/stem ratio found by Dikmen [16] was 0.55-0.72.

Numbers of racemes per main stem, raceme length, number of seeds per pod and 1000-seeds weight are important traits that are used to determine seed yield. There were no significant differences among alfalfa cultivars for the number of racemes per main stem. Number of racemes per main stem ranged from 11.99 to 16.63. The raceme length measured 3.15 to 4.38 cm in alfalfa cultivars. Raceme length reported by Soya *et al.* [18] was 1.0-2.5 cm. The highest 1000-seed weight (2.49-2.42 g) was obtained for cv. Marina and cv. Sitel. Aç1kgöz [19] reported similar range of 1000-seed weight (2-3g).

Heritability was low for number of racemes per main stem (28.3%) and leaflet length (81.8%). These traits may be affected by the environment. Broad-sense heritability estimates were relatively high for other characters. These results indicated that these traits were controlled by genetic factors. Our findings are similar to those of Orak [13] and Tekeli and Ates [4,5]. Orak [13] reported heritability values for number of branches, pods/plant and 1000-seeds weight as 87%, 79% and 70%, respectively. Tekeli and Ates [4,5] investigated the heritability and variations of some yield components in Persian clover (*Trifolium resupinatum* L.). They determined a high broad sense heritability value for seeds/head (95.75%). They also reported heritability values for stem height, leaflet length, leaflet width, 1000-seeds weight, herbage and seed yields to be 71.14%, 93.0%, 85.0%, 86.75%, 60.99% and 95.01%, respectively.

Number of racemes per main stem showed a relatively large difference in phenotypic and genotypic variance coefficients, whereas there was little difference in the phenotypic and genotypic variance coefficients for other traits.

The phenotypic variance coefficient was found to range from 1.61-9.30; the highest phenotypic variance coefficients being for main stem diameter (9.30), followed by raceme length (8.30). The highest genotypic variance coefficient was 9.10 for main stem diameter, followed by 8.20 for raceme length, as was the case for genotypic variance coefficients. Traits that showed a comparatively high genotypic variance coefficient may respond favorably to selection [20].

From the results of this investigation, it is concluded that environmental fluctuations have a greater effect on number of racemes per main stem and leaflet length than on other characters. So these factors may be considered as practical selection criteria for improving alfalfa cultivars.

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COMBINING ABILITY ESTIMATES FOR EARLINESS IN COTTON LEAF CURL VIRUS RESISTANT INBRED PARENTS

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Abstract: Four female cotton leaf curl virus-resistant resistant (cclv) parents consisting of advance strains and commercial varieties (VH-137, FH-901, CRIS-467 and Cyto-51) and four male parents, all clcv resistant Punjab varieties (FH-945, CIM-707, CIM-473 and FH-1000) were mated in a cross classification Design-II fashion. The results show that genetic variances due to additive genes were higher than the dominant variances, yet both types of variances were substantial, implying that significant improvement could reliably be made from segregating populations. The general combining ability (gca) estimates by and large suggested that for improvement in the appearance of first white flower and 1st sympodial branch node number, parents FH-945 and VH-137 whereas for 1st effective boll setting, parents FH-1000 and FH-901 and for percent of open bolls at 120 days after planting, parents CIM-707 and CRIS-467 may be given preference. However, for hybrid cotton development regarding earliness, hybrids CRIS-467 x CIM-707, VH-137 x FH-945 and Cyto-51 x FH-1000 may be chosen.

***Keywords*:** Earliness parameters, Design-II analysis, combining ability estimates

Introduction

In cotton breeding, earliness in maturity is an important attribute. Since cotton leaf curl virus resistant varieties are new entries to our cotton germplasm, determining their potentiality in terms of transferring earliness genes from one generation to another is important for designing an effective breeding strategy. Combining ability studies determine the type of genes controlling different earliness characters, thereby predicting the extent of improvement that could be made from the crosses of inbred parents. Earliness in maturity is in cotton as it saves the excessive use of inputs like fertilizer, irrigation and labour. It also saves the crop from late season insect-pest attack. Early maturing varieties fit better in cotton-wheat rotation, thus encouraging intensive cropping system [1].

Earliness is a polygenic trait; hence improvement in such characters primarily depends on progeny performance. In quantitative genetics, only additive genes determine true progeny performance. Dominant genes, on the contrary, are specific to only genotypic value of an individual [2], hence do not contribute to progeny from one generation to an other. Cotton breeders attempt number of crosses among inbred parents so as to determine type of gene actions and also the proportions of genetic variances attributable to additive and dominant genes for different plant characters. Thus, to recognize the potentiality of parents containing types of gene actions, it is imperative to estimate general combining ability (gca) and specific combining ability (sca) of inbred parents regarding different earliness parameters. In the present studies, mating Design-II analysis was applied to estimate the gca and sca effects and their variances for various earliness characters.

Materials and Methods

Four female cotton leaf curl virus-resistant resistant (cclv) parents consisting of advance strains and commercial varieties (VH-137, FH-901, CRIS-467 and Cyto-51) and four male parents, all clcv resistant Punjab varieties (FH-945, CIM-707, CIM-473 and FH-1000) were mated in a cross classification Design-II fashion. Hence 4 x 4 parents were crossed and 16 clcv resistant intrahirsutum hybrids were developed during 2002 crop season. Sixteen F_1 hybrids thus were planted during 2003 crop season in a Randomized Complete Block Design with four repeats. The plot size was 300 x 900 cm where row-to-row and plant-to-plant distances were kept at 75.0 and 22.5cm respectively. Plant to plant space was maintained by thinning after 25 days of planting. Inorganic fertilizers and irrigations were applied in recommended doses as and when required. The data on four earliness traits such as appearance of first white flower taken in number of days, 1st sympodial branch on main stem node number, 1st effective boll setting on sympodial branch number and percent of open bolls after 120 days of planting were recorded.

Results and Discussion

It is important to cotton breeders to know the genetic potential of new inbred parents in terms of transferring their desirable genes, in our case for earliness, from one generation to another. Mating Design-II analysis has been useful in determining general combining ability (gca) and specific combining ability (sca), thereby revealing the type of gene actions controlling different earliness traits in cotton.

The *per se* performance of 16 clcv resistant intrahirsutum F_1 hybrids for four earliness parameters is presented in Table 1. The data suggest that the genotypes differed significantly in producing first white flower where the days taken by the hybrids varied from 42.5 to 47.8. The hybrid CRIS-467 x

Table 1. *Per se* performance regarding earliness traits in intrahirsutum F_1 hybrids obtained from the crosses of cotton leaf curl virus resistant inbred parents.

Hybrids	Days taken to set first white flower	1st sympodial branch node number	1st effective boll setting on sympodial branch number	Percent of open bolls at 120 days after planting (dap)
VH-137 x FH-945	47.5	8.3	11.0	24.0
VH-137 x CIM-707	47.8	8.5	11.0	25.0
VH-137 x CIM-473	44.5	6.5	9.5	20.0
VH-137 x FH-1000	44.5	7.5	11.5	21.0
FH-901 x FH-945	44.3	7.3	11.5	17.0
FH-901 x CIM-707	43.5	6.3	13.3	32.0
FH-901 x CIM-473	42.8	6.5	13.3	35.0
FH-901 x FH-1000	45.0	7.5	14.0	25.0
CRIS-467 x FH-945	45.5	6.5	8.5	29.0
CRIS-467 x CIM-707	46.0	6.5	9.5	57.0
CRIS-467 x CIM-473	42.5	6.0	9.7	56.0
CRIS-467 x FH-1000	43.3	6.5	9.0	22.0
Cyto-51 x FH-945	45.8	6.0	8.5	34.0
Cyto-51 x CIM-707	43.5	6.0	9.5	28.0
Cyto-51 x CIM-473	43.5	6.0	8.0	30.0
Cyto-51 x FH-1000	45.5	8.3	14.3	17.0
Grand mean	**44.7**	**7.3**	**10.8**	**28.5**

CIM-473 took minimum days to flower (42.5) thus being the earliest of all the hybrids where VH-137 x CIM-707 took maximum days (48.5) and was the late flowering hybrids. Rehana [3] studied several earliness characters but observed that days taken to set first white flower is the most reliable indicator of earliness in cotton. The position of 1st sympodial branch on main stem node number is also another important criterion for predicting earliness in cotton. In hybrids *per se*, the 1st sympodial node number varied from 6.0 to 8.5 nodes. However, the lowest sympodial branches (6.0) were produced by the hybrids CRIS-467 x CIM-473, Cyto-51 x FH-945, Cyto-51 x CIM-707 and Cyto-51 x CIM-473, whereas the highest sympodial branches (8.5) were produced by VH-137 x CIM-707. Ahmed and Malik [4] estimated that one node decrease in sympodial branch matures the crop approximately 4 to 7 days earlier. Several other workers [3,5,6] have also noted strong relationship between the earliness and lower sympodial branch node number on the main stem.

Setting of 1st effective boll on sympodial node number ranged from a minimum of 8.0 to a maximum of 14.3 nodes formed by the hybrids Cyto-51 x CIM-473 and Cyto-51 x FH-1000, respectively. The maximum percent of bolls opening in a specified period of time also determines the earliness in maturity. The *per se* hybrid performance showed that the range of open bolls varied from 17.0 to 57%. CRIS-467 x CIM-707, which had 57% open bolls after 120 days of planting, can be regarded as the earliest maturing hybrid. In later stages of crop development, it has been suggested by Gody [7] that percent of open bolls provides a reliable criterion of earliness. The hybrid performance *per se* as a whole thus revealed that all the four parameters of earliness were generally correlated and favoured one hybrid over the other simultaneously. Based on hybrid performance *per se*, it was observed that, generally, the parents CRIS-467, Cyto-51, CIM-473 and CIM-707 formed good combinations with other parents regarding most of the earliness parameters.

Cotton breeders generally predict that parents that perform well in hybrids *per se* also perform similarly for general combining ability (gca) and certainly for specific combining ability (sca) effects. However, this type of prediction does not always hold true as reported by Baloch *et al.* [8,9,10]. These controversial results have thus warranted cotton breeders to carry out analysis for determining gca and sca effects and genetic variances thereby referring to the type of genes present in the inbred parents and also their functioning for various characters. For this reason, Cross Classification Design-II analysis was carried out.

The mean squares of hybrids (Table 2) for all the four earliness traits were significant allowing further partitioning of this source of variation due to male parents (it determines gca), female parents (it also determines gca) and male x female interactions (determines sca)(Table 3). The mean squares for all these three sources of variations were declared significant. Surprisingly, for all the four traits (i.e., appearance of first white flower, 1st sympodial branch node number, 1st effective boll setting on sympodial node number and percent of open bolls at 120 days after planting), the proportions of variances due to gca (either for male or females) were greater than the variances due to sca implying greater importance of additive genes and their variances against the dominant genes and their variances. These results further reveal that selection in segregating generation would bring substantial improvement in earliness traits. However, sca being significant for all the traits further suggests that both additive as well as dominant genes control the earliness characters and are equally important in the present study. Thus hybrid cotton development regarding earliness could also be useful to cotton breeders.

The mean squares as such do not provide precise information about the extent to which the

Table 2. Cross Classification Design-II analysis for various earliness characters in upland cotton.

Source of variation	Degrees of Freedom	Mean Squares			
		Days taken for first white flower	1st Sympodial branch node number	1st effective boll setting on sympodial branch number	Percent of open bolls at 120 days after planting (dap)
Crosses	15	9.916**	3.067**	16.800**	35.333**
Male (gca)	3	17.516**	3.875**	17.208**	49.792**
Female (gca)	3	14.433**	5.375**	42.542**	63.792**
Male x Female (sca)	9	5.877**	2.028**	8.083**	21.030**
Error	45	0.238	0.281	1.33	2.803

**Significant at 1% probability level.

Table 3. Proportionate contribution of males, females and their interaction to total variance.

Contributing factors	Days taken to 1st flowering	1st sympodial branch node no.	1st effective boll setting on symp. branch no.	% open bolls (120 days of planting)
Percent contribution of male	35.3	25.3	20.5	28.2
Percent contribution of female	29.1	35.1	50.6	36.1
Percent contribution of male x female	35.6	39.7	28.9	35.7

individual parents possess the additive and dominant genes. In this regard, estimation of gca and sca effects of each parent separately is very useful to cotton breeders. The gca and sca effects are presented in Tables 4 and 5, respectively. Among the female parents, CRIS-467 and Cyto-51, which generally formed good combinations in hybrids *per se*, surprisingly gave negative effects for all the four traits except CRIS-467, which expressed maximum (2.875) gca effect for percent of open bolls after 120 days of planting. However, VH-137 and FH-901 were poor combiners as *per se* hybrids recorded the best gca effects for first white flower (1.359) and 1st sympodial branch node number (0.813) for VH-137 and 1st effective boll setting (2.250) in case of FH-901. Among the male parents, CIM-473 which was good combiner in hybrids *per se*, performed very poorly for gca effects. In fact, it gave negative effect for three of the four earliness traits, excepting percent of open bolls (1.438) for which it ranked next. It was only the parent CIM-707 which was good in hybrids *per se*. It also performed well in gca effects, except negative effect (-0.063) for 1st effective boll setting on sympodial node number. In contrast, parents FH-945 and FH-1000 which were poor in *per se* hybrid combinations gave positive gca effects for first white flower (1.047) and 1st sympodial node number (0.125) in case of male parent FH-945 and 1st sympodial branch node number (0.563) and 1st effective boll setting (1.438) in case of male parent FH-1000. From the gca effects, it can generally be concluded that the parents did not perform exactly as did the hybrids *per se* and for gca effects as expected. It is for this reason that we studied the gca and sca effects of the parents instead of relying on hybrid performance *per se*. Thus, it appears from the results that the choice of parents should be based on priority to earliness traits. Baloch *et al*. [11,12] and Tunio *et al*. [13] have suggested that parental choice for gca be based on the character to be improved as none of the parents could simultaneously be better for many characters.

Table 4. General combining ability estimates of cotton leaf curl virus resistant inbred parents for various earliness parameters in upland cotton.

Male parents	Days taken for first white flower	1st sympodial branch node number	1st effective boll setting on sympodial branch number	Percent of open bolls at 120 days after planting (dap)
FH-945	1.047	0.125	-0.875	-0.875
CIM-707	0.487	-0.063	0.063	1.500
CIM-473	-1.391	-0.625	-0.625	1.438
FH-100	-0.141	0.563	1.438	-2.063
General mean	**44.7**	**7.30**	**10.8**	**28.50**
S.E. (gi)	**0.122**	**0.133**	**0.289**	**0.419**
S.E. (gi-gj)	**0.172**	**0.187**	**0.408**	**0.592**
Female parents				
VH-137	1.359	0.813	0.000	-1.750
FH-901	-0.828	0.000	2.250	-0.563
CRIS-467	-0.391	-0.500	-1.563	2.875
Cyto-51	-0.141	-0.313	-0.688	-0.563
General mean	**44.70**	**7.30**	**10.80**	**28.50**
S.E. (gi)	**0.122**	**0.133**	**0.289**	**0.419**
S.E. (gi-gj)	**0.172**	**0.187**	**0.408**	**0.592**

Table 5. Specific combining ability estimates of cotton leaf curl virus resistant inbred parents for various earliness characters in upland cotton.

Hybrid	Days taken for First white flower	1st sympodial branch node number	1st effective boll setting on sympodial branch number	Percent of open bolls at 120 days after planting (dap)
1. VH-137 x FH-945	0.391	0.438	1.125	1.250
2. VH-137 x CIM-707	1.203	0.875	0.188	-0.875
3. VH-137 x CIM-473	-0.172	-0.563	-0.625	-2.063
4. VH-137 x FH-1000	-1.422	-0.750	-0.688	1.688
5. FH-901 x FH-945	-0.67	0.250	-0.625	-1.688
6. FH-901 x CIM-707	-0.859	-0.563	0.188	-0.313
7. FH-901 x CIM-473	0.266	0.250	0.875	0.500
8. FH-901 x FH-1000	1.266	0.063	-0.438	1.500
9. CRIS-467 x FH-945	0.141	0.000	0.188	-2.125
10. CRIS-467 x CIM-707	1.203	0.188	0.250	2.500
11. CRIS-467 x CIM-473	-0.375	0.250	1.188	2.313
12. CRIS-467 x FH-1000	-0.875	-0.438	-1.625	-2.688
13. Cyto-51 x FH-945	0.141	-0.688	-0.688	2.563
14. Cyto-51 x CIM-707	-0.547	-0.500	-0.625	-1.313
15. Cyto-51 x CIM-473	0.328	0.063	-1.438	0.688
16. Cyto-51 x FH-1000	1.078	1.125	2.750	-0.500
Grand mean	**44.7**	**7.3**	**10.8**	**28.5**
S.E. (Si.)	**0.244**	**0.450**	**0.577**	**0.837**
S.E. (Sij-sik)	**0.345**	**0.375**	**0.816**	**1.184**

It is generally believed that the parents' hybrid combination *per se* mostly but not always reflects sca effects. Such prediction also holds true in our case. The three best hybrids *per se* i.e., CRIS-467 x CIM-707, CRIS-467 x CIM-473 and Cyto-51 x CIM-473, also gave higher and positive sca effects for all the traits simultaneously. However, hybrids superior in terms of sca effects for various earliness traits were: FH-901 x FH-1000 for first white flower, Cyto-51 x FH-1000 for both 1st sympodial node number and 1st effective boll setting and Cyto-51 x FH-945 for percent of open bolls at 120 days after planting.

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A STUDY OF CHANGING PATTERNS OF MORTALITY PEAKS, OVER THE CENTURIES, AMONG MONARCHS AND PRESIDENTS IN SOME COUNTRIES

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Abstract: As a follow-up of earlier studies on peaks of mortality in various samples of humans, a detailed study has been made of the change in the patterns of these mortality peaks over the centuries in: Monarchs of England and Presidents of U.S.A. The data from England cover 9 centuries, while those from U.S.A. cover two centuries. The data on Monarchs of England shows that, while the peaks are fixed at ages of 67 ± 1, 58 ± 1, 48 ± 1 and 34 ± 1 (with a small peak modify these above and below these), the position of the highest peak has been shifted, steadily, to higher ages over the centuries, being currently in the region of 70 and 80 years. The data on the presidents of U.S.A., extending over 2 centuries, generally confirm this conclusion, but with the 67 and 86 years peaks apparently shifted up by 4 years, and reveals two further peaks around 90 and 100 years. This is apparently linked with better health-care & nutrition and is in line with the conclusion of J.F. Fries (1980) that present approaches to social interaction, promotion of health and personal autonomy may postpone many of the phenomena usually associated with aging. The data on the nine Mughal Kings of India (1500-1850), when analyzed exhibits a similar pattern of peaks, but with 2 pairs of large peaks at 48, 57 years and 77 ± 2, 88 years, in contrast to the single high peak at 68 ± 2 years. It is hoped to study this separately, in comparison with other data e.g. from Central Asia.

Keywords: Aging, British Monarchs, American Presidents, Moghul Kings

Introduction

The subject of aging and consequent mortality in humans is of considerable interest to all communities. According to J.F. Fries [1] the present approaches to social interaction, promotion of health and personal autonomy may postpone many of the phenomena usually associated with aging. In a recent series of papers, the present authors [2,3,4] and other workers [4,5,6] have attempted, through careful statistical analysis, to bring out several facts:

(i) there are a series of peaks of mortality in the regions of 34, 45, 55, 65, 76 and 86 years, where mortality is several times higher than in the periods in between (see Figs. 1a and b for two samples [3,4] from different sources),

(ii) The first four of these series of peaks are associated with various killer diseases, while the last two largely correspond to progressive degeneration of one or more organs of the human body [5,6],

(iii) Various samples exhibit the peaks at essentially the same ages, but with varying relative heights.

In the present study, an attempt is made first to analyze a sample composed of the monarchs of England extending over 9 centuries, with a view to generally confirming the above findings under (i), while amplifying those under (ii) and (iii) as far as possible. A corresponding sample from U.S.A. (first 36 Presidents 1750-1994) and then one from the East is also studied for comparison. Some of the results of the comparisons between England and USA are found remarkable.

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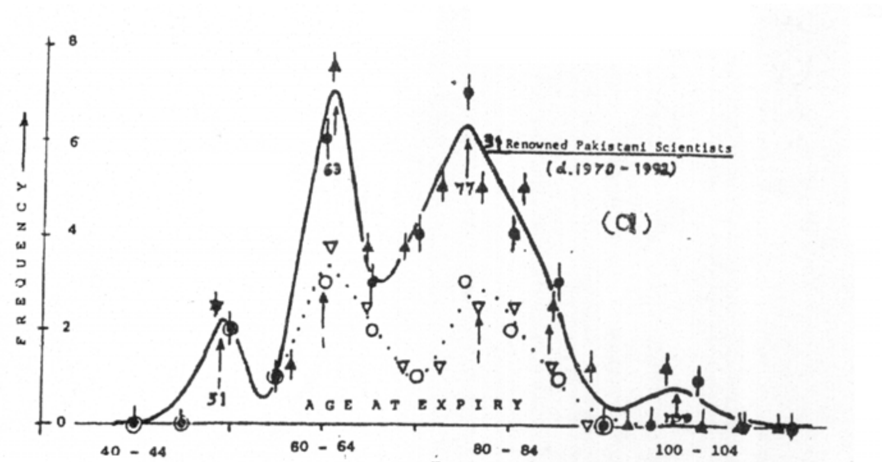

Figure 1 (a). Frequency distribution of life-span (age at expiry) of the sample of 31 renowned Pakistani scientists (solid line). Stability of the distribution can be gauged from comparison with the dotted-line curve (open circles and triangles)for the half sample (d. 1970-81): The circles and triangles are for sampling at 5 and 4 year intervals.

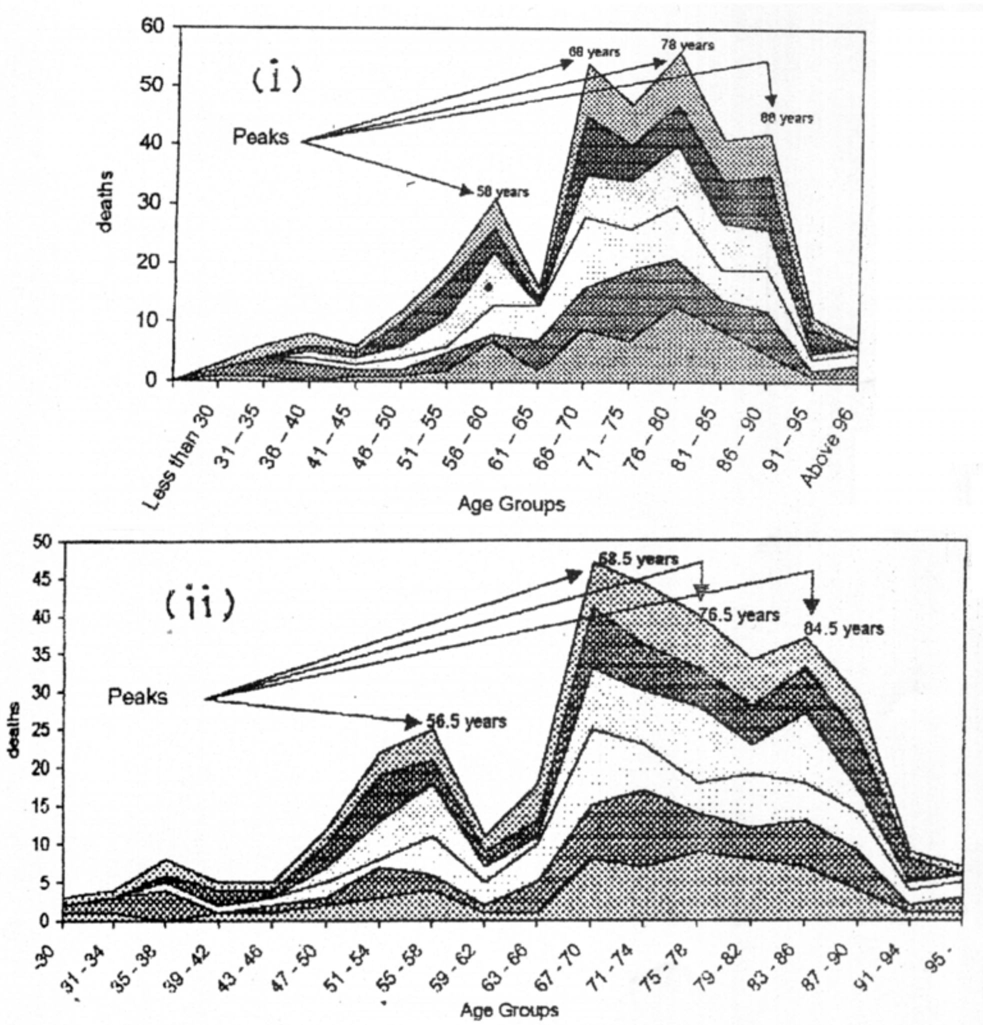

Figure 1 (b) (from A.F. Siddiqi (2000), worldwide sample). Shaded area Frequency-Curve for the Ages, when the Group-Difference is: (i) 5-years and (ii) 4 years, with Thorny Peaks indicated (Age 72 is lined up for all the three Figures.)

Materials and Methods

The data were obtained from various historical sources: Websites [7,8] for dates of deaths and births of Monarchs of England (from 1066 to 1952), (Table 1), Websites [9,10] for dates of birth and deaths of 36 Presidents of USA, from ~ 1750 to 1994 (Table 2), and Urdu Dyra Mostofa Islamia [11] for the 9 Mughal Kings of India (Table 3).

Table 1. Dates of birth and death of monarchs of England**.**

Name	Birth Date	Death Date	Age
William I	1027	1087	60
William II	1056	1100	44
Henry I	1068	1135	67
Stephen	1105	1154	49
Henry II	1133	1189	56
Richard I	1157	1199	42
John	1167	1216	49
Henry III	1207	1272	65
Edward I	1239	1307	68
Edward II	1284	1327	43
Edward III	1312	1377	65
Richard II	1367	1400	33
Henry IV	1367	1413	46
Henry V	1387	1422	35
Henry VI	1421	1471	50
Edward IV	1442	1383	41
Edward V	1479	1483	13
Richard III	1452	1485	33
Henry VII	1457	1509	52
Henry VIII	1491	1547	56
Edward VI	1537	1553	16
Mary I	1516	1558	42
Elizabeth I	1533	1603	70
James I	1566	1625	59
Charles I	1600	1649	49
Charles II	1630	1685	55
James II	1633	1702	69
Mary II	1662	1694	32
William III	1650	1702	52
Anne	1665	1714	49
George I	1660	1727	67
George II	1683	1760	77
George III	1738	1820	82
George IV	1762	1830	68
William IV	1765	1837	72
Victoria	1819	1901	82
Edward VII	1841	1910	69
George V	1865	1936	71
Edward III	1894		
George VI	1895	1952	57

Results of Analysis of Ages of British Monarchs over 9 centuries

Even a quick glance at Tables 4(a) and 4(b) shows the existence of at least four peaks in each case. These peaks are brought out more clearly on plotting the data in Figs. 2a,c as three plots (c: monarchs from 1066 to 1547, b: monarchs from 1547 to 1952, and a: total data for all 39 monarchs covering a span of 9 centuries). In these Figs. the circles are for the data-analysis with $\Delta t = 5$ years, while the triangles are for the analysis with $\Delta t = 4$ years, multiplied by the normalizing factor of 5/4. Each of these Figs. shows 4 prominent peaks in the regions of 67 ± 1, 57 ± 1, 47 ± 1 (marked "B", "C" and "D", respectively) and at ~ 35 years, as predicted from the previous studies. The total plot of Fig. 2b shows a further small clear peak at 82 years, marked "A". What is really striking is that the Figs. 2b and c on careful comparison show that the lapse of 4½ centuries does not seem to have altered significantly the *positions* of the peaks, but the main change is that the highest peak of mortality has shifted from 47 years (Fig. 2c) to 67 years (Fig. 2b).

This shift of the maximum mortality from the age of 47 years to 67 years over the four and a half centuries between the two sets of data (1066-1547 and 1547-1952), as well as the new peak that appear to be forming at 83 years, are to be interpreted as consequences of the improved health conditions in Europe with the passage of time. What is striking is the fact that ages for the various peaks remain more or less fixed at 67 ± 1, 57 ± 1, 47 ± 1 and 34 ± 1 years, while the relative heights change regularly in successive samples. This is in line with the views expressed by J.F. Fries [1]: "A steady rise in life expectancy in the early years of this century changed to a relative plateau after 1950, but the increase has resumed in recent years. Such data form the basis for predictions that more people will live beyond the age of 65 and for projections of medical facilities likely to be required in the future. Thus a person

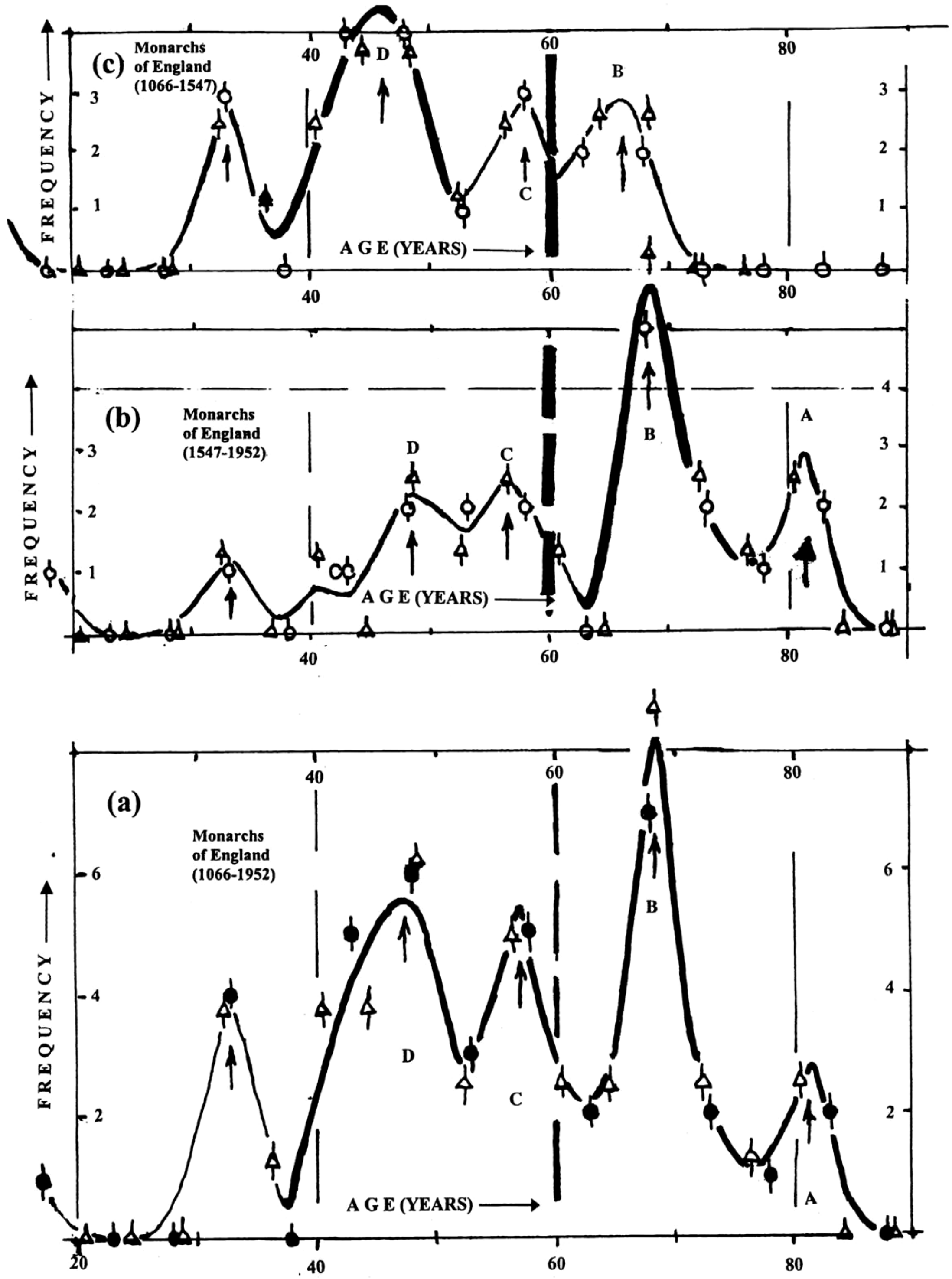

Figure 2. Frequency distribution of ages of Monarchs of England for various periods viz. (a) 39 Monarchs from 1066 to 1952, (b) 19 Monarchs from 1547 to 1952, and (c) 20 Monarchs from 1066 to 1547. Inspite of the small nos. (19-20) in the 2 sub-samples, the pattern of peaks at 33, 47, 56, 67 and 81 years is clear in all three cases. Moreover, the highest peak has shifted from 46 years (in Fig. 2(c)) to 68 years (in Fig. 2(b) over 6 centuries, depicting the results of improved health-care. Triangles: $\Delta t = 4$ yrs, open circles: $\Delta t = 5$ yrs, solid circles: total data (1066-1952).

genetically favored and fortunate enough to avoid disease might live much longer than actuarially predicted. Data fail to confirm the existence of such events. For example, adequate data on the number of centenarians have been available in England since 1837; over this time, despite a great change in average life expectancy, there has been no detectable change in the number of people living longer than 100 years or in the maximum age of persons dying in a given year."

Further amplification of this may be obtained by examining two half sub-samples of the 2nd sample for 1547 to 1952 A.D. viz. sample (d) from 1547-1702 and sample (e) from 1702-1952 A.D. Admittedly, these two sub-samples are small in nos. 9 and 10, respectively, but the corresponding frequency-distributions shown in Figs. 3a,b further bear out the above conclusions strikingly. Thus, we see that:

(i) the peak at 68 years in Fig. 3b has been replaced in Fig.3a by 2 peaks: at 69 years and 82 years, respectively; the latter clearly reflecting the effects of better health-care;

(ii) the broad large inflected peak near 53 years in Fig.3b has been replaced by two small peaks at 48 years and 57 years.

It would be seen later that the above-noted age-distribution of monarchs for 1702-1952 A.D. is in fact found to be nearly identical with the total distribution for the 36 U.S. Presidents from ~ 1750 to 1994 A.D., which has 2 small additional peaks showing up at 90 and 100 years (see Fig.4).

Table 2. Dates of birth and death of deceased Presidents of U.S.A.

Name	Birth Date	Death Date	Age
George Washington	1732	1799	67
John Adams	1735	1826	91
Thomas Jefferson	1743	1825	83
James Madison	1751	1836	85
James Monroe	1758	1831	73
Jhon Quincy Adams	1767	1848	81
Andrew Jackson	1767	1845	78
Martin Van Buren	1782	1862	80
William Henery Harrison	1773	1841	68
Hohn Tylor	1790	1862	72
James Knox Polk	1795	1849	54
Zachary Taylor	1784	1850	66
Milliard Filmore	1800	1874	74
Franklin Pierce	1804	1869	65
James Buchanan	1791	1868	77
Abraham Lincoln	1809	1865	56
Andrew Johnson	1808	1875	67
Ylysses Simpton Grant	1822	1895	73
Rutherford Birchard Hayes	1822	1893	71
James Abram Garfield	1831	1881	50
Chester Alan Arthur	1829	1886	57
Grover Cleveland	1837	1908	71
Benjamin Harrison	1883	1901	68
William McKinley	1843	1901	58
Theodore Roosevelt	1858	1919	61
William Howard Taft	1857	1960	103
Woodrow Wilson	1856	1924	68
Warren Gamaliel Harding	1865	1923	58
Calvin Coolidge	1872	1933	61
Herbern Clark Hoover	1874	1964	90
Franklin Delao Roosevelt	1882	1945	63
Harry S. Truman	1884	1972	88
Dwight David Eisenhower	1890	1969	79
John Fitzgerald Kennedy	1917	1963	46
Lyndon Baines Jhonson	1908	1973	65
Richard Milhous Nixon	1913	1994	81

Table 3. Data (birth and death) of the 9 Mughal kings of India.

Name	Birth Date	Death Date	Age
Zaheeruddin Babar	1483	1530	47
Nasiruddin Humayoon	1508	1556	48
Jalaluddin Akbar	1542	1605	63
Noorulddin Jahangir	1569	1627	58
Shahabuddin Shahjahan	1592	1667	75
Muhayuddin Almgir	1618	1707	89
Farukh Seyar	1663	1719	56
Shah Alam	1727	1806	79
Bahadur Shah Zafar	1775	1862	87

For analysis, the data for any one Table were arranged in ascending order of age at death, and this was then sampled at 2 intervals viz. $\Delta t = 4$ years and $t = 5$ years, as in previous papers. This gave the results shown in Tables 4a and b for the monarchs of England and in Tables 5a and b for US Presidents. In each of these Tables, analysis of the first half of the relevant data is presented in the first row, and the second half is given in the second row, as indicated in the right-hand columns of the corresponding row.

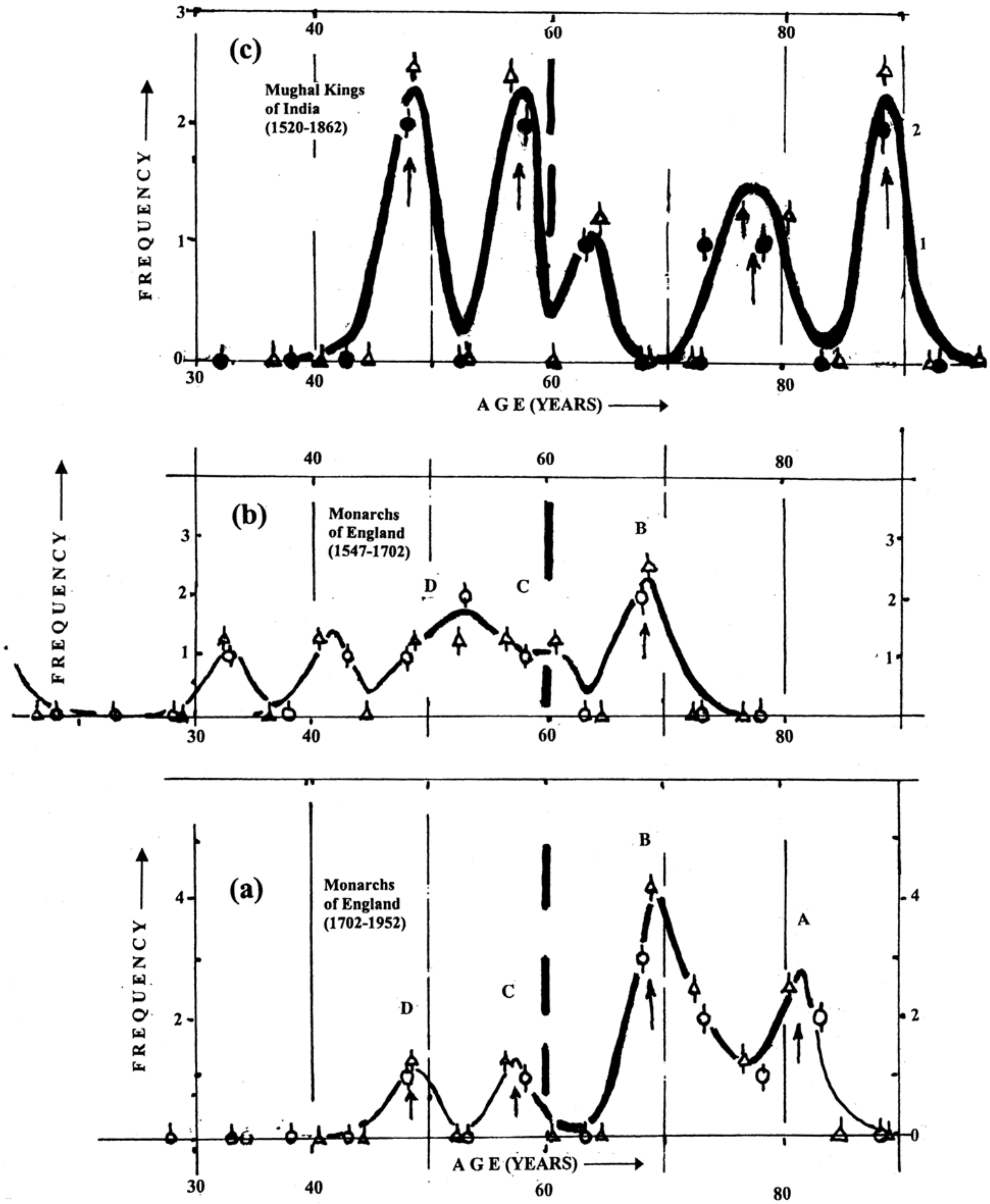

Figure 3. (a) & (b). Frequency distribution of ages two sub-samples of 9 & 10 Monarchs of England from (a) 1702 to 1952 and (b) 1547-1702, which further confirm the increasing height of the 67 years peak, plus the appearance of the peak at 81 years in recent times. **(c)** the corresponding plot for ages of 9 Mughal Kings of India (1500-1862), which shows a considerably different pattern of 5 peaks, with two pairs of large peaks (indicated by vertical arrows); those at 48 and 57 are seen in case of the Monarchs of England. Fig. 3a & b: triangles for $\Delta t = 4$ yrs, open circles for $\Delta t = 5$ yrs, Fig 3 c: open triangles for $\Delta t = 4$ yrs, solid circles for $\Delta t = 5$ yrs.

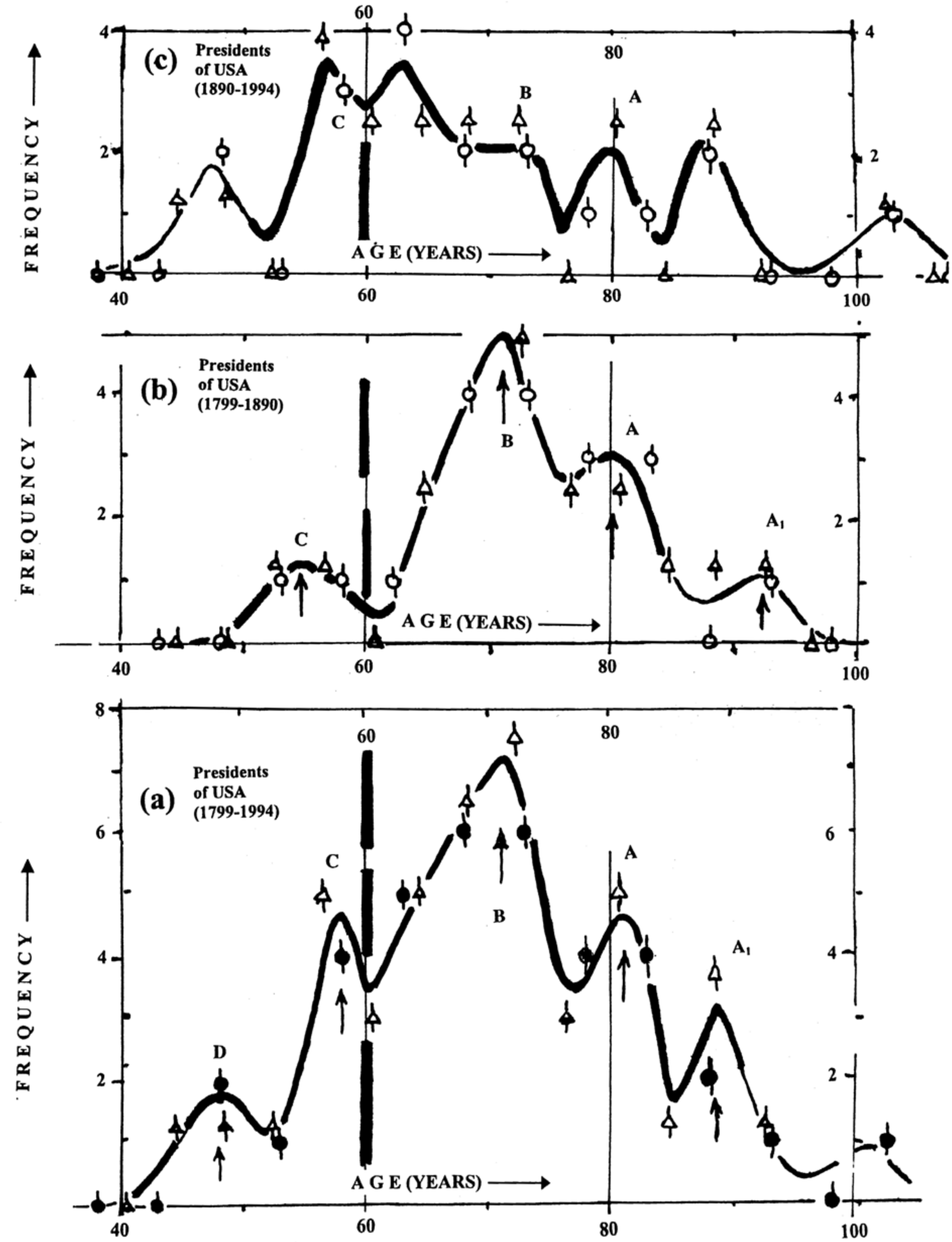

Figure 4. The corresponding analysis for ages of the first 36 Presidents of the U.S.A. (d. 1799-1994). Fig. 4(a) shows the total plot for all the 36 Presidents, depicting a main peak around 71 years, while Fig. 4(b) and 4(c) show respectively the corresponding plots for the first 18 Presidents and the second 18 Presidents. Prominent peaks are to be seen in all three graphs around 47, 58, 70, and 81 years, indicated by the letters D, C, B & A, respectively. In addition, peaks are to be noted around 90 and 100 years in Figs. 4(b) and (c), and also around 65 in Fig. 4(c). Triangles: $\Delta t = 4$ yrs, open circles: $\Delta t = 5$ yrs, solid circles: total data (1799-1994)

Table 4a: Monarchs of England [(1066-1547) and (1547-1952)], Δt = 5 years.

< 30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95
1	3	-	4	4	1	3	2	2	0	0	0	0	- (1066-1547) Σ = 20
1	1	-	1	2	2	2	0	5	2	1	2	0	- (1647-1952) Σ = 19
2	4	0	5	6	3	5	2	7	2	1	2	0	Total = 39

Table 4b. Monarchs of England, Δt = 4 years.

< 30	31-34	35-38	39-42	43-46	47-50	51-54	55-58	59-62	63-66	67-70	71-74	75-78	79-82	83-86	87-90	91-94, 95-98
1	2	1	2	3	3	1	2	1	2	2	0	0	0	0	0	- (1066-1547) Σ = 20
1	1	0	1	0	2	1	2	1	0	5	2	1	2	0	0	- (1547-1952) Σ = 19
2	3	1	3	3	5	2	4	2	2	7	2	1	2	0	0	- Total = 39

Table 4c. Two small sub-samples from monarchs of England (1547-1701 and 1702-1952). Top row with Δt = 5 years; bottom row with Δt = 4 years.

2	**1**		**1**	**2**	**1**		**0**	**2**	**0**		**0**	**0**	**0**		**-**	**Σ = 9**
< 39	39-42	43-46	47-50	51-54	55-58	59-62	63-66	67-70	71-74	75-78	79-82	83-86	87-90	91-94	95-98	99-102
0	1	0	1	1	1	1	0	2	0	0	0	0	0		-	Σ = 9

Note: Top row with Δt = 5 years; bottom row with Δt = 4 years.

2	**0**		**1**	**0**	**1**		**0**	**3**	**2**	**1**		**2**	**0**	**0**	**-**	**Σ = 10**
< 39	39-42	43-46	47-50	51-54	55-58	59-62	63-66	67-70	71-74	75-78	79-82	83-86	87-90	91-94	95-98	99-102
0	0	0	1	0	1	0	0	3	2	1	2	0	0	0	-	Σ = 10

Table 5a. Ages of deceased Presidents of U.S.A. (1799-1890 and 1890-1994), Δt = 5 years.

	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100	101-105	
1779-1890	-	0	1	1	1	4	4	2	3	1	1	-		Σ = 18
1890-1994	-	2	-	3	4	2	2	1	1	2	-	-	1	Σ = 18
Total	-	2	1	4	5	6	6	4	4	3	1	-	1	Σ = 36

Table 5b. Ages of deceased Presidents of USA (1799-1895 and 1896-1994), Δt = 4 years

	39-42	43-46	47-50	51-54	55-58	59-62	63-66	67-70	71-74	75-78	79-82	83-86	87-90	91-94	95-98	99-102	
1799-1895	-	-	-	1	1	-	2	3	4	2	2	1	1	1	-		Σ = 18
1896-1994	-	1	1	-	3	2	2	2	2	-	2	-	2	-	-	1	Σ = 18
Total	-	1	1	1	4	2	4	5	6	2	4	1	3	1	-	1	Σ = 36

Table 6. Ages of Mughal kings of India.

(a) Δt = 5 years

31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95
	0	0	2	0	2	1	0	1	1	0	2	0

(b) Δt = 4 years

31-34	35-38	39-42	43-46	47-50	51-54	55-85	59-62	63-66	67-70	71-74	75-78	79-82	83-86	87-90
0	0	0	0	2	0	2	0	1	0	0	1	1	0	2

Analysis of age-distribution of the Presidents of U.S.A. from 1750 to 1994.

Another good sample that is readily available is that of the 36 Presidents of U.S.A. (d. 1799-1994). The dates of birth and death of these 36 are collected in Table 2; two of these, namely Lincoln and Kennedy, are known to have been assassinated, but this could perhaps be considered a risk of the profession! Of course, the distribution is truncated below 40, because no one became President before this age.

The frequency analysis of the ages of these 36 Presidents has been carried out in Tables 5a and b as before, breaking them down into two groups: (a) first 18, who died between 1799 and 1894 ± 1, and (b) second 18 who died between 1894 ± 1 and 1994. The data is plotted in Figures 4a, b and c respectively, for: all 36, the first 18 and the second 18 presidents, respectively; the circles are for sampling interval $\Delta t = 5$ years, the triangles for $\Delta t = 4$ years, with correcting factor of 5/4 for the frequencies. These three plots exhibit the expected peaks of mortality in the neighborhoods of 82 years, 66 –70 years, 58 years, and 48 years, with an additional small one at the relatively high age of 90 years, as also a trace of one around 100 years! The curve does not go below 40 years, because no one became a President before that age.

Also, it can be seen by comparison with Figs.2a-c for the monarchs of England that four of the peaks, namely those at 47, 58, 71 and 81, are within a year or two of those (47 ± 1, 57 ± 1, 68 ± 1 and 81) found in case of the monarchs. Closer examination of the 3 distributions of Figs. 4a-c shows that the relatively small peaks at 48 years and 100 years are to be seen only in the distribution for the 2nd 18 Presidents. While the peak at 100 years can be attributed to improved health and health-care services, that at 48 years is linked with assassination and stroke, both of which could justifiably be considered today as a politician's risk! The 2nd plot for the U.S. Presidents (from 1890 to 1994) also shows the possible appearance of another peak, around 62 years of age, which needs further exploration.

Discussion and comparison with mortality peaks for Mughal kings

The above comparison provides grounds for the conclusion that the main peaks of mortality observed at or near 47, 57, 68 and 81 years are a definite feature of the life-spans in these countries, at least amongst people of Anglo-Saxon ancestry. We may note here that, as noted by Comfort [12] and Upton [13] in 1990, the survival curve in the United States was not very different from this situation. However, sequential survival curves throughout this century show progressive "rectangularization as the elimination of premature death results in a sharp down-slope to the natural life span (Fig.5). The serial data allow calculation of the position and shape of a survival curve if all premature deaths were eliminated: an ideally "rectangular" survival curve. If we assume a normal biologic distribution, statistics suggest that under ideal societal conditions mean age at death is not far from 85 years.

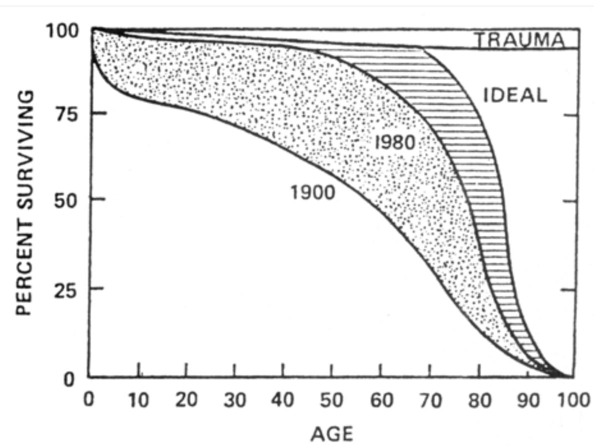

Figure 5. Mortality according to age, in the absence of premature death.

The data on monarchs of England and Presidents of U.S. not only bear out the above generalized statement, but in addition shows that the pattern of mortality in any one set of samples is in fact composed of distinct peaks, the main ones being at or around the ages of 47 ± 1, 58 ± 1, 69 ± 2, 81 ± 1, together with a smaller one around 91 and around 33 years. These four main peaks of mortality (labeled D to A respectively in the diagrams) are thus typical of the pattern of aging, at least in these two countries. As indicated in an earlier paper, the first two are mostly associated with various killer diseases e.g. cerebral hemorrhage and coronary or other stroke, while the two highest represent mostly the effects of general physical degeneration of the body organs.

From the curves of Figs. 2, 3 and 4, it is also seen that the result of better nutrition and health-care over the last few centuries has been to shift the maximum mortality towards the higher peaks. For example, in Fig.3b (1647-1702) and Fig.3a (1702-1952), 45% ± 5% of the total mortality among U.K. monarchs is seen to correspond to the largest peak, which has shifted from ~ 46 years to 68 years over a period of 2 centuries. This shift is apparently continuing a little further, as seen from Figs. 3b and c for U.S. Presidents (1786-1890) and (1890-1995). In fact, a small peak at 102 years is now apparent in Fig. 3c, corresponding to the latest situation in the 20th century, but this is compensated by another one coming up at 62 years in Fig. 4c (for the period 1890-1995), which needs further study.

J. Fries [1] states: "By implication, the practical focus on health improvement over the next decades must be on chronic instead of acute disease, on morbidity not mortality, on quality of life rather than its duration, and on postponement rather than cure----. An important shift is occurring in the conceptualization of chronic disease and of aging. Premature organ dysfunction, whether of muscle, heart, lung, or joint, is beginning to be conceived as stemming from disuse of the faculty, not overuse."

Finally we show, in Fig. 2c, a plot of the ages of 9 Mughal kings of India (1500-1900 A.D.), which shows a pattern that involves two pairs of large peaks at 48, 57, 77 ± 2 and 88 years. The peak at ~ 79 years is to be seen in the corresponding patterns of Mortality peaks of British monarchs (1542-1995) and also the U.S. Presidents, but the others do not fully fit either of these patterns at all.

So, there appears to be a need to make further comparative studies of this type, using appropriate samples taken from various regions and races of the world, in order to elaborate some of the points noted above.

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